The Layman's Guide to Microbial Whatsits

Or, Aquatic Ecology for the Rest of Us

By Greg Walker

1th edition

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Preface

This book assumes you already have a fundamental grasp of basic fishkeeping: nutrient cycles (yes, including nitrates), routine maintenance, filtration, and the general mechanics of keeping animals alive in glass boxes. It also assumes you understand that decomposition exists, fungi are not optional, and that an entire microscopic world is operating whether you acknowledge it or not.

If that's unfamiliar territory, some of what follows may feel challenging.

Can't help you there. Sorry.

With the formalities out of the way, introductions are probably in order.

My name is **Greg Walker**, and I'm the owner and founder of **Niskai Aquatics** — a small operation that has gone through more revisions than this book. I promise that detail becomes relevant shortly.

I grew up in the sleepy semi-rural town of **Bundaberg, Queensland** — home of some of the best sugar in the country, the most aggressively mediocre rum, and a whole lot of rich black volcanic and red clay soils. Those soils, paired with stable temperatures and humidity, turn the region into a quiet agricultural powerhouse: sugar cane, fruit, vegetables, and the occasional soft drink. The Bruce Highway heading south is also a notable export.

That environment matters, because it's where this story begins.

We always had a vegetable garden growing up. I learned about orchids and ornamental plants from my grandmother long before I had language for ecology or systems thinking. By high school, my mother had befriended the owner-operator of **Keatings Aquarium and Pets** — a family business passed down through three generations. Mum often helped out at the shop, and I'd swing by after school, initially just to scab a lift home.

Eventually, I started helping out properly.

That was the beginning of a lifelong obsession with aquariums.

After high school, I drifted through a handful of career paths — hospitality, paramedicine — none of which stuck.

Eventually I landed in a traineeship in **conservation and land management**, effectively training as a park ranger. That role kindled my love of ecology in a serious way. When the traineeship collapsed (long story, short version: the whole team got screwed), I moved south to Melbourne and took a job at a local aquarium store as a plant and nano-fish specialist.

I stayed there for five years. Then I got bored and became a professional chef.

Then the world changed.

COVID lockdowns wiped out hospitality almost overnight.

Years of work — done through chronic pain and declining health — evaporated. During those early lockdowns, the handful of aquariums I still owned were my main anchor to sanity, aside from weekly visits from the love of my life.

When restrictions eased, a friend approached me with a business proposal: leverage my background in aquatics to meet the sudden explosion of interest in home aquariums. Everyone wanted a tank — kids, adults, remote-work zombies desperate for something alive on their desks.

We started breeding cherry shrimp for wholesale.

That's how **Niskai Aquatics** was born.

Reality intervened quickly. Imports of aquatic species were (and still are) tightly restricted in Australia, with *Caridina* and *Neocaridina* shrimp outright prohibited. Quality local stock was scarce, inconsistent, or priced like it came with a complimentary organ. So we pivoted into aquatic plants instead.

For a while, it worked — even through the second round of lockdowns. But costs accumulated. Food, fertilisers, conditioners. Then we had to move. The new property didn't have space for forty-odd livestock tanks and a dozen grow-out systems.

So I sold what I could, covered the move, and pivoted again.

To support the remaining shrimp colonies, I began developing my own holistic fish foods. That work forced me to dig into topics like probiotics — which, after proper investigation, I concluded were largely irrelevant or misapplied for most fish species. I chose not to adopt them in my formulations.

Around that time, a good friend — Alex — finally convinced me to read **Diana Walstad's Ecology of the Planted Aquarium**. I'd known about it for years and ignored it, having bought into the usual internet rubbish that it was "just about dirt" or "being lazy."

I was wrong. Spectacularly.

Walstad's work is rigorous, practical, and quietly radical. The most important takeaway for me was this: **the bacteria driving nutrient cycles in aquariums are the same organisms doing that work on land.** The nitrogen cycle doesn't care whether it's happening in soil or water.

That realisation changed everything.

I understood that my background in soil ecology hadn't been wasted — and that there was a glaring gap in aquarium products and practices that genuinely engaged with microbial systems, outside of either six inches of potting mix or

marketing-grade nonsense.
So I set out to hybridise — and yes, occasionally bastardise — principles from **agriculture, aquaculture, and ecology** into something more cohesive.
I call it **eco-engineering**: using modern science to deliberately emulate nature, rather than fighting it.
That philosophy is what this book is built on.

Addendum

I say all of this, but the honest truth is a little simpler.
I wrote this guide because I'm tired of repeating myself.
After writing it, I now get to sit here quoting the damned thing instead of answering the same questions over and over again. It turns out that's surprisingly efficient. I can point to a page, a paragraph, or a diagram and get back to doing actual work — or, failing that, staring at tanks and pretending it counts as productivity.
In that sense, this book has already paid for itself.
If it saves you from asking the same questions I once did, or helps you avoid mistakes I've already made the hard way, then it's done its job. Everything else is just gravy.

A note on terminology:

Throughout this guide, some biological and taxonomic terms are used in their commonly recognised forms rather than the most recent formal classifications. This is a deliberate choice.

For example, several species historically grouped under Lactobacillus have been reclassified into new genera following taxonomic revisions in the early 2020s. At the time of writing, these changes have not seen widespread adoption in the aquarium hobby, product labelling, or general literature. Where newer names do not materially change function or understanding, the older terminology has been retained for simplicity.

Before I let this book stand on its own, there are a few debts I need to acknowledge.

My mother, who tolerated countless late-night rambles about ecology, patiently rubber-ducked more half-formed theories than I'll ever remember, and stood by me during the stretches when I couldn't stand on my own.

Tracey Harrold of Keatings Aquarium, who gave a bored kid a place to loiter, then a place to learn, and eventually a reason to stay curious.

My business partner Owen, who took a chance when this was nothing more than an idea held together with enthusiasm and duct tape.

And finally, **you.** This guide itself would not exist without the platform that helped me shape it. The ability to argue, refine, be challenged, and turn half-formed thoughts into something coherent has mattered more than I expected.
For all of that — thank you.

This book may carry my name, but it was never built alone.

Chapter 1: Meet the Microbial Misfits

According to the American National Science Foundation, there are an estimated 1 trillion species of bacteria on this little green rock we call Earth. Yep — that's a 1 followed by *twelve* zeroes (1,000,000,000,000) worth of microbial misfits. And here's the kicker: about 99.99% of them haven't even been discovered. They don't have names, they don't have character bios, and nobody's written their Tinder profiles.

To put some numbers on it: scientists reckon there are around 430 million bacterial species in soils alone, plus more than 5.6 billion fungal species. That's more diversity in a handful of dirt than in most zoos, aquariums, and dodgy pet shops combined.

Now, obviously, we're not going to sit here and list them all. You'd grow old, your fish would starve, and I'd lose my voice somewhere around page three thousand. So instead, we'll do what ecologists love to do: simplify. We'll sort microbes into broad categories by job — or what's properly called a microbial guild. From there, we can build out who's doing what in your tank or terrarium.

For our purposes, we'll keep the scope tight: soil and water microbes. They're the ones you'll actually be wrangling whether you keep aquaria, terraria, or any of those hybrid glass boxes in between.

Aquatic vs. Terrestrial

Technically, all microbes live in water — because every cell is basically a tiny water balloon full of biochemistry. But in practice, there’s a big ecological split:

Aquatic microbes are the ones that can survive and thrive fully submerged. They’re comfortable living in rivers, aquaria, wetlands — anywhere there’s a permanent water column.

Terrestrial microbes are landlubbers. They live in soil, leaf litter, roots, or other semi-dry habitats. They can handle a splash, but you won’t find them six feet under water for long; oxygen levels, pressure, and other “life support” quirks push them out of the running.

This split — aquatic vs terrestrial — is where we’ll begin our tour of the microbial guilds. But we'll refer to them as "Soil" or "Water" microbes as before to save my publisher on word count.

Aquatic Guilds

Read this bit. Seriously.

This section is important. The rest of the book assumes you’ve read and understood the aquatic guilds — so if you skip it, don’t come crying when your moss ball goes furry or your shrimp stop breeding.

We're about to break down the microbial cast of characters that show up in submerged environments — tanks, ponds, rivers, flooded terrariums, and anything else with more water than dirt. These are the microbes that make your biofilm tick, your nitrogen cycle spin, and your fish not die.

If you're running a planted tank, shrimp tank, aquascape, or just curious what's really going on behind that algae smear on your filter intake — this is your section.

Feel free to skip the Terrestrial Guilds section unless:

- You're also reading the chapters on terrariums and paludariums,
- You're interested in substrate layering or emergent root systems, or
- You're just a nosy little knowledge goblin who wants to know everything.

Whatever your purpose — welcome. Let's talk slime.

The Scaffold

We'll split our microbes down into a handful of distinct categories. Of course, these are just broad strokes — the aerial view of the factory floor. In reality, there's metric tonnes of redundancy, overlapping niches, and all sorts of fiddly bits we'll gloss over. I need to save my voice for… well, other stuff.

The most basic guild — and arguably the most important — is The Scaffold.

Scaffolding microbes are responsible for laying down the foundations of ecology: the roads, paths, homes, and corner shops that every other microbe uses to live, eat, work, and play. These are your builders, plumbers, and sparkies.

Their big claim to fame? They produce exopolysaccharides (EPS) — long-chain biopolymers. Think of them as organic plastics, or microbial concrete. Algae, fungi, protozoa, even tiny critters like seed-shrimp graze on it, live in it, or build off it. Without EPS, the whole city crumbles faster than a log cabin in a tsunami.

Notable players in the Scaffold Guild include *Flavobacterium*, *Zoogloea*, and *Bacillus*. And then there's my personal love–hate relationship with *Bacillus mucilaginosus*. On the good days, it lays down thick, robust biofilms. On the bad days, it turns into that mate who "just popped round to help" and ends up trashing your shed. If I don't stay on top of maintenance, it leaves the tank looking like someone spilled jelly down the back of the couch.

And that brings us neatly to the seedy underside of the Scaffold. Just like in the real world, some tradies do a brilliant job when you're watching them like a hawk… but give them an inch of rope and they'll take the whole roll, sprint off, and leave you in hot (or more accurately, gunky and slimy) water.

Case in point: *Flavobacterium columnare*. While its cousins build perfectly good scaffolds, this one's the rot in the foundations. It's the culprit behind **columnaris disease** — a nasty, cottony affliction that's taken down more than a few aquarists' prize fish. Proof, if you needed it, that even the most useful tools can be flipped into weapons

The Nutrient Cyclers

The next guild on our tour through Biofilm City is the Nutrient Cyclers — the microbial alchemists who turn toxic crud into plant snacks and fish fuel.

Members of this guild all share a similar role: they take basic elements — Nitrogen (**N**), Phosphorus (**P**), Potassium (**K**), and various micronutrients — and either convert them into usable forms, break them down, or detoxify them. It's all in service of the larger organisms in the system: plants, fish, shrimp, roots, or even guts. If you've ever wondered how your Java fern manages to not immediately keel over in fish muck soup, chances are you've got nutrient cyclers to thank.

In aquatics and horticulture, this guild's heavy hitters fall into three main crews:

1. Nitrifiers

These are the golden children of the aquarium world — the ones every aquarist learns about on Day One, usually right after killing their first fish.

Nitrifiers take toxic Ammonia ($\mathbf{NH_3}$) and its slightly less evil twin Ammonium ($\mathbf{NH_4^+}$) and convert them first into Nitrite ($\mathbf{NO_2^-}$) (still dodgy), and then into Nitrate ($\mathbf{NO_3^-}$) (mostly benign, at least in small doses).

Your typical cast includes:

- Nitrosomonas – turns ammonia into nitrite.
- Nitrococcus – same job, different result.
- Nitrospira – a more flexible player (some strains can do both steps, but we'll get to that kettle of fish later).

These are the microbes that quietly run your nitrogen cycle while you're busy picking aquascape rocks and arguing about filter placement.

2. Denitrifiers
These blokes work in the shadows — literally. Denitrifiers only function in anaerobic (oxygen-free) zones, which are pretty rare in the average home aquarium unless you've got some serious wet/dry filtration going or a very deep substrate.

Their job?

Take Nitrate ($\mathbf{NO_3^-}$) and convert it all the way down to Nitrogen gas ($\mathbf{N_2}$), or occasionally bounce it back to Ammonia ($\mathbf{NH_3}$) so plants can slurp it up again. Either way, they're closing the nitrogen loop.

Notable names include:
- *Paracoccus spp*. – common in waterways and sludge.
- *Pseudomonas spp.* – the freelancing all-rounders who sometimes play denitrifier, sometimes play pathogen (more on that later).

While they're powerful recyclers, they're also a bit hard to control. Without careful management, they can strip oxygen, create anoxic pockets, or accidentally feed algae the wrong kind of nutrients.

3. Sulphur & Iron Reducers
Not as famous as the nitrogen crew, but no less important. These microbes operate in low-oxygen or fluctuating environments like deep sediment or neglected filter chambers.

They help convert sulphur and iron compounds into forms that plants and microbes can use — or, in the case of the Dark Side, forms that smell like a hot swamp fart and turn your sand black.

Notable troublemakers include:

- *Desulfovibrio* – a sulphate reducer known for churning out Hydrogen Sulphide (**H_2S**), which is toxic to fish and smells like Satan's armpit.
- *Shewanella* – iron reducers that sometimes pull double duty as biofilm scaffolders.

When balanced, these reducers help keep trace minerals cycling. When unbalanced, they remind you what happens when you let muck build up in your canister for six months.
cycling. When unbalanced, they remind you what happens when you let muck build up in your canister for six months.

The Nutrient Transporters

Following hot on the heels of the Nutrient Cyclers are the Nutrient Transporters — the microbial equivalent of Uber Eats, but for plants.

These microbes don't break nutrients down or build them up — they move them. Their job is to shuttle minerals and trace elements from the surrounding environment (water, soil, substrate) directly to plant roots, so your greens get fed before algae gatecrashes the buffet.

They're especially important in systems where nutrients are present but not always plant-accessible — like in lean aquasoils, capped substrates, or areas with low water movement. And while they're fairly limited in fully submerged tanks, they thrive in emersed roots, hydroponic systems, or soil-heavy substrates.

In short: if you want these guys to work, **you'd better build them a highway**.

That's where substrate layering comes in — with the right mix of porosity, carbon, and microbial support (yes, we're talking bentonite, biochar, and brewer's yeast, not just gravel), you create the conditions for these transporters to thrive.

PGPR: The Plant's Personal Drivers
The stars of this guild are known as PGPR — Plant Growth-Promoting Rhizobacteria.

They form close-knit symbiotic relationships with plant roots, improving nutrient uptake, reducing stress, and sometimes even defending against pathogens.
They don't do this out of kindness — they trade their services for exudates (plant sugars, organic acids, bits of carbon-rich bribe). It's mutualism at its finest.

You can think of PGPR like this:

"Sure, the plant could go get its own groceries… but why bother, when you've got a bacterial driver delivering micronutrients straight to the front door?"

PGPR use a toolkit of:

- **Organic acids** to dissolve stubborn minerals.
- **Chelators and siderophores** to bind iron, zinc, manganese.
- **Enzymes** like phosphatases and nitrogenases to mobilise

otherwise locked-up nutrients.

