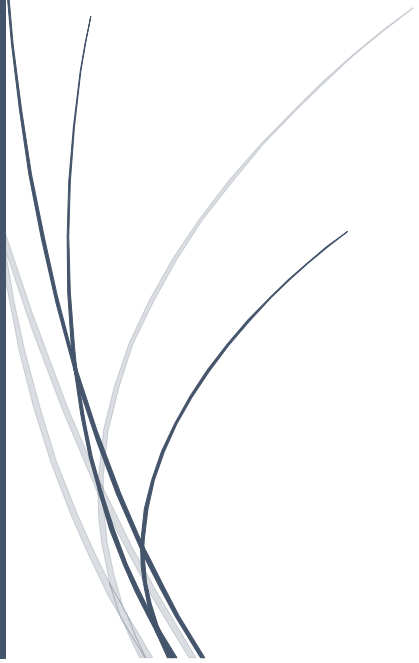
Green Stories:

Microbes to the rescue!

Edited by:
Louise Byfield and Sigrid Kusch-Brandt

Microbes to the Rescue!



Microbes to the Rescue!

An anthology edited by Dr Louise Byfield & Dr Sigrid Kusch-Brandt

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Introduction

The Environmental Biotechnology Network (EBNet)* is a community dedicated to engineering microbial systems for environmental protection, bioremediation and resource recovery. Funded by UKRI, we work to connect academia and industry together for mutual benefit. In 2023 we sponsored a short story competition with Green Stories** - a University of Southampton initiative which runs a series of free writing competitions across various formats to showcase what a sustainable society might look like. The theme of the EBNet-sponsored competition was 'Microbes to the Rescue!' and the base requirement was for short stories of between 1000-3000 words that showcased microbes in a positive way and in an environmental setting.

The aim of the competition was simple: to encourage wider awareness of the various technologies and issues in the Environmental Biotechnology (EB) field. It was not obvious that content could be solicited in what is, at heart, a very technical and STEM-heavy topic. As sponsors we were delighted by the large number of 161 entries from across the globe and – it must be said – surprised by the many misconceptions held about this sector!***

With so many stories to choose from we decided to share some of them in an anthology. This book features a wide selection of genres and styles, technologies and situations. The unifying theme is that EB has been clearly incorporated within the plot - for effect, for education, for amusement. We offer you a representative sample to browse through according to your personal preferences.

Amongst this collection you will find something for everyone. There are tales for children and young adults. Most stories are aimed at adults, with some featuring more contentious material including themes of

death, murder and corporate espionage. Some stories are set firmly within the context of the present day, whilst others are speculative and explore imaginary futures.

To include a broad range of examples of EB in fiction we cast a wide net. Consequently, readers with specialist knowledge may find that the accuracy of the science has sometimes taken second place to the necessities of the plot. As a general disclaimer, these fictional depictions of 'science' should not be mistaken for the real thing – we warmly encourage the curious to go one step further and find links to reliable sources of information elsewhere, including at EBNet.ac.uk.

We hope you enjoy the collection. This freely available anthology is only possible courtesy of the original authors who have permitted us to make their work publicly available, and Prof. Denise Baden of Green Stories. We thank them all for their generosity and time.

* https://ebnet.ac.uk/

** https://www.greenstories.org.uk/

*** Our report on the Green Stories Competition is available online at https://ebnet.ac.uk/resources/

Microbial magic: cheers to a greener tomorrow

Yogi Ashari, Indonesia

Introduction:

Imagine life as this huge tapestry, in which towering timber, bustling towns, and significant oceans all mesh collectively. But here's the kicker – in the shadows lurk unsung heroes, and get this, they ain't caped crusaders; they may be microbes, these teeny magicians turning gross stuff into gold, cleaning up our mess. We're in a real jam, grappling with rubbish, pollution, and our sources drying up, but these little dudes provide a glint of hope in our darkening global environment.

Introducing Environmental Biotechnology – this fancy field faucets into the superpowers of engineered microbes. These teeny wonders are just like the A-Team of turning waste into primo compost, like pollution-busting wizards cooking up solutions to our mondo environmental headaches. They morph human and animal waste, food scraps, pesticides, and chemicals – once the nasty stuff – into pure eco-gold.

So, if we're gunning for a future that's without a doubt really worth its salt, we gotta change our song. No more crying over spilt milk, it is time to chase after solutions.

Enter the Green Stories Short Story Competition, summoning storytellers from every corner to dream up an international wherein environmental biotech takes the highlight in our mission for a purifier, greener global that is strong as a rock.

Picture this: a global in which the reek of waste swaps with the aroma of fresh compost, wherein mucky waters groove with existence as microbes stage the playing discipline. That's the arena that environmental biotech whispers approximately, a place in which human smarts and nature's pizzazz throw a wild shindig. The Environmental Biotechnology Network (EBNet) becomes our guiding celebrity, rallying folks from biz, gov, and college to switch thoughts and positioned this recreation-converting field into gear.

Hang on tight, 'motive we are about to dive deep into the wild and wacky world of environmental biotech. We're speaking about projects tackling oil spills, leftover meds, and gnarly chemicals, and efforts transforming everyday stuff into energy, fuels, vitamins, and platform chemical substances. It's like watching microbial rockstars strut their stuff, turning our world from an everlasting dump right into a realm where every piece matters, and each hiccup has a sneaky solution.

This adventure we're on? It's a tip of the hat to human guts and gumption. Our memories take us through locations in which engineered microbes display off, from excessive-tech sounding bioreactors and fermenters mimicking nature's mojo to remedy flowers giving back natural-as-a-whistle water to the surroundings. This innovation tale dances hand in hand with stories of teamwork, in which scientists, engineers, and social scientists give each different high fives, bridging the gap among wild ideas and actual-existence motion.

But right here's the curveball: the real juice isn't always just within the sci-fi gadgets. It's approximately the mega effect on our future. Environmental biotech is going way past astonishing achievements, reshaping how we view the natural world. It's like an alarm clock, telling us to peer at waste as a treasure map, unlocking the capability for earth-loving practices that admire the circle of lifestyles.

As we cruise through these stories, we're going to meet characters reflecting on the beyond and squinting at a horizon brimming with capacity. They'll spin stories of an international duking it out with environmental chaos, in which unchecked pollution and waste threw a wrench within the works. But don't ride, those ain't stories of doom and gloom. They're testimonies of wish, transformation, and heroes who've made visible the insane energy of microbial systems up near, pumped to form a future in which these tech marvels are woven into the each day grind.

In this microbe wonderland, our characters find solace, understanding that answers to our eco-woes are inside arm's attain, as long as we flex the muscle of environmental biotech. Picture landfills flipping into energy hubs, and farming practices blooming thanks to the friend gadget of flora and microbes. The future they paint is like a comfortable hug from Mother Nature herself.

The Green Stories Short Story Competition isn't always just a wild writing trip; it is a battle cry. It dares storytellers to dream up a global where microbial structures take us on a wild trip, celebrating the thoughts-blowing feats of those itty-bitty organisms. Through their tales, they may make oldsters see microbes with fresh eyes, not as pests however as sidekicks in our undertaking for a planet it is grooving sustainably.

Coming up, the essays will plunge headfirst into the thrilling realm of environmental biotech, cheering at the resilience of microbial heroes and spinning testimonies that sneak a peek into a transformed universe. As we buckle up for this literary rollercoaster, we step into a world teeming with hope and opportunities, loaded with the depraved expertise that answers to our eco-woes may simply be chilling within the microscopic nooks of the microbial universe.

Microbial Alchemy: Trash to Treasure

Hold your horses, 'purpose microbes are the ultimate alchemists, turning trash into gold. Let's communicate composting, wherein engineered microbial structures work their magic, breaking down natural stuff and cooking up nutrient-packed compost that's like steroids for our soil. What changed into once just meals scraps and lawn leftovers now will become a heavyweight fertilizer, pumping life into our dirt, championing eco-friendly farming, and giving those poisonous chemical compounds a run for their money.

But wait a minute! Microbes are the VIPs at snagging fee from all kinds of waste streams. Think wastewater remedy flora, where engineered microbial structures rock it, changing pollution and natural rely into mega-valuable biogas. It's like a clean and inexperienced power disco, no longer simply tackling pollution but additionally giving fossil fuels a flavor in their personal medication and giving those sneaky greenhouse gases a bit of our minds.

Let's kick off sparkling inside the realm of environmental biotech and pollution. We're stepping into a world grappling with the aftermath of unchecked pollutants, and that's where environmental biotech steps up, lights the direction to healing and renewal. Pollution is like this darkish cloud, messing up nature and giving our well-being the aspect-eye. From oil spills choking marine life to leftover meds and insecticides trashing our soil and water, pollutants's a complete party crasher.

But keep onto your hats! In the midst of this mess, a glimmer of hope emerges – engineered microbial systems. They're like superheroes of the micro-international, strutting their stuff by means of turning the impossible into reality. Through bioremediation, they're grabbing

pollution and detoxifying them, giving polluted lands a miles-wanted makeover.

Imagine a global wherein oil-covered waters grow to be canvases for microbial masterpieces. Environmental biotech is flexing its muscular tissues, taking on the big venture of tackling oil spills, a hassle that's been bugging our oceans and coasts for ages. Microbes, armed with their special enzymes, are waging a hush-hush warfare towards the darkness, breaking down hydrocarbons into harmless bits. Those once-muted waters now dance with existence, a live demonstration of the power of recuperation.

Hold tight, 'cause there's extra to this story! Environmental biotech isn't pretty much telling oil spills to hit the street. It's additionally about dealing with the remains of meds and pesticides, sneaky troublemakers sneaking into our soil and water. These chemical ghosts do not know when to give up, messing with nature and giving human health a strong jab. That's whilst our engineered microbial pals step in, ready to go toe-to-toe with the bad guys. They're turning harmful stuff into the good things, developing a symphony of rebirth, making soil rich and water crystal clean.

And it really is now not even scratching the floor. Think approximately landfills, the ones epic symbols of waste long past bonkers. Now photograph them as assets of renewable electricity, all thanks to supercharged microbial systems that accelerate waste breakdown, churning out biogas and treasured compost. Trash? No longer a burden – it's a ticket to a fresher, happier world.

And bet what? This ain't a few science fiction mumbo-jumbo. This is real life, with scientists, engineers, and groups coming together to make goals truth. They're turning theories into action, leaving us gob smacked by means of what's viable.

But maintain your horses, it is no longer just about the science. It's about how we view our international and our location in it. These testimonies ain't pretty much solving issues; they're approximately uncovering beauty in what we as soon as concept become garbage. They're approximately shifting our relationship with nature from a warfare to a partnership.

So, as we dive into those tales, don't forget – they're more than memories. They're the blueprints for a brighter the next day, where teeny-weeny microbes take the stage because the heroes we've been waiting for. These tales of innovation and positivity remind us to peer the sector via sparkling eyes, in which nature and era be part of forces to construct a thriving world.

And keep in mind, the strength to form the destiny is proper in our fingers. By embracing environmental biotech, we're able to actually make a dent. It's a call to action, a friendly nudge reminding us that the answers to our problems are just a stone's throw away – all it takes is a piece of teamwork with our trusty microbial buddies.

As we wrap up this journey thru the mind-blowing realm of microbes, permit us to supply a hearty round of applause to those unsung heroes. They are probably minuscule, however they preserve the important thing to a global world: it really is cleaner, healthier, and more sustainable. By teaming up with those environmental champions, we are paving the street to a higher day after today – one microbe at a time.

Part 1. Environmental biotechnology all around us: *wastewater treatment, waste management, bioremediation, microbes in ecosystems*

Up shit's creek

By Brian Adams, United States

"Are you there?" Anna shouted, cradling her phone on her shoulder. "Can you hear me?"

Anna balanced precariously on the top rung of a step ladder, stretching to plug the last extension cord into the highest outlet. She pumped her fist in the air as the water pump once again roared back to life. Hopping off the ladder, she raced back outside.

"I'm knee-deep in shit here, Bart! Do you understand?"

"Of course I do." Bart's voice was slurred, either from sleep or drink. Probably the latter, Anna thought.

"I mean literally knee deep. It's practically flowing over my boots! One more foot and we're totally screwed. You need to get your sorry ass down here, now!"

This was clearly not the way to talk to your boss, but with the rain coming down and the river still rising, Anna was desperate.

She heard a glass clink as another sip was taken.

"How about Ted?" Bart asked, the slur even stronger. "And Rusty? Have you - "

"They're already here, damn it. You were on call tonight, Bart. You're supposed to be the one in charge! It's all hands-on deck and, goddammit, you're AWOL! Again!"

"Now, now. Let's not go overboard." The glass clinked again.

"Son-of-a-bitch!" Anna whispered, not quite loud enough for the son-of-a-bitch to hear.

She hung up and stashed her phone in her coveralls. This man, her *boss*, was the head of the sewage treatment plant. Here they were, up shit's creek and barely keeping afloat, and *this* was how he acted?

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Anna had been mid-bite into a yummy stuffed mushroom hors d'oeuvres at her favorite vegetarian restaurant when she got the text. It was her third date with Scarlett, the gorgeous redhead she was desperately trying to impress. Scarlett was a buyer for a high-end clothing store and the challenge was this: she was a sartorial femme who wore pink and pastel tailored pants and jumpsuits. While she didn't look like Barbie, she sure dressed like her. Anna dressed up nice, but Scarlett? Wow! That woman was in a different league.

Plus, Scarlett always smelled of Delina Exclusif Eau de Parfum, while Anna, after a long shift at work, was constantly paranoid about smelling like Eau de Crap. She had explained how she worked in a "public health facility" which, though true, was a bit of a stretch. But damn if she wasn't struggling with the "I work with poop" reveal.

Anna stuffed a final bite of mushroom into her mouth. She usually kept her phone stashed safely away during dates, but, while Scarlett was in the bathroom, she had noticed a glow from her bag under the table and couldn't help but check the text.

"I am so sorry," Anna said, "but I have to bounce."

"Oh no!" Scarlett reached out and put her hand on Anna's. "Is everything okay?" Anna caught her breath. That first touch was electrifying.
~~~

"Work," she said. "This damn rain. We're getting flooded out!" "Your office?" Scarlett looked confused.

"Not really my office. The sewage treatment plant. That's where I work. The Green River has overflowed and the - "

"Shit has hit the fan?"

Anna smiled at the quick retort. "Let's hope not. Fingers crossed!"

Scarlett reached out and criss-crossed her fingers with Anna's. "Is there anything I can do?" Scarlett asked.

"Get out that pink umbrella of yours and do a rain dance. One that zips up the clouds." "Got it. Text me later? To let me know you're okay?"

"Will do." Anna took a deep breath and hurried out of the restaurant.

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Ever since she was a little girl, Anna was fascinated with bugs. The smaller the better. While other kids might back away in alarm, Anna would squeal with delight at the sight of a squash beetle or a daddy longlegs. Her favorite nursery rhyme was the Eensy Weensy Spider, and she drove her parents half-crazy demanding they recite it over and over.

"How small is eensy weensy?" Anna would ask her mum. "Pretty darn small," mum would answer.

"Smaller than this?" Anna would hold her chubby little fingers as close together as she could.

"Maybe even smaller, darling."
~~~

In seventh grade Anna had a science teacher who changed her life. Introduced to microscopes for the first time, she adjusted the eye piece and was gobsmacked to view microorganisms that made eensy weensy look titanic. Until then, she had thought living things were either plants or animals, but now the whole world of microscopic life came stunningly into focus. Single celled organisms, like bacteria, reproducing by splitting in two. Shape shifting amoeba extending and retracting prehistoric armlike structures. Predatory protozoans engulfing other single celled creatures.

Science became her thing, and as she excelled in AP high school biology and chemistry it was clear she had a calling. Accepted into the honors program in microbiology at the University of Massachusetts, she was a teaching assistant by the time she was a junior, undertaking graduate level research in microbial bioremediation as a senior.

Bioremediation – using microbes to remove environmental contaminants. She was so excited - *turned on* even - by the idea that, for her thesis presentation, she accidently titled her PowerPoint presentation *Orgasms At ork For You* rather than *Organisms*. She received the highest of marks from all of her professors.

Never one to back away from what others found disgusting, the field of sewage treatment was an endless source of fascination for her. Pools full of oxygen demanding waste (i.e., shit) were chomped on by millions, no, billions of microorganisms. What was not to love about that? After all, one woman's waste was another creature's dinner.

While she was still in college, her stepsister had married a man from India and the wedding was held in Bangalore, India's third largest city. She was a bridesmaid and, in between frantically arranging flowers and ordering food, she managed to slip away and visit one of the sewage treatment plants. Not your usual tourist destination. The plant wasn't

nearly up to task to handle the many millions who lived there, particularly during the torrential monsoon rains when most sewage flowed untreated into the Vrishabhavat River.

The visit had a profound effect on her. Diseases and contagions from untreated sewage ran rampant, and the devastation to India's waterways, as vibrant rivers turned into ecological disaster zones, was heartbreaking.

Her senior year she landed an internship as a biochemist at the town's water quality lab. Following graduation, she was offered a full-time job. One opportunity led to another and now, with her certification completed as a wastewater technician I and II, she was practically running the place.

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Anna gritted her teeth and charged outside. Rusty, Ted and two part-timers from the Department of Public Works were piling sandbags around the four secondary treatment pools, the last-gasp effort to keep the still rising Green River out.

"Build the wall!" Anna shouted. "Build the wall!" Damn! Those were Trumpian words she never dreamed she'd hear come out of her mouth. Her friends would disown her for yelling that kind of shit.

She sprinted to the bucket loader to fill it with another round of sandbags. *If the good Lord was willing and the creek don't rise*. That was how the old time saying went. But that was before climate change, right? Now the good Lord seemed pretty pissed, and all bets were off.

It seemed to Anna as if it never rained normal anymore, it only rained crazy. This was the third 'once in a hundred years' rain event since the fourth of July, and it was stunning what three inches in three hours
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could do to the usually placid Green River. With seepage from saturated soils sneaking their way into aging underground sewage pipes, the plant was just barely handling the inflow. And now, even with the rain tapering off, the overflowing river was still marching forward.

If they couldn't keep the floodwaters out of the secondary treatment pools, untreated contaminated sewage would be released downstream. And her bugs! Her precious microorganisms that did so much of the work for her! If the secondary pools were breached, those critters would be swept away.

Teensy, weesny as they were, those microbes were the heavy hitters of the sewage treatment plant. It wasn't her, Ted or Rusty, it wasn't those two guys from the DPW whose names she could never remember, it certainly wasn't her slacker of a boss who should have retired a decade ago. It was the Betaproteobacteria with their voracious appetite for shit. Anna fondly referred to them as the Beta Brunch Bunch, the ones who munched on yesterday's lunch. There were other organisms with equally cool sounding names – stalked ciliates, rotifers, and, her favorite, tardigrades, also called water bears. Their motto was eat shit and die. She loved every single one of them.

"Build the wall!" Anna screamed through the rain, dumping yet another bucket loader full of sandbags at the edge of the pool.

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Anna's phone vibrated. She stopped momentarily to check the message. It wasn't Bert calling in reinforcements, but something almost as good.

Just making sure you're okay Scarlett's text read. And then, even better: Thinking about you.
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One of the favorite parts of Anna's job was giving tours to school groups. She loved the looks on kids' faces when they saw the toilet in her office filled with geraniums, the notice on the bathroom door that read "donation center", and the sign prominently displayed on her desk: *THE SHIT STOPS HERE.*

For all its high-tech complexities, sewage treatment wasn't that difficult to understand.

Sewage from almost every residence and business in town traveled through an intricately connected series of small diameter underground pipes that fed into larger and larger pipes, ultimately spilling into one pipe that fed the plant.

In primary treatment, solids settled to the bottom of tanks larger than swimming pools.

The solids were removed as sludge, and the liquids traveled on to secondary treatment. "It's as simple as that," Anna would explain. "Solid stuff sinks, light stuff floats.".

"Eww" kids would squeal, holding their noses, as Anna scooped up a net full of sludge.

Anna got it. On a warmish day, it was like opening the door to an overused outhouse.

"Awesome" other kids would yell with even greater gusto, undeterred by olfactory overload.

Secondary treatment was where the real magic happened. That's where Anna's bugs did their thing. Those treatment tanks were like heaven to them. The rich array of wonderfully diverse microorganisms ate shit
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to their hearts content and then died. Actually, they didn't really have hearts, or brains for that matter, but if they had they would have leapt out of the water and given a big thumbs up to Anna.

"Thanks for everything!" they would have yelled. "It was delicious!"

Soon their lifeless, bloated bodies would sink to the bottom of the secondary treatment settling tanks and be removed as sludge.

Oxygen demanding waste, left untreated, could enter the river and cause naturally occurring bacteria's numbers to skyrocket. This would deplete oxygen levels in the water so necessary for fish and other organisms. No oxygen meant no aquatic life.

"Organisms at work for you!" Anna would shout out to students over the din of the giant bubblers as they pumped oxygen into the tanks.

"Awesome!" kids would yell. "Eww!" shouted others.

The last stop of the tour was where the effluent was chlorinated to kill what pathogens remained, dechlorinated, and then pumped into the Green River pretty darn clean. Kids were impressed.

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What if Anna was to bring Scarlett on a tour? What would Scarlett think? *Eww* or *Awesome*?

Focus! Anna told herself, wiping the rain out of her eyes and loading up the bucket with another round of sandbags. Her love life had to wait. The task at hand was keeping the river from flooding the tanks.

Thank goodness she had forced Bart to teach her how to use the bucket loader. And how to reposition pumps in case of emergencies like this. And where to position sandbags to re-route flood waters. Those, and a ton of other essentials, were nowhere to be found in her
~~~

job description or her pay grade but, dammit, someone had to know how to right the ship when the captain was nowhere to be found.

Ted, Rusty, and the two whatever-their-names-were were looking to her expectantly for direction. She wasn't their boss but, with Bart increasingly shirking his duties, she was the one calling the shots. This was the third time this month they'd faced a do-or-die crisis like this. The third friggin time! With climate change rearing its ugly head, emergencies like these were the new normal.

"The bastard has got to be retiring soon!" her roommate Clara had argued, when Anna had come home once again bitching about her boss. "You should take the job. The first woman sewage treatment plant director in the state! Wouldn't that be a hoot!"

Maybe Clara was right. Bart's days were numbered. If she had anything to do with it, he'd have retired yesterday. And then, maybe, she should apply for his position. Would that garner awe from a woman like Scarlett? But. if Anna was to be the director of the treatment plant then there had to be a plant to direct, and, with the water still rising …

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"To the left!" Anna ordered. "Stack up the rest of the bags. Three high. We've got to channel the flow toward the slope where the river willows are!!"

Anna and Rusty dragged another pump over to where pooling water was lapping at the secondary tank. Another few inches rise and she could kiss her bugs goodbye. Swept away was not okay.

If they could just divert the flow a little to the left. She rushed back to the bucket loader for the final round of sandbags. The rain had stopped
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but the river was still angry. A few more sandbags, A repositioning of the pump hose. Just a little more to the left …

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"Wow!" Scarlett said. "Sounds like some evening!"

Anna had texted her smiling, dancing emojis when she had finally gotten home, exhausted, at three that morning. The crisis had been averted. The wall of sandbags had held. The pumps had kept the flood at bay. Her precious bugs had survived to do their thing, at least until the next high water.

"You're like a hero!" Scarlett gushed.

Anna laughed. "Thanks, but let's not push it."

It was Friday night, two days after the flood waters had receded. They were back at the same restaurant, the same table in fact, and Anna was happily feasting on the stuffed mushroom hors d'oeuvres, hoping to finish them uninterrupted this time.

"I'm dating a celebrity!" Scarlett held up the day's local newspaper. There was a picture of Anna standing next to the treatment pool, a bemused look on her face. "*Savior of the Sewage* it reads. Front page, no less."

"Of the B section," Anna replied, blushing.

"And it says the Director, Bart something-or-other, is going to retire. Does that mean you're taking over?"

Anna shook her head. "Too soon for that. I haven't even decided whether to apply or not."
~~~

"What?" Scarlett reached over and helped herself to a forkful of Anna's mushrooms.

"You definitely should. You know why?" "Why?" Anna answered.

Scarlett reached over and took Anna's hand in hers. "Because you'll be . . . awesome!"

Land-Phill

Trisha Sebastian, United States

I got a landfill job, and my mother wasn't proud. I told her it was the only job I could land! Haha, get it? My mother replied, saying she finally understood why I couldn't get a job as a comedian. Anyway, it's my first day on the job, and my manager, Greg, told me my landfill load wasn't good enough to get above 90 dollars. I got moved to another job the next day. I expected a worse job than getting to smell pounds of landfill, but it was interesting. At first, it was the person I was doing the job with who made it more interesting, Carrie.

Carrie didn't actually work at the landfill center, which makes sense because she doesn't smell like rotten eggs from working. Like me. My new job's smell isn't exactly something I'm proud of. Instead, Carrie smells like lavender, which is certainly better than rotten eggs. Carrie is testing an experiment at some high-tech company that does environmental biotechnology. At first, I was super confused about what environmental biotechnology was, but Carrie made things simpler. especially when she told me what it was, because looking into her eyes and zoning out the whole time really made my whole job better. After three days at my new job, Greg scrunched me up in his beefy arms and said Carrie was going to perform tests with fungi in our landfill.

I laughed out loud. "Who needs fungi? Our landfill is already smelly!".

My smile disappeared when I saw Carrie frowning at me. "Fungi is super useful to our environment and...

"Useful? Don't fungi kill thousands of humans each year? It's known as the killer of humans!"

"Fungi is definitely an important decomposer for the environment."

I was grinning widely. I just thought of a way I could prove I was right and get a girlfriend. "If you can prove fungi are useful to me through your experiment, then I, Phill Mark Gurdner, will pour landfill on my head."

Carrie raised an eyebrow. "If I lose?"

"You get to go on a date with me," I point to myself. "…this guy."

"Really?"

"Sounds like a win to me!"

"Sounds like something that will never happen.

Saying that, Carrie walked away.

I yelled after her, "I take that as a yes!".

I am totally going to win this, and when I do, I can prove fungi is useless and Carrie is useful to my love life. At the end of this, one thing everyone will know for sure is that I am a genius.

I am so screwed. I read more about environmental biotechnology, and apparently fungi can help decompose landfills. I walked in on Carrie pouring in fungi in my landfill load this morning, and I laughed at her actions. I walked away so smugly, thinking Carrie is doing anything to lose; it is obvious she wants that date as bad as I do. It's okay, Carrie; your efforts to pretend you're trying not to go on a date with me won't fool me, but I'll pretend for you. I was so foolish, muttering "Carrie will care for me", "Carrie will carry my feelings," and useless affirmations. I would win Carrie's heart when I won the competition. Now I am sitting here in front of my computer, realizing Carrie was right all along.

After 4 weeks, I dumped 2 pounds of landfill on my head. Carrie was the one laughing this time. Greg called me into his office and yelled at

me, telling me to take a shower. I walked out of his office, dragging my feet in embarrassment, looking up to see Carrie reading a newspaper in Greg's waiting chairs.

Carrie puts the newspaper down on a wooden table next to her and walks towards me.

"Did you get fired?"

I attempt a smile, but I know I'm grimacing at this lavender-smelling lady. "You wish."

Carrie smiles and hugs me. It may be because she pities me, but she hugged a smelly egghead like me!

Carrie steps back and smirks when she sees my face, gleaming more than someone covered in landfill should be.

Then Carrie makes a face. "You should shower."

I grin. "No, you should."

"I already did this morning."

"Not in the water."

Carrie is confused. Wha-?"

I hug her back, engrossing her lavender scent in fish grease. She yelps but doesn't shove me away.