Once the roots are coated in this microbial delivery service, nutrients don’t just drift in — they get absorbed with efficiency that would make a hydroponic lettuce blush.

PGPR also **produce plant growth hormones** - driving root and leaf growth, and signalling your plants that the soup's done.

The Dark Side

Of course, every delivery driver guild has its dodgy cousins — the ones who pinch your chips or never show up at all.
Some parasitic microbes use the exact same tools — chelators, enzymes, and root-binding techniques — but instead of helping, they steal from the host. They siphon minerals off the plant and offer nothing in return. Over time, this leeching weakens the root system, slows growth, and opens the door to disease.

Oomycetes like *Pythium* and *Phytophthora* are classic examples of this — they’re **nutrient hijackers**, plugging into root systems with surgical precision and bleeding them dry.

Once again:

- The tools aren't the problem.
- It’s how they're used — in mutualism or manipulation.

So far, we've looked at the microbial guilds responsible for building, maintenance, garbage collection, and utilities — the unsung workforce of Biofilm City. Now it's time to visit the communities that actually live there.

The Germans have a word for it (because of course they do):
Aufwuchs — literally, "*the small animals and plants that encrust hard substrates, like rocks, in aquatic environments*."
The nerds call it **periphyton.**
The shrimpers? "*Green Walls*."
Me?
I just call it Life.

The Grazer's Pantry

This is the communal kitchen, the buffet, the rooftop garden — the place where biofilm finally turns into food.

Here you'll find countless species of algae, diatoms, fungi, and other microorganisms — all either:

- Feeding directly on the biofilm,
- Extracting the nutrients stored inside it, or
- Using the biofilm as a foothold to anchor themselves to hard surfaces and photosynthesise.

Without the Scaffold (the EPS matrix laid down by our microbial tradies), none of these organisms would have a place to land, grow, or graze. And that's a serious problem — because this layer forms the **primary food source** for your shrimp, fry, catfish, loaches, snails, and just about anything else with a rasping mouth or a grazing habit.

No biofilm?

→ No Grazer's Pantry.
→ No food.
→ No fish babies.
→ No ecosystem.

It's that simple.

Species List? Don't Bother

We're skipping the Latin roll call here — not because there aren't important species, but because there are **far too many**, and most are **highly regional and environment-specific**. The community of Aufwuchs in an Amazonian blackwater tank is wildly different from what forms on driftwood in a cherry shrimp nano or a Lake Tanganyika biotope.

Think of this guild as a hyper-localised buffet — unique to your system's water chemistry, lighting, flow, substrate, and microbial base.

The Dark Side

Normally, the Grazer's Pantry is your best friend — teeming with biodiversity, stabilising the tank, and feeding your critters. But of course, as with all things microbial, there's a dark side.

The one universal villain in this guild is **cyanobacteria** — an ancient, photosynthetic pain in the backside. While technically a microbe and technically a grazer-layer resident, it's better known for taking over entire surfaces in thick, smothering, often toxic mats.

Beyond cyano, there are literally untold numbers of nuisance species that could show up under the right (or wrong) conditions:

- Algal crashers that coat everything.
- Fungal outbreaks that melt roots.
- Weird slimy blooms that clog filters.

But again, context is everything. What's a pest in one tank might be a prized grazer community in another.

The Micro-Predators

And of course — what pasture would be complete without something nibbling on it?

No, I'm not talking about your fish just yet. This community of grazers-on-grazers lives entirely at the nano-scale. Meet the Micro-Predators — a collection of **amoebae**, **ciliates**, **rotifers**, and other microscopic munchers that spend their time feeding on algae, fungi, and biofilm, not animals (usually).

Some of them, like **daphnia**, **cyclops**, **scuds**, and **ostracods** (aka "seed shrimp"), can be seen with the naked eye — though you might need a good squint or a magnifying glass to get a proper look. Others, like protozoa, ciliates, and amoebae, are invisible without a microscope, but they're just as busy doing their jobs.

What They Do

Micro-predators are your **biofilm balancers**.

They keep fungal threads from overrunning the tank.

They nibble algae back to manageable levels.

They reduce microbial overgrowth by **grazing on bacteria** like a tiny clean-up crew.

And as an added bonus?

They're a top-tier snack for small fish, shrimp, fry, and filter feeders. In fact, many fish larvae rely on these micro-predators as their first food source in the wild — tiny, twitchy packets of protein and movement that trigger the feeding instinct like nothing else.

If you've ever had a tank with no visible food but thriving fry? Chances are, you've got a **robust micro-predator loop** going on behind the scenes.

The Dark Side

As usual, though, there are a few bad apples in the mix. Some protozoa — like the infamous **Ich** (*Ichthyophthirius multifiliis*) — can flip the script entirely, going full parasitic and drilling into your fish like a tiny horror movie villain. Others, like *Costia* or *Chilodonella*, lurk quietly until fish are stressed, then strike.

And then there are the fringe weirdos:

- Planaria – arrow-headed flatworms that normally clean up detritus, but can harass shrimp and fry when populations boom.
- Hydra – fascinating, but potentially problematic; those tiny tentacles pack a sting and can take out small or weakened fish.

Most of the time, micro-predators are a net positive — essential to nutrient loops, food chains, and biofilm control. But when things go out of balance? That's when they get promoted from "microscopic janitor" to "tiny tank terror."

Terrestrial Guilds

Dry land's not so dry when you zoom in.

While the aquatic microbes tend to hog the spotlight, there's a whole world of microbial misfits that thrive in damp soils, leaf litter, moss beds, and root zones — especially in systems with good airflow, fluctuating moisture, and higher oxygen levels.

A lot of these species — especially the fungi — are built for life in high-oxygen, semi-dry environments. They've evolved all sorts of weird and wonderful tricks for breaking down gunk, feeding plants, and outcompeting pathogens. Honestly?
They're damn cool.

We'll also cover a select set of micro-insects and microarthropods that perform overlapping functions in some guilds — things like springtails and isopods. These are critical. Most terrariums will quietly collapse after a few months without them. (Plus, they're just so dang cute.)

As mentioned earlier:
Feel free to skip this section unless you're planning to read the terrarium, vivarium, or paludarium chapters later in the book.
Still, if you're into bioactive systems, or just want to understand what's going on beneath that lush moss carpet you mist every morning — this is the chapter that connects the dots.

Let’s dig in.

The Scaffold

This guild works almost identically to its aquatic cousin — in fact, biofilm plays just as critical a role in soil as it does in water. Ever wondered why rich, moist loam grows your basil like wildfire, but dry, dusty dirt kills it faster than a heatwave in a paddock? The secret’s in the slime.

Biofilm is the glue that makes the planet tick.

In soils, a combination of filamentous fungi and EPS-producing bacteria weave organic matter, dust, clay, and moisture into stable aggregates — aka “soil crumbs.” These micro-crumbs hold water where it’s needed, buffer nutrients, and create pore networks that let gases and roots move through. No structure = no function.

Our old friends — Flavobacterium, Zoogloea, and Bacillus — make their mark in compost heaps and veggie patches alike. But in terrestrial systems, they’re joined by a powerful fungal cast:

- **Arbuscular mycorrhizal fungi** (AMF) and e**ctomycorrhizal fungi** (EMF) both produce EPS and physically extend root systems through soil.
- Fungal genera like *Aspergillus* and *Trichoderma* also lend a hand, binding particles and stabilising the microenvironment.

Together, these scaffolders create a micro-ecosystem where nutrients move, roots breathe, and microbes flourish.

The Dark Side

Of course, it's not all sunshine and loam. Some bacteria and fungi produce **hydrophobic biofilms** — water-repelling slime layers that actually **prevent moisture** from penetrating the soil, turning fertile ground into something more like crusty concrete.

In some cases, these biofilms **choke out roots**, cutting them off from water and oxygen. In others, they **create dry zones** that lead to patchy plant growth or dead spots in what should be living substrate

Just like in aquatic systems, too much slime — or the wrong kind — breaks the balance.

The Decomposers

This guild is functionally identical in both soil and water — same job description, different toolshed. But as with the Scaffold, soil systems come with a bigger cast list. There's more diversity, more specialisation, and way more weirdos.

At the microbial level, decomposition bacteria like *Bacillus*, *Clostridium*, and *Actinobacteria* act as the general waste collectors. They cruise through the substrate breaking down proteins, starches, cellulose, and whatever else is rotting, stinking, or has fallen off the plant.

Their fungal counterparts are more like recycling managers. Using their own suite of specialised enzymes, decomposer fungi break down tougher organics like lignin, waxes, and cutin — stuff bacteria struggle with. But they don't just digest it — they reintegrate the nutrients into their own systems and move them around through vast underground mycelial networks.

Some species can transfer nutrients **over 15 centimetres** or more — which, at their scale, is the equivalent of an outback trucker hauling groceries across the Nullarbor. This nutrient redistribution helps stabilise your micro-ecosystem by **buffering spikes and dips** in key elements like phosphorus, magnesium, and trace minerals.

Special Case: The Detritivores
Now, if bacteria are the garbos and fungi the recycling plants, then detritivore insects are the mega machinery:

- **Springtails** (*Collembola*)
- **Isopods** (including woodlice and dwarf tropical species)
- **Enchytraeids** (aka "white worms")

These little beasts act like trash compactors, tip trucks, and industrial shredders. They grind down decomposing leaf litter, wood, moulds, and dead plant matter into smaller, more microbe-accessible particles. And as they move through the substrate, they help spread fungal spores and bacteria — acting as biological couriers for the decomposer guild.
Without detritivores, decomposition slows, waste accumulates, and terrariums can quickly turn from lush to rank.

The Dark Side

Naturally, no guild is without its rogues.

- **Anaerobic decomposers** produce gases like methane, ammonia, and hydrogen sulfide — turning your soil into a swampy stink-fest.
- **Greedy fungi** can hoard nutrients for themselves, locking them up and making them unavailable to plants or symbiotic microbes.
- **Slimes**, **moulds**, and **mildews** can run riot across the substrate, smothering moss, melting roots, and turning your setup into a soggy warzone.

The trick, as always, is balance. When the decomposers and detritivores are working in sync, they're the engine of your soil biome. When they get out of hand, they're the bin fire you didn't see coming.

The Nutrient Cyclers

Nutrient Cyclers are absolutely critical in soils, because they do what plants can't: they unlock bound nutrients from minerals, clays, and the atmosphere itself.

Where aquatic systems rely heavily on nitrogen conversion, terrestrial systems go deep on mineral extraction. These microbes break chemical bonds, solubilise stubborn compounds, and make essential elements like phosphorus, iron, and potassium bioavailable.

Let’s break it down:

- **Actinorhizal bacteria** pull nitrogen straight from the atmosphere — turning N_2 into plant-accessible ammonia (NH_3).
- **Denitrifiers** free up nitrogen stuck in nitrate form, handing it back to plants in a more usable package.
- **Nitrifiers**, interestingly, take more of a back seat here. In soil, **ammonia is king** — plants absorb it more efficiently than nitrate, so converting it into nitrate isn’t always helpful.
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Without these processes, plants would be stuck relying entirely on decomposition for nutrients — which is slow, uneven, and can’t keep up with growth.

Think of it this way:

> Nutrient Cyclers run the grocery store.
> Decomposers run the community garden.

Both are brilliant — but if you’ve got a family to feed, you can’t live off backyard parsley alone.

Microbial Players

- *Actinobacteria* – nitrogen fixers, iron liberators, and phosphate solubilisers.
- *Pseudomonads* – redox wizards that can switch between respiration modes.
- **Fungi** (especially **AMF**) – more on them in the next section, but let’s just say they’re like nutrient accountants with an underground highway system.

These microbes use:

- **Organic acids** to loosen mineral bonds,
- **Siderophores** to steal iron from locked complexes,
- **Chelators and enzymes** to pry phosphorus out of clay and compost.

The Dark Side

And of course, there's no shortage of greedy guts trying to hijack the farms and factories.

Fungi, microbes, algae, and even plants themselves compete fiercely for nutrients — and every one of them looks after number one. Some microbes produce compounds that **lock up phosphorus** so others can't get it. Some form biofilms that **hoard trace minerals**. Some just **squat on a nutrient source** and refuse to budge.

Left unchecked, this guild can tip from a well-oiled co-op into a turf war.

The Nutrient Transporters

This is where fungi really show off.

While nutrient cyclers unlock minerals, nutrient transporters make sure they get where they need to go — and in soil, fungi are the long-haul truckers of the microbial world.

The stars of the show are the **arbuscular mycorrhizal fungi** (AMF). These fungi dramatically e**xpand the effective root zone** of plants by plugging directly into the root system and then extending their hyphae deep into the soil. This gives the plant access to a much larger pool of nutrients and moisture than it could reach on its own.

But it’s not just about raw reach — AMF also **redistribute nutrients**, ferrying phosphorus, zinc, and other minerals from rich zones to hungry roots, helping to **maintain balance** across the entire system. It's like having your own underground logistics network.

Right alongside them are the **PGPR** — Plant Growth-Promoting Rhizobacteria.
They don’t move nutrients over distance like fungi do, but they play a critical local role:

- They solubilise nutrients near the rhizosphere,
- Stabilise the root zone, and
- Most impressively, they produce plant growth hormones like auxins, cytokinins, and gibberellins — chemicals that ring the dinner bell, telling plants to send roots toward food, push out new leaves, or thicken stems.

They’re more than transporters — they’re root whisperers.

Honourable Mentions: Messy Eaters
In a limited sense, detritivorous insects (like springtails and isopods) also contribute to nutrient transport — but it’s more a side-effect of their feeding habits than a deliberate service. They move decaying matter around, smearing nutrients across the substrate like a toddler with Vegemite.

Helpful? Yes. Precise? Not even close.

The Grazer's Pantry

Just like in water, soil supports thriving communities of biofilm feeders, seeders, and breeders — a bustling buffet for the micro-fauna that keep your system ticking.
The terrestrial Grazer's Pantry is a robust and often-overlooked community made up of:

- Fungi
- Moulds and slimes
- Mosses and liverworts
- Micro-crustaceans
- Worms and soil mites
- …and whatever else wanders in from the compost bin.

Together, they do more than just eat goo:

- They strengthen and maintain the biofilm matrix,
- Oxygenate the soil through movement and respiration,
- And provide a steady source of nutrient-dense food for larger species like isopods, springtails, and even reptiles or amphibians that forage in leaf litter.

As with the aquatic version, we won't bother listing notable species — the cast list changes depending on climate, location, season, and even the specific moss you planted last Tuesday.

It's a hyperlocal community, and that's part of the charm.

The Dark Side

Of course, the Pantry has its pests.
Slimes, moulds, and toxin-producing fungi can absolutely ruin

a terrarium or vivarium, smothering surfaces, souring substrate, and causing cascade failures across the system.

They're part of the ecosystem — but like spice, too much ruins the stew.

And then there's c**yanobacteria** — the evergreen villain of the microbial world. Just as happy on a soggy patch of soil as it is coating driftwood underwater, it forms dense, often toxic mats that can choke out mosses, poison microfauna, and turn your pristine forest floor into a greasy, green disaster.

Control it early. Or it'll take over everything.

The Micro-Predators

Much like in water, soil is crawling with micro-predators — all lining up to snack on the unsuspecting residents of your soil-based city. And true to form, because it's soil, the list of who's who is a billion times longer and weirder than what you'll find in aquatic setups.

These microscopic hunters include:

- Predatory fungi
- Slime moulds
- Micro-crustaceans
- Nematodes and micro-worms
- Predatory mites and insect larvae

Wanna Hear Something Cool?

Research shows that slime moulds exhibit remarkable problem-solving capabilities — despite having no brain or central nervous system. Each cell behaves as part of a distributed intelligence — a kind of biological cloud computing. They can map the shortest path through a maze, optimise nutrient foraging routes, and even shift collective behaviour based on environmental feedback.

And if that's not weird enough for you:

There's a fungus called Arthrobotrys oligospora that sets literal snares to catch and digest micro-worms. Like, actual noose traps. It's a fungal bounty hunter with a taste for wriggly prey. **Nature is metal.**

They play a vital role in regulating the Grazer’s Pantry, helping prevent overgrowth of mould, bacteria, and algae. They also stimulate diversity by forcing prey species to adapt, migrate, or specialise — keeping the soil biome dynamic and resilient.

The Dark Side

As always, it’s not all symbiosis and clever slime.

Some micro-predators **go rogu**e — eating too much, wiping out keystone species, or r**eleasing toxins** to chase off competitors.

These behaviours can destabilise the food web, kill off beneficial microbes, or spark a cascade of population crashes in otherwise stable systems.

Just because they're small doesn’t mean they can’t mess things up in a big way.

What All This Means

Nature is messy.
Nature is chaotic.
Nature is a meticulous, delicate balancing act — and whether it’s pulling up a square metre of moss or knocking down a million hectares of rainforest, tugging on one thread can unravel the whole system.

Take *Bacillus anthracis* — yep, **Anthrax** — as an example. Humans didn’t create it. But we absolutely helped turn it into the monster it is today. Seriously. Look it up. It's a wild ride. But zoom back in from the existential dread, and you’ll see something beautifully simple underneath it all:

Soil and water work the same way.
Same game, different players.

Both ecosystems run on the same microbial playbook:
→ Scaffold
→ Decomposers
→ Nutrient Cyclers
→ Symbionts & Transporters
→ Grazers
→ Predators

Both systems have heroes and rogues.
Both systems rely on redundancy and resilience.
Both use the same biochemical tools — enzymes, acids, chelators, signals — to drive their functions.
And in both, system health comes down to balance.
Too much or too little of anything — even something beneficial — tips the scale. That's when once-helpful microbes turn into freeloaders, parasites, or full-blown villains.

Author's Note

I've simplified as much as I can. But some terms are just too technical to unpack here without turning this into a textbook.
If you come across a word or concept that didn't make sense, check the Appendix/Glossary at the back of the book — I've added extra resources and definitions to help you out. And if you're still stuck or curious, you're always welcome to drop me a line.
Now that you've met the microbial misfits, it's time to see how they run the show. Let's talk cycles, slime, and the **Circle of Poop.**

Chapter 2: The Circle of Poop

Every organism poops.

Poop, excrement, crap, sheiße, faeces—it's all the same basic concept: the leftover bits after something's had a go at its lunch and taken what it needs.

It's the unclaimed baggage of digestion. The stuff that wasn't useful to that organism, but might just be gourmet for the next one in line. And that's the trick. In nature, one creature's waste is another creature's breakfast.

Poop gets eaten by smaller organisms—bacteria, fungi, microfauna—who extract all their useful bits, and then they poop it out. That waste gets eaten again, by something even smaller or more specialised.

On and on it goes, like a microbial conga line of decomposition. Eventually, all the nutrients—nitrogen, phosphorus, iron, carbon—are either used up for growth, turned into new life, or recycled back into the environment. Then the organisms that did all that growing? They get eaten by something bigger, and the cycle resets.
It's the circle of poop.

It moves us all.

But ironically, it's not a circle at all. Or even a true cycle. It *isn't* 1 food in, 1 poop out. Every step produces different results, with each layering complexities like feedback loops, nutrient sinks, nutrient use (because again, not every input makes it back out) and more. I**t's a delicate balance that spans entire eco-systems, entire countries... sometimes even entire**

continents.

Change one single input (for example, kill off a bunch of wolves in a national park), and the whole web goes to shit. Thriving forests become barren Plains in less than a decade because the predators don't manage the foragers.

Reintroducing those predators fixed the system... but it still took time... because ecosystems arent just cycles of waste production and consumption - they're complicated networks of cause and effect. And this is where things get real for Aquarists; you can't just shortcut a literal continent of balance with a handful if pebbles, a filter and a bottle of "Magic Fix Solution: One Drop Cures Cancer [in a Petri dish]"

The Yellowstone Incident (or, Why You Don't Just Remove Predators)

The gist of it? Wolves were keeping the local Elk population in check.

But hunting and trapping (because some idiot decided that wolves are less important than a handful of sheep) led to wolves disappearing from the region.

Without predators, the Elk population exploded—and promptly **ate every green thing in sight**. So **desperate for food**, they started **stripping bark off trees**, killing them in the process. The once-lush landscape turned into a chewed-up paddock. This affected everything from nesting birds to beavers and more besides.

Enter: wolf reintroduction.

Elk numbers dropped. Vegetation rebounded. Rivers stabilised. The ecosystem started to heal.

But here's the kicker—it **still took nearly a decade** to bounce back.

Because balance isn't just about fixing the population—it's **about rebuilding the relationships** between all the pieces

Scaling Down

When we create that wonderful microcosm that is an Aquarium, we often forget the bigger picture - the herds of grazers, the apex predators, the migrating fungi, falling leaves and seasonal floods. We just toss in fish, food and a powerhead.

And yet, we still expect it to work the same.

We expect poop to magically become plant food. We expect decay to turn into whimsical whisps of nothing. We expect the system to cycle - the microbial engine to burn... but nothing happens... why? We added fuel. The vehicle should run, right?except we're missing one fundamental thing... the engine itself.

Because a glass box isnt Yellowstone. It doesn't cycle unless you make it.

Walstad's Big Idea

Let me start by saying I have nothing but respect for Dr. Diana Walstad and her work.
It was—and still is—groundbreaking. (Pun absolutely intended.)

But I do think her method, while brilliant, still lacks a little of the big picture approach. It focuses primarily on nutrients, rather than the full nutrient cycle. Dr. Walstad also tends to gloss over the actual microbial species involved—which is fine for a general audience, but doesn't do much to help aquarists who want to go deeper… or avoid tossing random dirt into their tanks.

So what is the Walstad Method?

Contrary to popular belief, the Walstad method is not just tossing some potting mix in a tank and walking away. Most people clearly didn't read past the introduction, and as a result we've seen decades of misplaced mockery and bad YouTube advice.

Simply put, the Walstad method explores the relationship between fish, food, microbes, and plants—and uses the nutrient cycle to convert fish food into fertiliser, without needing additional dosing. I won't go in depth into the specifies of her work here, because she worked extremely hard on that data, and you should go read it for yourself.

She focuses on the nutrient content of fish food, and shows that—just like in nature—fish are the fertiliser factory. They eat, they poop, and the microbes take it from there. Those microbes break down waste, convert it into simpler forms like ammonium and phosphate, and the plants soak it up.

> But here's the kicker: **you don't need soil for that cycle to occur.**

So Why Soil?

Because back then, soil was the easiest—and cheapest—way to get microbial life into an aquarium.

Sure, freeze-dried microbial inoculants have been used in Aussie agriculture since the 1950s, but they weren't affordable or accessible to hobbyists. And they certainly weren't sitting on aquarium shelves in 1999.

Soil was viable. And it worked—if it was clean, uncontaminated, and biologically rich.
But that’s a big “if.”

These days, even basic potting mixes are laced with chemical slow-release fertilisers, wetting agents, and who-knows-what else. And on top of that, soil is messy. It’s hard to work with. It compacts. It turns anaerobic. And no—sand caps don’t fix that. They just bury the problem and reduce oxygen exchange.

Why Do These Problems Happen?

Because most aquariums lack diversity and function.
In nature, worms, insects, fungi, and bacteria all work together to:

- Turn over the substrate
- Oxygenate the root zone
- Prevent dangerous gas build-up
- And release nutrients at a controlled pace

Take away those players? And you're just left with compacted sludge and slow rot.

But that’s a convo for another chapter. Back to Walstad.

The Functional Loop

At its core, the Walstad cycle is this:

→ Food input → Fish Waste → Microbes → Nutrients → Plants → Oxygen + Growth

And it does work. But it still has gaps.

Food still needs to be added.

Not all nutrients get used—especially in heavily stocked tanks or low plant mass setups.

Detritus and complex organics may linger, building up into nitrate creep or mulm overload.

Some microbial transformations just don’t happen—either because the species required aren’t present, or the conditions aren’t right. (Looking at you, Anaerobic denitrification)

Contrary to popular belief, not all natural waterways are stagnant puddles.

So even in a Walstad tank, you need to do water changes. Not because you're “resetting” the tank—but because you're playing the role of rainfall.

In nature, rain causes floods, surface flushing, and groundwater exchange.
It washes away the excess.
No, **God doesn’t come down with a siphon hose** and a colossal bucket—but water movement does happen.

So What About the Key Players?

Okay, so here's where the science gets a bit dense. I'll do my best to simplify things, but there's only so far we can go before the concepts outgrow plain English.
We touched on the big names in Chapter 1: Meet the Microbial Misfits—a vast swathe of bacteria, fungi, and other microbes that break waste down into simpler, plant-friendly forms. But really, they're just the tip of the iceberg.

Functional Redundancy

In natural ecosystems, multiple organisms fill the same role. This overlap—called functional redundancy—means that if one species dies off or struggles, others pick up the slack. It's a built-in fail-safe.Nature also has organisms that perform interim steps in the decomposition cycle. Insects, worms, fungi, even snails secrete enzymes or acids that break complex organic matter into more manageable bits. Burrowing animals help too—mixing, oxygenating, and loosening the soil so that other organisms (like bacteria and plant roots) can do their jobs

Ever wondered why forests with thick layers of leaf litter don't smell like your rubbish bin at the end of a hot week? Thank the decomposition crew. They're digesting and processing that mess faster than it can rot.

Meanwhile, Back in the Aquarium

Of course, we don't have any of that in our glass box of wonders.But hopefully, you also don't have metric tonnes of dead animals and leaf litter in there either.(If you do… you probably have bigger issues than missing bacteria.)

So no—your tank's nutrient cycle isn't a neat little chain of:
→Fish poop → Bacteria → Plant food.

It's a relay race across multiple metabolic guilds. Each step is like passing a nutrient parcel through a weirdly complex post office.

The Nutrient Buffet Analogy

Imagine it this way: A farmer grows raw food. The supermarket packages it into smaller portions. The consumer cooks it (or at least microwaves it) to make it edible.

That's the nutrient web in a nutshell. Each group modifies the package a little: Some microbes unlock nitrogen from proteins. Others prefer it in different forms—nitrate, ammonium, or organic **N**.
Still others just wrap it up in biomass and wait for the next guy to eat them.

Not all nitrogen is equal. Some organisms like it wrapped in oxygen (**NO_3^-)**. Others want it paired with hydrogen (**NH_4^+**). It's like sushi vs steak—depends who's hungry. This microbial processing is why certain species cluster in certain environments. They're following the food. Just like we do.

Stacking the Deck in a Glass Box

Now, we obviously can't recreate a full forest floor in an aquarium (no matter how hard Father Fish tries). But we can game the system by:

- introducing the microbial guilds we actually want.
- Feeding them the food they're adapted to break down
- Creating the right structures to house them

Yes, you can shortcut the nutrient cycle by injecting artificial fertilisers into the water.But that method is neither hands-off nor stable

Unstable Inputs = Unstable Outputs

Fluctuating nutrient levels cause algae blooms, nutrient lockout, and stress. To fix this, people use: Big water changes. Chemical suppressants, Constant testing and tweaking. In a **CO_2**-injected, high-light aquascape, that may be worth it. But for the rest of us—those without unlimited time or disposable income—it's not sustainable.

Enter the Substrate

Even with a robust microbial guild, you need a support structure. Microbes need:

- Housing
- Storage space
- Workshops to do their metabolic tinkering

No, they don't just float around in the water column munching loose detritus. They settle on solid—but porous—surfaces: driftwood, leaves, filter media, plant roots, and most importantly, the substrate.

But here's the catch: a bustling microbial metropolis needs space, and space is always at a premium in aquaria

Walstad's Soil Solution

This is where Walstad's method shines again. Soil has:

- Massive surface area for colonisation
- High CEC (Cation Exchange Capacity)—essential for storing and releasing nutrients
- A rich stockpile of microbial life and organic matter

It's cheap, effective, and—if you don't screw it up—long-lasting. But modern potting mixes? They're often full of wetting agents, urea spikes, and polymer-coated fertilisers that melt into chemical soup. And yes—soil compacts. Especially if capped with sand. Sand doesn't solve the problem. It just hides it. Back in the day, we used fine gravel layered over laterite—a clay rich in iron and with decent CEC.

And we had undergravel filters to pull water down through the substrate and prevent compaction. It worked… kinda. But undergravel filters had their own quirks, and they fell out of favour with the rise of canisters, sumps, and high-flow power filters.

No One-Size-Fits-All Substrate

Here's the truth: there is no perfect substrate.
There is only the right substrate for the right tank.

A simple low-tech aquarium with a few plants and a modest bioload?
That setup won't benefit from the high CEC or nutrient load of aquasoil. It'll just leach excess ammonia and melt your stems.

On the flip side, a high-tech **CO_2**-injected jungle with fast-growing stems?
That setup will choke and stall in sand—the roots can't dig, the nutrients aren't there, and the microbes have nowhere to live.

And heaven help you if you're aiming for a middle-ground setup…
Or worse—if you want to prioritise aesthetics.

Want a white sand foreground with heavy root feeders?
You're going to need to get clever.

Enter: Layered Substrates

This is where substrate layering becomes not just useful, but essential.

You're building a system that hides the complexity beneath the surface—giving your plants, microbes, and nutrients what they need without compromising the look or performance.

Products like:

- Laterite (iron-rich clay, high CEC)
- Power Sand (porous base + organics)
- bio-Boost Substrate+ (carbon-rich, high cec, microbe-

enhancing powder)

These exist to bridge the gap—slotting quietly beneath inert sands or gravels, doing all the heavy lifting while you enFuel slow-growing microbes, reduce leaching, buffer pH
joy the view.

What These Layers Actually Do:

Layer Function	Benefits
Carbon sinks	Fuel slow-growing microbes, reduce leaching, buffer pH
CEC materials (like laterite or montmorillonite)	Hold onto nutrients until plants need them
Porous structure	Prevents compaction, enhances gas exchange
Microbial real estate	Provides surfaces for bacteria to colonise and build trophic guilds

Together, these:

- Limit water column nutrient spikes (less algae)
- Reduce substrate compaction (longer lifespan)
- Promote stable plant growth (especially for crypts, swords,

and red stems)
- And support robust microbial cycling—even in low-tech setups

It's not about how fancy the substrate is.
It's about how well it's built for your specific ecosystem.