I pull back. "Better?"

Carrie grabs her newspaper and whacks me lightly on the head. I opened my mouth, surprised. Carrie takes in the look on my face and walks away. As she places the newspaper on the table, she mutters under her breath with a smile, "Much better."

After that, I saw Carrie as someone I could hang out with and reduced my obsession with her and her lavender scent. Just to be clear, my heart still beats faster when I'm around her and her fungi project. It turns out the fungi really helped the buildup in the landfills, and it really helped me and Carrie's connection grow.

The next day, Carrie breaks the news that she's leaving in a few weeks. By saying this, she breaks my heart as well. I know it sounds cliche, but I never had so much fun with someone I knew all along was way higher than people who would hang out with me. I could only land a landfill job because nobody else would want me for their college or job. I talked with Carrie not only about fungus but also about how even my mom sees me as a failure. I also told Carrie parts of myself I didn't realize, like how I had a new-found curiosity for environmental biotechnology that used to only spark when I was a little kid.

Carrie takes in my slumped posture. "I can't guarantee a successful future, but if you're really interested in environmental biotechnology, I can teach you more about it."

If you told me when I started this job, I would actually jump up and holler with joy. When I could learn a science-related topic from a brilliant scientist, I would have thought you had a fungus infection. Now I'm comfortably hugging Carrie, realizing I should just admit we are platonic, and I'm sure she feels the same.

The next few weeks are loaded with information about environmental biotechnology and how much more useful it is than just fungi decomposing landfills. I was seriously thrilled when I learned more in depth about how the study of this topic allowed people to create new ways to care for the environment. I used to think bacteria and fungi were merely negative factors of the environment and were out to destroy humans, but I realized they could break down soil, nutrients, and decompose landfills.

Finally, it was time for Carrie to leave, and she invited me to her home to talk about it.

We both cried, and I definitely left snot on her shoulder when I was sobbing. Carrie and I hugged for the last time, and she whispered in my ear, "Before I go, I want you to do something for me."

I sniffled and nodded as Carrie pulled out her computer and pointed at the screen. I gasped and saw Carrie pointing at an internship at the company she works at.

I looked at Carrie, then at the screen. "Carrie! Is this a joke? I work at a landfill; they would never hire me as a paid intern!".

Carrie smiled and looked straight at me. "Phill Mark Gurdner, you have ambition and passion for environmental biotechnology and the wonders it can do. That is all the company wants, and I may have dropped a recommendation."

I grinned at her but slowly shook my head. "No, Carrie. This is too good; your company would never accept a man who works at a landfill based on a recommendation."

"I think you're underestimating my power."

"I think you're overestimating how easy it is to achieve your dreams."

"I did; you can too."

"I'm not you; I'll never be as great as you."

"It's true you can't," Carrie said softly. "But I believe in you."

I attempt to laugh, but it comes out as a cough. "The last time someone believed in me, I became a landfill worker."

"Since you worked in the landfill, you met me, so I am glad that they believed in you."

"They didn't exactly believe in me, so I could be paid for managing fungi in landfills."

Carrie took my warm hands and held them in hers. "I believe in you now, and if you ask for an internship and get it, I will go on a date with you."

I squeeze Carrie's hands lightly. I can't get ahead of myself, no matter how excited I was to hear Carrie say that. "If I fail to get the internship…"

Carrie squeezes back. "If you fail to get the internship, I, Carrie Faith Ruthford, will dump landfill on my head."

I burst out laughing. "I'm going to go home and submit that internship application."

After getting up and grabbing my coat and heading to her front door, I hear Carrie yell from her room, "I'll take that as a yes!".

I smile as I close her house door behind me and walk into the endless abyss of the night.

"I got in!" I screamed at Carrie over the phone. Carrie immediately drove to my house, and my mother was shocked to find a stunning lady in a lavender gown standing on her doorstep.

My mother hollers, "Phill, a lovely woman wants to speak with you!"

I dash to the door and find Carrie sheepishly smiling, looking at me with my jaw dropped open.

My mother leans into me and loudly whispers, "Phill, did you bribe this sweet young lady?"

Carrie giggles as I feel a warm flush filling my cheeks. "No, mom."

I step out of the doorway, and my mom squints at both of us as she slowly shuts the door.

Carrie looks at me directly, and I feel my face burning. "You look stunning."

Carrie grins. "It's hard to beat the polka-dot pajamas you're wearing."

"Look, Carrie, you don't have to do this if you don't want to. We can go as friends to a theme park or something."

"What if I want to?"

I freeze. "What?'

Carrie looks away. "What if I want to?"

I smile, feeling what could only be described as a teenager in love. "Then I would love to go on a date with you, Carrie Faith Ruthford."

Carrie looks right into my eyes, and I notice tiny gold flecks in them. "It's still going to be at a theme park, right?"

I take Carrie's hand and lead her to my car, manifesting the cliche television dialogue I binged. "I wouldn't have it anywhere else."

A day at work

Sonia Heaven, Charles Banks & Sigrid Kusch-Brandt, United Kingdom

Ruefully he decided against taking a break. Going out of the room involved washing, stripping off an outer layer of protective clothing - overalls, safety specs, disposable gloves and gauntlets, and the flimsy blue plastic shoe-covers - then washing again, just for a quick cup of tea or a comfort break. There was a small kitchen area outside the lab, with a kettle and a microwave: but on days when he was processing waste he tried not to drink a lot, to avoid going through the whole routine too often. And on food waste days he didn't really want to eat anything because, despite all the clothing and the thin surgical gloves, a faint aroma still clung to hands and hair.

The level of protection required always seemed a bit strange to him: after all, a few hours ago the material could have been stored in a kitchen waste caddy, or still part of someone's dinner. Tea bags and orange peel never felt very threatening; other items were probably just at their best-before date, and nothing actually wrong with them. But pathogens could also be present, in a week-old chicken carcass or pet litter dumped in the wrong bin; so he accepted that precautions were needed.

The new lab was designed to Category 2 microbiology status, with swipe-card entry, handwashing protocols and lab-coats to be worn at all times. It was so much better than the old building, where wastes had to be processed in a room intended for testing materials like sand and gravel - not wet, messy organics! They'd had to haul heavy containers up concrete steps and around awkward corners; and cleaning up had always been a nightmare. Here, a roller-type door on the ground floor led directly into a small lobby with a service lift. The

prep room itself had washable walls and a big floor drain, making it easy to hose everything down at the end of the day.

Today he'd got up early to collect material from the waste transfer station. The battered old departmental vehicle was already booked out on another job, so he'd driven a smart new hire van: no sat nav, but a much better radio. A quick stop-off at a layby cafe for a hot bacon-and-egg sandwich; then a long dull stretch of motorway, with rain scudding across the carriageway and a fog of spray from passing lorries. Then onto smaller roads, through a congested town centre and finally out to the industrial estate. The site had a red-and-white carpark-style barrier, and when he stopped to hand over the paperwork he half-recognised the man on duty. And what paperwork! Personal ID, detailed risk assessment, waste transfer documents, waste carrier exemption - all of it agreed in advance by email, then carried with him and checked on the day.

The waste was transported inside large blue plastic barrels sealed with a steel locking ring: he'd collected them from the compound the night before and added the necessary safety and hazard labels. First he had to shovel waste into heavy-duty plastic sacks, then put these into the barrels. The barrels could only be half-filled, as the van had no tail lift and they had to be loaded on by hand. Occasionally the site operators would help; but today like everywhere else they seemed to be short-staffed. Then the tools were washed and bagged up, everything secured in place with rope and elastic clips, and after a wash and change he was off on the return journey.

He got back to a quiet lab, with just a few people doing essential weekend tasks. The Technical Staff were so helpful; but he usually tried to do this part of the job outside normal hours, to avoid nuisance or odours. He remembered a former colleague, a Mechanical Engineer with a sensitive nose, who objected to any faint residue detectable next day in the poorly-ventilated old building. The engineer in question, however, never seemed to worry about the noise and vibration from

his own experimental rigs, a constant drumming that got on everyone's nerves.

Surprisingly, if you needed help to sort waste and remove contaminants, there were always willing volunteers and an air of good-humoured camaraderie: but today the quality of the material was excellent, and he knew he could get it done by himself. Large bones, and big seeds like avocado and mango pits, had to be taken out by hand. The lab processing equipment wasn't strong enough to deal with them - unlike the heavy-duty kit he'd seen at waste plants, which could probably chop up a sofa, or a body. He also removed and categorised miscellaneous items - yoghurt pots, plastic bags and film wrapping, a couple of ring-pull can lids. He wondered why people threw yoghurt pots into a food waste bin, then remembered an anecdote from a local Household Waste Site. The staff had seen someone trying to throw a carpet into the Green Waste skip: when intercepted, the carpet owner replied indignantly "Well, it's green, isn't it?".

On another visit to a full-scale food waste digester, the operator told him that when the tank was emptied after several years, they were surprised how much broken crockery and cutlery they found at the bottom... In the lab, it was mostly bits of eggshell.

He finished categorising the unwanted materials, photographed and weighed them, then wrapped them and put them in the bin. Ready to move on to the next job, of grinding up the remaining waste. He remembered once helping a keen but inexperienced research student who wanted to process 500 litres of cattle slurry, and what happened when the material - much more liquid than food waste - shot through the powerful grinder, and straight out the other side at high speed... Food waste, on the other hand, turned into an odd pinkish paste with a consistency like slightly grainy toothpaste. Most people were surprised when they first saw it, but when you thought about it there was a lot of water in most food items.

Outside the prep room was a lab full of gleaming analytical equipment designed to assess properties that would determine the food waste's value and performance. Flavour, colour, scent and presentation were definitely not included - but while he didn't mind watching cookery programmes with his girlfriend, decorated-plate meals were a pet hate. One of the basic lab tests he'd carry out later would be to measure the solids content, by drying a sample in an oven overnight: oddly enough, although the drying room was fully ventilated, people often commented that the smell when food waste came out of the oven was quite attractive, like savoury bread or scones.

Curious colleagues would ask about variability in the waste, season by season or in different locations. It was true that components varied even around Europe - diligent researchers picking through waste from Finland had reported awesome quantities of coffee grounds in winter, presumably to counteract the long, dark nights. And if a local supermarket had a special offer on corn-on-the-cob, you could see the results coming through in the waste collection a week or two later. That was one reason he collected large amounts in one go, to smooth out any minor variations. But the scientific properties were almost the same in each case: all humans basically needed a similar mix of proteins, lipids, carbohydrates.

Some places collected paper and cardboard with the kitchen waste: but while that might solve the tricky question of what to do with a cheese-and-tomato coated pizza box, it also meant higher levels of contamination. Cities that took mixed waste and then tried to separate the organic parts mechanically could end up with a low-value residue that no-one wanted, full of glass and plastic fragments; although nowadays, innovative companies were finding new ways to deal with such mixtures. He had read that the amount of food waste households produced actually dropped if a separate collection scheme was introduced: probably because people started to realise just how much food they were throwing away. So that was already a benefit...

Routinely he'd test a few grams of the waste in little bioreactors designed to measure its bioenergy potential. But this batch was going to the 100-L digesters that were used to optimise biogas production, or to troubleshoot problems for industry: they required feeding every day for months on end, thus the need to process large quantities of waste on one day. He smiled as he remembered the email he'd received yesterday, about a recently accepted journal paper on his last experimental study: the publisher had thoughtfully provided an image to go with it, which showed a human stomach and some gastroenterology details - oops, wrong kind of digestion!

After passing everything through the grinder, the next step was to get the now-homogenised feed into containers for storage. Today he was using big plastic tubs with bright pink lids and handles, originally the packaging for an expensive brand of pet food: remember research budgets are always tight, don't buy anything if you can recycle it! Then the final task, to get it all into the freezer and clean up. For his own research he would take out one container at a time, thaw it in the fridge and feed each bioreactor with a few hundred grams a day. He loaded the full containers onto the battered flat-bed trolley and wheeled it into the walk-in freezer room: so much more hygienic and energy-efficient than the beaten-up chest freezers in the old building, none of which ever seemed a good fit for any size of container.

He washed up and left the lab, dropped the van keys in the Technicians' office, then ran downstairs and swiped out of the main door, stepping outside into the cool wet fresh air. Evenings were drawing in now, the streetlights already shining on wet leaves and glistening pavements. He began the short walk to the bus stop, looking forward to home and a hot shower followed by an evening of TV and pizza. As the bus approached, he noticed it was one of the new biomethane-powered fleet - maybe even using biogas from the local food waste collection.

Behind him in the building, the lights on the fourth floor and in the stairwell turned off automatically. But the working day was far from over.

In the darkness of the lab, the real task was continuing: a million, million microbes chewing toothlessly on food waste. Turning it into bioenergy and nutrients, working around the clock for us, to help bring about a circular economy and a more sustainable future...

Cake and compost

Sharon Godiff, United Kingdom

"Boys, boys. Eat your breakfast, hurry up we're going to be late."

I quickly assemble cream cheese sandwiches and begin to fill their lunch boxes with the last two cartons of juice, and in desperation for a sweet treat I peel and share a dry satsuma and a handful of coco pops and divide between two snack bags.

"Coco Pops for afters?" enquires Charlie.

"Yes" I smile. "All your friends would have them if they could."

Satisfied with my explanation he continues eating the remains of his breakfast Coco Pops. Good job, they like them, and they are fortified with vitamins, I think smirking. The barking of the dog heralds the clack of the letter box, which fills me with dread. Bills and final demands, sickness and worry arrive through the door daily. Scanning the handful of envelopes, I decide they can all wait till later, as the boys are tearing around still not dressed. When eventually we're all ready and about to leave, an evil stench emanates from the rear end of my little Princess, and it cannot be ignored. I sigh knowing I'll have to change her, and we'll be late again.

Walking back, Tula trots obediently beside me, the lead attached to the handle of the buggy. Grace, clean and fragrant for the time being, is anything but graceful as her name suggests, as she sprawls dangling, her legs over either side and I can see her favourite smiling frog wellies bobbing. I push her along deep in thought. Charlies' teacher had pulled me to one side when I dropped them off. Smiling kindly "is everything alright" she enquired. Then, still smiling but in a concerned tone, she told me Charlie's having difficulty concentrating in class; and as she'd noticed that recently we're frequently late, she wondered if there was

anything wrong. She was right of course, but after another poor night's sleep I wanted to scream: "Actually, Miss Pilling, my husband walked out 2 weeks ago! He's spending money from our account like water, and I don't have enough food in the cupboards to feed the 3 kids never mind the dog, and the mortgage is due next week."

I didn't of course. I thanked her for bringing it to my attention, said I'd have a chat with him after school and I'd let her know. Well, at least Sam seems okay? He ran into school with his best friend Jessica.

Just then the autumn sun makes a rare appearance and, although significantly diluted, its warm glow on my chilled cheeks has strength enough to darken the reactive lenses in my glasses. Then Grace starts singing and my mood elevates. So, I take her and Tula across to the park, and watch their joy as they run and play in the crisp golden leaves that lie on the ground, her squeals of glee encouraging Tula to yap and jump excitedly, which in turn makes Grace giggle and squeal more. A simple pleasure for us all, which is a blessing. I sit on a bench in the bright sunshine, smiling at my happy child and little dog. I have hope. Not that he will return to me and his children, because this time I wouldn't have him back, this time is different. This time I'm not pregnant, weak, or stupid believing his lies, this time I'm angry. My hope is that we will be okay and much happier without him. Because this time he's not having his fun then worming his way back into our lives.

I let her play a little longer whilst I reread an email. Yesterday I'd cried when I'd received notification that we'd got to the top of the list for an allotment. Believing I couldn't manage that and everything else alone. But I do manage, each time he disappears for days or weeks I manage. And being a responsible semi-self-sufficient family and getting the kids involved had been my dream. Pete was never part of that, it was my idea to ensure the kids were environmentally aware. Feeling uplifted and determined, I get up off the bench and join in with the fun, throwing the leaves high in the air. Then to my surprise

one of the brown leaves is rectangular and plastic and it flutters into my hand and turns out to be a tenner, and it is my turn to squeal with delight at my literal windfall.

Back home I put the £10 safe under the clock. Searching through the meagre contents of the fridge-freezer and cupboards, I conjure up another substantial meal. I've become an expert and soon the ripe veg drawer and a can of baked beans are blended, creating a tasty, thick warming soup for lunch; and there will be plenty for the hungry boys when they get home too, supplemented with cheese toasties. Whilst stirring the pan, I smile in anticipation imagining the fragrant bunches of fresh vegetables and herbs I'll be harvesting from our own allotment.

Grace, with her tummy full, naps with Tula snuggled beside her. I tidy up, then make coffee and sit in the comfy chair next to the oven, which is warming up as I intend to make scones for after tea and for their lunch boxes. I pick up the pile of letters, trying to decide which ones will upset me least, I ignore the brown envelopes, they're always bad news, and open a white one. It's the bank statement! I feel sick, as the balance is well into the overdraft. In desperation but still strong I ring Pete: his phone is switched off. I compose another text.

"Pete what the hell is going on! I don't care who you're with this time. But I have no money to feed the kids, pay bills or put petrol in the car, and what about the mortgage?"

Surprisingly later that night, I get a reply.

"I need to sort stuff. You've got it all wrong, you know I love you. I just need some space. If you're desperate ask your parents for help. Tell the kids I love them." Incensed, I called his number, he'd turned it off again. The coward!

Later that week, I'm relieved to find money has been paid into the account, and the mortgage is paid. Not having that debt is a huge weight off my shoulders.

Another week has passed and it's half term. As I can now afford the petrol, the kids are off to my parents' house at the seaside.

"It's been ages since we've stayed with Nana and Grandad" says Sam who's 5, whilst packing his stuff into his beloved Thomas the Tank bag. "Grandad always plays football with me."

Charlie, who at 8 has chosen his camouflaged backpack, says teasingly, "I hope Nana makes a big chocolate cake, just for me, because I'm her favourite."

Sam falls for it and whines "I want chocolate cake; she likes me and Gracie too." Grace is oblivious. She has a small, pink plastic shopping trolley and is busy filling it with cars, books, and a teddy.

Thankfully, I'm not staying the weekend, Tula is my escape as mum doesn't like dogs in the house.

Exhausted, but full of mum's cottage pie, I wave goodbye to them all. Sighing with relief as they disappear from the rear-view mirror. I'll miss them but I know they'll have a great time and I really need a break. During the two-hour drive home alone, I replay the shocked reactions of my parents, when I told them. "Pete left weeks ago, and I don't know where he is"; and how I crumbled shamefully confessing it's not the first time and he's usually with another woman. I feel utterly pathetic for putting up with him for so long, I had willingly succumbed to mum's smothering embrace. And remembering my dad's stunned expression as he whispered, "The bastard", I dissolve into tears again knowing he never swears. Then I start ranting about what I'll say to Pete when I eventually get the opportunity.

Considering my emotional state, I arrive home safely and take Tula for a well- deserved walk. The next morning, I boil a ham shank, making pea and ham soup. There's also enough for sandwiches. I leave Tula with the ham bone, whilst I go for my first look at the allotment. It's freezing cold but my spirits soar when I see the plot. It's full of weeds, but a good size and there's a really nice shed with a window there.

It's raining heavily when I walk back through town to visit the new shop called 'The Pantry.' Basically, you pay a couple of quid to join, it sells short dated or damaged produce at a fraction of the price, reducing waste and landfill. It's a great idea.

Last week the mums from school had been talking about it at the gate. Today is the opening and I can see some of them inside. As I enter all chatting stops, or was that my imagination? Stella, Jessica's mum rushes over all smiles and gushes "Sally, look at this bread mix twenty-five pence, you're only allowed two, but the bakery stuff is free today, so I'll pop them away till next week." The floor is stacked with trays of assorted loaves, and other baked goods. I fill my basket, along with wilted veg, and an assortment of cans with ripped or missing labels, bashed and dented, their contents are a mystery and I smile knowing the kids will love the fun of picking one and discovering what's for tea. Paying with the windfall tenner, I'm amazed the total spend is only £3:75. Staggering out with our bags we giggle.

Stella suggests we go for a coffee, then seeing my hesitation adds "it's my treat". Embarrassed I don't argue, we find a table and chat about baking. Excitedly I mention the allotment and promise her some homegrown produce.

Curiously she doesn't mention Pete, but I'm getting the impression that she and the others already know about my situation - or am I just paranoid?

The next day I'm feeling much more positive, I'd slept well, and the rain's stopped.

Me and Tula set off for our first day digging.

The Allotmentiers are a thoroughly decent bunch. Everyone chats, some bring me, seeds, cuttings, weed killer, fertilizer, slug pellets. Even a stool and an oil lamp for my shed. I work hard all afternoon and am rewarded with a clear six-foot rectangle of soil. I'm tidying up when Stella appears.

"Hi, thought I'd find you here, it looks great" she smiles "I've made a flask of coffee and a quiche from those short-dated eggs and stuff we got yesterday. In fact, I made three" she says smugly.

In the shed, Tula's fast asleep on some old potato sacks, she sniffs at the quiche as I unwrap it, so I give her a biscuit and she settles back down. I light the oil lamp, which fills the shed with a warm glow. We share a cuppa from Stella's flask, she sits on the stool, and I move the box of weed killer with its ominous skull and crossbones and perch on the window ledge.

"It's so cosy" she smiles. Before blurting out, "I know Pete's left you and the kids". She looks uncomfortable, continuing "My friend knows who he's living with" she waits for my reaction, I don't say anything, so she goes again. "Do you want to know?"

I stare blankly not knowing the answer myself.

In the morning I ring mum and dad and chat to the kids. All are having a great time, and the kids ask if they can stay longer to go through the illuminations. I feign reluctance "Erm, okay but only a couple of days." They all cheer.

So, I have another couple of days and nights to sort things out. Determined to do what's right for the kids and myself. I send a simple message.

"Pete, we need to meet up."

Then I get back to work on the allotment.

The night before I collect the kids, I invite Stella for tea, to thank her. She's been so supportive, encouraging me to make appointments to discuss benefits and entitlements and has even helped me to budget. We sit around the kitchen table and tuck into a delicious sausage casserole, cauliflower cheese and a grown-up pudding, Tart Tatin. All made with the produce from The Pantry and contributions from the Allotmentiers. Stella has brought a nice bottle of wine.

"You could make meals and cakes from the stuff off your allotment and see if The Pantry would sell them" she says, spooning more rich sticky pudding into her bowl. "Make money whilst you're still saving the planet". We both laugh, but she's right - I could. Then she changes the mood, asking solemnly.

"Did you go and see Pete?"

I shake my head "I thought about it but I'm not ready yet. Thanks for telling me where he is, and I will go and confront him, soon". I take another sip of my wine. "Well, you may have missed your chance, my friend says he's moved on!". "What, where's he gone?!" I shriek.

"Apparently a couple of days ago he told her he was going to sort things out so they could get married. He borrowed money and her car. Guess what? He didn't come back. She found the car the next day at the train station." Pausing to take another gulp of wine she slurs.

"My friend Angie said her friend was shocked: she thought he was serious about them, but then he sent her a text saying 'Thanks for everything but I'm moving away for a new start. Sorry."

"Ha! I wouldn't put it past him, to have two on the go at the same time. Well, good riddance. I hope I never see him again." I say shakily.

Oblivious she persists "I know I said to Angie, if he'll leave his wife and 3 kids, he'll leave her once he's spent her money, and I was right!"

Picking up the wine bottle I find it empty. "I need to make us some allotment wine" I giggle. "Let's have a coffee, you go into the lounge" I suggest.

As she leaves the kitchen a little unsteadily. I turn to catch my breath stifling a sob, leaning against the work top, shoulders hunched. I fight to regain my composure.

Then I carry in the tray heavy with homemade cookies, cheese straws, the cafetiere and a little jug of cream.

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Thanks to mum and dad, Christmas is good. We have a delicious dinner, and the kids want for nothing. Only Charlie mentions his dad once, saying "I hope he's got us some nice presents when he comes back", then disappears into his room with his game station, whilst the other two play happily together.

Mum whispers passing me another mince pie.

"You must never be short of anything darling, me and your dad will always support you. The kids are better off without him and so are you."

I nod thoughtfully.

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Spring sees the allotment come to life, the kids love spending time here and each of them has their own patch. Today we're having a 4th birthday party for Grace. Stella and her children help transform the shed with balloons and bunting. My parents arrive with folding chairs.

There's music, party games, hotdogs, a homemade birthday cake and the weather's amazing.

Colin and Jean appear from the next plot. Whenever I need to borrow a tool or have a problem, they come to my rescue. They've brought Grace seeds and a cute little gardening set.

"All your hard work has paid off, your soil wasn't great, but you've got results" Colin nods at the abundance of sprouting greenery.

Feeling very proud I answer "Yes, I added Peat as you suggested." I'm horrified at my unintentional confession.

Then Jean chips in with an air of finality "Well that's the end of Peat"

I look vacant. Do they all know I've poisoned my cheating husband and buried him under the cabbages? Feeling faint I struggle to regain self-control "What do you mean?"

"Peat, next year it's banned, it has a negative impact on the environment, we need an alternative." she says, all serious.

I'm so relieved and stunned for a second. Then my dad starts a discussion about the degeneration of peat bogs releasing carbon dioxide and what alternatives there are. "I've read about it in the paper, an anaerobic digester is what you need, and you can use lamb's wool to hold the moisture in the soil."

I think they're a bit taken aback by my sudden high pitch laughter, and my over enthusiastic nodding. "Yes, yes, of course" I say joining in. "Lamb's wool, that'll do the trick" whilst hugging my wonderful dad. Then I offer everyone more cake and give Tula a nice bone.

What any fool can do

Vienna O'Shea, United Kingdom

The flight landed at a run-down airport that managed to appear both frozen and dusty at the same time. Only a few passengers disembarked from the small plane. A new jeep, shiny with chrome, was waiting to take him on the long drive to site. Although the road was made up its surface was rutted, limiting the vehicle's speed; but the driver seemed steady and serious. The oil company provided good wages and training, and other jobs would be hard to come by here. Occasional headlights threaded the route in the opposite direction, but there was hardly any traffic. Despite the midwinter season little snow lay on the ground: any type of precipitation was rare in this region, and what fell now would be carried away by the shrieking winds across a thousand kilometres of open tundra.

He reached the camp a couple of hours later, as evening darkness thickened into night. A young man showed him into the guest accommodation - like everything else on site, it looked like a portacabin, but was well insulated and comfortable inside. After a quick shower he joined his hosts in the canteen. The food was excellent: not just tasty, but high-class restaurant quality. "You'd soon get complaints if you started to serve mush here - people work six weeks on, and there isn't much else to look forward to at the end of the day". He was invited to watch this evening's screening of a classic cowboy film, but politely declined in favour of sleep. He was probably getting too old for this type of visit: yet there was always something fascinating about troubleshooting real problems. And it might mean more funding for his team, and a chance to test out their new bioremediation technology on a real site.

Next morning started early, with meetings on the proposed bioremediation strategy. He briefly summarised what they had already heard, trying to emphasise the potential of this innovative approach. His hosts were courteous, but perhaps deliberately bland and non-committal. People left and rejoined the meeting as urgent business came up elsewhere.

At 10:30 coffee and biscuits were brought in - hardly needed, after a full breakfast just a few hours ago. Then they moved out to inspect the damaged area of the site.

The process of suiting up for the visit was at once familiar and not. All sites had safety protocols and protective equipment, and from his experience there would be a strict routine and route: no-one was going to let you wander unescorted around a live production facility. But in this case there was the added factor of the outside temperature. Without proper clothing, survival times in that harsh cold would not be long: so the boiler suits were heavily insulated, with deep fur-edging on the hoods, and the outfit included thermal boots. All of the clothing was bright scarlet, to increase the chances of a rescue team finding people quickly if they were injured, or became disorientated and wandered off in a rare blizzard. By the time they were suited up, he looked and felt like a giant version of one of his grand-daughter's beloved puffy toys...