So... Where Does That Leave Us?

We've followed the poop—from fish to microbe to plant.
We've poked around nutrient webs, microbial guilds, and substrate real estate. We've seen why the glass box doesn't just "cycle" on its own. And we've learned that while soil helps, structure, intention, and diversity are what actually make the difference. But we've only just scraped the surface. Literally.

Because all of this—the cycling, the transformations, the web—relies on something we haven't fully explored yet:
The Infrastructure.
Not the filter. Not the gravel.

The living scaffolding of biofilms, slimes, and microbial mats. They're the glue that holds the nutrient web together. They're the habitats, the gatekeepers, the pipelines, the highways. And without them, no nutrient—no matter how fancy your ferts—is going where it needs to go. So if you're ready to get your hands metaphorically slimy...

It's time to meet the next layer of the microbial misfits.

Chapter 3 - Biofilms, Slimes and Scums: The Hidden Infrastructure

Welcome to the sticky underbelly of microbial architecture. Here, we'll explore the goopy and gross sludge that drives the nutrient web - if the Circle of Poop was about the microbial architects, this chapter is all about the real estate. The houses, workshops and office buildings that allow our microbial pals to live, eat and breathe.

We'll be diving into the biofilms, polysaccharide nets and microbial mats that form the real infrastructure of soil, water and everything in between.

What is Biofilm, Really?

From a macro perspective, biofilm is any surface-attached colony of microbes embedded in their own homemade slime—a matrix of extracellular polymeric substances (EPS). You might remember EPS from Chapter One: it's the microbial equivalent of duct tape, bubble wrap and gaffa-covered bunker walls all rolled into one. It hydrates, insulates, binds, and defends. In short, it's home.

But biofilm isn't just a bacterial invention. It's a shared apartment complex. Once a few microbes set up shop and lay down the slime carpet, others move in—fungi, algae, archaea, protozoa, even baby invertebrates come to visit. It quickly becomes a messy, metabolically active community. In aquatic systems, this messy mix is known as periphyton (to ecologists), or aufwuchs (to Germans, who—as usual—have a word that sounds exactly like what it describes).

So if Chapter One introduced you to the microbial citizens—the fermenters, grazers, nitrifiers and rogues—this chapter is about their infrastructure. We'll be taking a hard look at the slimy buildings, gooey scaffolds, and biochemical plumbing that make microbial life not just possible, but powerful.

We'll explore how biofilms form, how they mature, how they protect their residents, and what happens when things get crowded. We'll also dive into what they do—because these aren't just passive structures. Biofilms are active hubs of nutrient cycling, chemical gradients, and microbial warfare. They're responsible for everything from purifying groundwater to making your aquarium glass look like it's been sneezed on by an amoeba with a cold.

Why is Biofilm the Foundation of a Living Ecosystem?

(Yes, that's a reference to my biofilm generator: Bio-Boost: Foundation—because biofilm really is where it all begins.)

Simply put, biofilm is the concrete that microbes use to build their homes, warehouses, workshops and, frankly, entire cities.It's made from a sticky soup of extracellular polymeric substances (EPS)—a self-produced matrix of polysaccharides, proteins, DNA, and lipids that microbes secrete when they settle down.

This biopolymer glue lets them anchor to hard surfaces, stash nutrients for later, and build physical barriers against threats like temperature swings, dehydration, or antimicrobial compounds. **It's microbial MacGyver goop**.

EPS is so versatile, in fact, that a UK-based company called Shellworks (as of September 2025) is using it to make an eco-friendly plastic substitute called Vivomer. That's right—

bacteria invented bioplastics billions of years before we started 3D printing toothbrushes with them. But it's not just about bacteria. **Biofilm acts as the structural glue for entire microbial communities.**

Fungi, algae, archaea, and protists all take up residence in these slimy settlements. The EPS matrix helps them stick where they want to be—on a leaf in the sun, on a root tip full of sugars, or next to a nutrient-rich bit of decaying shrimp poop.

Without biofilms, these microbial citizens would be floating drifters. With them? They become the bedrock of stable ecosystems—filtering water, cycling nutrients, breaking down waste, and laying the groundwork for everything else to grow on top.

The Biofilm Production Cycle

(a.k.a. How the Slime City Gets Built)

Biofilm production occurs in several phases. Some microbes play through them all, some skip the non-essential (for them) phases, and others just loiter about leeching off the hard work of others. Classic city dynamics, really.

This framework applies in both aquatic and soil-based ecosystems.

Phase 1: Initial Attachment

Individual planktonic (free-floating) microbes land on a surface—glass, wood, gravel, leaves, substrate, or purpose-designed materials like ceramic or sintered glass.

This is the reversible toe-dip stage. If the surface isn't up to snuff, they'll launch themselves back into the soup to find greener pastures (or slimier ones).

Phase 2: Settling Down
If conditions are right—temperature, nutrients, surface texture—the microbes settle down. They metaphorically buy a parcel of microbial real estate and begin producing EPS.
This sticky matrix anchors them permanently to the surface, **creating a foothold for colony expansion.**

Phase 3: Maturation I
The microbes begin to divide. EPS production ramps up.
Colonies form and expand like a bacterial housing boom.
The slime roads get paved, and city infrastructure starts appearing: microcolonies, water channels (in soil), and nutrient gradients emerge.

Phase 4: Maturation II
Now it gets complex. **Three-dimensional structures** form: mushroom-shaped towers, biofilm chimneys, and other gooey skyscrapers.
And then, the city starts to organise itself. Cooperative behaviours emerge:

- Quorum Sensing – A microbial group chat. Cells communicate chemically to gauge population density and coordinate behaviour.
- Gene Sharing – No gatekeeping here. Plasmids, resistance genes, and other goodies are traded like baseball cards.
- Metabolic Zoning – Microbes with different energy needs form layered communities. Aerobes on top, anaerobes

below, with cross-feeding in between.

Phase 5: Dispersion

Eventually, some cells decide it's time to leave the city—either of their own volition or because they've been booted out by overcrowding, nutrient shortages, or shifting environmental vibes.

These pioneers return to their planktonic, free-floating state and drift off to start a new colony somewhere else... with blackjack, and perhaps other questionable life choices.

(Or, more realistically, to find a fresh surface, lay down some EPS, and repeat the whole cycle. But let them dream.)

Phase 6: Immigration

Once the city's slime infrastructure is established and resources are plentiful, it's time for new arrivals. The Grazers' Pantry opens—feeding grounds for shrimp, snails, and filter feeders. And hot on their heels: Micro-predators. Nematodes, rotifers, and protozoa move in to feed on the bustling bacterial population.

Biofilm isn't just a microbial condo—it's an ecosystem launchpad, laying the groundwork for increasingly complex food webs.

How Flow Shapes Biofilm

(Or: How to Build Cities Out of Slime, Depending on the Weather)

Whether it's airflow or water flow, the fluid dynamics of an environment have a drastic effect on the style of biofilm produced—as well as the types of microbes that choose to

settle down there.
(Yes, air behaves like a fluid. Physics is weird like that.)

Low Flow:

Encourages flat, sprawling biofilms. Larger, slower microbes settle more easily, and unusual processes can take hold. Reduced oxygen penetration allows for anaerobic activity, which can be a mixed blessing.
Thicker mats of algae and fungi often dominate, creating localised decomposition hotspots—great for some grazing species, but problematic if waste builds up faster than it's processed.

Think of low flow as a rural town—sprawling, sedentary, and sparsely populated. Great for cattle, not so great for nightclubs.

Moderate Flow:

Produces structured, robust biofilms. Strong oxygen gradients allow for both aerobic and anaerobic processes to occur side-by-side.
Fast-growing generalists like Pseudomonads thrive here, facilitating rapid colonisation and nutrient cycling.

Moderate flow biofilms are like urban sprawls—busy, dynamic, and bursting with microbial diversity. They rarely sleep, and there's always something going on in the chemical alleyways.

High Flow:

Yields dense, compact, often filamentous growth—think streamers, tendrils, and tough, clingy mats.
Only the fastest-growing, most shear-resistant microbes survive here. Older biofilm layers are regularly sloughed off by the current, creating a natural self-cleaning system.

High flow is the high-rise metropolis of the microbial world. Vertical, efficient, and absolutely not for the slow or fragile.

But unlike human cities, **biofilm is adaptive**. If the conditions change—say, a sponge filter clogs or your hydroponic flow rate shifts—the microbial real estate market adjusts.
Unhappy species move out. More suitable ones move in. The EPS composition, architecture, and population balance all shift to meet the new demands. It's microbial urban planning on fast-forward.

Biofilm Zoning: Who Lives Where in Slime City

Like any decent city, a biofilm isn't just a blob of goo—it's zoned.
From the fast-paced surface to the quiet corners where the weirdos ferment things in the dark, biofilms self-organise into chemical neighbourhoods based on oxygen levels, nutrient gradients, and whatever metabolic junk their neighbours are spewing out. It's not planned.

It's not pretty. But it works.

Surface Zone — The High-Rise Apartments

This is where the oxygen flows freely and the rent is high. Microbes here are the **fast-living, fast-dying** types who love a bit of fresh water and a strong current.

Typical residents:

- Nitrifiers (*Nitrosomonas, Nitrobacter, Nitrospira*)
- Fast-growing aerobes (*Pseudomonas, Bacillus*, etc.)
- Algae and Cyanobacteria (in well-lit systems)

This is the clean-up crew: they process ammonia, chew through simple organics, and keep the lights on for everyone else. Think of it as a stack of high-density apartments near public transport. Oxygen-rich, nutrient-loaded, and always just one new tenant away from an algal bloom.

The Mid-Zone — The Industrial Park

Down here, oxygen starts to thin, but nutrients are still plentiful—especially the complex, half-digested ones drifting down from above.

Typical residents:

- Facultative anaerobes (microbes that can swap between oxygen and no oxygen)
- Fermenters (producing acids, alcohols, gases from complex carbs)
- Polymer busters (e.g. cellulose, chitin, and EPS degraders)

This is where things get processed. Proteins, fibres, dead algae—it all gets broken down here. Some of it gets re-used, some of it gets turned into weird gases.

Think of it like a warehouse district. Quiet, efficient, a bit smelly, but if it shut down, the whole city would grind to a halt.

Bottom Zone — The Sewerage System

Way down in the anoxic depths, there's no oxygen, no traffic, and not much light. But there's still life—just not the kind you usually see in the average aquarium. Typical residents:

- Denitrifiers (turn nitrate into nitrogen gas)
- Sulphate reducers, methanogens, iron-reducers
- Old, slow-growing microbial holdouts

This zone handles the true waste—detoxifying nitrates, balancing pH via carbonate or sulphide cycles, and sometimes belching out methane or hydrogen sulphide.

It's essential in wetlands, sediments, and wastewater plants.

> Here's the thing: most aquariums never develop a proper anoxic zone. They're just not big enough, deep enough, or slow enough. The water turns over too quickly, and the oxygen gets in too easily.
>
> But in truth, your tank probably doesn't need a sewer system. The mid-zones take care of business just fine.

Mixed-Use Pockets — Cafés, Co-ops and Chemical Black Markets

Zones aren't always cleanly separated. Biofilms have pockets of activity, layered microclimates, and cross-feeding interactions everywhere.

Quorum sensing coordinates activities across zones.
Cross-feeding means one microbe's waste becomes another's lunch.
Some bugs even specialise in electron shuttling between layers
It's a slimy, interconnected community with no central government—but plenty of chemical gossip.

Zoning is Dynamic

If conditions shift—flow rate, oxygen levels, nutrient input—the entire structure adapts:

- Aerobic zones might deepen
- Anaerobes might move up or die off
- EPS production might ramp up to shield sensitive species
- New microbes might move in while others get evicted

Biofilms are constantly renovating themselves to suit their environment. No Council approvals required.

Location, Location, Location

Zoning Laws for Microbial Metropolises

Like the British Empire, microbes love to colonise untouched (at least by them) territory. But unlike the Brits, microbial colonies don't just plop down anywhere, nick all the valuables, and sod off back home.
If microbes settle, they're here to stay—and harder to dislodge than a tick in springtime.
And because they're stuck where they are forever, microbes can be incredibly picky about where they build their city.
Texture, material, regional chemistry, and even the ionic charge of the surface all matter.
This section explores how different substrates influence

microbial development—and why natural rock and wood outperform rainbow gravel and plastic pineapples. And no, it's not just snobbery. There are practical reasons.

Surface Material

Rough, pitted, or porous materials are ideal.
More surface area = more anchor points = better EPS retention = faster settlement.
Smooth surfaces like glass or most plastics are harder to colonise unless already "conditioned" (read: scratched to pieces or coated in grime).
Rougher materials also help protect microbes from shear force, allowing colonies to settle faster in higher flow environments.

Surface Chemistry

- Ionic charge and polarity affect microbial attachment:
- Hydrophilic surfaces (like glass and ceramic) favour microbial adhesion.
- Hydrophobic surfaces (like most plastics) are often less inviting—unless pre-conditioned by biofilm, slime, or surface roughening.
- Organic materials (e.g., driftwood, leaf litter, botanicals) offer:
    - Carbon sources (as fuel)
    - Chemical cues (e.g. tannins and organic acids)
    - Excellent texture (rough, fibrous, or spongy)

Over time, microbes will "condition" inert surfaces by laying down EPS, but it's a slow process and never as effective as settling on a prime natural site.

Thus, the source of my disdain for plastic ornaments and

painted gravel:
If you provide minimal colonisable surface area, you get slower-growing, weaker ecosystems.

A few bits are fine—but only if properly managed.

Porosity and Capillarity

Porous surfaces are basically pre-fab microbial housing. All the microbes have to do is fill it with junk, and they're home.

- • Porous materials (like sintered glass, ceramic media, lava rock, and aquasoil) offer internal niches for oxygen-sensitive microbes to settle deep inside.
- • Capillarity—the ability to wick and hold moisture—is crucial even in aquariums.

It keeps biofilms hydrated inside porous structures, allowing deeper colonisation without cutting off oxygen supply.

Sponge filters and aquasoils don't just trap debris—they're microbial apartment complexes.

Mobility vs Stability

Stable, fixed substrates (rocks, roots, wood) allow for long-term colonisation:

- Mobile surfaces (shrimp shells, detritus, sand grains near the filter) encourage transient or fast-rebuilding films
- Animal bodies can also host biofilms—snail shells, shrimp carapaces, even fish gills.

In fish, this isn't great.
Pathogens like *Flavobacterium columnare* (**Columnaris**) form thick biofilms on gill tissue, cutting off oxygen and leading to rapid suffocation.

Biofilm Preferences by System Type

- Aquariums → Hardscape, filter media, leaf litter, driftwood, high-flow zones with organic input
- Soil systems → Particle shape, clay content, organic matter, and moisture retention all influence microbial hotspots
- Terrariums → Fibrous mats (sphagnum, jute), bark, and wood provide excellent colonisation sites

Substrate Strategy

Your substrate choice directly influences your microbial community—and with it, your tank's long-term stability.