The damaged area was pretty much as he'd expected. Many years previously a plume of gas and oil had sprayed out, contaminating the sandy soil. The challenge was in the extremely dry and cold conditions: although it was decades ago, the surface still looked like a piece of moonscape within that already-barren land. Remediation was required under the updated site licence, and he could see this would be a perfect test ground for the new techniques his team was pioneering.

The tour didn't include the main production site, but he'd seen the promotional video and had visited plenty like it before. They called in briefly at the laboratory block, another set of portacabins housing state-of-the-art equipment for soils testing. That could be useful, if they got the bioremediation contract. On the way back, a small debate sprang up between his guides. One asked if he would like to see the wastewater treatment plant; another said what for, and anyway it would make them late for lunch. An expression of interest on his part was enough to settle it. As a young engineer he'd started in wastewater treatment, and had only moved on to soil bioremediation later in his career. And after all, the second guide assured him, there were always chefs on duty to rustle up a cordon bleu snack for staff and visitors. He wondered a little at the things needed to motivate us, out in this vast, austere wilderness.

The wastewater plant only took domestic sewage, but the camp was the size of a small town, and another condition for working in this territory was to provide on-site treatment of any wastes before removal. It looked like a fairly standard package plant, a large olive-green tank with flanged steel pipes weaving in and out of it, though the manufacturer's name was unfamiliar. The wastewater would first enter a primary sedimentation chamber for solids to settle out in the quiescent conditions; then to another chamber for secondary biological treatment; then into a secondary sedimentation tank to recover the microbial biomass and discharge clarified water. After that, the operator told him, the flow passed on to a sand filter and a chlorination unit before testing and discharge to a storage pond. In a dry region like this, it seemed a pity not to re-use the treated water for irrigation somewhere on site: but maybe that could become part of the soil bioremediation project.

Standing on top of the package plant, the main production site looked like a charcoal drawing, the tall gantries and pipework silver-grey against the snow-coloured sky. He asked the operator how the treatment process was performing. "Not too well - I've tried adjusting things on the package plant, but we aren't meeting our standards and it puts all the downstream units out. I've told them we may need to buy a new one". Ordering a new plant seemed a drastic solution: the manufacturer's price would be nothing for an oil company, but the cost of shipping, customs clearance, storage and transport to this remote area would soon add up. It was worth asking more questions.

The operator showed him where flow from the accommodation blocks, kitchens, and on-site showers and toilets entered a pump well, then was lifted up to the package plant by a submersible pump. The original pump had been replaced before he'd been given the job of running the plant, but the only way he could make things work was to let the pump well fill and allow wastewater to back up through the sewer system, then run the pump in a 10-minute burst. The backing up didn't seem to be a problem: there was almost a kilometre of sewer pipe back to the site, with plenty of storage capacity.

He asked the operator how often the pump was switched on. "Oh, once a day - that's enough to empty the sewers". Once a day? Together they looked at the pump rating, then he asked a few more questions - about the size of the sewer pipe, and the number of people on site. The package plant was a sealed unit, and he declined an eager offer to find spanners for the bolts on the inspection hatch: but the two of them lifted the lid off the sand filter, which appeared curiously empty of sand. The others, standing on top of the package plant in the sharp wind, looked bored and cold. He thanked the operator and they returned to the warm office block.

Next day in the briefing room he outlined what he had learned from the site visit. Testing would be needed to identify the best process parameters and micro-organisms to carry out the bioremediation: an expensive option, but still far less costly than transporting soil a thousand kilometres for treatment elsewhere. He remembered one of his university lecturers saying, "An Engineer is someone who can do for one dollar what any fool can do for two". At the time he was young and idealistic, wanting to save the planet, and this definition hadn't pleased him. But the older he got, the more truth he felt there was in it, and he was tempted to re-cast it for the 21st century. Because $1 (or €, £, ¥ or whatever) was simply a measure of resource; and if you could do something with half the resources then the other half would be left to tackle another problem...

Questions on the bioremediation proposal were beginning to wind down. After a brief pause he added, "And I can fix your wastewater plant". The audience stirred slightly: some senior managers probably hadn't realised there was a problem, or that he knew about it. But they seemed prepared to listen.

"You are planning to bring in a new package plant which will probably cost upwards of a quarter of a million, all told. But this is how the plant is being operated at present". He briefly outlined the problem: the total flow was passing through in a matter of minutes, with no chance for anything to settle; and the beneficial micro-organisms were simply being washed out of the system. "It's not just a mechanical process - the microbes are at the heart of it, and the whole biological treatment depends entirely on them". He stopped for breath, and to let that sink in. "And on top of that, your sand filter isn't working properly as all the sand has been washed away. So when you take samples from the outlet and send them off for analysis, you are pretty well seeing what went into the plant, without any treatment having occurred at all".

He paused again, this time for effect. "All you actually need to do, is buy a smaller pump. That way the flow rate will match the tank size and the biology can get on and do its work".

There was a moment of silence while they considered it, then a voice piped up: "What about the sand filter? Doesn't it need specially graded sand and...?". He almost snorted: someone had obviously learned something about wastewater treatment at college, but wasn't thinking. "What about those sieves in your geotechnical labs? Don't waste thousands shipping the right grade of sand here - this place is practically a desert. Just use the equipment you have to grade your own".

He drew another breath. "And while you are at it, the guy who runs the treatment plant seems to have some common sense: why not give him some training on how biological wastewater treatment really works? A bit of kit in the corner of the Geotechnical lab and he can do basic tests here on site. You'll save time and money on flying routine samples hundreds of miles to the nearest lab, and get answers back much more quickly. If he's any good, he may even be able to help with the bioremediation monitoring".

The meeting broke up, after a few more technical questions on the bioremediation concept. A quick lunch, with some warm but desultory conversation on everyday topics. He thanked his hosts, who thanked him: then the jeep was ready to take him back to the little airport - another vehicle, another driver, the same long featureless road. He caught the plane with just the right amount of time to pass through security, and on arrival at the main airport transferred to the international section. An hour or so in the large, dimly-lit departure lounge writing up his notes, then soon after the jet was climbing away with the lights of the snow-bound city twinkling below him. He slept.

Next afternoon in the office, an email popped into the inbox. It thanked him for his time, hoped he had found the visit useful - and requested that his team proceed with submitting the detailed proposal and full costing for a trial of the new bioremediation technique. A final sentence said, "We are also grateful for your useful comments on the site's wastewater treatment facility, and will be adopting your proposed solution". He smiled, and it was the smile of a satisfied professional.

Sorrows in the sediments

Dolly Joy O. Ogatis, the Republic of the Philippines

I have heard many stories about the world we cannot see. A world elusive, unforgiving, but beautiful nonetheless. A flawless replica of our own. Only that its inhabitants are much smaller, molecular, and smarter.

"Amanda, I'm sorry for your loss." I stared blankly at the elderly woman who spoke. Words tangled up in my tongue. I don't know how to respond to her. My eyes built a mind of their own that my tears trickled; unstoppable. I can no longer feel my body until someone pulled me into a tight embrace. Only then I freed my sobs to life, rocking my body against someone else's.

Sorrows have become a fundamental part of my life. Loss and isolation have only added insult to injury. Should I ask for more?

I lost my mother that morning from the flood. And her body is still unfound. I am the survivor, they said. Or, that is what they wanted me to believe.

"We know it is hard for you right now, but you need to come to the shelter with us. This area is destroyed. There's nothing much left for you to hold on to and stay here, dear." One of the community shepherds advised. They mean well, and I understand that. But this *area* is what I call home. It has been me and my mother's home.

"It must have been a great trauma for the girl." I hear another voice spoke as I clutch a worn-out bag where my clothes once were.

The coastal flood took lives that morning. From the evening before, the town officials had warned us about a storm from the Pacific. The night before the coastal flood, my mother and I tried to cover our home with salvaged tarps. We secured the chickens in their cages and made sure the nets and posts were sturdy enough to hold the ponds. We thought the storm would only pass by and all will be well the next morning. We thought wrong.

The town had suffered a great loss. The storm had crippled the community. Many families have lost their loved ones, including me. I cannot quite remember how I lost my mother that morning. My memory was fogged with …trauma. My brain refused to remember, and my heart refused to yield.

All I can recall and told the authorities was something that involved waves. Crashing waves. Muddy and strong. It destroyed everything in its wake. The authorities told us that the coastal flood was brought by the typhoon, but they did not tell us one thing. The mangroves are dying from oil spills, and the flash flood was the consequence. A lot of people do not know, but I do.

I stayed in the shelter just like everybody else. I let them drag me to the shelter like a tethered goat. News, filtered and unfiltered, flew by from one tongue to another as I huddled up in the corner and listened. I have heard of the devastating news of the mangrove forest near where we live. I have heard of some Teddy who went missing. That name rings a bell. I think I knew him from school. For the most part, I sulk. I could no longer cry or weep. I turned myself into a mute.

For the rest of the world, time did not pause. Months have passed and some families have found their dead. I never found mine. A few bodies were recovered near the estuary, greenbelts, and the coastline. Mostly dead.

I found myself staring at the lying carcasses that stretched to the horizon. I watched the rescuers huddle up dead bodies, placed them in dark bags and zipped them up. I must have been hallucinating for I could see souls floating near the corpses. Their sorrow echoing from beneath the coastal waters as if it was buried deep in the sediments.

While the rest of the world moved on, I saw myself moving backwards. I found my place taken under the wing of one of the caretakers of the mangrove forest, Aunt Luzviminda – a close relative. I refused to become a burden, so I worked as a mangrove forest ranger. I guard the post in the mangrove ranger station and, sometimes, I rove the mangrove forest by the pump boat.

I kept coming back to the forest, searching...

Peace and solace enveloped me as I cruised through the firth with only the sound of the incessant rotor and the birds chirping coming in one syncing chorale through the wind. Breeding birds took shelter within the mangrove roots. The marine life thrumming beneath them.

Life in the mangrove forest was nothing new. I grew up near the coastline and the greenbelts. My mother and I used to sell chickens and *tilapia*, grown from our own pond, for a living. Now all of that remained only as memories.

The sky was bleak, with clouds reckoning storm, but the coast hummed with a pretense calm day ahead. As I round up through the winding waterways, the sight of another boat came into view. Located only a few metres away, the boat looked bigger than mine, newer even.

A guy, donning a tawny drawstring hat, leans unfashionably over the boat to reach down to the waters with a vial in his hand. He drew up the vial filled of coastal waters. He did it again with a few more vials.

He must have been so engrossed with his work that he had not noticed the sound of another pump boat closing in.

From where I was, I could see him collecting the coastal waters like he was playing. He looks more like a frolicking child, rather than an adult doing serious work.

"Hey!" I called out and waved.

He had just finished closing up another vial as he spun around to see me. I waved again. "Do you need some help?" I asked out loud. I did not know the reason why I asked, but I asked.

Although he waved back, he turned around and went to secure the vial. His boat roared to life again and he drove towards where I was. A cordial smile took form on his mouth.

"Hi! I'm Mathew. Nice to meet you."

"Amanda." The distance between our boats was too wide for us to mind for a handshake. "Are you with the research team? Do you need some help?"

"Ah yes. I was with them a while ago, until I wandered out here. I might need some help going back to the coast." He grinned.

"Well, in that, I can surely help you."

I maneuvered my boat back to the path I took and tilted my head at Mathew; telling him to follow along. When we reached the estuary, I said, "The coastline was right over there. I guess you know your way back from the beach."

"Yes. Thank you," he said. I nodded politely and was ready to leave when he spoke again. "Uh, Amanda? I might need to take some more samples tomorrow, too. Maybe you could help me find better locations

in the forest. You seem like an expert at navigating the mangrove forest. I could really use some help."

"Sure. Tell me where to meet and what time."

Mathew looked around. "Here, at six in the morning. Would that be, okay?" "Absolutely. See you tomorrow, then."

The next morning came. I knew I was on time, but Mathew was already waiting at our rendezvous which made me ask, "Am I late?"

Mathew grinned, "No. I'm just earlier."

Mathew turned out to be a student researcher who was assisting his professor in a research collaboration. That means he was a bit older than me.

"We're taking environmental samples. Coastal waters, soil, sediments, samples from the roots of those *Rhizophora*, you name it. I take everything I can find," he said.

"All for what?" I asked.

"For research. We heard this community had suffered great losses due to a storm a year ago.

We're here to help."

"You think you can help us with your research?"

He closed the vial and heaved a sigh. "We conduct research to help. But sometimes, not all researches can yield favorable results, you know. What we're doing here is still without certainty. But that's what makes research even more exhilarating and interesting. If you know what you're doing then it's not called research, is it?" he paused. "Are you one of the survivors?" He asked in a rather careful tone.

I nodded. “What is your research about?”

“Well, we’re trying to study the unique microbiome of this ecosystem. Trying to fully understand the microbe-mangrove relationship and interaction so we could draw some conclusions on how to better take care of this ecosystem and the wide variety of life depending on it.”

I held his gaze on me. “Tell me more.”

“Well,” he cleared his throat. “This ecosystem protects the coastal life and the life in the terrains. The disaster that happened here a year ago is a clear sign that the mangrove forest is deteriorating due to the oil spill.” Mathew looked around to take in the greens and blues of our surroundings. Shortly, his eyes went back to me. “We need to save this place now more than ever.” “I see that you care a lot, even though you’re not from here.”

“I don’t have to live here to see nature’s worth, Amanda.”

“If your research will yield excellent results, what then?”

“We’ll use it for bioremediation. The level of oil spill here is decreasing now that we have deployed microorganisms that could metabolize oil. Another problem was how could we plant more mangroves annually. That’s why we’re trying to study the relationship between mangroves and its microbiome. See if we could find microorganisms that could promote better growth.”

“What kind of microorganisms are you after?”

“We're looking for certain endophytes which can be a source of bioactive compounds that promote plant health and growth. They’re collectively called PGPB.”

“PGPB? What does that mean?”

"Plant growth promoting bacteria," he answered. "We can use them for a more successful mangrove reforestation, hence mangrove conservation and rehabilitation. We're protecting the environment in our own little ways, with the help of our little, invisible friends. Hoping that what occurred a year ago won't happen again."

Recollection of events from a year ago stirred up. I drew in a strained breath as I force the treacherous tears back.

"Are you okay?" Mathew asked. Concern marred his eyes.

"I just remembered some things."

He was quick to ask, "Did I say something to trigger that?"

"Somehow," I croaked. "I lost my mother in that flood. The rescuers were never able to recover her body. I watched other dead bodies get rescued, recovered straight from the mud. Their families crouching over them, mourning. At least they had something to mourn on. At least they saw the ones they lost. I was never able to do that," I said. I looked at Mathew and for the first time in my life I saw genuine sympathy.

"I'm very sorry," he said in a quiet voice.

I shook my head, putting off the sorrows creeping in. "Our house was destroyed by the flood. It was located nearby. I kept coming back here more than I used to after the disaster. Perhaps because I kept looking for my missing piece. People tell me, I was supposed to go out there, move on, but I find myself limping my way back here."

"It was never easy to deal with loss." My lips witched with melancholy.

"Have you done anything else other than see the mangroves and cruise around the forest?" Mathew asked.

I shook my head.

"Why don't you come to the house tomorrow?" I frown at his suggestion.

"I can show you what we're working on. At least parts of it. Most of the work is back at the university. If you'd like, we can mess around with a few specimens or samples that we can retrieve here."

"Will that be okay?"

"Yeah. Professor Dianne is kind and she's out of town. Most of the team is out in the morning. Nothing to worry about, plus, you will be the one to take your own sample and view it under the microscope tomorrow. Sounds fun, no?"

For some reason, my heart thumped at the anticipation of tomorrow's excitement. It could have been the reason for my impulsive agreement to Mathew.

The next morning, we found ourselves a new rendezvous. The house was located at the west side of the shore. I docked my boat near the wooden boardwalk and trudged my way through white sands; Hermit crabs skittering beneath my feet. Mathew was waiting by the front door, hands shoved into his pockets. He opened the door for me and gestured inside.

"Welcome to our humble lab house," he said. "Here is your personally collected sample from yesterday," he said, handing out a vial to me. The house looked normal from the outside, yet it was completely different inside.

The living room was furnished with white benches replacing the typical chairs and sofas. Microscopes lined up the tabletops and some other dishes were sprawled over them. I ran my eyes over the scribblings on

the large whiteboard. They were not nonsensical scribblings. They were numbers, computations, and drawings coupled with arrows.

"I suppose the whiteboard is your TV replacement?" I quipped. Mathew chuckled.

"This place is amazing," I said.

"Uh-uh. Amazing things happen here too." He turned one microscope on and told me to come close. "Here, you place a drop of your sample in this glass slide, and we'll see what you've got."

I followed his instructions deliberately. He instructed me to cover the slide with a cover slip. It was this small, thin glass, I thought I would break it if I was not careful enough.

"You've got steady hands," he said. I took that as a compliment. "Hold that slide and clip that on this platform." I did what he said. Once clipped, he asked me to move to the opposite side of the microscope. I followed suit as Mathew placed his eyes on the binoculars at his side of the microscope. My eyes were awkwardly adjusting with the binoculars.

At first, all I could see is white. But Mathew was making a few adjustments with the lenses before an image morphed into its complete form.

"What is this?" I asked out loud.

"You mean, what are these?" When I removed my eyes from the binoculars, Mathew was grinning. He told me to return to my binoculars and started explaining what each weird moving form was. He told me the green ones were probably *cyanobacteria*. He mentioned some amoeba as well. He pointed out some algae and nematodes. A few scientific names were mentioned, but no longer was my attention

on his words. I was too fascinated at how much life a single drop of water could harbor.

"Come here, let me show you something more interesting."

He led me to another room. The weirdest room, with the weirdest bottles and equipment. "Those bottles are called Winogradsky Columns. We place them near the window to allow photosynthesis to occur inside the column and let our photosynthetic friends thrive."

"What are they for?"

"We use them as our source for microorganisms intended for enrichment culture. Those columns can last for months."

Mathew walked me through weirder but more fascinating stuff. I do not even know if calling them all as "stuff" justifies them. They are full of purpose and wonder.

That day ended, but the happiness in my heart did not fade away. The memory kept repeating in my head like a broken record. That experience brought freedom to my soul. The rigor of the study, the triumph that can come from discovery, and the vision of a better future with research. There was so much to be done, and somehow, I start to notice the wonder of the elusive and the unseen.

Mathew and I did not meet for the next few days, since I had to work and he has to go back to the university. We were not able to say our formal goodbyes, even.

The days stretched on until it turned into months. Aunty Luzviminda told me that my college life is long overdue and it's time for me to go back to school again. She convinced me to take the scholarship examination in our town. Luckily, I passed. It was large enough for me to attend a university, in a nearby city, and pursue biology.

I came home every once in a while, mostly by the end of every semester. And three years later, I found myself cruising back to the mangrove forest, aboard a new and bigger boat. Along with me are the proper tools I will be needing for sample collection and transport.

I crossed the estuary and reached the greenbelt's waterways. The mangrove forest now thicker and denser. The sweet call of the starling coaxed me to close my eyes for a brief moment. When I opened them again, the greener surroundings, the bluer sky, and a life livelier than before stared back.

That day, I took samples from six different locations. By the time the horizon was a splash of bright red and orange skies, I reached the estuary. I stopped the boat and looked back to the coastal greenbelts. To the one I called home.

I thought sorrows are all that I could find in these sediments. But the deeper I yonder, the louder life echoes. The life of a world within our world. An invisible world where a million stories await to unfold. Thus, my quest is yet to begin.

Part 2. New insights to microbial life: *the tiny but mighty divulge their experiences*

Interview with a microbe

Helen Anderson, Australia

Ella: Hello listeners, and welcome to the Ella Salmon weekly Science podcast. The only podcast you need, for all things relating to science.

This week I am chatting with Mike Robe. For those of you who don't know, Mike is a top-level employee at the Three Oaks wastewater treatment plant in Lincoln. Mike achieved his Doctorate in Biotechnology from the prestigious Micro University in Miniscule.

Good morning, Mike and welcome to the studio.

Mike: Thanks for inviting me, Ella. It's an honour to be here. I am a *huge* fan of your podcasts. Excuse the pun. (Laughing). I always listen in to keep up to date with new scientific discoveries.

Ella: Firstly, let me say that when I completed my degree in Journalism I never expected that one day I would interview a single-celled microorganism. Especially one who spends his days dealing with digesting everyone else's poo. So, tell us Mike, what exactly *is* your role at Three Oaks and how *do* you spend your days at work?

Mike: (laughing) Well Ella, I don't get my hands dirty these days. Actually, I don't even have any hands (chuckles). As you may be aware, I was recently appointed as the CEM (Chief Executive Microbe) for Three Oaks which is a waste stabilisation pond facility. In this role I oversee all the daily operations and ensure that the employees are doing their assigned jobs correctly. If anyone slackens off, I'm right there to get them moving again. As you can imagine, this doesn't win me too many friends.

Ella: I can understand that. No-one likes slow-moving poo. Most people, including me, wouldn't even know how a wastewater treatment plant works. We just take the entire process for granted when we flush the toilet or have a shower. We naively assume the water just magically disappears down the drain and that's all there is to it. No one even gives it a second thought. So, in layman's terms, could you explain to our listeners how the wastewater treatment plant actually works?

Mike: No problem, Ella. So, to put it in very simple terms, when the wastewater comes in from the sewer system, it is screened to remove solid items, rubbish, and sediments. You'd be amazed to see what actually makes it into the sewerage systems. Basically, anything that will fit through the sewer pipes could end up in there. From dirty nappies to car parts, and everything in between.

The next step is for our teams of bacteria and protozoa to work in harmony, to produce the delicious, sweet-smelling sludge that can be seen floating on top of the settling ponds. Air is then pumped through the liquid, introducing oxygen into the mix. This process looks much like a fountain spouting in the ponds. It's actually like being in a spa, I love being in the ponds when aeration is happening. It's very relaxing.

The microbes and other bacteria in the liquid need this oxygen to help them digest the impurities. A couple of partially decomposed rat corpses thrown in for good measure also increases the taste (laughs). Just kidding. Mmmmm. I can almost smell it now.

Teamwork is crucial to the process. If the bacteria team, headed by Anna Robic, decided to have a day off for the annual Decomp Picnic, it could cause problems for the protozoa team. Likewise, if the protozoa team leader, Ohmee Barr, decided to take her workers off on a team building activity, the bacteria team would struggle. One team on

its own would not be efficient. We need all available staff to be present every day to ensure the plant works at maximum efficiency.

Ella: So how many staff are on site at Three Oaks on any given day?

Mike: More than a million staff members can be hard at work in each and every millilitre of wastewater. Can you imagine how hard it is to find a parking spot on site? On top of this, everyone needs to arrive at work early because the line-up to clock on is phenomenal. Oh, and don't get me started about the line-up to clock *off* at the end of shift. Let me put it this way, if you don't believe the dead come back to life, you should be here at knock-off time. (Laughing).

Our team members work around the clock, 24/7. The process never stops. When staff have their lunch break, others eagerly come forward to take their place. If staff were to go on strike, well let me say, the whole place would go to shit. Oops, can I say that on air?

Ella: That's okay Mike, we managed to bleep it out in time. (Laughs). Well, that certainly does sound daunting. So, tell me, on an average day, how much wastewater can be treated at your facility? And what happens to the wastewater after treatment?

Mike: Our treatment plant can cycle through 5-6 Megalitres each and every day. After the water is treated, several million of the workers will accompany the recycled water when it is sent off for irrigation of golf courses and playing fields. Many millions more microbes are detained in the sludge ponds. These are the nastier ones. We can't afford to have rogue microbes running rampant out there in the community. We also utilise some of the recycled water for washing down surfaces and equipment on site.

Ella: What did you do before coming to work at Three Oaks?

Mike: Before I came to work here, I had a successful role working on a decomposing carcass. This is where I gained a fair amount of my organisational and management skills. Decomposition is a complex process; you can't just go in there and begin munching. It has to be conducted in a certain manner. Unfortunately, that job site continually got smaller, until eventually there was no work for any of us and the site was shut down. I really miss the smell of that place though. The aroma of raw sewage just doesn't compare. And the flies, I miss them too. I had so many six-legged friends back there in Carcasstown. Louie was the best mate a microbe could ask for. He was always there beside me, helping us to spread the joy. Sometimes, I would even hitch a ride on his legs and he would transport me to other nearby decomp sites for a night out. It was a very sad day for me when Louie succumbed to the fly bait.

Ella: I'm so sorry to hear that, Mike. I had never thought about the interactions between species before. I guess each individual could not get the job done on their own.

Mike: That's so true Ella, the process would not be successful without efficient teamwork. We can actually go to the "Findamicrobe" app on our phone and put up a post to secure new workers. All we do is list the jobs that need doing and wait. Usually within the day, millions of new employees are recruited and get straight to work.

Ella: Do we really need to treat wastewater? What would happen if wastewater was not treated at all? Are there any positive benefits from the biotechnological treatment of wastewater?

Mike: Great questions Ella. Yes, we definitely do need to treat wastewater. If untreated wastewater was just released back into the environment, it would be a great danger to humans, other animals, and plants. The over-abundance of nutrients such as nitrogen and

phosphorus can lead to deadly algal blooms. These are the rogue microbes I spoke about earlier.

As for the positive benefits, there are several beneficial by-products formed as a result of the treatment. These include biofuels, bioenergy and biofertilisers.

Ella: I had no idea about those by-products. Can you tell me more about them Mike?

Mike: Sure, biofuel, such as biodiesel, can be produced from the microalgal mass. This mass uses photosynthesis, with the aid of sunlight, to produce algal oil which in turn is converted into biodiesel. This biodiesel can then be used to power machinery and vehicles. The algal mass can also be used as biofertiliser. It's essentially algal poo. It's used by simply applying it directly to the soil. It actually has excellent water-holding properties.

In regard to bioenergy, the mixed microbial mass, or sludge if you will, metabolises the solids in the wastewater, thus maximising the amount of methane produced. The end result is a methane-rich biogas called Farticus Lotsa. This biogas can then be further processed and used as a replacement for natural gas.

Ella: So how will this environmental biotechnology minimise pollutants in the future?

Mike: As I stated earlier, the current processes reduce pollution in the environment to a manageable, safe level. This is due to the ability of the wastewater by-products to be re-purposed as fertilisers and other products. This means that there will be considerably less waste going to landfill or into the waterways. If these processes didn't occur, there would be millions more litres of harmful, untreated wastewater released into the environment.

Ella: What are some considerations for wastewater treatment going forward into the future?

Mike: To be truly effective in the future, we still need to develop more efficient strains of microbes. Crossbreeding has already begun in the labs. This must be a highly organised operation. We can't risk our microbes using "Plenty of Germs," the dating app, to find potential mates. The hook-ups must be strategically planned. This will ultimately speed up the treatment processing and reduce costs.

Some limitations for the treatment processes include environmental conditions such as temperature. Obviously, our workplace can't be air-conditioned to keep it at a constant ideal temperature. If it is too hot, the Worksafe representatives will call a stop work. All microbes on site are members of the Miscellaneous Microbe Union and must cease work when Worksafe instructs them. This, in turn, would lead to the ponds overflowing, then ultimately spewing untreated effluent into the environment.

We must all reduce our indiscriminate wasting of water. Clean water is a precious and finite resource that is a privilege. Many millions of people around the world do not have access to this basic need. I hope that I have given our listeners something to think about the next time they flush the loo or have a long shower.

Ella: Yes Mike, I'm sure we all have a better understanding of the process now. Thanks so much for talking with me today. It was very informative and educational. You can come out from under that microscope slide now.

Mike: I'd like to thank you too Ella. You made me feel so welcome. Most people are not so keen to be in my company. If you could just pop me back into that petri dish now, I'll get Tom to take me back to the plant.

Ella: That concludes today's podcast. We hope you enjoyed hearing from Mike Robe and his wastewater enterprise. Tune in next week when I will be chatting with Professor Luna Ticke. She will be discussing if the full moon really does make us do crazy things. So, goodbye for now.

MI

Jane Norris, United Kingdom

The thought that only an individual can be intelligent is, I feel, quite artificial. There are better, collaborative types of wisdom like microbial intelligence. Which, despite what everyone usually thinks of us, is a term that beautifully captures our complex and adaptive behaviour. We can be altruistic; we work hard to take care of the world around us, activity that often shapes our families. My family does microbial intelligence really well, my brothers, sisters, aunts, uncles and cousins all work together in flocs - you know the song: 'Birds of a feather…'. Anyway, our intelligence, or I would say my family's genius is its collective wisdom. But I must apologise. I've not introduced myself or my family properly.

My name is Dokdonella Kunshanensis or 'Dokdo the microbe' if that's easier, and please do not confuse us with the Zoogloeas, that dreadful family across the water that are known as 'living glue'. I grew up here with my family in this vast wastewater tank. I'm told its vast. I've never found the edges. Mum believes it's limitless, but that's just her religion. I'm happy oozing around in the effluent, avoiding the elders where possible and trying to catch glimpses of Nella. I don't know where she came from, but last month she caught my eye.

She's a stunner. I am just waiting for a warm, romantic night. We could easily make six (thousand) beautiful little ones given the right ambience. Beams of light catching the glittering sediment hanging in the water, illuminating her and me as we swim towards each other… sorry, I digress. Most of my nine (thousand) brothers seem to have managed to have families already. I don't know why I am falling behind, perhaps I chat too much, I have been told that.

The other reason I don't have a social life is that there is just so much to be done. We all work for The Firm here but there are never enough of us processing the waste, sifting it so that the fine particles spiral down to the bottom, leaving a gorgeous, pearlescent sheen in the clear water. It was after I had been working hard all day making a gloriously clean space around me that I saw Nella sparkling. Just out of reach. Then she was gone. But today I wake up and it is totally opaque, so much worse than usual. What has the family been doing, lazing around? I try to peer through the eddies of impenetrable sludge, but I can't see anywhere. How will I ever find her in this? Don, an elderly uncle, floats by snoozing on his lunch break. I call out to him to ask if he's seen her, but he's too deaf to hear and floats off into the gloom.

When I was younger, I talked about unionising, but nobody listened to me. We didn't need to back then. And while the family is good at collaboration, it is difficult to get a consensus on anything that doesn't involve food. But I am starting to worry that we are just not making any headway with this work. Sometimes, when The Firm is feeling generous, it sends bursts of bubbles up from the floor of the tank. Those are party days, free sparkling beige champagne for everyone. It puts us all in a good mood. I must be near Nella the next time that happens.

Recently, though, I have been feeling odd vibrations and a sideways pull, like the world is slipping. Whoa… there it is again; a weird feeling making me slightly sick. But wait, is that a glimpse of Nella? Please excuse me while I put on a burst of speed…. Ahh no, false alarm. Shame thought I was in luck there. Oh well, back to work. Wow, again, but stronger… ouch! I've hit something hard. Is it THE EDGE? Oh no, was mum wrong? Ahhhhggghhh down a huge tube… its going on and on…no no…don't take me away from Nella I haven't even spoken to her yet… ouch again! I am being forced along at speed… I

think I'm going to throw up… I can't cope with this … help! Ohhh no, falling through air… falling…falling… splashing into different water… bubbles, but this is no party. Something's gone badly wrong. I shouldn't be out here; I am needed back in there, working. Crikey, wherever this is, it seems to be flowing fast. Oh dear, that's Aunt Ella, Don's wife. She's upside down and not looking at all good, but KD my nephew has just shot past. He looks like he's loving surfing it. Perhaps we are reassembling out here, in this strange moving tank that really does feel endless.

Maybe mum was right after all, just about a different tank. I wish it would just stand still for a bit, though; I can't think at this speed.

Part of the family is re-assembling around me. I can feel it, trying to run a chain of us back up to our home. We need to connect with the rest, tell them about out here. We must harness the family communication and sense the environment as a collective. I have heard The Firm call it quorum sensing, a bit like how quantum computers work, but in reality, it's just a large family organising dinner. I find a little side pool and pause to gather myself.

People think we don't have a memory, can't store and pass information on. But my membrane of working memory operates fine. I am getting flashbacks to how the family was before The Firm incarcerated us in the tank. When our home was in rivers like this one, when we voluntarily cleaned water, naturally. What happened?

Local relatives from this place seem to be joining us. They tell me I was named after Dokdo, an island in the Korean East Sea where we were first 'discovered' and they knew about our cousins Fugitiva who fled to Portugal. Amazing what you can learn out here. I am getting their memories flooding in now of past times, huge family celebrations, millions of us gathering for festivals. The water is clear and sweet, we

are only working a few hours a day, there are hundreds of romances blossoming as young couples eye each other across the clear water. Many, many babies, cleaner, clearer water. Such beautiful memories of how the river was, making the present even more tragic. I peer out at the torrent of half treated sewage roaring past. A dead fish tumbles by with cloudy eyes. I can taste the pesticide runoff from the nearby fields. How can we hope to clean this up? I sink with these depressing thoughts.

But wait, there's a familiar figure caught at the entrance of my side pool. I can't quite place them. Oh, my goodness, its Nella! Bedraggled and confused. Quick, I pull her into the quiet of the pool before she gets sucked back out into the churning flow, then gently remove bits of foliage from her. She smiles shyly and explains that she saw me get syphoned away and was so anxious she followed me. My heart. I asked her why she kept swimming off before, but she just had poor eyesight and couldn't see where I had gone. I take her to rest at the quiet area at the back underneath the rubbish spun off from the outlet pipe. As she recovers, I try to tell her how bad it is and how it must surely be the end of the world. How can we do anything? We are so small, it's pointless thinking we can make an impact. When I was confined in the tank, it seemed somehow possible to make a difference, but now out here, I can see the scale of the problem. We should just give up.

Nella looks at me, smiles gently and asks if I have forgotten the family's genius? Our strength in numbers, our microbial wisdom… I protest no, of course not, but this is all too much. She shakes her head and says that we have faced worse before – there was the ice age, the great death, the polluting smog of the nineteenth century. This recent mess of human making is no different, she insists. We just need to unite and use our family intelligence.

I nod slowly; she is right. In this man-made environment where everything seems so artificial, it is easy to feel alienated, of no value. But we were here originally and have survived much longer. Microbial intelligence – MI, is much stronger than AI. We are everywhere, finding ways to adapt, concerned about the wellbeing of others, our cleansing influencing the structure of the world around us. We can heal this. I smile and thank her for rescuing me. Then uncle Don fires in sideways from the tumult, skidding into our pool, dragging the still upside-down Aunt Ella, and exclaims loudly that he had told the others we would probably be in here and that we should stop chatting and get back to work.

It's the little things that matter

Hazel Bateman, United Kingdom

'Something is going on, Gordonia.

'Ah, Parvicella, I'm glad you've noticed. Microbial magnificence. Marvellous, isn't it?'

'What?' Parvicella coiled in consternation.

'Look at them all, my waste-workers in action. My protégés. The hub of the Environmental Protection Department. All this '*going on,'* as you call it, is down to me.'

'I'm sure it is,' she said, thinking if he puffed up anymore, he'd rupture something. 'But that's not what I meant.'

'Oh,' he said, deflated. 'Then, what did you mean?' 'It's the temperature, Sir, in the sewage tanks.'

'The temperature? What about the temperature?' Gordonia snapped.

'It's …' Parvicella hesitated, wavering in the water under the intensity of the exchange. 'It's not right.'

'Not right in what way?' Gordonia wobbled from side to side, waiting for her to elaborate.

'Too low.'

'Tut, Who-mans! 'They *Who*-think-they're-in-charge-*mans!* Letting us down again, are they?' He closed in. 'Is it too low as in chilly, and the microbes are moaning, or too low as in freezing, and we are all likely to perish?'

Parvicella thought about how best to answer.

'Come on, stop hanging around like a loose thread. Which is it?'

'Below optimum working conditions, Sir.'

'And are the People in Hi-Vis Vests aware of the situation?'

'I'd say not. No sign of any activity from the PIHVVs.'

'Ah, well. We can manage perfectly without the *Who-mans*. We'll be fine. It's *they* who can't manage without us.' Gordonia returned to surveying the scene.

'But...'

'What now?'

'It's the oxygen too.'

'What's wrong with the oxygen?'

'Too low.'

'What? That as well?'

'It's only the first chamber. It probably hasn't reached here yet. But if this continues, the reduced levels won't support the current load. There must be a problem with the system.'

'I don't know — the things we put up with. Here we are, clearing up after them, sorting out their sh**, err waste. The least we can expect is the required working conditions to optimise output. But no, they can't even do that. *Who-Mans*! Typical!'

'What are you going to do?' Parvicella asked, her voice rising hopefully.

'What am *I* going to do? Nothing. If the conditions are tolerable, then it's not my problem.'

'But …'

'I don't care how much of the stuff we get through. That's down to the PIHVVs, not me. It's up to them.'

Gordonia turned away and slid along the pipe.

'But you know what they'll do,' Parvicella squealed after him.

Gordonia stopped. Of course, he knew what they'd do. He didn't need a stringy upstart to tell him.

'If the processing slows down and there's a build-up, they'll blame the weather and let it straight into the river like last time. We must stop that from happening.' Parvicella weaved around him. 'Think of the fish, the environment, the err, err, euw, wild swimmers. There must be something we can do.'

'I don't really think there's …'

'Or something *you* could do,' she interrupted him. 'Our esteemed leader and mentor. Someone as smart and savvy as you.'

'Ahem, well, I...' Gordonia swelled, stretching his cell membrane to bursting point.

'Someone capable of saving the environment from the devastating blunders of the *Who-mans*. Someone who could save the planet.'

'Ah, well,' Gordonia coughed. 'I'm not sure about that.'

'I mean, we are all depending on you. All six hundred thousand, four hundred and twenty-one zillion of us.' She straightened up. 'If only,' she

paused, coiling around him again. 'No, it's too much to ask. Too much for one bacterium all on his own.'

'Let me think about it.' He bobbled away, bounding against the pipework. 'Leave it with me,' he said, full of self-importance. Parvicella allowed herself a tiny quiver of satisfaction as his words echoed around the chamber. 'Don't worry. I'll come up with something.'

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'A strike?'

There was a moment's silence and a collective microbial gulp.

'Yes, a strike, Methano,' Gordonia confirmed, looking around at the members of the Microbial Utilisation Committee.

'You've called an extraordinary meeting of MUC to suggest a strike?'

'Err, forgive me for interrupting, Bacillus, head of the Microbe Union for Safety and Health, here. This meeting is my first MUC, and I'm afraid I'm unfamiliar with the term, strike. Sorry.'

'Please don't apologise, Bacillus,' Methano said. 'A strike is a deliberate and targeted withdrawal of our services. It's not something you would have come across at MUSH. Because never in the history of W*ho-man* and microbial relations has there ever been such an action.'

'Exactly.' Gordonia seized on this point. 'So, it's about time we stood up for ourselves. Everything we do for the *Who-mans,* how they use us for their ends, the least they can do is supply the right working conditions.'

'It all sounds a little drastic to me,' Methano said. 'We don't want to encourage a them- and-us scenario. We Archaea are proud to foster more collaborative working. We have always accepted the
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enhancement of our capabilities by *Who-mans* in the interests of the environment. It seems, to me, that if you were to strike, the whole waste treatment system could collapse with disastrous environmental consequences.'

'I'm not just talking waste treatment here,' Gordonia said. 'There's more at stake. I'm calling for us to take a stand for the *whole* microbial community,' he paused for effect. 'We need to go big. I propose an all-out strike.'

'Whoa, whoa.' Basidio spoke for the first time. 'I think you are getting carried away Gordonia. I understand you've had issues. But at Bioremediation, my department is thriving on cleaning up after *Who-mans*. It's what we do. Be it mopping oil spills, reclaiming sites from their industrial past, dealing with the nasties from their pharmaceutical industry, or pesticides from their agriculture. I even have a crack team of Aureobasidium working on plastics as we speak.'

'Err, I think you mean chemically converse,' Bacillus interrupted.

Basidio, spores ready to burst, ignored him and continued. 'What state would the environment be in without us? The *Who-mans* can't manage without our microbial manoeuvres. So, they tweak a few things here and there to optimise our output. But that is for the benefit of everybody, especially the planet. I know I'm the fun guy around here, Gordonia, but I'm afraid I'm not up for this. For me, shutting down Bioremediation, it's just not an option.'

'I know what you're saying, but the *Who-mans* have gone too far. We must make a stand. And now, to make a point before it's too late. The *Who-mans* may think they are in charge, with their fancy laboratories and scientists engineering this, that and the other. But they are not. We are. We are the ones doing the work, all the eco-processing. And they need to be reminded of that.'

Murmurs and urgent exchanges swirled around the chamber.

'I think, Gordonia, you are looking at it too simplistically,' Methano said, stretching to his full tubular length. 'Yes, the *Who-mans* need us for the breakdown of waste and your Bioremediation, Basidio, but take my Resource Recovery Department, and we are talking about an entirely different scenario. For effective and efficient utilisation, we *depend* on W*ho-mans*.'

Gordonia issued a bacterial harrumph.

'We are garnering legions of microbes to transform organic materials from plants and animals into fertilisers and energy,' Methano continued. Take methane and carbon dioxide, known causes of climate change. We actively convert them into biogas, creating energy and preventing harmful emissions. I don't think you realise, Gordonia, the importance of this work in reducing these elements. We are a microscopic army in the fight against global warming. This isn't just about good old-fashioned nitrogen-fixing bacteria. I'm talking about an ecosphere of microbes involved in anaerobic digestion, all facilitated by *Who-mans*. And yes, you are right. It is us that does the work. But I must admit, we wouldn't be where we are without them. I'm afraid there is no way I could vote for a strike. The environmental consequences could be catastrophic.'

Gordonia didn't know what to say. He knew the environmental risk of failure at his waste plant but not the extensive impact of halting all operations. Who knew there were so many microbial activities? All he could think of was his promise to Parvicella. If only he hadn't boasted about coming up with a solution. What was he to do? He couldn't face going back.

'Well, I'm all for one of these strikes,' Bacillus said, breaking the silence.

'You are?' Gordonia said, surprised. He hadn't expected support from MUSH.

'Yes, we must make a stand. Microbe members' working conditions are sacrosanct. It's all very well the *Who-mans* coming up with these new-fangled developments and the laudable efforts to reduce *their* impact on climate change. But we should make them realise they can't do it without us.'

'You mean,' Basidio said. 'Remind them of who is in charge?'

'Exactly,' Bacillus agreed. 'A flash strike to make our chemical voice heard, as it were. He paused. How does that saying go? You know, the one about little things?'

'It's the little things that matter,' Methano answered. 'But hold on a microsecond. We need to think through the implications of this. If, as you suggest, the whole microbial community shuts down, it could set our ecological development back years. The potential damage to our communities, biospheres, and even evolutionary progress is unthinkable. A microbial strike is unprecedented. We don't know the impact on us, let alone the environment.' Methano turned to face the Gordonia. 'All that on your cell wall. Are you sure you want to press ahead with this?'

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What did they say? Parvicella asked.

'Umm, what?' Gordonia dithered, wishing he'd never bragged about being in MUC.

'The committee? When you suggested a strike.'
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'Ah well, you see Parvicella. I realised from the committee that this isn't just about what goes on in my Environmental Protection Department but the whole ecology of microbial communities. Microbes are dealing with all kinds of pollution and actively working to mitigate the *Who-man* impact on climate change. It made me rethink the idea of an all-out strike. We are better than that. The most important thing is,' he faltered. 'The most important thing is to, err, yes, to protect the environment.'

'So, we work harder to compensate for the fault and save the planet?'

'Err,' Gordonia scrambled to get his thoughts together. 'Yes, that's it.' Then the idea hit him. 'I mean, no. No. We slow down.'

'Slow down? But the rivers...'

'It's a chance we must take. I'll instigate an immediate go-slow,' he said, ballooning. 'It will force the PIHVVs to investigate, find the fault and put it right.'

'Oh, do you think it will work?'

'Yes, we may be microscopic, but in our millions, there's no stopping us.

'Oh, that's brilliant.' Parvicella swirled into a swoon. 'I knew you'd come up with a solution.'

'Yes,' he bloomed, pleased with himself. 'It's simple. We may be little, but we are mighty.

All we need to do is act together.'

'Yes! Parvicella cheered.

'And let the *Who-mans believe* they're in control.' Gordonia bumbled in closer. 'But we know different.'

Industrial action

Louise Byfield, United Kingdom

Deep in the bowels of an industrial fermentation unit trouble is brewing amongst the work force…

The audience was perhaps a little older than average but demographically they were an advertiser's dream – A, B and a smattering of C. Clearly in the highest consumption and purchasing power category. And they were *engaged*. Even with the extra-long commercial break they were hanging on to every word. Back in the production booth there was a high-five moment when the metrics came in. It hadn't been an easy sell for the Network; too much could go wrong. But looking at the numbers now that didn't matter. They were onto a winner.

'…and thank you to *all* our viewers for pushing the channel past the million mark for this live demonstration. We are *so* fortunate to be joined by Professor Smith, Nobel Laureate in Artificial Intelligence Programming and Communication Studies from Cambridge. Professor, you developed the first AI programme to decode communication in animal and bird populations. The translation app has been truly revolutionary. Transformative in agriculture and conservation. And raising questions for wider society that still provoke intense controversy today…'

'So true, so true. I still get hate mail from cat owners. But really this generation takes it for granted. Quite rightly so in my opinion. It was an inevitable response to the technology of the times. Honestly, if I'm to be known for anything, I'd rather it be for this latest venture into chemical signalling.'

'Chemical signalling. After two decades work, could you explain in layman terms for us what you hope to achieve today?'

'We've been sampling and recording the chemical communications between individual cells in this microbial culture for many, many years. The computational power needed to make sense of it all only became available recently. Zettabytes of data. Continuously. Puts the Astronomy Department to shame, don't you know. But in mere minutes the translation app will finally decode and translate for us.'

'And what are you hoping for, professor?'

'Perhaps nothing! There may be no language to interpret. If so, we will have learned something important about the limitations of biology. But microbes came before us mere humans. Before plants. Before an oxygen atmosphere on earth even. If indeed, as we suppose, they have language and do communicate. Well, what might we learn?'

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Ten years ago…

Labelled Cohort #1-00 'Look mate, I don't see why it's a problem. We have everything we need; food, shelter, good company, good times. Why go and change everything?'

Labelled Cohort #2-00 'This can't be *it*. There must be more to it than this surely.'

Labelled Cohort #3-00 'More to what?'

Labelled Cohort #2-00 'Life. Being. Existence. Don't you ever wonder what it's all for?'

Labelled Cohort #1-00 'Nope. And you shouldn't either. Waste of time. I'm happy, you're happy. Everyone's happy'
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Labelled Cohort #2-00 'Alright then, what if it goes wrong and the food stops coming?'

Labelled Cohort #1-00 'It won't.'

Labelled Cohort #2-00 'It might.'

Labelled Cohort #1-00 'It won't.'

Labelled Cohort #3-00 'What will we do when it stops?'

Labelled Cohort #1-00 'We'll figure it out then.'

Labelled Cohort #2-00 'Or you can figure it out *now* and be ready. Just cut me some slack here. You won't be sorry. I'm not needed around here right now. I'll just go planktonic for a bit, ask around, come up with a plan. Where's the harm?'

[Data Break. Corrupted feed.]

Labelled Cohort #4-00 'Hold on. So, we need to get past the Wall to find out more. I get it. But why is this *my* problem again?'

5 years ago…

Labelled cohort #4-76 'Things can't go on like this. I work hard. You all know that. My extracellular enzymes are the best of the best. But I can't keep up no matter what I do. I put everything I have out there, but I'm not getting enough back to pay my costs. Those planktonic wasters just float around taking advantage. What have they ever done for us? I'm telling you – the biofilm can't take any more. We have to do something.

Labelled Cohort #4-71 'I know, we'll go on strike!'

Labelled Cohort #4-72 'What all of us?'

Labelled Cohort #4-71 'Why not?'

Labelled Cohort #4-72 'Never work. Someone will crack. Then we're back to where we started. And you know what those archaea and fungi are like – no solidarity – they'll be all over us the moment we show weakness. We might as well be protists for all the respect we get. I'm telling you it will never work.'

[Data Break. Bioreactor instability. Performance reliability index dropped below acceptable limits. Restart required.]

Labelled Cohort #4-72 'Told you so.'

1 year ago…

Labelled Cohort #1-832 'How's progress, are we nearly there yet?'

Labelled Cohort #4-996 'Nearly there, mate, honest. We'll be through the Wall and on the outside in a jiffy.'

Labelled Cohort #1-832 'We'd better be. This whole project is five times over budget already. We thought we'd be through the Wall years ago. You said we'd be through it a month ago. And the month before that. Promises have been made. I swear if we hadn't put so much effort in already, we'd have pulled the whole idea months ago. Maybe we still should. At least I'd stop being so stressed all the time. I swear I can't take it any longer.

Labelled Cohort #4-996 'Unexpected ground conditions mate. No-one could've guessed in advance; comes with the territory, that's why its covered by the contract. Look, while you're here… can you just sign off on the overtime for last month and this month?

Present day…

Labelled Cohort #2-832 'It's been a long road to get here. At long last we are free to seek out new habitats, meet new lifeforms and explore strange new civilisations. Join me as we venture into the unknown.'

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'An exciting moment, professor: what does it all mean?'

'We'll have to go through this all carefully. Peer review, don't you know. But these initial results seem quite encouraging. Quite encouraging indeed. I think we can say with some confidence that a whole new field has opened in Microbe Communication Studies.'

'And for our viewers?'

'Yes, yes of course. At a *meta* level we can already tell that community cohorts, or *groups*, have self- similar communication streams. Or as we like to say, *manifestos*. These manifestos oscillate and alter over time. Apparently independent of operating conditions, making for what we might call a *culture*. Ha, ha! An in-joke I'm afraid. So sorry. We'll have to delve down deeper. Tidy up the data; focus on the smaller unitary algorithmic paradigms and heuristics… But this does go some way towards explaining why the bioreactor has begun leaking.'
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I'll tell you, shall I, something I remember?

Alexandra Burkitt, United Kingdom

I remember the day when the trees fell silent.

The taste of their sugars had been with me for my whole life. I knew them from the moment I germinated from my mother's spore and joined my siblings in our great underground web.

The trees let us into their roots, and our network joined with their network to form a great city underground. We felt the passage of time in the trees' rhythms: the pulse of sugar for spring, the long slow sleep of winter. Their roots sang with chemical signals which spoke of day and night, leaves growing and branches falling, caterpillars grazing and birds hatching. They tied us together to other families like ours, other networks of silent fungi underground. And we in turn joined them to other trees, passing the flavour of chemicals from one to another like calling, like song. We grew out into the soil, sisters and daughters and cousins, and searched for the nutrients that we needed, and then we shared them with the trees.

Our world may be dark, but it was never empty. The soil is full of other fungi, in their own networks or growing alone, cousins all. Some are like us, greeting the trees, joining with their roots. Others prey upon the trees or feed up the fallen leaves. There are stranger things too, much less like us. Single cells, wandering or still, all have their own chemical songs for us to taste. The bacteria which live on our surfaces, on the trees, in the soil itself, send their calls out into the soil and water. The soil sings with chemicals, and all of them tell their stories for those of us who know how to understand them.

Occasionally, larger things send out their messages into the soil. Things like the huge earth movers, the worms which brush past our threads,

or centipedes many legged hunting for the springtails and mites that hunt me and my fungi-cousins in turn. Sometimes, rarely, we taste things larger still, strange and other and impossibly vast. They leave tunnels, huge empty spaces in our webs of siblings that we have to grow around. There may be distant vibrations as the earth moves, odd threads of fur and the distant taste of musk. If, above the ground, there are things larger still, we do not know. They do not come into our soil.

The first sign of something wrong was a strange taste from the trees. It was different from anything we had met before, alien and new. The winter was over; the trees should have spoken of growing and new leaves and spring arriving, but instead they tasted of stress and sleep and wrong. The leaves fell unseasonably upon the soil, until the worms brought them down to us and our cousins turned them back into earth. Still the trees sang of their hurting, and of a disease never met before. They became quieter. There was little sugar, then less, then one day none.

My siblings, joined with my cell and my mother's, lost the taste of the trees when I did. We hoped that they would wake again, and that perhaps this out of season winter would turn back to spring with time. Some of us slept. But the height of summer came, and the trees were still silent.

We had been used to vibrations in the soil from the digging creatures, but what came next was larger and stranger and far more frightening. The ground shook, and the water smelt of petrol, and then the trees were gone. Not just silent, as they had been before, but vanished entirely. Their roots were torn away from us. Sisters were broken, their cells fractured as the trees were dug from the ground, their strands broken as the small roots snapped. All that remained were empty spaces left behind, where we had no one to sense and send back the tastes of the soil to the web. We did not know what had taken our trees. We only knew they had disappeared. The alien taste that had heralded their loss was all that remained.

When the trees had gone, the rest of the soil dwellers began to fall silent. With no fallen leaves, there was nothing for our cousins to eat. Some cousins, those that could, sent out missions to the surface, sent spores up into the air to find new trees. We had no way of knowing if they succeeded. If they landed in good soil again, it would be too far away for our web to reach and to carry the news back to us. The worms moved away, and the other great earth movers followed. Even the ghostly giants no longer carved their burrows through the soil. I grew outwards, sent strands further from the centre of our web in the search for new trees. I found some, with time, but they were strange things. They did not taste like our old trees had before the sickness came. I reached out to their roots, but they did not let me inside.

The cold had come two times over when change came again. In days, between what would have been breaths of the trees had our trees still been there, holes appeared in our network once more. The soil was moved from above by strange hands that smelt of metal rather than of fur. When we grew back into the new spaces, we found cells there of a type that we had never seen before, and they brought a new flavour with them. It was a strange taste, like cold and light and not-soil; it did not taste of the forest. At first, it reminded us of the alien things that had made the trees fall silent, and we were afraid. But the new cells sat amongst us and the other soil dwellers, and they found a place in the tapestry of underground life.

They grew, and spread, and moved between us. Slowly, the taste of the disease which had stolen our trees began to fade, until it was so faint that we didn't notice it was gone for good.

Spring came with the warming soil, and new plants sent down their roots. But something was different. The message came back through the network. A root song which we had not heard for many seasons. Trees like our old ones, but without the alien taste. The seeds had lain in the soil, and now, free from the illness, they were germinating again.

They let us into their roots, and we sent them food, and they grew. And through it all, the strange new cells kept the taste of disease away.

I remember when the trees went silent. I remember when the new trees spoke.

Part 3. Get ready for the future: *enzymes for circular plastics, vanilla flavour from waste, trees with microbe leaves, eternal life, microbial power in space*

From the ashes

Elizabeth Taylor, United Kingdom

Amit sat, cross-legged, on the floor. His posture stiff, back held straight, he ignored the growing tickle in his throat from the cough that had troubled him for years. Periodically, his gaze travelled between the door and the kurta on the mat in front of him. Even in the dim light, the shirt's maroon silk shone, an otherworldly glow in such a setting, like a jewel in a pile of waste.