- Want to feed grazers? → Rough wood, botanicals, sponges
- Need strong nitrification? → Porous, oxygen-rich flow-through media
- Looking for microbial resilience? → Structured, stable materials with long colonisation windows

Design your ecosystem like you're designing a city.
Plan for the right tenants, and the microbes will move in.

The Bacterial War of Succession

Power. Politics. Polysaccharides.

Sometimes the pioneers of the microbial world—the first colonisers who built the slime city from scratch—don't stick around. Maybe conditions shift. Maybe they were outcompeted. Maybe the locals got uppity and staged a coup. Whatever the reason, the early settlers up and vanish, leaving behind their extracellular infrastructure like biofilm ghost towns.

Other times, the founding microbes build their towers so high, they lose touch with the ground entirely—abandoning the low-oxygen basements, the messy fermentation zones, and all the nitty-gritty waste processing that keeps the city alive.
And when that happens?

New microbes move in. Opportunists. Symbionts. Scavengers. **Predators**.

On and on the cycle goes—a microbial war of succession, until you either end up with:

- A city that's forgotten its roots, now running on borrowed oxygen and repressed memories
- Or one aristocratic lineage of bacteria lording it over the peasants, bloated with quorum power, prone to collapse the moment conditions shift

What this means for your aquarium

Biofilms are not static.
You can't just set up a tank, ignore it for 10 years, and expect the microbes to hum along like clockwork. That's not how nature works.
Environmental factors—**flow, nutrients, light, grazing, temperature, redox, competition**—all change over time. And when they do, so does the makeup of your biofilm.

- **Species come and go**
- **Functions shift**
- **Balance is lost… or regained**

Sometimes the whole system reboots.
Sometimes it sinks into stagnation—nothing new happens,

nobody makes waves, and the microbes just keep their heads down and go through the motions. And then—
BAM.
A temperature spike.
A nutrient surge.
A sudden change in flow.
The house of cards tumbles. The whole system grinds to a halt.

Other times, it just quietly slips into **monoculture**—a slow erosion of diversity until all that's left is a brittle, one-note slime with no backup plan.
And when something finally goes wrong? It breaks. Hard.

> Biofilm isn't just gunk on glass—it's a living, evolving society.

Ignore it too long, and you might come back to find a hostile slime dictatorship in charge.

Scum vs Slime

When Biofilms Go Bad

By now you've probably realised that not all slime is created equal.
Some of it's the glue that holds your entire ecosystem together.
And some of it… well, some of it's just gross.
It's important to draw a line between functional microbial architecture—the good kind of slime—and blooms, mats, gunk, and goo that point to something being very wrong under the hood.

Good Slime (Functional Biofilm)

This is the microbial mortar. The stuff that makes ecosystems tick.

- Often invisible, or appears as a thin, fuzzy coating on surfaces
- Supports grazers, shrimplets, and biofilm-loving fish
- Grows steadily, doesn't choke out light or smother everything
- Smells earthy, not funky
- Usually clears water, not clouds it

Think of it like a community garden: diverse, productive, and humming with tiny life.

Suspicious Slime

This is where things start getting dodgy.

- Thick mats in weird spots (especially low-flow or high-organic zones)
- Starts feeling greasy or sticky to the touch
- May smell faintly off—not sulphur yet, but not compost either
- Often a monoculture (e.g. Oedogonium, Rhizoclonium, or cyanobacteria)
- Doesn't clear up with healthy grazing pressure

It's like when one bloke takes over the neighbourhood garden and decides to grow nothing but zucchini.

Bad Scum (The Unwelcome Kind)

This is biofilm gone feral.

- Dense surface slicks, bubbly foam, anaerobic mats on substrate
- Rotten egg smells (hydrogen sulphide = red flag)
- Blocks flow, clogs filters, kills roots

- Feels like wet snot. You’ll know it when you touch it.
- Often spreads aggressively or collapses suddenly, crashing your system

And here’s the kicker:
Persistent cloudy water—especially if it’s milky, oily, or accompanied by a biofilm sheen—is often a sign of scum takeover.
Note the word *persistent*.

Some microbial products (like Foundation) will cause short-term cloudiness. That’s normal—it's just microbial activation. But if your water stays foggy for days, smells odd, or gets worse after feeding?
That’s not a bloom. That’s a problem.

Final Thought:

Slime says “build with me.”
Scum says “deal with me.”
One holds your system together.
The other holds it hostage.

The tour's done, and we’ve covered a lot.
Well done for making it this far.
(And in my defence, I did warn you it gets more complex from here.)
In this chapter, we explored the architecture of Biofilm City: The houses, shops, factories, and high-rises that our microbial mates call home.
We looked at how environment shapes slime, how slime shapes environment, and how to tell the difference between helpful fuzz and full-blown scum invasions.

We also covered a few do’s, don’ts, and “dear god, what is that smell?” moments.

Next up?

The Great Aquarium Balancing Act

—aka—

"How the hell do I keep my tank from turning into a swamp, how can I tell when it’s hit the point of no return, and how can I fix it if it does?"

So stretch your legs, grab a snack, and make a strong coffee.

You’re gonna need it.

The science only gets worse from here.

Chapter 4: The Great Aquarium Balancing Act

So far, we've met the invisible players in the great game of life. We've explored their roles, their darker sides, and the structures they live in—the microscopic infrastructure that makes ecosystems function.

Now it's time to put all that theory into practice. And unfortunately, that means brushing past the basics. Designing an ecosystem — which is exactly what we're doing here — requires at least a little careful thought.

But I'm not here to tell you how to build an aquarium. That's been done to death, resurrected, and beaten to death again.

Instead, this chapter is about myth-busting the common ways aquariums quietly fail. I'll be leaning heavily on my own experience — mistakes included — to challenge some of the assumptions that get passed around as "best practice," and to tip the balance back toward systems that actually sustain the life inside them.

"But Greg," you might be thinking, "if they're best practice, how can they be myths?"

Candidly? That's a fair question. And the answer is both boring and uncomfortable: because they usually work well enough. They prevent obvious disaster. Fish don't immediately die. Water tests come back green. So the practice survives — not because it's optimal, but because it's familiar, repeatable, and rarely challenged.

I had a long conversation with a gentleman on a Facebook forum recently. I won't bore you with the blow-by-blow, but the core of his argument was this: the only microbes that ever matter in an aquarium are nitrifiers — *Nitrosomonas* and *Nitrococcus* — and that anything else is irrelevant because aquariums aren't nature.

And he was… technically correct. Aquariums aren't nature. They're simplified, artificial systems. But that's exactly where his argument collapses. Because simplification doesn't erase biology — **it just narrows the margin for error**.

As we've already seen in **Chapters 1** and **3,** microbes don't stop mattering just because the box is made of glass. This is the kind of thinking I'm talking about. Not malice. Not stupidity. Just ideas that have fossilised into doctrine because they've been repeated since the 1990s without being meaningfully revisited.

Traditional nitrifiers do play a role in the web — but they are not the web. And frankly, on their own, they're not even especially good at what we ask of them. Single-step nitrifiers are scaffolding, not structure. They're step-stools toward balance, not the balance itself. **The trouble starts when scaffolding is mistaken for a finished building** — and the rest of the ecosystem is quietly ignored because nothing immediately breaks.

So now we're going to tackle a whole catalogue of myths, misconceptions, and flagrant loads of crap.
Because this Guide isn't about telling you what to do — it's about teaching you how to question everything you've been told.

A cycled tank is a stable tank

A freshly cycled aquarium is a bit like the dishwasher in your kitchen .If you've got a small household, that little machine does its job just fine. Plates go in dirty, plates come out clean, and nothing starts to smell. As long as the workload stays within its limits, the system looks reliable. Now take that same dishwasher and drop it into a restaurant. Three hundred plates a night.

Pots.
Pans.
Grease.
Food scraps.

Suddenly, dishes start stacking up faster than the machine can process them. The problem isn't that the dishwasher is broken — it's that it was never built, trained, or equipped for that kind of load.

That backlog? That's your ammonia.
A newly cycled tank is very good at handling the exact waste load it was cycled under. No more. No less.
Change the input — more fish, more food, a missed water change, a dead plant — and the system can fall behind alarmingly fast.
Where the analogy gets interesting is this: **unlike a dishwasher, an aquarium can adapt**. Microbial communities scale with demand — but only if that demand increases gradually, and only if the system has the physical space and diversity to support them.

Given time, surface area, and consistent inputs, the "dishwasher" gets upgraded. More workers show up. New processing lines appear. Bottlenecks ease. That's stability. Stability isn't the absence of ammonia today. It's the system's ability to deal with tomorrow. A tank that has just finished cycling can process waste. A stable tank can absorb mistakes.

Mistaking one for the other is why so many aquariums never quite settle — and why "perfect" parameters can coexist with stressed fish, persistent algae, and systems that tip over the moment something changes.

While we're talking about ammonia, it's worth briefly covering where it actually comes from during a fishless cycle — because the method you choose has a big impact on how predictable (or chaotic) the process becomes. (And yes, we're assuming you're sane and not doing a fish-in cycle.)

The most common approach is a measured dose of liquid ammonia. This is typically sold under trade names like "cycle aid" or "cycle right", and comes at a known concentration — for example, 5 mL per 50 L producing a reading of ~10 ppm ammonia.

This method is popular for a reason. It's **simple, controlled, and repeatable**. You know exactly how much ammonia you've added, which makes it much easier to observe how long the system takes to process it. Standard instructions usually read something like: "When a full ammonia dose is converted to nitrate within 24–48 hours, the aquarium is cycled."

As cycling methods go, this is about as clean and predictable as it gets. Control is high, cost is reasonable, and aside from the occasional user error, it's fairly bulletproof.

Another commonly suggested method is adding a pinch or measured amount of fish food. This can work — **but it comes with caveats**. You don't have direct control over how much ammonia is ultimately released, nor over when it's released. Breakdown depends on microbial activity that may barely exist yet, so ammonia can appear hours or even days later.

Functionally, the endpoint looks similar: once ammonia is processed within roughly a day, the system is considered "cycled." The difference is that the path there is far less controlled, and far harder to interpret.

Then there are the more… creative approaches.

Raw prawns.
Chunks of fish.
Salmon fillets.

These follow the same basic logic as fish food, but introduce

Bacteria in a Bottle

We see these products a lot: shelf-stable, room-temperature liquids that claim to "instantly cycle your aquarium" or contain "live nitrifying bacteria", often with vague or extremely long shelf lives.

Here's the key thing to understand:

Living nitrifying bacteria are metabolically active and temperature-sensitive. In unrefrigerated liquids, they rapidly consume available resources and die off. Refrigeration can extend viability briefly, but efficacy still declines over time.

As a result, most bottled products do not deliver an instant, self-sustaining nitrogen cycle. At best, they act as supporting aids — supplying enzymes, nutrients, or starter biomass that can help existing microbes establish more quickly.

They are not a replacement for proper cycling, and they work best alongside measured ammonia dosing, seeded media, or other controlled methods — not as a subsitute.

additional problems. You're no longer just adding a nitrogen source — you're adding fats, oils, connective tissue, skin, and bone. Many of these break down poorly in aquariums, and often favour opportunistic bacteria that have little interest in building a stable system.

At that point, you're not cycling an aquarium — you're running a decomposition experiment, without the requisite microbial communities that make such processes predictable or safe.

And finally, there is a tiny but persistent school of thought that advocates burying an entire fish — occasionally a whole salmon — under the substrate and "letting nature take its course."

This is… bad. Please don't do this.

Not only does this invite opportunistic pathogens, it creates ideal conditions for anaerobic decay, hydrogen sulphide production, and other toxic by-products. It also carries the added risk of introducing parasites, diseases, or contaminants that have no place in a closed aquarium system.
Yes, this approach may work in a garden. Soil ecosystems have centuries of biological infrastructure to process large organic inputs. Your brand-new aquarium does not.

Proceed at your own risk — but understand that this isn't cycling. It's uncontrolled rot, and any success it produces is accidental.

Pre-Established Media
Rule #1: there are no shortcuts to cycling. Except… there are. But only if you understand why they work.
If you're setting up a new tank that is genuinely similar to an existing one — and I mean properly similar — then transferring established material can give you a head start. Same pH range, similar hardness, comparable temperature, similar livestock, similar substrate. Same ecosystem, new address.

In that case, moving up to half of the existing filter media into the new system can significantly reduce the ramp-up time. Note the wording: reduce, not eliminate. The new tank still needs time — several days, ideally a week — for microbes to settle, spread, and rebuild capacity around the new layout and flow patterns.

Hardscape matters too. Old driftwood, well-used rocks, "mucky" ornaments, and even established plants all carry their own microbial guilds. Transferring these surfaces helps seed the new tank with organisms already adapted to life on solid substrates — which is where most of the real work happens.
If the parameters are very different, this approach becomes much less effective. Some microbes will survive, many won't thrive. Even then, it's usually better than starting completely cold — just don't expect miracles.

Crashing the Mode
(aka: My cycle crashed, why?)

If your cycle "crashed", your aquarium was never fully cycled to begin with.

What Actually "Crashes"

When people say their cycle crashed, what they really mean is one of three things happened:

- The bioload exceeded the system's processing capacity
- The microbial community was too narrow
- The system relied on a single point of failure

None of those are sudden. None of them are mysterious. And none of them involve bacteria vanishing overnight in a healthy, mature system.

What failed wasn't the cycle.
What failed was the assumption that the system was resilient.

Cycling vs Stability (These Are Not the Same Thing)

Cycling answers one question:
Can this system process ammonia right now?
Stability answers a very different one:
Can this system keep doing that when things change?

Those are not interchangeable.

A tank that only works when everything is perfect isn't stable — it's brittle. And brittle systems don't crash because of bad luck. They fail because they were never designed to cope with reality.

Why This Keeps Happening

Because the hobby fixates on numbers, not behaviour.
People watch test kits instead of watching:

- feeding response
- waste accumulation

- biofilm development
- plant growth or stagnation
- how quickly the tank recovers after disturbance

You can have “perfect” parameters and a system that’s hanging on by a thread. You can also have “imperfect” numbers and a tank that shrugs off abuse like nothing happened.

Guess which one is actually cycled.

If your tank fell apart the moment you:

- added stock,
- fed a bit heavier,
- cleaned the filter,
- or missed a water change,

then nothing crashed.

You just found the edge of a system that was never finished building.
Cycling isn’t about ticking a box.
It’s about creating buffer, redundancy, and forgiveness.

New Tank Syndrome

(or: My tank wasn’t properly cycled, and now everything looks like a fever dream)

This one’s easy.
If you’re dealing with “new tank syndrome,” your tank was never properly cycled.
Period.
What people call new tank syndrome is just an ecosystem that’s been pushed harder than it can support. Too many

nutrients, too much light, and not enough internal cycling to deal with either. Algae, bacterial blooms, melting plants — none of this is mysterious. It's exactly what you'd expect when inputs outpace processing.

This isn't bad luck. It's impatience.

New tanks don't fail because they're new.
They fail because they're treated like mature systems before they've earned it.