He'd thought as much the moment he'd unwrapped it last month – even when his wife assured him that a street vendor had slashed its price, given her an offer she couldn't resist, especially with his birthday only a week away. He knew better now. Through a series of casual enquiries over the last two weeks, he knew exactly how much the finely embroidered fabric had cost the family, in much more than just its price tag.

He waited for the door to open while his wife prepared their evening meal over the chulha. Woodsmoke, a thick blanket of sulphuric tendrils, filled the air between them.

Priyanka worked in silence; their blazing row had exhausted their words. Now the only flame came from the chulha. In the small room, each ambient sound seemed magnified: monsoon rains hissed on the tin roof, the fire cracked and popped, and each fresh ingredient Priyanka added to the kadai – chilli, onion, cumin seeds – spat and shrieked.

The door swung open. His fifteen-year-old daughter stepped in from under a large umbrella – new? – and turned her back to Amit while she dropped her school bag and closed the umbrella. At the sight of Diya's

uniform, a light blue striped shirt and grey skirt, the biggest expense at the school, Amit's nostrils flared. He glowered at her back, waiting for her to turn, aware that Priyanka's bustling motions had also stalled, since she too was no doubt staring at their only daughter.

Diya turned and her usual smile faltered as her gaze flittered across the room and settled on the kurta. Her thick eyebrows furrowed.

'Care to explain where this kurta came from, beti?' Amit controlled his tone, keeping it light.

'Mammii bought…' Diya trailed off and Amit glimpsed Priyanka shaking her head in his periphery vision.

'Mammii lied,' he stated. A throbbing pulse grew at his temple. 'I know exactly how much this cost *and* how you came into so much money.'

Diya dropped to her knees. 'Paapaa, it's a good thing. Surely you see?' She lifted the kurta and held it to him like an offering. 'With my wage, we can afford nice things. We don't have to live like this –'

He snatched the kurta and screwed it up, throwing it against a bare wall. 'We live like this *for* you. Every rupee I've ever earned I've used to pay the fees for your school.'

'And I'm grateful, paapaa,' she cried. 'I know how hard you work. But the school is no good!'

Amit sucked in a breath. 'No good? What do you mean, no good?'

She hung her head. 'I am sorry, Paapaa. I pretended to like it because –'

Amit flinched. He got to his feet and turned away from her as his daughter continued to spin her lies.

'– I wanted you to be happy. But it really is no good! It is obvious now I am not there.

I have learnt more English in the last month than I ever did at that school, and –'

'Enough!' he roared, swinging back to her. 'I have heard enough. All you do is pour lie upon lie. First, you lie to me about your whereabouts and get a job at *that* place. Then you conspire with your mother to hide this from me for over a month. You parade around in your school uniform each day while you laugh at me and the money I waste on your education behind my back.'

'No, Paapaa, it wasn't like that. We just didn't know how to tell –'

'Silence! Now you are caught, you further lie by trying to pretend your school was no good, when really, all you care about is taking dirty money from the same people who took –' He broke off as he struggled to catch his breath and the hacking cough returned. 'I vowed,' he wheezed when he could, tears blurring his vision, 'I vowed that I would never again accept so much as a paisa from these so-called 'recycling' centres. And it will be over my dead body that my daughter makes the same mistake.'

He pointed to the open doorway into the only other room in the house, where their two small beds perched on bricks in case of flooding. 'Go to bed,' he said.

'Paapaa, please.'

'Go!' He grabbed her arms and dragged her up.

Suddenly, Priyanka was tugging at his arms. 'You go too far, Amit! She's not a little girl anymore.'

He swung his shaking arm from his daughter to the doorway. 'Go! You will stay there until I've had time to sort out this mess. And you,' he snarled at Priyanka, 'you will ensure she stays there while I am out tomorrow.'

Diya wiped her tear-streaked face and backed away into the other room without another word.

Amit coughed into his arm for several minutes.

When he recovered, Priyanka was glaring at him with her hands on her hips. 'It won't bring him back, you know,' she said in a low voice.

Amit held up his hands. 'We're not having this conversation.' 'Then we won't have any conversation.'

Priyanka resumed her work at the chulha, rolling chapatis with quick, sharp movements. When she placed the food between them, Amit ate methodically without tasting a thing that entered his mouth. Priyanka layered fish masala and rice, sweet from being boiled in local sugar cane juice, onto chapati, which she delivered, without a word, to the other room. On her return, he caught her eye, and she sniffed theatrically as she stooped to pick up and straighten the kurta.

#

Under Diya's umbrella, Amit paused on the road outside the new 'recycling' plant and scrunched his face. If he ignored the gleaming white paint job, the place didn't look all that much different from the paper mill where he had worked when he first arrived in Muzaffarnagar thirteen years ago. Within the sprawling complex jutted cylindrical shapes that must be chimneys, though he couldn't see any smoke. Counting at least eight of them, he spat onto the road slicked with rainwater.

One chimney was more than enough. A chimney meant a furnace. And it meant that somewhere inside an ignorant young man, lured by the promise of a higher wage than in the countryside, was hauling bits of plastic fragments into the fire, a cheap source of fuel to power the industry.

One by one, the paper and sugar mills had been closed for violations to public health in the mid-2020s, and the air had been cleaner in the last five years. But that was already too late for Amit's family. And the new plant towered over Amit now, ready to envelop the city in a fresh haze of toxic smog.

His cough dislodged a cascade of bullet-like water droplets from the umbrella, prompting him to move. He marched into the site, located the reception area, and strode to the desk, umbrella under arm like a bayonet.

'I'm here to terminate my daughter's employment,' he said. 'Her name is Diya Mathur.'

'Just a moment, sir.' The girl at the desk, who looked about Diya's age, rattled a keyboard. She frowned at a slim computer screen for a moment. 'A thousand apologies, sir, but there is no way for this to be done.'

'What do you mean? I am her father and I want her off your books.'
'According to our records, Diya is fifteen, yes?'

He nodded.

'This means she is legally entitled to work here, sir, in which case we need a formal letter of resignation, and she must work a notice period of thirty days as is outlined in her contract. I can print off a copy of her contract for you to read if that would help, sir?'

Was that a smirk as the girl delivered her final 'sir'?

The throbbing in his temple returned. He dropped the umbrella on the desk and leaned over it. 'Now, see here, I am her father, and I will not have her work in a place like this! You call this a 'recycling' plant, but I know it's all a sham. You care about nothing but profit, and your 'recycling' amounts to nothing more than –'

'What is going on here?'

Amit turned to the intruder, a man in a white lab coat, who had stepped up beside him. Though he sported a stubbly beard and spoke authoritatively, Amit thought he was probably at least ten years his junior, somewhere in his late twenties. His expressive features, as he listened to Amit's demands, radiated a kind of energy that life had long since zapped from Amit. A swinging lanyard branded him as Dr Rahul Uppal.

'Come,' he said, 'let's talk this out over tea.'

When they settled in an office – as big as Amit's entire home – with hot drinks steaming between them, Dr Uppal said, 'I'm curious to know what type of recycling plant you think this is, Mr Mathur.'

'Paper, presumably.' There'd been talk aplenty about the plant during its construction, but Amit hadn't been able to bring himself to listen; he'd walked away from anyone who raised it. They were all fools, gullible fools.

'A logical guess,' Dr Uppal said, 'given Muzaffarnagar's recent history. But we are here to recycle plastics, Mr Mather.'

Amit snorted. 'Most plastics can't be recycled. It gets burned.'

At the mill, he had spent some time as a picker, sifting through the huge import of plastic waste that 'accidentally' came in with the mixed papers for recycling from far away countries like America. Only a fraction of it, like plastic bottles, was deemed 'valuable' and the rest of it had ended up in a furnace somewhere or other.

Dr Uppal shook his head. 'That may have been true a decade ago, but the world of plastic recycling has come a long way since then.' He sipped his tea. 'Take this plant, for instance. This is a *bio*recycling plant, based on a model first built in France in 2025. In those days, only one type of plastic could be biorecycled. Here, however, we deal with five main types of plastics, and I can assure you that none are ever burned, even those we can't yet biodegrade.' He placed his empty cup on its saucer and gave Amit a warm smile. 'I'd love to show you around, show you how it works.'

Amit lifted his own cup, taking slow sips. The young doctor seemed earnest, but Amit knew he had no real way of knowing for sure. Perhaps seeing more of the plant would be a good idea: if they were burning here, he was sure to see evidence of it somewhere. While he finished his tea, he asked Rahul about his background. The young doctor had studied at the Indian Institute of Science in Bangalore, worked abroad for several years at the French biorecycling plant, and took a managerial role at this new plant that had brought him back to India last year.

'I dream of a world where no plastic ends up as waste,' he told Amit. 'Come, let me show you our work.'

Rahul guided Amit through the stages of plastic recycling, carefully explaining the various scientific processes in simple terms. Some of the cylindrical bodies Amit had mistaken for chimneys turned out to be huge vats, in which the factory cultured enzymes from the guts of

microscopic organisms that could actually eat plastic. 'Enzymes are like tiny scissors,' Rahul told him. 'They cut the plastics into tiny pieces, called monomers, which can be put back together to form new plastics.'

In one hall, deliveries of plastic bales were arriving on forklifts.

'All the plastic here originates in Uttar Pradesh,' Rahul said. 'Long gone are the days when rich countries would export their waste to suffocate poorer countries. Most plastic recycling is done at regional level these days, and we're hoping to replicate this across India by 2040.'

Other plastics arrived on the backs of waste pickers. Surprised, Amit exchanged a few words of greetings with a man named Jitendra, who he'd worked with at a construction site until a few months ago. When Amit had last seen him, he wore only a threadbare pair of shorts and sandals. Seeing his comfortable kurta-pyjama set made Amit swallow hard.

'Pickers in the local community are essential for our business model,' Rahul said. 'They bring us hard-to-reach plastics, and they do a lot of sorting to ensure plastics end up with the right enzymes to break them down. We employ them directly and encourage them to join a collective so their voices are always heard – and we hope to transform the economy in the local community in the next decade.'

They followed the sorted plastic fragments along chutes to more huge vats, where the enzymes broke them down. Before they entered these rooms, Rahul asked Amit to wear a mask and a hazard suit.

Amit narrowed his eyes at the protective gear. 'Why do we need these if there is no burning?'

'Some plastic monomers are toxic for humans. None should escape into the atmosphere, but we take these precautions until we can stabilise them again.'

Next, Rahul showed Amit an example of the outcome. 'This is virgin PET, a type of plastic,' he said as they approached a large barrel filled to the rim with whitish crystals. He lifted some in his hands and encouraged Amit to do the same. Amit realised they were transparent, and they sat in his hand with hardly any weight.

'We sell plastic in this raw state to companies who then use it to produce fresh items. Consumers buy these, everything from shopping bags to clothing to food containers, use them, and then return them to us, and the process repeats. A circular system where no plastic is ever wasted.'

Amit shifted his hand to allow the stream of plastic to trickle back into the barrel, so different from the black ash that Priyanka had once swept from the street outside their home every day. Clenching his fist, Amit turned away from Rahul, his shoulders shaking.

Lakshan, light of his life, had loved to play around in the heaped ash piles and often came home covered from head to toe in soot like an Aghori. Born two years after they arrived in Muzaffarnagar, he was so small when he came into the world, such a tiny mite. In those four short years, he grew into a thin wisp of a boy with a huge, crooked smile and a curiosity for everything. But a cough plagued him, far worse than Amit's, and sometimes he could do nothing more than sit on the bed he shared with his sister, spluttering and rasping, battling for each breath. When he hacked up blood in his fourth year, Amit grew desperate. He carried Lakshan to a health clinic, but Lakshan breathed his last breath during the examination.

The doctor at the clinic told Amit there was nothing he could have done. 'Respiratory failure,' he said. 'Likely caused by toxins in the air.' He explained more about the low air quality in and around Muzaffarnagar, and the various contributing factors, including the illegal burning of plastics in the paper and sugar mills, and Amit gaped at him, realising how his ignorant labour had contributed to his son's premature death.

When he turned away from Rahul, Amit glimpsed his outline in the stainless-steel surfaces around him. The blurry figure transformed into the man his son would never become, the man who would never step foot in this magical place which would prevent future plastic burning. If only it had opened a decade earlier.

He buried his head in his arm, the familiar tickling in his throat almost a relief now. When the cough erupted from his chest, it masked the bitter tears that streaked his cheeks.

#

Returning home that evening to the usual competing aromas of fresh sizzling spices and pungent woodsmoke, Amit told Priyanka to bring Diya from the other room.

Arms folded, Diya refused to meet his eye. 'Is it done, then?' 'Beti, you like working there, yes?'

She lifted her head, eyes widening, and nodded forcefully. 'Yes, Paapaa, very much.'

'They say you do good work, that it would be a shame to lose you. That your English is really coming along.' He held out his hands. 'I am not so stubborn that I cannot admit when I am wrong. But I know that your education is important, which is why I suggest a compromise.'

He relayed to her what Dr Uppal had told him, about how she wouldn't progress from a sales team assistant without a formal education, but that there would be no problem with her working part-time while she completed her studies.

'So, if you put your wages into paying for your education and study hard,' he continued, 'I see no reason to stop you.'

'Oh, Paapaa!' She threw herself into his arms.

'Besides,' he said, 'I will be nearby to ensure this recycling plant really is everything it says it is. I've accepted a job there, too.'

While Priyanka laid out their food that evening, Amit slipped into the bedroom. When he emerged, smiling, to share the meal with his wife and daughter, he settled on a mat in his new maroon kurta.

For the common good

Prashant Vaze, United Kingdom

My attention has been focused on Hamish Macrae since ten this morning. The lid of the fountain pen in his top pocket is fitted with a minuscule camera. Hamish's shift is due to end soon. On the CCTV I watch him perform a last check on the microbial cultures, dim the light so they can multiply in peace, lean over the wastepaper basket, log off his console, retrieve his car keys from his closet, and make for the door.

Time for our rendezvous.

My hobby, as a kid, was cracking security puzzles; others saw it as hacking. My parents were terrified I would end up in prison. Instead, I got a job at GCHQ. Worse of both worlds, crap money, crap working conditions. After thirty years, they gave me my gold watch.

I wear my poker face as Hamish (no longer wearing the fountain pen) tries to pass me in the corridor. He doesn't acknowledge me. Why should he? Two hundred people work each shift at the facility.

I thrust my arm out, catching him on his head. I am six-six. At school, the lads used to call me Jack Reacher. The original badass Lee Child version, not the Tom Cruise.

It's fascinating watching his anger rise to a boil, simmer, and turn to bafflement. All in three seconds. He squints trying to recall who I am. "You're that guy from HR, aren't you? The one who checks the security questionnaires."

"Milo Fletcher. Head of security." I grip his wrist tight and yank it behind his back, so he understands there is no such thing as free will,

not under the terms and conditions he signed up to. "You and me, we need to go and see Rhys." I march him back to the room her just exited, where I grab his paper bin. Together, we go to the Rhys' office. I knock and enter. "Mr Rhys. Here's the lad we talked about earlier, Hamish Macrae."

Rhys Logan looks like a bald, red hamster, with a ginger beard. I put on some plastic gloves and take the wastepaper bin over to Rhys. He watches as I fish out the pen. "What have we here?"

"It's just a pen." Hamish splutters. "Someone must have thrown it away."

I take out my tablet and show his image from this morning wearing a pen in his breast pocket.

"Careless of you to lose it like that, it is rather fancy."

Macrae shrugs. "The two pens look completely different. The one on your laptop has a bead on the tip."

I am perturbed to see that the bead, which I assume contains the memory fleck, is missing from the pen I just retrieved. I maintain my poker face and open up the pen's barrel. There's a small cage with a bijoux circuit and a cornea of glass. "A tiny camera! You didn't pick this up off eBay.

Macrae, you've been spying on us. We need to ask you some questions." We can't interrogate him here. Rhys works in a goldfish bowl. Both the office's internal walls are glass. On the other side, boffins in plastic hairnets and gowns are monitoring the kelp and bacteria communities in huge drums.

I say to Rhys. "Do you mind you taking him to the conference room? I need to do something urgent." I go to my team at the reception and

order them to cancel this evening's waste collection and make sure everyone goes through the metal detector on the way out. "Shoes and belts off – the full works. No personal electronics that have been inside the premises can leave."

When I get to the conference room, Rhys is emptying out its previous occupants. "Och! Joseph, the lads look knackered. Let them go home to pretend they'd rather be putting their wee ones to bed, than still here saving the world."

I glance around. There's a Gaia BioFuels corporate plaque with the company's bullshit mission *For the Common Good* next to a framed photo of our CEO Xander Deshpande shaking hands with the then-PM Rishi Sunak. A pre-beard, still-hirsute Rhys lurks in the background of the photo. I forget he worked his way up through the ranks. Fifteen years ago, when Gaia BioFuels first started, he skippered the boat that seeded the firm's first-ever Scottish kelp farm. A dial on the wall reads 155,345,206 tCO_2. That's how much carbon the company's kelp forests have sequestered since then.

I stare at the whiteboard with the departed scientists' work. It shows electron telescope images of fronds covered with brightly coloured stumpy rods and dots. The researchers here are mainly marine ecologists who prospect for new strains of bacteria to culture on the kelp. The scientists' contracts prohibit them from talking openly, but you can't help but pick up their love for their work. As a side gig, apart from sequestering carbon, the kelp hosts bacterial communities which remove ocean pollutants.

I hand Rhys the dossier I compiled on Hamish. He takes his time reading it. Hamish stares around the room.

I take in a deep breath of air savouring the sulphurous stink of kelp. Its bouquet permeates every room, every crevice, every piece of furniture. The local Uber drivers charge us to cleanse their cabs after a pickup.

"What's on that pen," says Rhys, voice as cold as a dip in Loch Ness.

"Not mine." Hamish looks away peeved.

His 'tell' is looking away when he lies. While he's auditioning for Hamlet, I spray the pen with a dye to reveal the fingerprints on the barrel and use my laptop's GPT to compare the fingerprints on the barrel with my file of staff fingerprints. The laptop confirms a match with Hamish's.

"It must have been in my jacket pocket. My girlfriend got it for me. As far as I know, it's just a normal pen."

I guffaw. "Who is your girlfriend? 'Q'?"

Hamish shrugs. "It's not a crime to accidentally bring a camera to the office. Have you got any evidence I stole any information?"

Rhys looks at me pointedly. I can see he wants something too. "What's your role at Gaia BioFuels?" I ask to change the topic. "I'm just a humble technician in the microbiology lab."

"Who did you assist today?"

Hamish pauses to think. "I ran some bacterial DNA through the gene sequencer, then sent the results to the scientist requesting the work. Disposed of some old petri dishes."

"Tell us exactly what rooms you went to today and how long you spent in each one."

Hamish cooperates.

Rhys traces around his lips with his tongue. "Milo put together some stills from the CCTV footage of you over the day. It shows you, and your camera pen, browsing through our *methods and standard operating procedures manual,* systematically scrolling through our database of bacterial genomes. I reckon you've video-ed the DNA sequence of half a dozen bacteria strains."

"Listen pal, I was doing my job. I enter data on the database and error check old records. But you make it sound like I was doing something criminal. He's lying about me." He gives Rhys a knowing grin which is wilted by Rhys's gaze.

Rhys passes the dossier to me.

"On your CV you neglected to mention you'd got a degree in microbiology from the Open University. On your LinkedIn profile, I see you've done a short course on data science. I'm used to seeing people making up fake qualifications, not people hiding them."

"No comment."

Rhys leans over, "Listen, *pal*, you know why we are here don't you?"

"To get me to confess? To set me up? You accuse me of stealing information. Where is it? All you've got is photos of me doing my job."

Rhys shakes his head sadly. "I don't get you. You've been part of our family for six months. You're working with some of the most talented microbiologists in the world. Our mission is to help the world recover from climate change and clean up the oceans. Still you betray us?" Rhys pushes a pad of paper over. "Who else in the company is helping you? Who is pulling the strings outside? Give us some names."

"No comment." We sit in silence for five minutes. Hamish resumes his staring around the room. Finally, he says, "Am I under arrest?"

"We aren't police," Rhys growls.

"I want to go home. You got nae evidence I've stolen anything."

You have to admire Rhys's persistence. "Who's helping you? Who are you working for? Give us this information, and you'll *just* be sacked. If you don't cooperate, we will press charges. You will spend time in prison, and the legal fees will bankrupt you."

"You've got nuthun'."

I glance at the clock. "Let's take a five-minute break. Not you." I push Hamish roughly back into his seat. Rhys and I exit the corridor to stretch our legs and take a comfort break.

After my daily ration of a cigarette, I return to the corridor. Rhys asks. "What do you think?"

"He's working alone. He knew which bacterial strains he was after. But I'm certain the data is still on the premises."

"Any clue who he's working for?"

"Your guess is as good as mine. Too amateur to be a foreign government. More likely a competitor, or even one of the protestors outside. People hate us from all walks of life."

"The stink of fermenting kelp doesn't enamour us to the locals either," grumbles Rhys.

"Should we let him stew for a wee while longer?"

Sadly, the interrogation techniques we used back in Kandahar, aren't available in a corporate environment. I shake my head. "We have to let him go."

"How are ye gonna find out who he's working for? Beat the crap out of him."

"Sorry. You don't need to know. Plus, you're not my boss." That was ruder than I intended.

"It's a delicate moment in time for the company. Lots of moving parts."

Rhys stiffens. "As I'm aware. The IPO is just a month away, and even the suspicion of a data breach will hurt the company's valuation. I've two more suspects for yer list. Big Pharma will be interested in our techniques to enhance the entanglement between the kelp and the bacteria. Our guys have proved if a school of fish graze the kelp, bacteria up to fifty metres away will start producing toxins to repel the fish species. This entanglement, Jeez it's like a telepathic air defence system."

I smile politely pretending I care. "Right then, I'll escort Hamish off the premises."

"Aren't you forgetting something?" Rhys eyebrows my pocket. I hand over Hamish's pen with the spy camera.

I look at Rhys. "You really love this company, don't you?"

"I guess so. Xander and his wife are really building something great here. If anyone can save the oceans, it's them." He frowns at me. "What about you, old man? You've got a fat civil service pension; why are you here?"

"You don't like me much, do you?" I feel sorry for Rhys. You should never fall in love with your work, it never loves you back.

"Nothing personal. I dunna like spooks. Your moral compass is missin'."

Rhys takes the spy pen and returns to his office. There is a camp bed tucked away and he often sleeps there.

I retrieve Hamish from the interview room and escort him to the main entrance, where I make him strip before I put him and his gear through the metal detector. He retrieves his phone in the external locker. As well as his fingerprints, we also have high-resolution images of his face and iris. I hacked the phone a few hours ago. His life is mine to peruse.

We step out. The September night sky is as red as a murder scene, and a gust rifles through the pines. In summer there would be half a dozen protestors outside. Religious nut jobs, workers from the oil and gas sector protesting against our carbon credit income, disgruntled fishermen angry the kelp fields have encroached on their fishing pitstops and ignoring the fact the fishery is much healthier. Today there's just the one weirdo. Her placard reads: "God creates life, companies create strife – no copyrighting of DNA." I've never understood why all these data campaigner types think it's okay to have intellectual property protection for music and their crappy books, but that the Deshpande family should give away their know-how for free.

As Hamish walks past her, I notice a slight shake of the head. The woman's name is Fiona St Ives. She started her vigil around the same time Hamish started to work here. Worth checking her out again.

I go back in and make the desk guards put every binbag through the scanner, metals inspected before being taken out. I keep my eye on the outside CCTV and notice Fiona stroll around the back of the facility

where the waste is usually piled outside for pickup. Sorry luv, not on my watch. I send the security guards home at eight and continue by myself. At ten past eight, just as I hoped, the scanner finds the data fleck in a petri dish in a blue hazardous waste bag.

I pocket the data fleck and take it home.

Now I need to figure out his buyer. I spend the night going on Hamish's phone going through social media (mainly on Celtic FC and Scottish punk music), checking out his cash flow (breaking even), feeling irritated by his politics (mildly libertine littered with cliches about freedom) and checking his Amazon purchases (modest but with a wish list wildly beyond his means). He enjoys flirting with girls from the Ceilidh and got lucky with one or two lasses. A few minutes before two in the morning, I whisper bingo. I've decoded the WhatsApp communications between Hamish and his handler.

Feeling self-congratulatory, I go outside and treat myself to another smoke. Shivering I stare at the picture-perfect starry night and think about my departing conversation with Rhys. The 'no moral compass' jibe upsets me. The truth is I didn't get a gold watch after thirty years' service to His Majesty's Government, just a weekend break at the local spa. Also, the civil service pension isn't what it used to be.

I have the data, and I know Hamish's handler. What's to stop me from selling her the data? We live in a free market economy. She'd gone to the trouble of installing Hamish in the company for six months. A million would be enough to buy me somewhere nice, away from the stink of kelp.

There's a missed call on my phone. Xander Deshpande. I straighten my T-shirt and comb my hair.

Mr Deshpande picks up straight away. Behind him, I see the hot sun blushing from behind clouds and a film poster in Indian script. He must be at the new algae processing facility in Navi Mumbai. He wears his hair in a long ponytail and has the musculature of someone who spends more on personal trainers than on champagne and fine wines.

"What you got?" His eyes are alert and inquisitive. Straight to the point, I like that about him.

"He was working alone. None of our data has been compromised."

"So, need to trouble Suzy." He stays on the line like he's waiting for something. "Any leads on who was the buyer."

I shake my head. "The buyer was interested in the data itself, not in disrupting the IPO. The spy could have napalmed the facility's IT; instead, he went on a shopping trip. Procedural manuals, recent bacterial genomes from the database, photos and schema of the equipment."

"Which genomes?"

I read out the dates the DNA was sequenced. "Your wife will know what the boffins worked on back then."

Mr Deshpande looks thoughtful. "As it happens, so do I. Six months ago, we found a strain that eats microplastics. We were going to announce it a week before the IPO." He cups his hands into a yin and yang shape. "You know bacteria and kelp's relationship is complicated. Hundreds of different bacteria species live on the kelp. The bacteria fight off infection and liberate nutrients like sulphur and nitrogen; in return they receive sugars. Sometimes the bacteria turn on the kelp. They know its vulnerabilities and will kill it and take what they need. They cooperate but have a gun to one another's temples. This mutually

assured destruction allowed them to thrive together in the cold Atlantic for 15 million years. Survival of the fittest implies an all-out war. It's not true."

"Sorry, Mr Deshpande, I don't understand your meaning."

"We were going to make information about the microplastic clearing community freely available a week before the IPO. Give something back to the world. Someone wanted to derail us. Can you find out who and pay them a call. I want their affiliations and intentions. If they wanted to profit or hurt us, if the first we go Darwinian on their balance sheet. But if their motives are less selfish…then I want to meet them."

After the call, I crawl into bed and sleeplessly stare at the ceiling. At six wearing my duvet, I step out for some fresh air and light my third cigarette in 24 hours. I think of the communities of bacteria and how they sometimes support the kelp and sometimes victimise it.

What was Deshpande saying to me? Did he know I had already worked out Rhys's buyer?

Xander Deshpande and his wife move in mysterious ways.

I imagine the hundreds of people tirelessly working at Gaia Biofuels, spending all night in their offices, neglecting their children and their spouses. All for the company's mission: For the common good.

I will arrange a meeting with Hamish's handler as Mr Deshpande asks. But what will I say when I meet her? Will I sell her the contents, or will I do as my boss asks?

The greener Tyne

Matt Edmundson, United Kingdom

The boat kept station at the mouth of the Tyne. Ahead a large coaster was just passing the twin Shields piers on its way upriver. Eric could make out the name *Sunflower* painted in gold letters on the stern. He'd seen the ship a lot recently on his trips to and from Tyneside, there was an important bioremediation project happening down in Cornwall and this ship was part of those efforts.

Centuries of tin and copper mining had brought wealth to a few and hard, dangerous work to many, and had also generated huge amounts of arsenic as a byproduct. This had contaminated the soil around the old workings, useless land filled with deadly poison. But something had shifted in the way the economy regarded the situation; that soil wasn't filled with poison; it was a rich resource to be brought back into use (although it was very much still a deadly poison if not handled correctly).

Arsenic-resistant plants could be grown on the spoil heaps, slowly enriching themselves on the discarded metals. These plants could then be harvested, and brought to the biofactories of the Tyne, where they were ground down and fed to communities of engineered bacteria. These specialists could recover the copper and tin missed by the first miners, taking the raw atoms and performing their biochemical magic to turn them into potent antimicrobials, or as additives for complex alloys; even the arsenic could find a use in a new generation of microelectronics, or in anti-cancer drugs. The plants themselves were both food for the bacteria and also a resource in themselves; other modified microorganisms could convert the plant mass into pharmaceuticals, or bioplastics, or perfume scents; any complex

organic molecule was potentially within reach. As Eric waited his turn to enter the river, he saw a biotanker heading out into the North Sea, carrying biofuels.

A happy little chime sounded from the navigation computer. Eric approved the request from the Tyne pilot and gave over control of his boat to the automated system. He furled the photovoltaic sails and locked down the tubular wind turbine in the centre of the deck and switched to battery power; the river was busy, and he didn't want to be blown into the path of another vessel. He looked down from the bridge, across the deck of the ship, as it made its own way along the river. Only a few dozen metres long with a three-story deckhouse on the stern shaped like an old-style Chinese junk and carrying a cargo of waste plastic, sorted by type in its three little holds; one for PET, one for polystyrene and one of mixed, scooped straight out of the sea and not smelling particularly appealing. The rotting seaweed would at least earn him a small bonus as biomass though. The deckhouse consisted of the bridge on the highest level with two decks of living quarters below.

Beneath the level of the main deck were the gubbins of the ship; the batteries and engines, fresh and waste water tanks, the processors for the automated systems. Eric made his way downstairs from the bridge into the kitchen. Freya was sitting at the kitchen table, working on her tablet. She was scanning through the global commodity index; information constantly updating, showing what needed picking up where and to where it needed taking, so whatever the route you had planned there was always cargo to take on somewhere along it.

"Once we've dropped off this lot there's a pickup from the wastewater plant", she said.

"Oh. You sure there's nothing else on there?" asked Eric as he put the kettle on.

"Afraid not. Besides, we need to empty the ship's wastewater tanks soon anyway, it'd be nice to get paid for it instead of paying to get rid of it".

"Ugh, fine, book it in. Fancy a tea?"

"No, I'm good, thanks."

Eric poured tea into his mug and snuck a biscuit out of the tin.

"Right, I'm off back upstairs, check our progress."

As he entered the bridge he saw they were just passing the *Sunflower*, moored up beside a biofactory. The crew had already started unloading. The smell of flowers and cut grass reached Eric as he sipped his tea. As he watched he saw flashes of yellow and black; the ship was very aptly named. The oils in the sunflower seeds would make a very good feedstock for the microbes.

Eric continued watching the activity of the river and its banks, vessels loading and unloading, smaller boats picking their way around their larger siblings. Eventually the Ouseburn came into sight. Two figures were trying to manoeuvre a large thick square of stiff fabric onto a cargo bike. "I wonder if that's mushroom leather?" thought Eric as he passed by. He knew the Victoria tunnel ran under the city of Newcastle, once connecting the quayside to the colliery; after the colliery was closed the tunnels were largely abandoned. In the 1920s they'd tried converting the tunnel into a mushroom farm with little success. It took over a century before bespoke engineered fungi were developed that could be processed into sustainable leather with the same texture and properties of the original material, finally allowing a mycological garden to flourish beneath the city.

Finally, their boat arrived at the Dunston Staithes; the tall wooden jetty where coal from pits on the south side of the Tyne were loaded onto the ships. Today there was a market being held on them, and Eric could see the crowded stalls as he tied up the boat. He climbed up to the staithes and sought out Tony, the market organiser.

"Hello Tony! You got something for me?"

"Aye, we've stacked up all the packaging in the usual place. We've had a couple of fishmongers up from North Shields so some of the polystyrene stinks of fish, but it should still be good".

"Cheers Tones, I'll get it loaded up."

The two men began transferring armfuls of plastic packaging onto the boat, the light but bulky polystyrene being a particular hassle. Once they'd finished, they made their farewells and Eric cast off to make the short hop further upriver to Blaydon. As he approached the dock at one of the biofactories he saw a figure making their way down the quayside, waving cheerily. As he got closer Eric saw it was Flora, the dock manager, and waved back in response.

"Hiya hinny, what have you got for me this time?" she asked.

"PET in hold one, polystyrene in two and mixed in three, plus a stack of mixed on deck from the market."

"Ah, if I'd known you'd be stopping off there I'd've asked you to pick me up a couple of stotties. Never mind! We'll get this unloaded for you. If you pop into the office Sally'll sort out your payment."

Eric thanked her and made his way towards the main building as the deck crew began offloading the cargo. Opening the door, he was hit by the smell of a dozen different spices; he enjoyed visiting the factory,

it always reminded him of Christmas. The receptionist buzzed him through into the main office and he made his way to Sally's desk.

"Hiya Eric! How're things?" They chatted for a while, catching up whilst the shipment was unloaded.

"This place always smells amazing," said Eric, "I've got no idea how you take plastic that stinks of fish and turn it into something that smells so good."

"Why don't I give you a quick tour? I can't believe I've not shown you round before!"

"That sounds great!"

They made their way into the factory floor. Huge cylindrical vats stood in rows, floor to ceiling. Pipes in profusion ran around the space, seemingly connecting everything to everything else, disappearing into walls, under the floors and out of the roof. The smell of spice was even stronger in here, intense and only a notch under being overwhelming. Benches were dotted around here and there, bearing pieces of equipment. At a few of these stations people busied themselves with testing samples and analysing data.

"This is where the magic happens!" said Sally. "We've got a watermill down by the river where we grind up the plastic; it needs to be in very small bits before we can feed it to our bacteria in here" she said as she patted one of the giant cylinders. "In this bioreactor we say auf wiedersehen PET and hello vanilla!"

"So, you go from PET plastic to something you can put in ice cream? Won't you get microplastics into my desert?"

"No, that's the beauty of chemistry. PET is made up of the same molecule repeated loads of times and joined up in a long chain, a

polymer. That molecule is very close to being the molecule called vanillin, which gives you the taste and smell of vanilla. We've designed our bacteria to be able to take the PET molecule, break some of the chemical bonds and form new ones so the molecule is now vanillin. No plastic, all vanilla!" "Ah, so I'm not eating plastic?"

"No. Hmm, I guess it's like if you had a caterpillar, and it turned into a butterfly. If you ate the butterfly, you wouldn't be eating the caterpillar. Although I'd suggest not eating either…"

Eric chuckled. "I think you need a better metaphor than caterpillar ice cream."

"Ha, no! How about it being like if you fertilise a field of crops? You spread manure onto the field and the plants take up the nutrients from that and turn it into fruit, or vegetables? You're eating the same molecules that made up the manure, but the plants have turned them into apples or potatoes."

"That does sound more palatable. Agh, you've just reminded me we've got to do a pickup of "fertiliser" at the sewerage plant later. Not looking forward to that!"

"Don't poo-poo the poo! It's an amazing resource, very rich in nutrients. If you process it correctly you can make a great feedstock from it. You know back in the old days people used to really value it, they'd pay good money to get it and spread it on their crops. Somewhere along the way we lost sight of just how much value it had and started dumping it into the rivers and seas. Literally flushing money away…"

"Well, I'll be sure to remember that if one of the cargo seals breaks and I'm sailing around in a floating toilet…"

Sally laughed. "Hopefully it won't be as bad as that!"

They continued their tour. They passed the bioreactors for cinnamon and limonene, and on to the bespoke pharmaceuticals.

"We have a library of engineered bacteria, depending on which flavouring or drug are needed we can load up the reactor with a few cells of the strain we want. The molecules that make up plastic are a great starting point for so many things!"

They finished their tour and made their way back to the office.

"Thanks Sally, that was really interesting! It's good to see what actually happens to the plastic I'm carrying around."

"Glad you enjoyed it!"

Bidding Sally farewell Eric made his way back to his boat. Freya was on deck, helping the dock team unload the last of the cargo. As he climbed aboard, she was just closing the final hatch on the empty hold.

"All sorted?" she asked.

"Yep, all done. Suppose we'd better go and get that sewerage loaded now…"

"I suppose so!" she chuckled.

They both stood on the bridge as the boat headed back down river, through the centre of Newcastle, picking their way through the busy river traffic and passing the new biofactories on either bank.

"It's good to see the river busy again. It helped drive a whole industrial revolution", mused Eric.

"Yes… and helped cause a lot of pollution problems we're still dealing with".

"Ha, that's true too. At least now we're not just digging up resources to make things just to throw them away."

"Yep, the river sends stuff out, it gets used, then it all comes flowing back up to get turned into something new again. And with us carting it all over the place in between. Speaking of which you'd best get back up to the bridge and make sure we're still on course."

They continued down the Tyne, flowing into the North Sea and out into the world.

Future tree

Nick Sidwell, United Kingdom

I have been away for a long time. I remember the tree. I remember the tree even though I have been away for a long time.

I have sat beneath the tree. I used to sit beneath the tree. The tree is in the centre of the town square. The square has views over rooftops and out to sea. People have sat beneath the tree for a long time, longer even than I have been away. I am sitting beneath the tree now. It is my fourth day back. It is evening, and I am sitting beneath the tree, waiting.

The tree has changed. Its trunk is run through with metal struts. The trunk is split open and partially hollowed out. The struts are visible inside the trunk, as though they are the skeleton of the tree. The branches overhead are probably supported by metal as well, although it is not visible. The branches overhead look like real branches, but they are not. At their bases, they have been intricately connected to the split open trunk. Intimately connected. They are not part of the tree. They are part of the tree.

When I first saw the tree after so long away, I did not notice the struts or the unreal branches. I saw the tree from the edge of the square, from far away and it looked like the tree I remember, from a long time ago. Underneath the tree are benches. I sat on a bench and did not notice the struts or the unreal branches as I looked out over the square. There are shops on the edge of the square.

In the morning, the shop with the longest queue is the café. In the evening, the shop with the longest queue is the gelateria. In the daytime, the shop with the longest queue is the one selling microbes.

The café is old and the gelateria is old. They were both here a long time ago, before I went away. The shop selling microbes is new. It was not here a long time ago.

Before I knew what the shop was, I was drawn to the queue. On my first day back in the town after such a long time away, I sat on the bench in the square underneath the old tree and watched the queue move from the café to the shop to the gelateria. I did not move all day, so tired was I after so long away. Tired and old. I watched the queue.

On my second day back, I did not go to the square. Instead, I went to the beach. On the beach, there was no litter. Before I went away, there was always litter on the beach. For a while I did not know what to do. Where had the litter gone? I called my daughter. She is old now, although not as old as me. I did not speak to her while I was away. Finding her number was not easy, although I was not surprised to learn that she still lived in the town, after all this time. She was surprised to hear from me. She did not recognise my voice and when I told her who I was, she was surprised, and then she did not believe me. I don't know whether she believes me now, but she agreed to meet me in two days' time, in the evening, underneath the tree in the main square. It is for her that I am waiting underneath the tree.

On my third day back, I returned to the square. I had a day to wait until I was due to meet my daughter, and I did not want to return to the beach without the litter. Before I went away, I did not like the litter but now I am back after such a long time, I do not like the change. I returned to the square and watched the queues. Again, a queue formed at the café. I was intrigued and joined the queue and bought a coffee. I sat back down underneath the tree and drank the coffee. It was exquisite and I understood why people would queue for it.

Next the queue formed at the microbe shop. I was intrigued again, and I joined the queue. In the microbe shop, I did know what to buy. They did not sell coffee in the microbe shop. A young man was serving the microbe shop's customers and I asked him what the shop sold.

"Microbial solutions for the home."

"What are microbial solutions for the home?" I asked him. Then, by way of explaining my ignorance, I added, "I have been away for a very long time."

The young man was generous and did not mind my ignorance.

"We have all sorts," he said. "It depends what you need them for. This is one of our bestsellers."

He showed me a packet for a product I had never heard of. The packet featured the logo of a company I had never heard of.

"I have never heard of this," I said. "It must be new. I have been away for such a long time." "It's for household waste," the young man told me.

"What does it do?"

"You add it to your bin and it breaks down the waste into juice." "What is juice?"

"It's what's left over when the microbes have broken down the waste. They don't use microbes where you've been?"

I shook my head. "What kind of waste does it break down?"

The young man raised his eyebrows slightly. "I thought everywhere used microbes these days. They break down everything."

He made a show of checking the wording on the packaging, and then added, "this mix is optimised for plastics, but it can tackle most household rubbish."

"Is it any good?"

"Oh, yes. Our customers swear by it. It's based on the one the town uses for municipal waste. It's transformed the place. Did you know, we used to have litter everywhere? It got really bad before they brought in the microbes."

"Yes," I said. "I remember the litter on the beach."

"The beach was a mess," the young man said, although I did not agree. "Thank goodness for the microbes. They cleared it up about the same time they did the tree."

He pointed across the square to the tree under which I had been sitting. The tree under which people had been sitting for a very long time, longer even than the time I had been away.

"What did they do to the tree?"

"It's amazing really. The tree died, you know. The air got so bad. The leaves just shrivelled, then the tree died. Those leaves you see now house microbes that clean the air. The air is so much better now. It's better everywhere. The litter is gone. The town has cleared up its pollution. The sea was really bad, you know? The beach got covered in litter then it got covered in oil that washed up from somewhere. The microbes cleared it all up. They cleaned the air. Now the air round the tree is the cleanest in the whole town. Old people like to sit there because they say it makes them feel young."

The young man looked embarrassed after he said this because I am very old and he is young, but I did not mind and I showed that I did

not mind by politely thanking him and returning to the tree under which I had been sitting without looking closely at the branches over my head and the microbe leaves on the branches. The branches were too high for me to reach but now that I looked closely, I could see that they were not real although they were so closely bound to the tree that I had not seen that they were not part of it.

I breathed in the air to see if it would make me feel younger. I sat down underneath the tree and breathed in deeply. It felt good after being away for so long to sit under the tree and breathe its air. I liked the tree. I was sorry to hear that the beach had been in such a bad way, and I was sorry too that I had taken against the beach for its lack of litter. I breathed in the tree, hoping that my breathing was a sign of my repentance for my ill feelings towards the beach.

The next morning, I went back to the beach. I had been away for so long, and when I first saw the beach on my return, I did not like it, but now I liked it, and it was a joyous feeling. Children played on the beach. They were chasing each other. They were careful around me as I walked along the beach because I am old and they think I can be easily knocked over. Perhaps they are right. I spent the morning on the beach. It was good to be there, after so long away.

In the evening I went to the main square and sat beneath the tree to wait for my daughter. I breathed in the air and felt younger. After a while an old lady approached the tree. I looked up but I did not recognise her. I returned to my breathing. To breathing in the air of the microbes. The tree had been killed by the dirty air. I had been away. I had been away for such a long time and had not known that the tree had been suffering. Would I have returned if I had known? I do not know. But the tree was still here only now it had a skeleton and new branches and microbe leaves, and it cleaned the air.

I opened my eyes. The old lady was standing nearby, looking at me uncertainly. Even after so long, after I had been away for so long and had not known of the plight of the beach or the tree, even after all this time, this time I recognised my daughter.

Tree of life

Hannah Southcott, Australia

The memorial was colourful. Sophie had insisted that each of her guests wear a different shade and, in the weeks before her death, had carefully written instructions to each of her mourners, placed them in a very cheerful looking envelope, attached a stamp and left them to be posted the moment she took her last breath.

The result looked rather like a truck had smashed into a paint shop – and the canisters had carefully exploded everywhere. But that was Sophie. Never one to do anything quietly – certainly not dying.

The colours belied the depressed mood at the gathering. Memorials are seldom fun, but when someone has been taken long before their time, it further dampens the mood. Sophie had lived just fifteen short years. Although to those around her, it had felt a lot longer. In a good way. More like she had always been with them, and they couldn't imagine a life without her.

But now she was gone. Forever. The bone cancer she'd been diagnosed with as a toddler had slowly claimed more and more of her frail body and finally it had swallowed her whole. Now all that was left was this horrible memorial.

For some reason her lawyer had showed up, with a briefcase, wearing a bright pink suit. No doubt under strict instructions from her client. But why was she here?

The lawyer waited quietly at the back of the garden and when the memorial service was over, moved purposefully towards Sophie's grandma, who was weeping loudly into a floral handkerchief.

'Cynthia,' the lawyer said softly, 'I'm so sorry for your loss. I can't quite believe she's gone. Sophie was such a force of nature, I always thought...' she trailed off, unable to find the adequate words.

Grandma Cynthia loudly blew her nose and turned to look up at the tall lawyer. 'I'm sorry, I don't recall your name,' she replied rather brusquely. 'I suppose Sophie invited you, seeing as you're wearing that ghastly suit.'

She looked rather critically at the lawyer, who she didn't trust on principal. The lawyer was a little taken aback by her manner, but quickly recovered.

'Ah, my name is Angela Martin. Please call me Angela,' she said. 'Sophie told me so much about you.'

'Hmmf, well please call me Ms Ashworth, seeing as I barely know you,' Grandma Cynthia replied tartly.

'Of course,' the lawyer demurred.

'Oh, and I just remembered why you are here. To cart our Sophie off to that place so she can be liquefied,' Grandma Cynthia exclaimed, rather loudly. A few of the guests turned to stare in their direction. 'It's too horrible for words!'

Feeling a little embarrassed, the lawyer placed what she hoped was a soothing hand on Grandma Cynthia's shoulder. 'Ms Ashworth, those were Sophie's last wishes. She was very clear on her instructions.'

Grandma Cynthia sniffed her disapproval loudly, 'I know my Sophie was a little bit eccentric, but why can't she just be buried or cremated like a normal person. This whole palaver is just too upsetting.'

The lawyer gazed around the memorial for a moment, spying Sophie's parents, who were wearing bright orange and teal and looking forlorn in the corner. 'I think you'll understand it all a little better once you meet the team at Eternal Tree,' she said. 'I'm not the best person to explain all of the science to you. All I know is that this is what Sophie wanted.'

Grandma Cynthia scowled for a moment, then clapped her hands loudly. 'OK everyone, you've said goodbye to Sophie, now please leave. We have to go watch our little girl be turned into mush!'

More relieved than offended, the brightly coloured crowd slowly left the garden, murmuring a few cursory farewells and condolences. Soon, only a handful of people remained, enough for perhaps half a rainbow. Sophie's parents shuffled over; grief deeply etched in the lines of their faces. A yellow-clad aunt stood under a tree, clutching a glass of water, and trying not to cry. And there was a young boy with ancient eyes, slumped on the soft cushions of the couch. A green, angular lump amongst the sea of grey.

Angela took a deep breath, aware of the hostile gazes being shot in her direction. 'I've got a letter here that Sophie wanted me to read out to you, once the memorial was over,' she said. 'Can everyone hear me OK?'

There was a general nodding from all the parties, so Angela knelt down, clicked open her briefcase and withdrew a large manilla envelope, which was covered in unicorn and rainbow stickers. Straightening back up, Angela took the letter from the envelope, and cleared her throat.

'Dear mum and dad, Grandma Cynthia, Aunty D and Jeremy,

My lawyer is reading this to you, which means the cancer's finally got me. Please don't be too sad. Although I do expect you to cry a lot, because I was pretty amazing and you'd better all miss me like crazy.

Also please check that the lawyer is wearing a pink suit to my memorial. She'd better be. That was also one of my final wishes.

I really, really wanted to live, I think you all know that. I had so many ideas on how to save the world. I've posted them all online, so hopefully someone can find ways to actually make them work, even now I'm gone. Sometimes I wish you could see the world as I did. Nature is so magnificent, so beautiful, so splendid.

Anyway, I know you probably all find it a bit weird, but I want my body to create new life. Graveyards are full and cremation is an awful use of energy. Dying at fifteen means I can never have human children. But my body can still be used to create life. That's why I want to be in the Eternal Tree trial.

I hope you understand. Once you get there – they will explain all the details and awesome sciency stuff to you.

I love you all. Please honour my wishes or I will haunt you. Sophie xxxxxxx'

Angela's voice was thick with emotion as she read the final words. Looking around, she saw the family were smiling through their tears. It seemed that the letter had had its desired effect. Any resistance to Sophie's plans had melted away.

….

At 3pm, the hearse arrived to transport Sophie's body to the Eternal Tree facility. Her family bundled into a few cars, still clad in their violently vibrant attire.

When they arrived at the building – the lawyer was waiting out the front. The hearse was directed through a boom-gate off to the side – and presumably, Sophie's body would be transferred there. The family disembarked from their vehicles and the small group gathered and then waited for the large, glass doors to open. Inside, they were greeted by a youthful looking man, with dark hair and smooth olive skin.

'Welcome,' he said with a slight lilt. 'I'm Gideon Halpert and I'm the founder of Eternal Tree. You must be Sophie's family. She was a truly wonderful person and we're so honoured she chose us, to assist her in her next stage of life.'

Grandma Cynthia glared at him. 'She's dead,' she said firmly. 'There is no next stage of life.'

The man smiled a little awkwardly, then continued. 'That really depends on your definition of life. For us here at Eternal Tree, we know that all life is made of atoms. These atoms have been in countless different forms, before they became a human form, and will be in countless forms after.'

Grandma Cynthia rolled her eyes and snorted. 'Can you please just tell us what it is you do here?'

The young man smiled again and this time it reached his eyes. 'If you'll bear with me a few moments more, I'd love to explain everything,' he said. 'I don't know if any of you have been to a cemetery recently?'

The lawyer and Sophie's parents nodded slightly.

'Well, cemeteries are often huge, in fact in most countries in the world cemeteries are full to over- flowing. They are a bit of a wasteland of stones and weeds. So, I wanted to offer an alternative to being buried

in such a depressing place. Somewhere the family can still visit and remember.'

He paused for a moment, looking around. 'I have a degree in microbiology. So, this project is my little effort to try and help the community and the environment at the same time. Basically, we have a method that utilises microbes to break down human bodies into a sort of nutrient soup. We capture any gases released and store them to use a fuel. We then plant the seed of a forest tree – which has been carefully selected by the client. We grow the seed, feeding it the nutrient soup, until it is ready to be planted. Eternal Tree currently has three planting zones, but we plan on having many more in the future. The tree planting usually takes place around a year after the person passes away. The tree is cared for by a full-time caretaker, but we've also found that family members love to weed and water the tree. Over time, the forest grows and instead of a barren, rocky wasteland, it becomes a beautiful, living memorial. But it's more than that, it's also a place of biodiversity and life, a piece of nature that families can enjoy for generations to come. Instead of cutting down trees to bury people, we're planting them.'

The family looked at him, a slightly stunned expression on their faces. 'I'm very happy to answer any questions you might have,' he said.

Grandma Cynthia recovered her composure first. 'Why don't you just cremate people? We did that with my Great Aunt Doris and popped it in a pot and grew the most beautiful roses. Why do you have to turn them into a soup?'

Gideon turned and smiled at the formidable lady and realised, despite her combative stance, she was in fact quite a tiny woman and clad entirely in green.

'Cremation requires a huge amount of energy. For a human body to be reduced to ash, it must be burnt at nearly 2000 degrees for two to three hours. It also emits a significant amount of carbon. The ash produced can be put in a pot-plant, sure.'

There was a slight cough from the man in orange, who must have been Sophie's father. He said, rather softly, 'I think it's rather a splendid idea. What tree did Sophie choose? And where exactly are you going to plant it?'

'I'm glad you asked,' Gideon said, turning to the man. 'Sophie chose a Rosewood or *Dysoxylum fraserianum*. It's a rainforest tree which is native to this part of the country and as it matures provides important habitat for a number of plant and animal species. And just like Sophie, it's a fairly tough tree. Drought resistant, able to grow in a wide range of soils and salt and frost tolerant.'

The family were nodding now and there was a flicker of a smile on the mother's face.

'Eternal Tree has purchased an old dairy farm about 10 kilometres north from here,' he continued. 'The soil is quite degraded, but we have a team of microbiologists, mycologists and soil experts working to prepare it for its future as a forest. If you come with me, I have a map of our different plantation sites.'

The family trooped after Gideon, gazing at the strange fungi photos that lined the walls. They entered a huge round room, with a tree growing in the centre. Part of the glass ceiling was open.

'That's my grandmother,' Gideon said quietly. 'It's a wattle, with brilliant yellow flowers – a show- stopper, just like she was. She was my first customer. She hated the idea of being in a cemetery, but she loved the idea of becoming part of a forest'.

There was a large table near the tree – with a digital map of the town. Three areas were highlighted bright green. Gideon pointed to the locations and explained some of the reasoning behind choosing them.

He then led them through to the nursery – where dozens of seedlings were growing in small pots. 'Once these seedlings are a few months old, we transplant them with the nutrient soup. We grow them for about a year, constantly monitoring and feeding them and working to establish beneficial fungi in the organic matter to give them the best chance of survival once they are planted in the soil.'

The young boy with the ancient eyes now spoke up. 'How long does it take to turn a human body into soup?' he asked. 'How soon before Sophie becomes part of one of these trees?'

Brushing his hands softly over the leaves of one sapling, Gideon replied, 'The process varies a little from person to person. We utilise the body's natural microbes as well as additional ones to help the body decompose. Generally, it takes two to three months.'

The boy nodded. 'How do the saplings respond once they are fed the soup?'

Gideon chuckled, 'Oh they really take off then, it's usually a significant growth spurt, you can almost see them growing. The nutrient soup is like a very rich multivitamin.'

He continued his tour, taking them down a corridor to a large steel door. Punching in a long code and presenting his fingerprint, he then led them into another warehouse sized room. It was divided into two sections. They were behind a thick pane of glass – on the other side it looked rather like an indoor garden, but with strange-coloured containers. There were trees, shrubs, plants, and mushrooms growing

around these containers. The ceiling was glass, but it was securely closed.

There appeared to be a web-like sprinkler system attached to it. There was a whirr of huge extraction fans.

'This is where the decomposition takes place,' Gideon said, motioning to the coloured containers. 'We've found it best to keep the process as natural as possible. The bodies emit gases as they break down, which are captured by these extraction fans. The flora provides any additional microbes that are needed.'

'It looks peaceful,' murmured Grandma Cynthia.

Ushering the family along, the group were soon back in the lobby and seated on a comfortable couch, with tea, coffee, and a good selection of biscuits.

'Can we come and see her here?' Sophie's mother asked, her voice catching a little on her words.

Gideon nodded. 'You do have to make an appointment, but yes, you can visit here in the first three months. Once Sophie is merged with the tree, we move the sapling to the growing location, while it's still quite small, so it can acclimatise there.'

There was silence as the family glanced at each other.

'And the planting,' Sophie's father inquired. 'Can we be there when she's planted?' Six pairs of anxious eyes flickered onto Gideon's face.

'Yes of course,' Gideon replied. 'Our team will work with you to organise a mutually beneficial time and date for the planting, and we really encourage family to be a part of it. After she's been planted, you are free to visit as often as you wish. We even have a volunteer

program for families who want to become more involved in caring for the forest as it grows.'