The fix isn't clever. It's boring: keep lighting modest and photoperiods short, stock lightly, fertilise conservatively, and let the system build capacity before you ask more of it.
That's it.
You don't "beat" new tank syndrome. You grow out of it.

Old Tank Syndrome

(or: My system isn't working like it used to — what do?)

This is the downside of a glass box.
It isn't nature. It's a contained approximation of nature, and over time that containment matters.

Organics accumulate. Nutrients creep upward. Mulm compacts. Microbial communities settle into comfortable, low-effort routines. Things that once processed waste efficiently start doing just enough to get by.
The tank doesn't fail.

It just… ages. Sound familiar?
Yeah. Happens to humans too, *grandpa*.

This is where it gets messy — literally. Old Tank Syndrome isn't a single problem you can test for.
It's a slow loss of system efficiency, usually masked for years by habit and familiarity. You don't notice it until the tank stops responding the way it used to.
At that point, people tend to choose one of two paths: **the hard reset** — tear it down, clean it out, start again, or **life support** — heavier and heavier water changes, chemical band-aids, and a growing sense of resentment.

Neither option is inherently wrong. But neither is a cure. There isn't a one-size-fits-all fix, because there isn't a single cause.

Old Tank Syndrome is what happens when inputs quietly exceed maintenance for long enough that the system loses its margins.
The only real way to beat it — or at least delay it — is unglamorous: regular water changes, removal of accumulated mulm, maintenance of filters and pumps, keeping fish loads reasonable, and letting plants do some of the heavy lifting.
You're not chasing perfection here. **You're buying time.**
Aquariums don't collapse suddenly when they get old. They erode when we stop treating them like systems that need tending.

CO_2 Is Hard

Is it, though?
CO_2 has a reputation for being difficult. It isn't.
It's just another layer of the system — and like any added layer, it demands redundancy and consistency. CO_2 affects pH. That much is unavoidable. And yes, that means you need to measure it. But here's the part nobody likes to admit: once it's

dialled in, CO_2 is one of the least fiddly parts of a planted tank. Put the regulator on a timer. Set it. Then leave it alone. (Just don't forget to refill the bottle). Most CO_2 problems come from people constantly chasing it. Forget "Bubbles Per Second". "Bubbles per second" is meaningless.
It tells you nothing useful, because the amount of CO_2 actually dissolved in your water depends on:

- tank volume,
- diffuser type and efficiency,
- flow patterns, surface agitation,
- and the size and pressure of the CO_2 system itself.

One bubble per second in a 30-litre tank is not the same thing as one bubble per second in a 400-litre monster. Treating them as equivalent is how people gas fish and panic.

The Only Measurement That Actually Matters

The most reliable way to assess CO_2 in an aquarium is relative pH drop. Here's the idea — no charts, no gadgets: Measure your pH after the tank has been sitting with CO_2 off for a few hours .Measure it again after CO_2 has been running steadily for a few hours. Compare the two numbers. If your pH drops by about 1 full point (for example, from 7.4 to 6.4), you're typically sitting around 25–30 ppm CO_2. That's the sweet spot for most planted aquariums. Plants can tolerate — and even thrive at — much higher CO_2 levels. In the wild, some waterways hit 400–500 ppm (which is the 2020's ambient concentration). But they also have depth, flow gradients, and oxygen exchange your glass box simply can't replicate. Push that hard in an aquarium and fish pay the price.

The Tom Barr Chart

It's worth briefly mentioning the work of Tom Barr, because a lot of modern thinking around planted aquariums and CO_2 builds on it. For context: Tom Barr was one of the unsung heroes of early 2000's planted tank internet forums, and you can still catch him dishing wisdom on facebook pages today.

One of his most widely adopted contributions was formalising the relationship between pH, KH, and dissolved CO_2, and presenting it as a simple reference chart. Measure pH, measure KH, cross-reference the two — and you get a rough estimate of CO_2 concentration, assuming CO_2 is being injected at all.

At the time, this was transformative. It gave aquarists a way to monitor CO_2 without specialist equipment, and helped demystify what had previously felt like guesswork. It's important to understand what the chart is — and what it isn't.

The chart assumes a relatively clean carbonate system. Modern aquariums often use substrates, buffers, or additives that stabilise or influence pH independently of CO_2, which can skew the relationship. For that reason, it should not be treated as a precision tool, nor as a target-setting device. Where it still shines is as a relative indicator. Used sensibly, it allows you to observe trends over time and notice when something has drifted unexpectedly. It tells you that things have changed — not whether those changes are safe, optimal, or appropriate for your particular system. Like most tools in this hobby, the chart doesn't make decisions for you. It provides context. And context, not numbers, is what keeps systems stable.
I'll include a copy of the chart in the Appendix.

The Part People Forget

CO_2 doesn't exist in isolation. When you increase CO_2, plants grow faster — which means they demand: more light, and more nutrients. Fail to meet those demands and you don't get lush growth — you get instability and algae. That's not CO_2 being "dangerous." That's imbalance.

So… Is CO_2 Hard? Not really.

It's predictable.It's measurable. And once set up properly, it's remarkably hands-off.

Is it expensive? Absolutely.

But complexity? That's mostly a myth — kept alive by bad metrics and too much tinkering.

Why Most Advice Fails Outside the Tank It Was Built For

This one's easy.

Most aquarium advice fails because nothing is the same.
Advice that works in one tank cannot, by definition, be guaranteed to work in another. Different glass, different water, different flow paths, different lighting, different substrates, different feeding habits, different maintenance rhythms, different hands on the tools.

Even tanks built from the same shopping list diverge the moment water hits glass. **Pinpoint advice only ever applies to the system it was developed in.**

And unless you have the extreme luck of recreating a functionally identical setup — not just similar equipment, but similar biology, history, and handling — that advice is already out of context. **Even professionals struggle to reproduce systems perfectly.**

Expecting hobbyists to do so is fantasy. This is why copying setups often fails. Not because the original advice was wrong — but because it was situational. The mistake isn't following advice. The mistake is treating advice as transferable. When people say "this worked for me," what they really mean is: T*his worked in my tank, under my conditions, at that moment in time.*

That doesn't make it a rule. It makes it a case study. **If you take one thing from this chapter, let it be this**: every new tank should be treated as a new system.
Not a continuation of someone else's success story.
Not a template.
Not a recipe.
Borrow ideas. Borrow concepts. Borrow questions.
But assume nothing carries over intact — because it usually doesn't.
Aquariums don't fail because people ignore advice. They fail because people apply the wrong advice with too much confidence.

Take everything you read online with a grain of salt.
Also… a slice of lime and a shot of tequila. Helps it go down better.

Forum-based advice is usually a blend of good intentions, misplaced confidence, and one or two people who actually know what they're talking about — whose answers are promptly drowned out.

Without experienced professionals providing grounded, contextual advice, these spaces are better avoided when something genuinely goes wrong.

You are generally better off speaking directly to aquarium store owners or consulting their published material. A good store's systems are visible — often literally. Look at how they run their tanks. Check their social media and websites. See what they keep alive long-term, not just what looks good on delivery day. **Vet them thoroughly.**

The "Inch per Gallon" Rule

(or: One Oscar does not have the same footprint as ten neon tetras)

I will not put this delicately. **This factoid refuses to die**.

No matter how many times we demonstrate that waste production, oxygen demand, feeding behaviour, and territorial needs do not scale linearly with the length of a fish, there are still stubborn holdouts clinging to this rule like it's sacred scripture.
It isn't.

At best, the inch-per-gallon rule applies to a small handful of species, under ideal conditions, for very short periods of time. Outside of that narrow window, it collapses completely.
Ten neon tetras do not demand the same oxygen, food, space, or behavioural territory as an Oscar.
They don't compare to a pleco.
They don't compare to a school of rainbowfish.
Length is not biology.

And yet, despite decades of debunking — and despite the very real damage this kind of advice causes — the inch-per-gallon rule is still handed to beginners as gospel. Usually by someone trying to streamline and "simplify" the hobby for an audience that hasn't been taught what actually matters.

It's not simplification.
It's abdication.

And the tanks pay for it.

The fact is, there is no single rule that can define safe stocking levels for every species.
We can recommend minimum tank sizes and group sizes for individual fish, but even those are conditional.

They depend on the tank's footprint — tall versus long versus shallow — as well as filtration, substrate, hardscape, planting, and how the system is maintained. A mature tank can safely support more life than an immature one.

That isn't opinion.
It's biology.

Reducing all of that to a single number isn't simplification.
It's fiction. Aquariums are systems, not spreadsheets.
And no amount of tidy math will change that.

Tactically Nuclear

(or: Why dosing medication weekly as a 'preventative' is a terrible idea)

There is a particular kind of aquarium logic that decides the best way to avoid problems is to periodically sterilise the entire system.
Not because anything is wrong. Not because there's a diagnosed issue. But because something might happen.

So out come the medications.
Every week.
On schedule.
As "prevention."
This isn't caution. It's panic with a calendar.

A Necessary Clarification (Before Anyone Gets Clever)

There are situations where a mild oxidative or antiseptic intervention makes sense.
Substances like methylene blue or hydrogen peroxide don't work by "treating a disease." They work by temporarily shifting redox balance and knocking back surface-level opportunists — fungi, some bacteria, free-floating nuisance organisms — without permanently rewriting the biology of the system.

Used sparingly, in specific contexts, they can act more like reset buttons than weapons.
That does not make them preventative treatments. It makes them situational tools.

Why This Is Still Not "Preventative Medication"
The problem with weekly "preventative" dosing isn't the chemical — it's the mindset.
Preventative medication assumes:

- the system is fragile,
- problems are inevitable,
- and biology should be suppressed preemptively.

Mild oxidisers don't fix fragility. They only buy time — and if they're used on a schedule instead of in response to a specific, observable issue, they end up doing the same thing as stronger meds, just more slowly:

- reducing microbial diversity,
- selecting for tougher survivors,
- and training the keeper to treat symptoms instead of causes.

At that point, even “gentle” tools become tactically nuclear.

The Line You Don’t Cross
There’s a world of difference between: “Something specific is going wrong, and I need to interrupt it,” and “I dose this every week so nothing goes wrong.” The first is intervention. The second is institutionalised mistrust of your own system. And systems that are never trusted are never allowed to mature.

Preventative medication isn’t about protection.
It’s about fear — and fear makes people reach for bigger tools than the problem requires.

The Zero Water Change Fallacy

(or: Nature doesn’t grab a siphon hose — and no, floods, overflows, or constantly flowing waterways don’t count)

“**Nature doesn’t do water changes.**”
This line — or some variant of it — crops up every few weeks online, usually wrapped in language about being natural, ecologically sound, or delivered with a tone that’s equal parts smug and self-satisfied.

It’s presented as a profound philosophical truth.

In reality, it’s a misunderstanding of scale, time, and physics in under thirty words.

But even if it were remotely true, there’s a much bigger problem:
Your aquarium is not nature.

It’s a closed glass box. There’s no inflow of fresh water. No outflow of “dirty” water. No meaningful export of accumulated by-products unless you remove them.

Comparing that to a river, floodplain, or seasonal wetland isn’t clever — it’s a category error.

Floods dilute concentration and wash out debris.
Rain resets chemistry.
Groundwater exchanges minerals.
Your tank does none of this without human intervention.
(If yours does, I tip my hat.)

What “Zero Water Changes” Actually Means

In practice, so-called “zero water change” systems aren’t zero input or zero export. They’re systems that rely on plants, microbes, and dilution-by-neglect to mask accumulation — until they can’t.
They work best when:

- stocking is minimal
- feeding is minimal
- plant mass is very high
- and nothing ever goes wrong

In other words, they work under conditions that already require very little intervention.

The moment load increases, something shifts, or maintenance slips entirely, the illusion collapses and the system drifts into what people politely call old tank syndrome.

Accumulation Is Not Optional

Water changes don't exist to "reset parameters." They exist to remove things you didn't plan for.
Organics accumulate.
Metabolites build up.
Trace imbalances creep in.
Mulm compacts.
Buffers drift.

None of this is dramatic. None of it triggers alarms.

And none of it fixes itself just because the tank has plants.
A system can look stable for years while quietly losing margin — right up until it doesn't.
That's not balance.
That's deferred maintenance.

Why This Myth Persists

Because "no water changes" sounds elegant.
It sounds natural.
It sounds hands-off and enlightened.

And because when it works, it works quietly — which makes it easy to mistake luck, restraint, or good initial design for a universal principle.
It isn't one.

The Takeaway (Because This Isn't a Debate)

Water changes aren't a failure of design.
They're an acknowledgment of reality. You don't do them because nature does. You do them because glass boxes don't.
You can minimise them. You can space them out.

You can design systems that rely on them less.
But pretending they're unnecessary doesn't make your system more natural — it just makes it less forgiving.
And unforgiving systems always collect their debt.

"Too Many Phosphates Cause Algae"

I hear this one a lot. And like most persistent myths in the hobby, it has a kernel of truth — which is exactly why it refuses to die.

Yes, **organophosphates** can contribute to algae blooms. But when that happens, phosphate isn't the cause — it's the symptom. Organophosphates build up primarily through overfeeding, decaying plant matter, and neglected maintenance. In other words: excess organic load.

That's not a phosphate problem.
That's a husbandry problem.

Mineral phosphates, on the other hand, don't have anywhere near the same effect — unless the system is already imbalanced. In a healthy, well-matched tank, phosphate is just another nutrient. Plants use it. Microbes cycle it. Algae only capitalise on it when something else is already broken.
So let's step back and look at what actually drives algae blooms.

What Really Fuels Algae

Algae doesn't explode because of one number. It blooms when inputs outpace processing.

Common triggers include:

- Excess nitrogen — especially ammonia and nitrate, which are often far more limiting than phosphate
- Too much light without enough CO_2 — energy without carbon is an invitation for opportunists
- Insufficient plant mass — not enough competition for available nutrients
- Poor circulation and oxygen distribution — creating pockets where algae gains the upper hand

Even well-run systems aren't immune. A clogged filter, a dead flow zone, or a subtle drop in circulation can be enough to tip the balance. When algae shows up, it's usually reporting a mismatch, not pointing at a single nutrient like a smoking gun.

The Real Mistake

Blaming phosphate is attractive because it's easy. You can test for it. You can remove it. You can feel like you've done something decisive.

But algae doesn't care how tidy your test results look.
It cares whether the system makes sense.
Phosphate doesn't cause algae in isolation.
Imbalance does.

And chasing one nutrient while ignoring light, carbon, flow, and biomass is how people end up fighting the same bloom over and over again — convinced the problem is chemical, when it's ecological.

The Biggest Myth of All

We've tackled a whole pile of myths in this chapter, and I hope you skimmed it to find the bits you actually cared about.
If you didn't — kudos. You win a prize.
(It's my undying gratitude. No refunds. No gift certificates.)

But it's time to address the biggest myth in the hobby.
Or maybe it's a cosmic joke. We'll see.

Balancing an aquarium is not about finding a perfect knife-edge between light, fertiliser, and CO_2.
It isn't about running one neon tetra in a thousand-litre tank packed with plants.
And it definitely isn't about keeping a betta in a coffee mug and calling it "minimalist."

The truth is much less glamorous.

You balance inputs against outputs.