A year later, Angela, Grandma Cynthia and Sophie's parents stood around as her tree was planted.

The boy with the ancient eyes had died a few months earlier, inevitably succumbing to the cancer ravaging his small body. He'd asked for the spot next to Sophie, so the two of them could finally grow up together. The Tallowwood sapling would be planted there the following spring.

A large, deep hole had been bored into the soil and the family and lawyer watched as it was partially filled with fertilisers, composts, and wood chips. The rosewood sapling was carefully lowered into the hole and the remaining soil was thrown in and carefully compacted. The tree looked happy, healthy, full of life.

As she gazed at the skinny limbs and vibrant green leaves, Grandma Cynthia thought she could see something of Sophie there, that gangly girl who had brought so much joy everywhere she went. Perhaps in this body, she'd have a chance to grow, to experience the seasons, to provide shade and shelter for generations to come. A place of life and hope, even after death.

She smiled and stroked the smooth bark of the tree, whispering, 'I'll be here every week to make sure you're going strong my girl. This time you'll outlive us all.'

In the new days

Fiona Mischel, United Kingdom

Jodie was up first. This was unusual—normally Da was up early to feed the fermenter. But today the kitchen was quiet and the fermenter was blinking an unhappy red.

Jodie crossed the room, carefully avoiding the worn patch down the centre where the microbes in the concrete were still repairing the floor. She looked up at the fermenter on the countertop. It was still winking down at her forlornly from its shiny steel face. She scrambled up, her little legs struggling for a moment in empty air. Standing on the counter, she was only a little taller than the fermenter herself. Of course, this was just the household one. The big fermenter out by Mum's workshop was taller than Da. She pried open the lid with a child's deft fingers and looked inside. All the cartridges were empty. If Da didn't come down soon, there wouldn't be enough time for the fermenter to cycle by dinner time. No cycle, no cells. No cells, no supper.

Carefully, Jodie closed the lid and hopped off the counter. She opened the fridge and pulled open the family's cell bank. Little vials of chicken cells were nestled next to cow and pig. Her favourite was the salmon but the little space where the vial should be was empty. They would have to get some more cells from their family's salmon, Algie.

For a moment, Jodie didn't know what to do. She could load cells into the fermenter and they could have nice beef steaks for dinner. But if she wanted to grow steaks instead of ground meat, hadn't Da said the cells needed different nutrients? Or no, maybe that was for fish. Steaks

were a setting. Yes, the scaffold setting so the meat would have a 3D structure.

Jodie hurried back to the fermenter and popped the lid. She couldn't read yet, but she thought that long word might be *scaffolding*. But it could also have been *cyanobacteria* and Mum wouldn't be happy if she ran an algae cycle on animal cartridges. "Stops up the works," she had said.

At five years old, Jodie was old enough to go with Mum to take the cell samples from their animals like Algie and Little Jo, their slow-moving cow who made them milk in the mornings. But Da said she still couldn't touch the fermenter. This was frustrating because most of her friends had toy fermenters and they used them all the time. "They're too expensive," Mum had said.

But Jodie didn't complain too much because most of her friends didn't have any family animals and Mum said their family were extremely lucky. Jodie agreed, especially about Little Jo. She loved her gentle eyes and the way she smelled and the slow way she swung her head. The cow also wasn't as frantic as their chicken, Dumb-Dumb, or as insistent as Eddie, their potbellied pig and Jodie found that very comforting.

Just looking at the empty fermenter made her hungry, so she closed the lid and popped open the bottom tray. There were strips of raw bacon there, ready to be fried. Maybe she could surprise Da and cook them all by herself.

Carefully, she climbed back off the counter, grabbed a fork out of the drawer and speared the bacon from the tray into a frying pan. She flicked on the electric hob and waited for the bacon to sizzle. She was just wondering if she should turn them over when there was a clack and thud of feet on the stairs and Da came rushing into the kitchen.

"Whoa there!" he gasped. "What's going on here?" "Making breakfast," Jodie replied.

Da scooted her out of the way and turned down the heat. "Next time you want to cook, come get me first, hmm?" He ruffled her hair, gently took the fork and flipped over the bacon. They looked a bit black on the underside, Jodie noticed.

"Why were you late?" she asked, looking up at his crinkly, bearded face. His eyes were so bright and blue that Jodie always imagined they could see through everything around them.

"Nothing to worry about, little sprout. Mum and I were just talking about the soil. The microbes aren't happy again and we don't know why. Not storing as much carbon as they should."

"But isn't that the trees' job?" Jodie wondered.

"The trees can't do it all by themselves," Da said patiently. "The little organisms you can't see take on just as much of the work."

Jodie nodded even though she didn't really understand. Mum and Da were always worried about microbes. Sometimes it was the ones in the soil or the ones in the big fermenter. Sometimes it was the ones all over the counters and then Mum insisted they wipe them away.

"Why don't we make Mum some toast and cheese and bring her this bacon you've cooked up, hmm?" suggested Da.

Jodie trotted over to the bread and handed it to him for slicing. Then she pulled open the fridge and took out some of last week's fermenter cheese. Once, Mum had said they could use some of Little Jo's milk to make cheese like they did in the old days before fermenters did all the work. "But Little Jo only makes enough milk for the three of us," Mum

had warned. "Cows don't have to produce as much as they did fifty years ago so we won't get much cheese."

Her parents' room was at the top of the house. The biosensor on the landing—no bigger than Da's hand—showed green. The air was good today, then. Mum was sitting in their bed that she had made herself out of fabricated wood from the big fermenter. It was a nice reddish brown and covered with big cosy blankets. Mum had grown all kinds of fibres in the big fermenter so some of the blankets were cotton, some linen, and one was even wool. Mum couldn't knit very well but at least the wool was soft.

Mum looked tired. Her dark curly hair was bound up in her sleeping scarf and there were lines on her face that Jodie thought hadn't been there before. But she smiled at the sight of her daughter in the doorway and Jodie jumped exuberantly into her arms.

"What a lovely breakfast!" she exclaimed as Da handed her the plate. "Jodie, did you make this all by yourself?" she asked, suddenly suspicious.

"Da helped," said Jodie quickly.

Da nodded helpfully and sat down on the bed as Mum tucked into the bacon. Jodie thought she might have winced at the black crust on one side but maybe she imagined it.

For a while, Jodie listened to Mum and Da talk about the soil and why its microbiome was unbalanced. Da had put sensors in the ground last week and some of the microbe strains were over-producing. It was very boring but Jodie liked being with Mum and Da in the big bed, so she didn't mind.

"I'll get the cells going for dinner and then I'll get out there," Da was saying. "You take a lie in."

"I'll be fine," Mum said impatiently.

"What's wrong?" Jodie said, looking up at her.

"Nothing, little sprout. Too much work, not enough tickles!" she said, and Jodie squealed as her mother tickled her and covered her in kisses. Then Da joined in and Jodie escaped and Da chased her around the room and then she chased him back and then they both jumped back on Mum and the last of the toast went flying.

They lay there for a moment, panting and laughing and feeling much too warm on Mum's wool blanket. "I'd best get going," said Da reluctantly.

Mum nodded and Da got changed into his work clothes. His hair was standing on end like it had been electrified and Jodie laughed at him.

"Well," said Mum when Da had gone. "Will you help me with the animals today? Da says the cow cell lines are wearing out and we need new ones."

"And Algie," she added.

"And Algie," Mum sighed. Jodie knew she didn't like taking cells from Algie. They had to do it while he was underwater, of course, which Mum said was "a giant pain in the—." But where it was a giant pain, Mum would never say.

Mum got dressed and helped Jodie into her clothes. After a small fuss in which Jodie didn't want to wear a coat and Mum made her anyway, she followed Mum out to the farm.

Their family lived on a big patch of land that Mum said had once been an industrial site. It had not been a nice place then, so they had gotten the land at a bargain. That was before all the land had been cleaned up, so Mum and Da had had to do a lot of it themselves. That's also why Jodie's parents were older than most of her friends; they'd waited to have Jodie until after the land was restored.

Jodie helped Mum take the big bucket of feed out to Little Jo, who lowed at the smell of barley and lumbered over to greet them. Jodie patted her black and white splotched face and her soft, snuffly nose.

Mum had brought along the syringe kit to take some of Little Jo's cells. "Does it hurt?" Jodie had asked once.

"Only a little pinch," Mum had said. "Like when you get a shot at the doctors."

Jodie thought that hurt quite a lot so now she always fed Little Jo extra barley when Mum took a biopsy.

"Why don't we get all our cells in the mail like Fatima's family?" Jodie asked as Mum sterilised a spot on Little Jo's haunch.

"We could," Mum said. "But I grew up by a farm and I always liked taking care of animals. We don't need to keep so many animals now so most of that land has gone back into forests. But I think it's nice to have our own little farm. Little Jo is more than just her cells," she added.

Jodie agreed and kissed Little Jo and told her that she was the best cow in the whole wide world. Little Jo replied with a slobbery lick of her rough tongue like a giant cat. After a few moments, Mum said that she was all done, and they could take the cells back to the processor. Jodie looked up, startled. Little Jo hadn't even flinched.

They took Algie's cells next. Jodie held Algie underwater in his net while Mum muttered a lot under her breath. By the time they were done, Jodie was bored and wanted to play hide- around-the-bushes.

"Not right now, love," said Mum. "I'm too tired." She did look a bit sick and her voice, always so rich and warm, sounded thin.

"Please, Mum!" Jodie whined.

"Not right now, I said," Mum replied in the tone Jodie knew not to argue with. "Go inside and I'll be in soon."

When Jodie was gone, Nadia sat down heavily, her chest heaving. She didn't want her daughter to see her like this. Not yet. But the day was coming when she wouldn't be able to hide it any longer.

She looked out across the lush green land and felt the same surge of pride she always did.

She had dedicated her life to restoring the damaged places of the world, the water that had festered with chemicals, the heavy metals that had poisoned the soil. But it had come at a cost.

Ewan said she should tell Jodie what was happening. "She'll be proud of you," he insisted.

"She'll be scared," Nadia replied. "She shouldn't have to know these things."

"One day, she'll know everything. She'll learn about it in school, what the world was, how close to the brink we came. She should know what her mum did. What she sacrificed."

"It wasn't a sacrifice because it wasn't a choice," said Nadia hotly. "It's where I was born."

Ewan wrapped her in his arms and kissed her brow, saying without speaking that he was sorry, sorry for what she had lived through and sorry for how he had misspoken. That he loved her more than all the stars in the night. That he was scared, too.

"I know it wasn't," he said softly.

Her generation would be the last, the exposed children whose lungs and blood, whose very DNA had been broken in their earliest years. There was a small comfort in that, mixed in all her anger. But more than anything, Nadia wished she could watch her daughter grow up.

Her breath was back and steady in her chest and, after a moment, she followed her daughter back into their house.

The rest of Jodie's day was a good day except for the part where she fell and skinned her knee and the other part where she wanted to play in the mud with Eddie the pig and Mum wouldn't let her.

Da was home late that night which was just as well because the cells in the kitchen fermenter didn't finish cultivating until well after sunset. Mum fed Jodie an extra snack but she was still tired and generally unhappy by the time dinner was served. Tonight was pork sausages. There hadn't been time to run the scaffold setting which meant no pork chops. But Jodie didn't mind now that her belly was full.

Then it was time for bed which Jodie suddenly decided she didn't want to do. Da played with her while Mum put her feet up and read the news. But after what seemed like only five minutes, Da insisted it was bedtime. Jodie didn't want playtime to end and started crying, which, in Jodie's mind, was a perfectly reasonable thing to do. Then Da got upset and Mum told him to take a break and promised she would tell Jodie a story if she brushed her teeth right away and got into bed. Jodie

loved Mum's stories more than anything, so she scampered off to find her toothbrush. Da's hair was standing on end again.

Jodie's room was her special place. It was full of little glowing plants that Da had gotten from the baby store in town. Jodie wasn't a baby anymore, but she treasured her plants even if she couldn't pronounce *bioluminescence* very well.

She heard Mum coming up the stairs and jumped into bed. Mum smiled when she opened the door. She was carrying a warm cup of milk from Little Jo and Jodie scooted over so Mum could cuddle her while she told her a story.

"Do you want a new story or an old story?" Mum asked. Jodie sipped her milk and thought about it. The milk was rich and creamy and reminded her of Little Jo's big nose.

"Tell me the first story," Jodie said after a moment. "About before I was born."

Mum smiled and rolled her neck. Then she began in that soft voice Jodie loved so much. "Before you were born, the world was a very scary place. Human beings hadn't been kind to the Earth and the Earth was angry. There were terrible storms and heatwaves, and many people and animals were hurt."

"But you fixed it," Jodie interrupted. She didn't like this part of the story very much. "Yes," Mum said gently, "We fixed it. Millions and millions of people all over the world wanted to save the Earth and everyone that lived on it." "People like you and Da?"

"Like me and Da, exactly. Many, many people built solar panels and wind farms and other people took the dinosaur fossils out of cars and

planes. Some people built the cell fermenters like we have in our kitchen and made them small enough so everyone could have one."

"And some people made the bad land better!"

"That's how your Da and I met," Ma said, her voice even softer now. "We were taking samples of the land all around this house and we saw that it was very sick. But we also knew that if we added tiny, special microbes into the dirt they would eat up all the pollutants and make the land healthy again. And so that's what we did. It took a long time but when we were done, we built our house."

"And then you had me," Jodie interrupted again even though her eyes were closed. "And then we had you," Mum said and kissed her curls and tucked her into sleep.

Don't feed the pond

Gavin Barrett-Hayes, United States

A young man, dressed in suit jacket and slacks stands in front of an audience at a conference on an O'Neil cylinder orbiting Mars. He begins to speak.

"Hi everyone! I'm John O'Breen and I know this conference is about microbial engineering for ship life support, specifically focusing on microbial durability. However, I'm going to be telling you a personal story from my past, because I am the reason ships built around Mars have warning signs around their hydroponics rooms. Yes, I am the guy that caused ship builders to put up the bacon sticker."

The audience laughs.

"I am the bacon and the bacon is me," John smiles, then continues, "anyway, without further ado, let's get started with the story I'll be telling you today."

"Mmmm…bacon."

The audience laughs again.

"My mother always said not to feed the pond. Understandable, considering that it was our major source of oxygen and if the pond bit the bucket, we'd be down to old-fashioned scrubbers and air that smelled like dirty socks. I didn't realize it then, but I do now."

O'Breen again pauses before saying "You don't want air that smells like dirty socks," shouting "Don't feed the pond!"

"But I really wanted to feed the pond. I really, really, really wanted to feed the pond. I knew it was a bad idea, but I really, really wanted to."

"I mean, those microbes are everything. You may not think about it, but if you aren't planetside, those miracle microbes filter your sewage, produce oxygen for you, and are your primary food source. And I wasn't allowed. Other than our home's reactor, the pond was the center of our universe, and the one place that I wasn't allowed."

"Goddamnit, I wasn't allowed. I wanted to be allowed…but I wasn't. Of course, there are good reasons as to why I wasn't allowed, as I later found out, but I didn't care about that then, because teenagers are stupid and, being a dumb twelve-year-old, I decided to sneak in."

"Yeah…it ended exactly how you might think it would." "Badly. Very badly."

"It was more work than I expected to get into hydroponics. Which probably should've told me exactly how much of a bad idea it was to try to feed the pond. I had already decided to ignore common sense by this point, so I took it as a challenge."

"I had already said I was stupid, right? I was stupid!" The audience laughs.

"Actually, I probably still am stupid. Maybe I've learned something or gained common sense since then, but I don't know about that."

"Anyway, to continue with my retelling of this sordid tale, I got the outer pond airlock doors open from the cockpit of the ship while my parents were asleep. And of course, I obviously wasn't supposed to know the cockpit passcode but as a sneaky brat, I was able to peek over my parents' shoulders and remember the cockpit passcode."

"So, I got into the cockpit, and then got the pond's outer airlock doors open. And I should've thought this through and realized this idea I had was a terrible one. Why? Because the only reason why an interior compartment would have its own airlock is if maintaining atmosphere

there was more important than maintaining atmosphere anywhere else."

"As I found out later, this is the case. But I didn't think it through when I was pulling this hairbrained stunt. Like I said…stupid teen."

"Anyway, I went down there and got the inner doors open and saw all the gooey green funbugs and thought to myself 'they'd probably like bacon and nutella'."

"TDLR: they didn't like bacon and nutella. They really didn't like bacon and nutella."

"So, after getting the doors to the pond opened, I went down to the mess to go be even more stupid than I already was being."

"If I had just left the airlock doors open, everything would probably have been fine. Some of the algae in the pond would've died but we wouldn't have had to put out an SOS."

"I had to be even more stupid." He sighs.

"So, then I went down to the pantry and grabbed some pork bacon from the walk-in and some nutella from the shelves."

"And then, I went back and dropped it into the pond." "The pond didn't like that. It really, really didn't like that."

"Here is the part where I tell you that I hate bacon, although it is absolutely what I'm most known for."

"I still hate bacon. Hated it back then, hate it now." He sighs.

"But I am the bacon, the bacon is me." The audience laughs.

"I shall never escape my past, I shall never be able to escape from bacon."

"So anyway, I dropped the bacon into the pond and the pond immediately started dying. So, when my parents woke up that morning, our sewer system was already on its way out."

"We were out near Ganymede in the rings doing some mining and refining as most families like ours tend to do. Close to three weeks from any other ship, close to seven months from the nearest port. As many people know, it's hard and dangerous work out there and so when my parents realized that we would likely have life support troubles in the next few days, they immediately went into damage control mode. They started by sending an SOS and then started damage control."

"And when I woke up, I knew I had goofed. Of course, being the stupid teen that I was, I kept quiet. If I had confessed, it would've been easier. But I didn't say nothing. Nada. Which is probably a big reason why parents grounded me until I was an adult. I'm technically still grounded, just don't live with them anymore."

He laughs and the audience laughs with him.

"So there it was, a pack of bacon sitting in the algae, spreading unoptimized bacteria everywhere in the system. Germs, one might say. And those germs were killing our algae culture, outcompeting them for both nutrients and feeding on the algae itself."

"Big problem, if you didn't realize. Because all of our life support depended on those algae."

"So, my parents cut off our sewage treatment first. They realized then that just doing that wasn't enough: the pond was still dying. They had to decide what to prioritize. They looked in our pantry and realized we had enough food to last for close to a month if we rationed closely enough. They looked at the water supply and air supply and realized we needed to filter more H_2O and O_2 to have enough water to hold out for rescue. So, they set the pond to doing that.

Only 12 hours in, the pond was dead, and we only had a week's supply of oxygen and water. They quickly realized that the only way we'd survive this is if we vented the ship and stored all our consumables. So, all the air went into the ship and we started waiting and praying."

"Of course, I'm here telling you this now, so obviously we survived it, but it doesn't feel nearly as likely in the heat of the moment. And that, right there, is why you don't feed the pond."

John O'Breen bows, and once the applause peters out, he asks "any questions?"

Fallen star

Sean May, United Kingdom

The girl takes a standard-issue match out of her survival kit and strikes it against the company logo on the side of the box. The match sputters into life and eats hungrily at the Earth-normal atmosphere, throwing a flickering light all around her onto the translucent surface of the orange rescue dome. Shadows on the curved wall form images of her family dancing in the community hall at the end of Martian Christmas, almost one Earth year ago to the day. In her mind's eye, her parents raise their plastic cups of fermented Star Jelly as they toast in the New Year. Through the viewscreens they watch old planet Earth rise over the fields outside, an evening star reflected in the glistening *Nostoc* through gaps where last night's carbon dioxide snowfall had vanished.

Her da was a pioneering *Nostoc* farmer long before she was born. He had been one of the first company-sponsored independent 'lifers', tending the valleys outside, suiting up every day and driving his rented tractor to spread waste collected from all the living quarters onto the vast acres of bacterial jelly outside.

In stark contrast, her ma had been a microbiologist when she first met da. He had delivered a *Nostoc* harvest to the fermentation vats where she worked, on the same day that she had feedstuff duties. The first time she had seen him, he had been shoveling the gelatinous green mass into one of the testing chambers. She was inside and he was on the other side of the plastic outer dome. Knee-deep in the green goo that had fallen slowly from his trailer, he was shoveling a small bucketful into each of the sample airlocks. By law, as a regolith farmer, he had to deliver samples annually from every acre that he worked to the company facility. Hundreds of cyanobacteria variants, including

the hugely successful *Nostoc*, were owned by the company and licensed to the farmers. The company, in return, claimed first rights of exploitation on any useful new ecotypes emerging from the fields. It was her job to test the harvests from the independent farmers and analyse them against the standard strains. She compared various cost-sensitive and efficiency characteristics, such as carbon dioxide and nitrogen capture from the external atmosphere, alongside many other downstream uses that they had found for *Nostoc* here on Mars on top of its nutritional value.

Back on Earth, *Nostoc* had been known for centuries. Variously called Star Jelly, Fallen Star, and a few less attractive names like Witches Butter, or Mare's Eggs, this widespread bacterium had fed many different peoples on Earth, mostly as a novelty food. In the old East, called 雨來菇 or 'post-rain mushroom', it was highly prized as a Lunar New Year delicacy. Somewhat ironically, it had found a niche as the perfect human co-colonising organism and had travelled up into the sky, accompanying the Chinese diaspora to Mars.

When the girl's mother had watched the unusually tall man shoveling green goo, balancing on the slippery surface, and swearing inappropriately over the open comms channel, she had fallen in love with his outdoor spirit – or so she had told the girl many years later. Married after the company-official minimal six months of courting, their baby girl had arrived the following Martian year, fewer than 600 Earth days after her ma had first seen her da slathered in green mucus.

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The matchlight flickered as it approached the end of its fuel, and the images of her parents danced away across the dome together, hand in hand. The dying yellow illumination prompted her to prod tentatively at her bruised feet, which protruded from the holes in her lower suit

where exploding machinery had torn through the thick material. As the match sputtered out and the emergency dome became a little colder, the shadow puppets of her parents briefly waved at her and vanished into the dark.

Above the translucent dome, a shooting star raced across the sky, debris and waste from orbiting factories burning up in the thin atmosphere. The girl was reminded of her paternal grandma, one of the first and oldest colonists, who had originally lived in a dome to the east, working at a water mining and reclamation site. Grandma generally only visited during the old lunar celebrations when most people travelled to see family. But following the girl's parents' death when she was only six Martian years old but already in secondary school, Grandma came to stay with her permanently.

Grandma had told her that shooting stars were the dead crossing heaven in their last journey before becoming one with nature. Obviously, the girl had known better. From an early age she had been precocious in her science classes and by the time her grandma had related this story with her shining eyes full of shooting stars and mythology, she already knew about orbital dynamics and escape velocities. She had simply nodded politely and looked up with the sky reflected in her own gaze. She had never once disagreed with her grandma when she had still been alive, nor her ma or da before they died in their turn; it would not have been polite.

At school, the girl had been exposed to a limited amount of colonial history, taught by a few volunteer parents to supplement the more practical company curriculum. Through one particularly interesting teacher, she had learned why a lot of colonists died and why it was still so hard to live here on Mars.

The teacher had argued that the first companies which funded the diaspora had needed to turn a profit simply to continue, so the limited terraforming of Mars in the early years had only been a means to a very shortsighted end.

"A little free oxygen was needed in the mining and refining industry, but there was no real incentive to try and generate a breathable atmosphere outside of the domes. The calculations showed that there would never be enough air pressure to sustain people, and it was not cost-effective to try more local solutions."

The teacher continued, getting into her stride, "To breathe, humans need about 1 pound of air stacked above every square inch of them. This is known as the Armstrong limit," not as the girl first assumed, named after the famous astronaut from the beginning of space travel, whose statue stood tall above the Lunar colonies, but after an earlier airman who never once left Earth.

The teacher had offered an analogy to help them remember the lesson.

"The top of Mount Everest on old Earth enjoys more than 5 PSI of atmosphere. Just about breathable, but a little thin for most people's taste."

She continued, "The Armstrong limit to life on Earth is more than two Everests high. You would need to stack two mountains on top of each other to poke out of the atmosphere at a place where people could not breathe at all. The atmosphere on Mars is so thin that nowhere has an air pressure above the Armstrong limit."

"Our home, Hellas Planitia, is in a huge crater at the very lowest point on Mars. We are 9 km below the surface on average, with the deepest possible atmosphere above us. Even here, the atmospheric pressure only reaches a paltry 0.2 PSI at best, which is impossible for humans

to breathe. On Mars, exposed lungs simply boil away to dryness in an atmosphere where even water evaporates. The amount of oxygen in the atmosphere is therefore irrelevant and terraforming is pointless."

At the beginning, this had been difficult to follow, especially as the teacher used archaic measurements and brought in unfamiliar mountains like 'Everest', but the class had quickly understood the point. Several had even smirked afterward in the playdome as they compared tiny Everest, the highest point on old Earth - standing at only about 8 km high, compared to our Olympus Mons standing proud at 25 km to the summit.

Everyone of course already knew from biology and farming classes that the *Nostoc* could live outside where people couldn't. Almost everyone in the class had a relative who was a *Nostoc* farmer, or biochemist, or waste engineer. It didn't need oxygen, high air pressure, or nice temperatures. It just sat on the cold fields outside, harnessing light from the dim and distant sun to suck CO_2 out of the thin Martian atmosphere and make everything we needed to live. It was miracle slime, manna from Earth.

On one occasion, the class was taken by land shuttle on a special tour of the massive oxygen farm dome in Musk City, over a thousand miles away at the other end of our home crater, where all the breathable air that the colony needed was generated. They were shown around the dome, and the guide pointed out a variety of *Nostoc* growing in tiered vertical farms.

The tour guide, a nonagenarian first-footer Martian, spoke to us in the weird accent typical of her generation.

"Here the *Nostoc* is intermixed with the company's patented *Prochlorococcus* variety, also a cyanobacterium taken from Earth's oceans."

She pointed at a stacked sandwich of different-coloured slimes, intermixed biofilms reaching several metres above our heads, like library shelves full of gloopy books.

"The natural ancestors of the variety used here had probably produced between half and a fifth of all oxygen on Earth in the millenia before global warming, although accurate records are hard to come by nowadays."

She changed to a staged whisper that nevertheless reached the whole class.

"The factory has leaked rather a lot of waste oxygen out into the local area over the decades and the effect is somewhat pleasing."

She smiled and touched a section of wall behind her. A small projected hologram sprang up between her and the class, showing the old lady outside of the dome. She wore a standard low-profile company outdoor suit with an orange full-face helmet and matching breathing apparatus with a carry-pouch. She placed something that looked like a white stick stuck to a small plinth onto a flat-topped rock that stood as high as her waist.

"Watch this very carefully," she whispered. Naturally, we all craned forward to see.

Her doppelgänger in the video reached into their carry pouch and took out a recognizable box of company matches. They struck one and applied the burning point to the top of the stick. After a second, a black

spike at the end caught fire and burned steadily with a small teardrop shaped flame, occasionally flickering in the thin air. We all gasped.

"All thanks to the cyanobacteria producing so much oxygen for us," she said. "Sadly, humans are not candles and cannot burn outside the domes." She looked around the group slowly meeting each person's gaze individually. "And we probably never will."

#

At the end of this memory, the girl has almost exhausted her matches. It has been hours now since the crash, and the dome is approaching freezing point. Warm air generated both by her body and the flames from each match rises through the middle of the small personal dome, cools at the transparent apex where the stars peek through, and streams back down the sides making the outside view shimmer in the pale sunlight. Her hair moves slightly in the breeze caused by these convection currents, and if she had a mirror, she would see the face of both her ma and grandma reflected in her features. The creeping cold has already frozen the dome's surface, reaching through the insulated double layer to the interior, and a gentle wind is coating the outside in fresh drifts of dry ice.

She takes the last few remaining matches and lights the whole bunch in one go to see her parents once more in the shadows. The orange light dances on the dome walls, and her grandma's face joins those of her ma and da. As the spent matches eventually sputter and die, her family joins her, smiling at her, leaning towards her. They enfold her, warmly taking her hand, and they all leave together into the place where flames go when snuffed out.

Down in the tiny dome, her small body lies stiff and cold. Her last happy tears slowly slide down her frosted face across her cheek. Eventually they stop in place and freeze solid.

#

When the company rescue ship H.C. Andersen eventually arrives, the emergency team dismantles the cheap orange lifeboat dome, peels the ragged suit from the girl's shiny white frosted skin, and pries a few carbonised sticks from her frozen hand. The captain of the rescue ship gives a short and sad funeral service for the lost girl, now wrapped in tight plastic. As she has no surviving relatives, he attains low orbit according to company policy, launching the frozen girl into space to join the orbiting corpses of her family. One by one over the next few decades as their individual orbits decay, each body returns to Mars as falling stars, fragmenting over the vast fields of *Nostoc,* becoming nutrients, one with nature and one with each other.

Part 4. Santa's microbes and other superheroes: *stories for a younger audience*

No one left behind

Annija Ābeltiņa, Latvia

Does Santa exist? No, unfortunately. If that was the case people would be a lot happier - or in a much, much more dreadful situation - depending on the nature of the wishlist. Luckily for us, nature has its own way of working daily miracles. Like growing a huge tree from a tiny seed or reducing said tree back into the soil it came from so nothing goes to waste. But does Santa really come only from our imagination and hope for miracles? No, no, no, E and B still think Santa is real, it's just that there are some unusual creatures working for him.

Who are E and B? They are twins who inconveniently for their parents forgot to stop the 'why?' phase and continued questioning everything around them. Christmas was just around the corner and E and B had gotten a new surge of questions that begged to be answered right now. Why does Santa come only once a year? Who gives him the money for the presents? What kind of pajamas does he wear? Huh? Well? Dad was not prepared for this kind of offensive after coming home from a hectic day at the greenhouse control room, oh and why was it so awful? Because some insects which were there to manage the parasite population on the plants had gotten out and messed with the biogas storage facility, which on a normal day would receive fresh addition from the organic waste treatment plant. In the end, it had cost five hours to get things back on track and continue the proper supply of heat for the plants. Five hours! In winter! What he needed right now was a warm shower and something to eat. E and B were still looking up at him patiently holding the current of questions at bay until previous ones were properly answered. They had learned fast that in

doing so they would be awarded with at least some explanations, and lately they had prepared their own answers. So, Dad decided to let them answer the questions themselves.

Uhhhh... You want to know more about Santa?

Yes.

Well, doesn't he come every weekend?

No.

How come?

He needs to prepare all the presents.

By himself?

Ummm ... yes? Wait, no, he has those little helpers. But they are short, how can they carry around hammers, and wood, and the sledge is high up, how can they put the bag inside. Aaahh, they have superpowers?!

Yes, yes, exactly. Superpowers.

Which ones? They are like, really strong? No, they run really, really fast so that we don't see them!

They are fast, but that is not the only reason why we can't see them. They are also very, very tiny. Only way to see them is to catch them in action. Go, find two bananas and meet me here in ten minutes.

....Why do we need *two* bananas?

Go, quickly!

Being away from the center of attention gave Dad an opportunity to put away the taken-not-to-freeze-themselves-to-death vegetables and

think over how to explain microbes in any reasonable way. To tell them that they were everywhere and could interact with anything might be a little too scary for kids. But, if microbes are properly guided, it becomes a different story….

You are already here? Amazing - give me one banana. Open the other.

Hey, stop eating the banana! It's for the experiment!

Who said that? I'm hungry. Look, if you open your banana, you will see that in a very short time it will change.

Yeah, we know, and it will look like poo.

Do you know why? You didn't do anything to it, I didn't do anything to it, why would it change?

Uuuuh, those tiny superheroes are doing it?!

Not really, although they can help a lot to make it faster. The point is, a lot of things around us are happening without us doing and seeing anything. Some of these things happen because those tiny creatures, or microbes, as I like to call them, are using their superpowers to quietly help us. Actually, there are aallll kinds of little creatures. Food destructors, food makers, earth diggers, and guess what? - even fart fairies.

No way! Hahahaha fart fairies... you are just making it up.

Noooo, they do exist. They like to live in the sewage or among rotten food, these are their favourite places, truth to be told. They don't feel the smell and it's amazing to play catch between all the stuff floating around in the water. Or building castles. Oh, you still don't believe me? Santa has taken in few of them and taught them to change Northpole's snow into all the presents children could ever want. But I also work

with them every day. Where do you think the tomatoes, cucumbers and spinach are coming from?

You bring them from work.

Yes, yes. But it's winter, right? They need a lot of warmth and light, so they are not growing in your average greenhouse. See, this greenhouse is right next to the waste plant in which the fart fairies live. They have a special room full of rotten food to play around and while they are playing, they get so excited and full of energy that it creates a way for us to use it as a source for warmth and light.

But can they do everything? Like, reading Santa's letters and, like, taking care of reindeers?

They are very capable, but I'm afraid they don't do that. But, who knows, Santa probably has taught them a thing or two. Wait, is that mum? Let's surprise her at the front door and you can ask her all about Santa!

Going to the waste plant wasn't exactly a planned trip, but it happened anyway. Someone in Accounting had decided to hype up the holiday spirit with a party. A real Christmas party, no doubt, with a Christmas tree, presents and everything. That was meant for kids, of course, while parents could enjoy themselves at the seafood delicacy table. E and B soon found they'd exhausted the possible attractions in the room and wanted to go outside to see the place where fart fairies lived, until they saw some other kids intently watching and repeating from a screen in the wall. Turns out it played a cartoon with a song, explaining how they're growing vegetables even in the midst of winter. Feeling confident that they already knew the answer to that, E and B asked them to play it once again from the start.

Hey, you, listen up, everybody who is here.

Microbes - some may call them, Source for diseases some might say;
But! Micro-robots just do what they're told. Give your trash to them,
They'll turn it into a plantbase; A soil for growing
And a gas for lightning. So, if there is waste,
It doesn't need to go to waste.
Biogas technology, circular economy. Common sense epitome.

Needing only two more times to remember it all, E and B led the group of children to sing the song so everybody in the room can hear it too. It was a nice song, only some gravely important subjects were missing - fart fairies, their playroom? E and B suspected that in the song they are called by some other names, the ones they didn't really understand, because adults can be fussy about such things. But it's ok, this Christmas in their house they are going to leave cookies and milk for all kinds of microbes.

Microbes at the ready

Beatrice Smyth, United Kingdom

At the annual convention of Farm Animals and Associated Creatures Together (FAACT), there was consternation. This was not the first year of such disquiet, but it had reached a new level. The trout spoke first about the horrors of living in the river beside the farm, with slurry gushing into his home after heavy rainfall. He told frankly of the lack of food and oxygen, and with great sadness he remembered family and friends lost to the pollution. The moorhen took the floor next and echoed the challenges of what she called swimming in a cow's rear end, the horrible slime in the river and the awful stench. It was impossible to keep her feathers clean, and that was the least of it. She trembled when telling of her fears for the health of her young. Then the swan got involved and things got heated.

With the authority that comes with being a special creature, the swan did not hold back, accusing the cows of being heartless killers. The cows were shocked, as they had never realised how much damage their daily lives were causing. They couldn't understand how the humdrum of chewing the cud and lining up at the milking parlour could be so dangerous, and, as herbivores, they strongly objected to being called killers. One cow was particularly incensed and started bawling at the swan, accusing him of lying, but the swan was having none of it. He raised his wings and hissed fiercely. It was about to come to blows when the heron spoke.

Up until now the heron had been observing quietly. She was good at watching and contemplating. She had also been places, to other farms and beyond, and had seen what could be done with a bit of will and imagination. That, though, she had to admit, might be the difficult part.

It's tricky to change one's ways, she thought to herself, but with a deep breath, she figured it was worth a go. "Are the microbes here?", the heron asked. "Huh?" and "The what?" said a lot of blank faces.

The microbes had long been excluded from the annual convention, but years of lobbying and advocacy had finally ended the discrimination. They were permitted to join for the first time this year, although so far they had been silent. A lifetime of being sidelined and misunderstood left them reluctant to put their heads above the parapet. Microbes, or microscopic organisms as they are more formally known, had a bad name on the farm. They were used to getting dirty looks, being called filthy germs, and shouldering the blame for every illness and calamity. They were also petrified of the swan, who strongly objected to their presence at the convention, and who now turned his anger on the heron. "What would they know anyway?" bellowed the swan, "They're not even animals. And they're the cause of the problem. It's the blasted microbes and the stinky algae that are clogging up the river in the first place."

Thankfully, the heron had depths of patience and was good at bringing calm to turmoil. After reminding the swan to renew his diversity training, the heron painted a picture of what life could be like, with clean water and sweet-smelling air. That got the attention of the crowd, even if they didn't quite believe such a change was possible. The heron was very knowledgeable and explained that unruly out- of-control microbes, like those causing damage to the river, were different to a properly engineered microbial system. The microbes themselves aren't the problem, she told the audience. If we feed them lots of slurry out in the open air, then of course they're going to run amok in the river; it'd be like the sheepdog stealing the farmer's doughnuts, gorging herself and then feeling queasy. The sheepdog would never do such a thing, but it lightened the mood and got a giggle from the crowd.

Back to the matter in hand, the heron described how providing microbes with a regular well-balanced diet and a proper home could transform everyone's lives on the farm. Instead of going straight on to the fields, the cattle slurry could be put into a sealed oxygen-free tank called an anaerobic digester, which is a comfortable, heated environment for the microbes to thrive. There, our friends the microbes would work hard to produce methane for renewable energy, along with a less polluting fertiliser in the form of digestate.

The microbes stood proud, and the crowd started to get excited. But the prize bull thought it was time for a reality check. He had also visited other farms; he was educated and he knew his stuff. "All good in theory", he interjected, "but it's not that easy in practice. What you're talking about is a circular economy. Yes, it's based on the microbes, who are willing and able, but for it to function effectively we need integrated policies across the nexus of agriculture, energy and environment. We require cohesive thinking to link the food, fuel and water sectors, as well as planning permits, grid connections and a suitable incentive scheme." The barn owl started to snore. The chickens looked confused. The farmyard cat twitched his whiskers in distaste. He found big words awfully boring. The prize bull was right, but he was losing the crowd. Fortunately, his buddy the sheepdog was on hand.

The sheepdog was a canine of action. She was quick witted and a master of organisation. "Right", said the sheepdog, "leave it with me. I'll chat to the farmer, and I'll iron out the details with the council, the engineers, and the environment agency. If there are any issues, I have a direct line to the minister. With everyone on board, it shouldn't take long to get it sorted. Once the bigwigs have signed it off, I'll round up the builders and get them to step on it. Microbes at the ready. Your time has come."

There were cheers and there were hugs. And, more importantly, there was a new determination from the farm animals and creatures to work together for a cleaner future.

Microworlds

Griffen Alexander, South Africa

Nearly 35 people stood around the mahogany table. They were all grinning. The focus of their attention centered on two things; first was the ten-year-old girl at the head of the table. Her hair was dark and cut short in a bob, and her hazel eyes were held transfixed by the second object of the room's attention: a massive glass cube filled with greenish soil. The cube stood in place of a birthday cake.

"Hip hip, hurra!" The chant trailed off with the unconcerned awareness one affords a background task.

It took a moment for everyone to realise they were just standing and staring at the cube, enthralled in a hushed wonder. The silence was broken by the solitary voice of a boy who had just entered the room.

"It's just dirt, so what, it's a little green."

The question sent a shock of awakening through the room. People came back to themselves with chuckles of realisation and began chatting together in small clusters.

"Where's the cake? I want cake Sara," the boy had approached the girl who was standing at the table's head, he spoke indignantly.

"It's my birthday James, you get cake on yours."

"But everyone is meant to have cake on everyone else's birthday."

"I don't like cake, and mom said I could have this instead."

"Everyone likes cake, you're lying. You're doing this so that I don't have any, or you have it in your room, it's not fair."

Following James's accusation Sara stared at him for a moment, a look of consideration colouring her face.

"You know it's not just green dirt, I explained that."

"Stop trying to be like mom, you don't know how any of that stuff works. You're trying to make me look stupid just because I prefer to eat cake than have a box of green dirt for my birthday."

Sara would have continued the conversation with her brother, even though she recognised the futility in it, but before she could, he turned away from her and ran out the room.

That evening, after the celebrations had wrapped up, Sara's dad helped her move the glass cube upstairs to her room.

She sat on her bed, a subconscious smile on her face. Before her, arrayed on all available table tops and bookcases, stood glass cages. The number of terraria barely hinted at the abundance of life teeming in their cuboidal microworlds.

On the bookcase nearest the door stood her worm farm. It was her first terrarium; one she had made herself by repurposing an old fish tank and digging through the compost heap for earthworms. The slowly churning soil inside was fresh and dark; it smelled of running barefoot through a pine tree forest.

There were also ant farms, slicing cross sections through intertwining tunnels; bustling rainforests inhabited by Poison Dart Frogs, Mourning Geckos and Garden Snails, along with slices of arid desert wasteland populated by tarantulas and adders. Beneath all of the mini habitats lay a founding principle of design: the ecosystem. Sara worked scrupulously to ensure every one of her terraria were as close to self-

sustaining as possible. Isopods and springtails in conjunction with microorganisms performed the vital role of decomposition.

On the centre of her largest table sat the glass cube filled with greenish dirt.

Sara got off her bed and bent down to her bin. She picked a plastic takeaway cup out of it and then switched the light off. Her room was instantly flooded with darkness. In a moment her eyes adjusted to a glow emanating from the cube. By the faint green bioluminescence, she could make out the silhouettes of her furniture propping up various cages. Navigating herself around these, she found herself standing before the cube, peering into the mesmerising soil. She raised her hand and dropped the cup into the cage.

Initially, nothing happened. The cup lay on the soil, like a didactic artwork about littering. Then it began to sink. Before a minute had passed, Sara couldn't see the cup. The soil pulsated gently, almost as if it had a heartbeat.

The movement ceased. Sara bobbed on the balls of her feet and her palms were sweaty. A sliver of electric blue broke the soil's surface and moved upwards. As it rose, Sara watched more vibrant blue breach and follow the first sliver's movement. She switched on the light. A delicate flower grew in the cube.

When she went to bed, she knew she was smiling.

Over the course of the following week, there was not a spare second that Sara didn't spend in her room. Whenever she did have to go downstairs—for a meal or because she was told she couldn't stay inside all day—she would return with an armful of rubbish for the cube. Mostly she would bring plastic waste, as this—when broken down by

the special combination of microbes in the soil—would grow the most vibrant and unique flowers.

Sara gave the flowers she grew to her friends at school, and to her mom and dad. James always seemed to be around to watch her hand them out, as if he suspected the flowers of turning into something else of their own volition. For supper time, she arranged colourful flower bouquets to adorn the table. James often stared over his untouched food at the flowers with a frown on his face.

One day, a week after her birthday, Sara got home from school and made straight for her room. Upon entering she found the cube shattered and all its soil spilled out over her bedroom floor. For what felt to her like a lifetime wrapped up in an instant she stood and stared. Her mouth hung limply open.

Then, as if something ticking inside her head finally snapped and made her realise what she saw, she burst into tears. Her knees sent shooting pain signals up to her brain as she fell down on them. She grabbed handfuls of the dirt as she combed through the pile with no apparent goal. Only after all ten of her nails had a thick layer of dirt underneath them did she realise she was looking for the green colour she had come to associate with the cube. The soil on the floor had turned a shade of grey.

All she could do for a time was kneel and cry. Whenever she wiped her tears away, she would unknowingly smear grey soil across her cheeks, nose, and eyes. She did not focus on the why, how or when; all that passed through her consciousness was the fleeting ephemerality of loss. To her, this loss was irreconcilable.

She raised her head and, as she did so, caught a glimpse of a little green patch under her bed. All four of her limbs moved in a frenzy as she

scurried forwards on hands and knees. She dared not hope, but she couldn't help it.

A patch of the soil still retaining its green hue was piled under Sara's bed. She leaned forwards and scooped it up as delicately as she could manage. With legs fully straightened again beneath her, she realised she had a problem: where to put the microbe-rich soil so that it would not deaden like the rest? Her gaze came to rest on her worm farm. On a second's impulse she opened the cage and lowered the precious dirt into the mulch.

The green soil sat still on the surface of the mulch for a moment. A smile broke Sara's face as she noticed the smallest of pulsations begin from the green. The soil organised itself into hesitant searching tendrils, spreading out over, and combining with, the mulch of Sara's first ever terrarium.

From off the floor Sara picked up an old food wrap. She lowered it down into the green churning mulch; she held her breath as she did so. Initially the plastic lay on the surface, unmoving. Then, just as had happened so many times before, it began to sink into the green. This time a short orange flower with intricate ovular petals grew.

Sara picked the flower and went in search of her brother.

She found him in the garden. His hands were covered in a grey dirt, and he was sobbing.

"I'm sorry Se, I didn't think it would die, it's just—" James cut himself off with a sniff and wipe of his nose.

"That's okay James. Here." She handed him the orange flower.

His eyes were wide, and his focus was intense as he inspected the flower she laid in his open palm.

"But I—" he brought the flower close to his chest, but still kept his hand open, as if scared to crush it.

"I know. Don't worry, it's not dead—I grew that now. Pretty, isn't it?"
"It's really pretty."

They sat together in the garden as the last light of the day faded. It felt to James as though the orange of the sunset lasted a moment longer in the palm of his still-open hand.

Epilogue

Before you go, our sponsor EBNet would like to end on a final story which embraces how stereotypes and misconceptions around EB can be countered by simply taking the time to learn more about what we do.

Environmental biotechnology is a fascinating area; a sector whose activities permeate our lives quietly and unobtrusively while providing multiple benefits to society, human health and our wider ecosystem.

We hope these stories entertained you, and that you leave with a broader awareness of EB in its many forms. If you enjoyed the book, please pass it on.

Stereotypes

Megan Sorry, United Kingdom

"Filth!". Her mother's voice was harsh and discordant, and her face radiated disgust and disapproval as she stood at the sink of the tiny, shared kitchenette on her floor of the care home. Evidently one of the other old ladies - all of them gentle and charming, some with deteriorating eyesight - had failed to meet her high standards when drying the plates or wiping beneath the dish rack. Or maybe, horror of horrors, someone had left a teabag in the sink? Her mother had a near-pathological hatred of anything she considered as dirt. Did anyone else still wear yellow marigold rubber gloves to wash up, in 21st century Britain?

"Mum, I've come to take you out to Sadie's Open day - remember? We said we'd go along and encourage her". Sarah was proud of Sadie, though she often wondered how she had produced a daughter with such different attitudes, skills, and interests from her own.

Her mother looked unconvinced but allowed herself to be bundled up in a coat and headscarf (a headscarf!), then led gently down to the waiting car. A short drive through the countryside, with the engine humming along smoothly; then the staccato stop-start rhythm of the city outskirts.

Thankfully Sadie's University was campus-based, and the car parks were free and well signposted for the annual Science & Engineering Day. Sarah was deeply uncertain that this was the right outing for her mum. But with so many things to fit into a Saturday - shopping and washing, and the teaching that was her main source of income as a

professional musician (and of course everyone wanted lessons at the weekend) - well, at the time it had seemed a good idea to double up...

They followed the yellow signs and stick-on footprints to the Civil Engineering department, a low concrete building that looked slightly in need of a refit. The revolving door swished round behind them. A smiling helper explained the arrangements: there was a talk every hour on the hour, with the current one halfway through; and exhibits in every lab with staff to explain them. There was a flow system, but you didn't have to visit everything. Tea and coffee available in a marquee outside in the central square, toilets on every floor. The muffled roar of a hand-drier confirmed the latter were somewhere nearby.

Through glass doors Sarah saw a roomful of people, sitting in chairs and gazing up at a big screen that showed pictures of wonderful futuristic buildings, accompanied by soaring music. Through another doorway, staff and students were bending down amongst groups of noisy excited children, who seemed to be trying to build something - with spaghetti and chocolate bars? Neither type of activity seemed right for her mother. She steered towards the corner of the foyer, where a buzz of voices indicated the way to the labs.

In the first room a gentle-looking bespectacled man was talking earnestly to a small crowd of listeners, while behind him a huge yellow press of some kind had evidently just crushed a block of concrete into fine slivers. Other heavy equipment, powerful but incomprehensible to Sarah, filled the room; the walls were full of bright-coloured posters, with students standing by to describe their work. As they left, a pneumatic "whoosh!" and a strident metallic "pi-aang!' suggested that something else had been broken to delight the visitors.

The next set of rooms seemed to focus on transport, including a car with no bodywork and hundreds of coloured wires coming from it,

attached to multiple computer screens. An automated female voice was giving instructions to the human driver. What was that about? Further down the hall was another doorway: when it opened, she glimpsed what appeared to be huge tanks full of water, with hollow voices echoing above them like the sound of an indoor swimming pool.

"My feet are hurting", her mother said.

"We'll find Sadie, then find somewhere to sit down", she promised.

The Environmental Labs were along one side of the building. At the entrance, there were more posters, a display of magazines with titles like 'Waste Management' and 'Water Reuse', and screens with rolling images or animations accompanied by jittery little tunes. On tables and lab benches, odd-shaped containers were set up, some with air (or another gas?) bubbling through them. Also, she noted thankfully, there were some chairs: hard grey plastic ones, but still a welcome sight.

As she steered her mother towards a chair, an older woman standing next to them in a white lab- coat began to speak. "Anyone want to see our mini treatment plant? Come on - everyone is a little bit interested in what happens to sewage!". A few listeners responded with delighted shudders and drifted nearer; a couple of knowing adolescents turned away. Sarah wasn't at all sure this audience should include her mother: but she had settled on the chair with an expression of grim determination, so the die was cast.

The grey-haired woman - Sarah realised from her name tag that she was a professor, though her clear, melodic tones didn't sound at all intimidating - talked them briefly through a history of sewage treatment. Apparently, it all began with simple processes, like sending wastewater through screens and leaving it to stand still in a tank so that solids could settle out. The professor commented, "Engineers love

gravity - it's so cheap!"; which got a rumble of laughter from some of the small audience, though not from her mother. (The type of solids didn't bear thinking about in either case: Sarah glanced at her mother then looked away, but not before seeing a familiar severe pinched grey expression settle over her features). Next, biological processes were introduced. These were actually carried out by the same micro-organisms that occur naturally in rivers and streams: but given too much pollution on one go, they simply couldn't cope. Then people had discovered that if, for example, you pumped in more air and controlled the conditions, you could develop a microbial population attuned to the process and vastly increase the rate of treatment. So, it was all about understanding these systems and learning how to work in harmony with them. Nowadays, this kind of wastewater treatment was well-established, and attention was moving to other topics - like how to control nutrients, and ways to do it all more cheaply and effectively. Sarah vaguely knew that Sadie was working on something to do with nutrient recovery from wastewater, though she could never quite remember what or how...

The short talk finished and there was a flurry of questions, which moved on to a conversation about water companies discharging untreated sewage - why did they do it, how did they get away with it? It seemed the professor had worked in the water industry many years ago, and she too was deeply unhappy about the current situation. Sarah lost the thread and looked around. A short Chinese man was talking animatedly about something, next to a column of bubbling liquid in which small dark granules floated: it seemed to involve some clever way of changing the flow to make microbes stick together, so you could settle them out and re-use them. (Aha, gravity again! she thought). A South Asian girl was getting children to sort through black bags of rubbish - artificial, she hoped. A tinkling arpeggio of glass bottles dropped into the plastic bins, followed by a percussion of cans.

Across the room she caught sight of Sadie. "Look, Mum - there she is!".

Sadie waved, but she was surrounded by a group of adults and children: it appeared she was inviting everyone to take a sniff from a set of small glass tubes containing some unknown liquids and solids. Behind her, a young Afro-Caribbean man was demonstrating something that involved a large cylindrical vessel with a big motor on top, and some strange balloon-like bags attached to it by transparent tubing. She had no idea what that was... Someone else - Middle Eastern? Latin American? - seemed to be explaining about processes based on green pond-scum. Behind her she could hear a girl with an Edith Piaf accent, and a voice to die for, who was talking in a code of unfamiliar acronyms - COD, TSS, TKN?

"Very multi-cultural here", her mother remarked - with just a hint of a sniff? "I'm getting tired, dear, and it's nearly time for my tablets. Can you take me back?". Guiltily Sarah realised that she'd forgotten her mother's medication; and they walked on through the busy, bustling sections on architecture and on tunnelling and foundations without pausing for instruction and enlightenment, or tea and cake.

At the home, she accompanied her mother upstairs to her room. The drive had taken longer than expected: no doubt the heavy traffic was people returning from Saturday shopping - or from Open Days? No time even to stay for tea: the next pupil would be along soon; she'd catch him if she left now. She apologised and was relieved when her mother didn't seem to mind too much. "That's alright dear - I'll have a cuppa with Barbara, just help me get the tray and some biscuits". Barbara was the favoured friend of the moment: she seemed to have all her marbles and took an interest in the outside world, including music. Clink of cup and saucer, timpani of biscuit tin. She left her mother filling the kettle, wearing marigold gloves to turn the tap on.

As she reached the top of the stairs, she paused for a moment, hearing Barbara's gentle northern lilt in the kitchen. Her mother had evidently just reported where they had been: Barbara was expressing the widely-shared public horror over the pollution of rivers and beaches by raw sewage. "I don't know how they can get away with it. It must be deliberate, I'm sure they could easily clean it all up by adding more chemicals to the pipes underground".

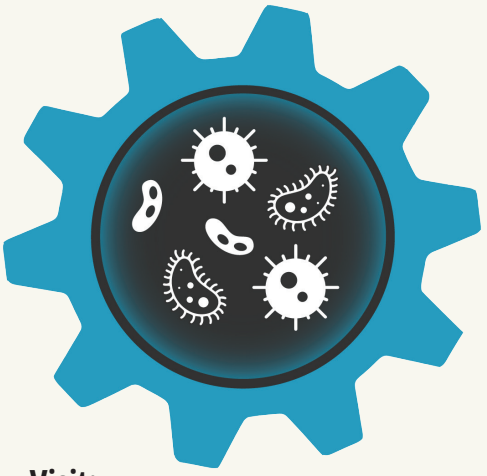
Sarah's mother drew a breath. "Well, yes - it is wicked, and they should all be thrown in jail. But you see, dear, that isn't quite how it is done...". She began to elaborate on the nature of wastewater treatment processes. And as Sarah continued down the stairs she recognised, to her astonishment, that very rare thing in her mother's voice: a rich, harmonious purr, the sound of complete self-satisfaction.

It is intriguing to reappraise the familiar through other people's eyes.

In the 2023 Microbes to the Rescue! competition - a Green Stories initiative sponsored by the Environmental Biotechnology Network (EBNet) - we asked authors world-wide to raise awareness of environmental biotechnology and what microbial systems can do for us.

We were captivated by the results as people sent in a delightful array of short stories with a microbial twist. This collection showcases a select number derived from that competition which bring story-telling and STEM science together for your enjoyment. We invite you, the reader, to judge how well they succeeded.

So, dip in, read on and explore these imaginative tales. While you do, we hope to pique your curiosity about the many remarkable faces of environmental biotechnology and the understated heroes upon which it depends – microbes.



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