That's it. That's the whole trick.
Bit of a rort, isn't it?

Every system takes things in — food, light, fertiliser, livestock.
Every system must also move things out — through plant uptake, microbial processing, export, or intervention.
When inputs exceed outputs, instability follows.
When outputs exceed inputs, systems starve or stall.

Everything else we argue about in this hobby is just decoration around that fact.

High-input systems demand high export.

Low-input systems only work because they don't ask much of themselves.

Problems don't appear because you broke a rule.

They appear because the system stopped making sense.
There's one more piece to this, though — and it's where a lot of otherwise good tanks get quietly sabotaged.

Balance isn't just about inputs and outputs. It's about **stability**.

Once you find something that works — really works — the worst thing you can do is keep changing it because someone on the internet insists there's a better way. Aquariums don't reward constant optimisation. **They reward consistency**.

Balance, like microbial diversity, is deeply specific to each system. Advice that demands exact replication is only ever valid for the tank it was developed in.
Even experienced keepers struggle to reproduce systems perfectly — expecting universal rules to hold is wishful thinking.

If your aquarium is stable — if your animals are behaving normally, plants are growing, and nothing is slowly trending downhill — then congratulations. **You've already won.**

Chasing tiny improvements at that point is how people create problems they didn't have.

You don’t need to hunt for perfect numbers.
You don’t need to chase tenths of a pH point.
You don’t need to reset a working system just because someone else runs theirs differently.

If your parameters sit comfortably within the tolerance of the species you’re keeping, leave them there. Stability matters far more than precision. Aquariums are living systems, not lab experiments, and trying to pin them to exact decimals is a reliable way to invite drama.

Change things when something actually changes — new livestock, new plants, a shift in load or layout. Otherwise, resist the urge to “improve” a system that’s already doing its job.

Don’t fix what isn’t broken.

That’s the balancing act.
No magic numbers.
No universal rules.

Just ecology — whether we like it or not.

And just between us: **There's no such thing as a stupid question**. If anyone treats you like an idiot for asking a question you don't know the answer to: punch them. Sorry, my editor says i can't give that advice, so instead... Walk away. Find another expert - one who respects you, not just your wallet.

Chapter 5: Seeding, Feeding and Breeding the Invisible Herd

So far, we've covered who the key microbial players are, what they do for a living, and where they choose to live. Luckily for you, my editor says revisiting any of that will "cost a fortune" and that "we don't have the budget."

Shame.

Instead, dear class, we'll be covering the following: how to accelerate colonisation, how to feed your bugs without nuking your system, and how to tell the difference between encouraging growth and starting a bacterial house fire.

The first settlers in a new microbial colony matter. A lot. They shape the fundamental layout of the microbial ecosystem that follows.

Your tank — I'm sorry to say — is going to get seeded no matter how hard you try. Microbes arrive on the wind, on your hands, on your tools, and in your water. They're everywhere.

The NIH estimates that the microbial count contained in or around the average 70 kg adult male is roughly **38 trillion microbial cells**. Yes. *Trillion*.

Now, not all of those are making it into your fish tank. But it should give you a pretty good idea of what you're up against.

There is no such thing as a sterile start.

The general idea, then, is to prime your tank with the good stuff rather than pray and hope. As mentioned in prior chapters, pre-established filter media, pre-colonised hardscape, and live plants are all excellent ways to seed a system.

So are the right microbial starters. If the packaging declares species, bacterial concentrations, or similar specifics, it's probably not snake oil. Just be aware that many so-called "powdered microbial supplements" are largely *lactobacillus*-heavy blends — microbes commonly associated with human gut products that may have short-term effects, but do very little long term in aquaria. Almost none of these products contain nitrifiers, but they can help set the stage for nitrifiers and comammox organisms to establish later.

Choose products for your needs, not for the brand on the label.

So, how do we feed our herd?

It's simple. Microbes need **labile carbon** — carbon that is easy to digest or convert. Less energy spent on digestion means more energy available for growth and reproduction. Carbon also fuels EPS production, among other things.

Microbes require certain trace minerals — calcium, magnesium, zinc — to produce enzymes and chemical signatures. They need oxygen, moisture, and temperature within workable ranges. And yes, they also require small amounts of proteins and lipids.

So don't try to cycle a tank with cold, sterile water. Bring it up to temperature, get your filters running, and remineralise with appropriate **KH** and **GH** remineralisers.

Carbon
I won't delve deeply into this, but carbon is critical for EPS production. EPS is primarily composed of polysaccharides — carbohydrates built from carbon, hydrogen, and oxygen (hence carbo and hydrate. Scientific Latin is refreshingly literal).

Carbon is the limiting factor — the bottleneck and throttle — of microbial reproduction. In new systems, it is burned through rapidly, particularly when ammonia is the only supplement being added.

The most useful forms of carbon are labile ones — easily digested and readily available. These are often grouped under the umbrella term "prebiotics" and include digestible fibres, simple and complex sugars, and short-chain fatty acids (including omega-3s and omega-6s).

So yes — we're learning about digestion now too. It's microbes all the way down. I find this stuff fascinating.

Fish food technically provides all of this, but often not where it's needed or in appropriate proportions. What you want is lots of carbon and minimal lipids. This discourages fat-loving opportunists from colonising too early and making a mess.

Carbon, however, is a double-edged sword. Too much of it can cause cloudy water, bacterial blooms, and one hell of a stench.
Ask me how I know.
(Or check my Instagram. There are pictures.)

Lipids
Same as before, we'll keep this light.

Lipids (or fats, for the layman) are used in EPS for structural stability (that slimy, sticky, slightly wobbly bit), to create hydrophobic barriers that limit water uptake and loss, for certain signalling and communication purposes, and to help protect against invading microbes and antimicrobial agents.

Why this needs to be limited
Simply put, some microbes that feast on lipids can make a hell of a mess — spreading cloudy water and producing some truly unpleasant stenches. If you've never smelled rancid fat, consider yourself lucky.

Other microbes that thrive on excess lipids can also be opportunistic pathogens. These usually aren't a problem unless they begin to significantly outnumber beneficial microbes, but when they do, things can go sideways fast.

Excess lipids can also cause surface sheens and shimmers, which are harmless in small amounts but often unsightly — and usually a sign you're feeding the wrong things, in the wrong proportions.

Proteins
Proteins are required to form the core scaffold of a biofilm. Like carbon, EPS cannot form correctly without suitable proteins present. These proteins create the structural framework that allows EPS to anchor to surfaces — and, by extension, allows everything else to stick to it.

Certain proteins also perform critical enzymatic functions related to digestion and biodegradation. Microbial decomposition becomes difficult without them. Proteins are fundamental, and a lack of even a small reserve can significantly delay a tank's stability and maturation phases.

As with lipids, beneficial microbes aren't the only bugs hankering for some beef. All microbes require proteins to function, and certain more aggressive or opportunistic species will appear when excess protein is present in a system.

And then there's the obvious part: protein scums and films look and smell gross.

Ever been to the beach after strong wind or heavy surf and noticed that brown froth building up around rocks? That's protein scum.
It's gross.

Feeding the Fish ≠ Feeding the Microbes
This is an important distinction.

Microbes don't meaningfully benefit from fish food — or most other complex nutrients — until those materials have been partially broken down by enzymes and acids. In established systems, this usually occurs as a by-product of your fish doing what fish do (pooping). It can also occur externally, but only once sufficient microbial activity already exists.

In a brand-new system, there usually aren't enough microbes present to do that work.

I think you can see where this is going.

To be clear: I'm not saying you can't toss in a pinch of fish food, or that it won't do anything. Just don't be surprised if it goes fuzzy first.

Minerals
This should go without saying, but I apparently love the sound of my own font — so here we go.

Almost every biological function requires trace minerals. They govern everything from cell structure and shape to communication and chemical signalling. Hormones, enzymes, even the taste and smell of a fresh side of salad are all influenced by mineral content.

Among the most critical are calcium, magnesium, iron, zinc, and selenium. All are commonly found in aquarium GH salts.
Not a coincidence.
Without these, life cannot function. Period.

Oxygen & Water
Oxygen and water should go without saying, so I won't.

Except to remind you that the microbes we want in aquaria are aerobic — which means they require oxygen to function.

Temperature
Too low, and microbes slow to a crawl.
Too high, and they die.
Enough said.

Light
Microbes don't actually require light to function. However, adequate light encourages micro-algae to colonise EPS more quickly — and that's generally beneficial.

Another critical point: microbes run on a **biological clock**. Not all species reproduce at the same rate, and very few ever operate at their theoretical maximum. Most common aquatic bacteria have reproduction cycles on the order of **16–30** hours, which means it simply takes time for them to establish themselves across every available surface — and that's assuming your system is otherwise running close to perfectly.

Dormant microbes, like those found in most biological supplements, also experience what's known as a **lag phase**.

This is the period between a microbe being rehydrated and it actually waking up and doing anything useful. Depending on the species, the method of preservation, and how long it's been dormant, this lag phase can last anywhere from a **few hours to several days** — assuming the microbe wakes up at all.

So even with all the right tools and inputs, a true cold start will still typically take **two to three weeks**, at an absolute minimum.

We discussed microbial colonisation phases in **Chapter 3**, but it's worth reiterating the core point here: when microbial colonies are establishing, **stability is critical**.

Upset them too much and they'll throw a hissy fit and start all over. Avoid large water changes unless absolutely necessary, and keep temperature and food inputs consistent. If the rest of your setup is suitable, the single best way to optimise colonisation is to **leave them the hell alone**.

Water flow will do a better job of distributing microbes once they reach **Phase 5** (Dispersion) than you ever could manually.

Forcing colonies to move before they're ready is a great way to ruin their day — and yours. Adding random bits of plants, wood, or rock during this phase can also slow the spread, as shifting flow patterns and altering chemical and oxygen gradients may cause colonies to pause and reassess rather than expand.

On that note, small weekly water changes won't hurt — think **10–20%** at most — provided the replacement water is properly remineralised and brought up to temperature. This gently conditions the system to expect minor adjustments while ensuring microbes don't run short on the minerals required for continued colonisation.

Once you've nailed all of this down, the next step is simple: step back and let your microbes do their jobs.

Even a system built entirely from pre-seeded components will still go through a lag phase. That's not failure — that's biology.

Be patient.

I know that's hard. But you have to wait.
Good things do come.
I promise.

Chapter 6: Terrariums, Vivariums, Paludariums and the Wet/Dry Spectrum

This is where worlds collide.
The uncomfortable truth is that terrariums and their assorted -*iums* all work in much the same way. They have substrate that processes waste, and a whole lot goes sideways when the microbes aren't doing their job.

You can skip this if it's not your jam. I won't get mad. Promise.
But there *is* fun stuff to be learned here.

If you're sticking around, know that I appreciate your attention.

So. On to the crux of the matter:
Take everything you learned from the wet stuff, and imagine it dry.

I wish I was kidding.
It really is that simple (mostly).

You still need water. You still need substrate. CEC. Surface area. Layering. Fuel.
Flow still messes with biofilm (although this is airflow, not water flow. Same physics — just marginally less moist).
You still need oxygen penetration in your substrate.

But this is where terrariums diverge. I hope you read the terrestrial side of **Chapter 1**. If not, go read it now. It'll put things into better perspective.

Oxygen gradients in soil are controlled primarily by things moving around inside it.

Isopods, springtails, worms, cockroaches… the list goes on.

Aquatic systems don't need this process because they tolerate passive substrates.
Water moves oxygen and nutrients for you.
Terrestrial systems… do not.

Without insects to push around oxygen, waste, and other bits and bobs, your system will collapse. Roots will die. Microbes will die. Fungi will dominate without counterbalance. Rot will form. Mites and other opportunistic scavengers will swoop in like vultures and make one hell of a mess. Anaerobic microbes will take advantage and *voilà*: one-way ticket to the grossest smells imaginable.

In addition to oxygen, insects move microbes and nutrients. They physically consume decaying plant material and microbes, then poop it out elsewhere — usually under the surface, where roots can feed. This makes plant matter more bio-available, and functions in a similar way to fish and shrimp grazing on biofilm and rasping wood.

Insects do not homogenise soil. They create shifting micro-zones and steep redox gradients that allow aerobic and anaerobic microbes to exist in harmony, bringing balance to the Force that all living things benefit from (please don't sue, Mr Mouse).

The neat part? Bugs, like microbes, self-regulate. Not enough food? Populations shrink. Excess? The opposite. This acts as a biological throttle on decomposition, and means you should never end up with more insects than grains of dirt. And the best part? It's all automatic. No fiddling necessary.

Isopods, springtails, and other "clean-up crew" are very fussy about what they eat. They prefer certain fungi and microbes over others, leading to natural suppression of pathogenic and runaway fungal species, while effectively farming beneficial microbes that they don't eat as often.

Whilst they go about this busy task, they also facilitate the mixing of organic and mineral components in the substrate. They drag sources of carbon down, bring minerals up, and punch holes in organic material, preventing root suffocation and anaerobic explosions.

Roots don't just benefit passively either. They give back, and encourage bugs to bring lunch. They leak exudates — sugars, hormones, and the like — which attract bacteria and fungi, which in turn attract insects, which in turn bring oxygen, which… you get the picture.

These processes are critical. Nature (even the glass-box facsimile) cannot function sustainably without them. Fertilised water alone will not allow for a healthy, hands-off ecosystem. You will have to refresh your soil regularly if you aren't careful.

Just… go and get some springtails or isopods. It's not hard... unless you hate bugs. In that case, Good Luck!

With the bugs come the fungi. Artists, comedians — just all-round fun at parties. If insects are bulldozers and microbes are chemists, then fungi are the logistics and infrastructure heroes.

They smash up all the complex stuff: **lignin**, **cellulose**, **waxes**, and **tough plant tissues** all melt like butter at their tender touch. Without fungi, leaf litter piles up, carbon movement stalls, and decomposition has to wait around for physical decay to occur (which stinks).

Once fungi have chewed tough tissue down to its basic compounds, they hold on to them tightly and slowly ration nutrients out like a bank that's going out of business. They immobilise nitrogen and phosphorus, preventing nutrient spikes, bacterial blooms, and root burn.

To continue that analogy, they distribute their funds slowly over massive underground networks of hyphae, transporting water and nutrients across dry gaps, compacted zones, and (relatively) vast distances. These processes take on exaggerated importance in terrariums, where capillary water is patchier, roots can't explore everywhere, and substrate layers tend to compact.

But much like banks, fungi can get greedy without oversight. Insects graze on hyphae, releasing nutrients, keeping mycelium young and soft (and thus better able to move nutrients), and preventing hyphal mats from choking the surface of the substrate.
This is not accidental.
This is **co-evolutionary design**.
A terrarium without grazers is a fungal mono-culture waiting to go wrong.

But neither of these can function without water. That's right — we're about to make things… *moist*.

But first, let's define moisture in the context of our assorted -ariums.

Moisture isn't a matter of how wet or dry something is. It's a matter of where the water is, how long it sticks around, and what removes it from the system (hint: it's usually air).
In wet systems (aquariums), water is freakin' everywhere. Kinda has to be.

In drier systems like terrariums, water is far less present.
In those mid-ground systems — paludariums, vivariums, swamp boxes, rainforest simulators — water can be anywhere, at any time (flip a coin).
Moisture is **temporal**, not static.

And you can't talk about water without mentioning oxygen. Every pore can hold either air or water. Never both. Treat it like a negotiation. More water = less oxygen. Less water = more oxygen. Unstable moisture levels = unstable oxygen levels. This is the root (heh) of all moist-system drama.
In reality, "wet" and "dry" aren't binary. There's a massive gradient between the two, and different parts of the substrate sit at different moisture levels. Surface films, capillary bridges, saturated micro-sites, dry voids… all existing millimetres apart.
Moist systems are not uniform. They're more like a patchwork. That's why they're so microbially rich — and so failure-prone. (But oh, so much fun if you get it right.)

Moisture is critical. It governs:

- microbial metabolism
- nutrient mobility
- gas exchange
- decay speed
- pathogen advantage

Change moisture, and you don't just "water the system" — you change who's allowed to breathe.
It also acts as a rate controller for chemical reactions.

Wet systems have fast chemistry, but are buffered to limit the scope of reactions.

Dry systems have slow chemistry, buffered to limit swings and spikes.

Moist systems have rapid chemistry, and often lack the buffering needed to prevent swings.

Moist systems boom fast, crash quickly, and turn rank overnight.

Paludariums are not as easy as they look, and they demand careful tuning. But get that balance right, and you'll be well rewarded.

The worst part is this: oxygen works in gradients too. Oxygen is also a patchwork, and things can go wrong if there's not enough oxygen — but also if there's too much. Most life doesn't need lots of oxygen. It just needs predictable access to some oxygen.

Oxygen moves poorly compared to water. It relies on physical proximity to diffuse, or physical displacement to move larger amounts over any distance. Oxygen is slow. Oxygen is fragile. Oxygen gets pushed out too easily, and can be hard to move back in once it's gone.

This is why compaction and over-watering are deadly.

Oxygen content defines the types of microbial interactions that occur within each substrate layer. High-oxygen / hyperoxic zones (typically surface areas) run aerobic processes — efficient, clean, and stable. Low-oxygen / hypoxic zones (typically deeper in the substrate) run anaerobic or facultative processes — messy, smelly, opportunistic.

Typically, we try to reduce or eliminate anaerobic conditions for smell, but they can be leveraged strategically if you know what you're doing (this isn't my specialty, so I won't comment on it further).

These zones and processes apply to microbes, roots, fungi, and invertebrates. Changing oxygen availability doesn't just "stress" the system — it often forces organisms to physically switch operating modes.

Hypoxia isn't an immediate "oh shit, there's no oxygen". It's often subtle and slow, creeping in when you least expect it. That's the danger. Roots survive briefly, microbes (where possible) flip metabolisms, fungi surge, and smells take time to become detectable. By the time you notice the symptoms, it's often too late.

Here’s the thing: you don’t just… add oxygen to a substrate.

You preserve pore space, prevent prolonged saturation, encourage root and insect movement, allow substrates to dry slightly, and avoid unintentionally sealing layers. Oxygen availability is about proper design and constraints — not inputs.

And that’s the key.
Set it up, and it will come.

Layers upon layers upon layers.
(like an onion, but hopefully less smelly).

Back in **Chapter 3**, we talked about substrate layers. Onions have them, ogres have them, terrariums have them. All the same.

Where terrariums differ from aquariums is when you bring oxygen and moisture control into the equation. This doesn’t explicitly change what the layers do — it just adds more items to their job description, as well as a few supplemental layers that aren’t necessary underwater. Proper substrate layering lets you control oxygen and moisture gradients without touching them directly.

And the cool part? These layers are pretty much the same materials too. Let’s go through it step by step (in no specific order), revising wet functions and exploring the additional or modified dry functions.

Carbon Sinks
Wet function: Microbial fuel, pH buffering
Dry functions: Adsorb stenches, preserve porous space for oxygen, retain moisture, create boundaries that limit redox transitions (oxygen reduction driven by chemical or microbial processes).
Carbon sinks don't fix problems — they slow them down enough for nature to catch up.

High CEC Materials
Wet function: Mineral Vault (locks in nutrients until needed).
Dry functions: Provide chemical buffering during oxygen swings, stabilise substrate structure during wet–dry cycles, and limit sharp redox swings.
These materials become a shock absorber, not just a pantry.

Porous Structures
Wet function: Anti-compaction, gas exchange
Dry functions: Oxygen diffusion corridors, support substrate recovery after saturation, insurance against hypoxia.
Porosity is pure **oxygen strategy**.

Microbial Real Estate
Wet function: Colonisation surfaces
Dry functions: Formation of oxygen-stratified neighbourhoods (segregation based on oxygen needs), physical separation of microbial metabolic zones, permitting the co-existence of aerobic and anaerobic microbes without mixing.
Layering lets microbes specialise without clashing or competing.

It's important to note that **layering does not prevent anaerobic**

zones. It controls where they exist, how stable they are, and how much work they're allowed to do.

Additional Layers That Appear in Dry Systems

Drainage / void layer: Not a mere water sink. The drainage layer acts as an emergency oxygen reservoir, pressure relief in case of accidental saturation, insurance against substrate compaction, and buffering against over-watering. False bottoms don't prevent rot — but they do buy time to rectify it.

Otherwise, layering works more or less the same. Materials function in similar, albeit expanded roles, and in many cases work better than if fully submerged.

Important!

Layering controls oxygen movement and retention. Bad layering doesn't remove oxygen — it typically traps it where it can't do its job, while starving regions that desperately need it. Over-layering can cause similar failures, including blocking insects from moving through, sealing off moisture channels, and more. For layers to be effective, they must be:

- permeable
- traversable
- biologically connected

Otherwise, you've built stratified failure.
Each layer:

- dries at a different rate
- saturates at a different rate
- recovers oxygen at a different rate

Layering gives the system temporal resilience. It's important to do it properly.

Wet layering and dry layering are very distinct. Wet layers are governed by water dominance. Dry layers are governed by air dominance.

Moist layers exist in contested territory. **Nothing owns the space for long** — not water, not air, nor microbes. Intermittent saturation, thin water films, and rapidly shifting oxygen availability define these layers. They function as transition zones between wet and dry sections, and as boundaries between aerobic and anaerobic processes.

Oxygen is borrowed, not stored. **Insects become critical** for maintaining oxygen gradients, while also providing avenues for evaporation and capillary action. They facilitate waste export and mineral turnover that would otherwise stall under constantly fluctuating conditions.

This is where things accelerate.

Constant moisture and intermittent oxygen speed up decomposition, nutrient release, and microbial metabolism. Paludariums become biological battlegrounds, where fungi, bacteria, insects, and plants all clash. When something goes wrong, it usually starts here.

Most moist systems fail due to over-reliance on heavy organics (peat, coir, excess moss), sealed fabric or geotextile layers, compacted anaerobic zones beneath false bottoms, and poor moisture control. A wet surface does not guarantee appropriate moisture gradients below.

Moist layers only work when something is actively managing the air–water boundary. Insects, roots, airflow, deliberate layering, and intentional drying cycles all play a role.

Moist layers are inherently unstable. There’s no single correct recipe here — only constraints, warning signs, and damage control.

We talked earlier about how oxygen deficiency sneaks up on you. This is important to remember. By the time things start to stink, it's too late. And it's also very easy to prevent.

Most basic systems are built using organic-laden materials so that the system stays wet — **but those same materials collapse pore space, seal oxygen out, and rot faster than roots can keep up.**

And **wet** isn't the same as *moist*. Think of a rainforest. It’s always moist — but if the forest floor were mud, the whole thing would collapse. A proper organics-based system uses leaf litter, sticks, and woody debris — materials that decay slowly, maintain structure, and keep air moving and feeding microbes — rather than heavy layers of peat, coir, or moss. It also relies on insects and larger animals to aerate, consume rot and turn over anaerobic zones. Without this mechanical intervention, the whole system would become a swamp surprisingly fast.

But moisture isn’t defined exclusively by rainfall or humidity. Humidity slows drying in the top layers. Rainfall, misting, and sprinklers saturate deeper layers.

Sealed environments prevent excess moisture from escaping. This traps water where it doesn’t belong, inviting rot and decay.

Air movement and temperature create localised surface drying, which helps limit decay and reset oxygen availability.
Artificial false bottoms can act as reservoirs that wick moisture upward into drier zones — but only when paired with airflow and proper drainage.
A balance can be maintained.

This can be controlled through airflow design — either via humidity-controlled air extraction (fans on timers or hygrostats) or passive air movement. Allowing localised humidity to dip past a certain point (mostly determined by plant tolerance) can be used to rate-limit rot in surface organic layers.

Controlling misting frequency and volume also allows for precise modulation of moisture levels.

Want less time for drying? Mist more frequently, but for less time.

Want a wetter system with larger moisture swings? Mist less often, but for longer.

Want both? Do the math.

The crux of the matter is that moist systems don't need more water. They want predictable drying. Controlling your watering cycles and air flow are the key.

If you stuck around for the whole chapter, hopefully you learned something. If not, I stand by my use of the word *moist.*

Chapter 7: Microbes with Benefits

We've discussed microbes in abstract terms up to this point — using metaphors, shorthand, and job titles to make sense of an invisible workforce. Now it's time to talk about **how they actually perform these roles… and why**.

Put simply: **microbes don't work for free**.

Like most citizens of a town, microbes expect their labour to generate a return. Unlike humans, they don't work for cash money — they work for food and fuel. Their world is transactional, and their cooperation is conditional. This concept is called mutualism: the familiar "you scratch my back, I'll scratch yours." It isn't charity. They aren't doing you a favour — they're providing a service.

And if that service stops being profitable, they'll stop providing it. Often to the detriment of your beloved aquarium.

This is why microbes aren't inherently *good* or *bad*. Their behaviour is deeply contextual. In one tank, a given microbe may be beneficial; in another, the same organism may become a nuisance — or a genuine problem. This uncertainty is why effective microbial approaches don't rely on a single species or strain, but instead **support diverse communities** and the conditions that allow useful relationships to emerge. We can't precisely predict the needs of every system, so we plan for resilience rather than precision.

Of course, this is a double-edged sword — especially in systems that are poorly built or poorly maintained.
In most functioning aquariums, microbes use mutualism to feed themselves. Waste is decomposed into mineral forms

plants can use. Those plants, in turn, release root exudates — simple sugars and other compounds — which microbes consume as fuel. Energised microbes then continue decomposing waste, releasing more nutrients, and the cycle reinforces itself.

In this context, biofilm becomes critical infrastructure, not mere set dressing. Like factories, warehouses, and offices in a town, it allows the system's economy to operate with relative stability. The more stable the system, the better the cooperation. The better the cooperation, the smoother the nutrient web functions. And when that web runs smoothly, everything grows better.

Everyone thrives when they can predict their workload — and their pay check.

So what do microbes actually eat?
To an extent, they feed on the decomposition work they perform. But this is inherently supplemental — like the sandwich you take to work. Their preferred meal of choice (the steak-and-three-veg equivalent) is a by-product of plant growth known as **root exudates**.

To keep a very long conversation about sugar short and sweet, root exudates are simple sugars, amino acids, and organic acids that plants
deliberately leak from their roots. This leakage creates localised pockets where microbes love to congregate, which in turn benefits the plant. By making their immediate surroundings attractive to microbes, plants effectively guarantee access to the nutrients they want — nutrients microbes produce as payment

for their own food. It's a neat little loop of supply and demand that works well, so long as both parties keep playing ball.

This mechanism is less relevant in aquariums for a few reasons. Dilution, water flow, and a general lack of fine root hairs limit the benefit aquatic plants gain from releasing root exudates, so they typically don't bother. Instead, they source most of their nutrients from a different takeaway store — the water column (usually. There are always exceptions).

Microbes that live in and around roots are collectively referred to as rhizobacteria — bacteria that inhabit the rhizosphere (literally, the region of soil surrounding plant roots). These organisms can fix nitrogen, produce plant growth hormones, mobilise minerals via siderophore production, and even secrete antimicrobial compounds that suppress competing microbes.

In aquariums, however, we generally don't concern ourselves with them. For one, aquatic plants rarely possess the ultra-fine root hairs that drive meaningful exudate release. More importantly, most rhizobacteria are relatively oxygen-hungry — far more so than a typical submerged aquarium can reliably support. As a result, rhizobacteria are far more relevant in emersed plant systems, ripariums, and hydroponics-adjacent setups than they

On Plant Growth Hormones

Many rhizobacteria — and a few microbes outside that group — produce plant growth regulating hormones. These compounds are not food. Instead, they act as chemical signals that tell plants, in effect, "this would be a good place to grow roots."

When plants detect these signals, they infer the presence of an established microbial community and often respond by directing new root growth toward that area. While this mechanism is extremely important in soils and emersed systems, it has limited practical relevance in fully submerged aquariums for the reasons discussed above.

are underwater.

But of course, not all microbes are invited to the barbecue. There's always one weird chap in the cul-de-sac that everyone quietly avoids. Unlike a traditional neighbourhood, though, our resident microbes don't rely on social cues — they employ chemical warfare to deter unwanted neighbours.
They'll also happily eat their rivals out of house and home, only to turn around and declare, "Sorry — no food left here. Sod off."

We call this behaviour **competitive exclusion**. Microbes establish themselves early — along with their preferred companions — and hoard resources so nothing else can move in. Gated communities ruin everything, right?

Except that when the right microbes get there first, this works in your favour. A well-established community will naturally suppress opportunistic pathogens simply by occupying space, consuming resources, and making the environment hostile to newcomers.

Of course, this cuts both ways. If less desirable microbes establish first, they exclude beneficial ones just as effectively. And once a community is fully settled, removing it becomes extremely difficult — often requiring drastic intervention, up to and including full sterilisation and a system reset.

But more on that in a bit. First, I want to explore a term that's used almost daily when talking about microbes — often in completely the wrong context. And the kicker? This is frequently deliberate.

That term is probiotic. Which, by itself, means… almost nothing without context.

Merriam-Webster defines a probiotic as *"a microorganism that, when consumed, maintains or restores beneficial bacteria to the digestive tract."*

The International Scientific Association for Probiotics and Prebiotics (ISAPP) defines probiotics as "live microorganisms that, when administered in adequate amounts, confer a health benefit on the host."

Both definitions are reasonable — and both are largely irrelevant to aquariums.

Marketing mush tends to use the word *probiotic* to describe any microbe that has a positive effect (or at least doesn't have an obvious negative one). In reality, none of that matters if the microbe in question doesn't actually provide a benefit in your system. Many so-called "probiotic" bacteria used in aquarium products offer little to no tangible benefit in aquatic environments — assuming they're even alive to begin with. I won't go down that rabbit hole here. We'll save that for **Chapter 8**.

The point for now is simple: for a probiotic microorganism to be useful, it must be present in sufficient numbers, in the right place, and under conditions that allow it to function. Short of that, *probiotic* is just a label — one that conveniently adds about 20% to the price, and very little in the way of real-world benefit.

There are vast differences between medical **probiotics** (digestive aids like *Lactobacillus*, or *bifidobacterium*), **agricultural inoculants** (typically soil microbes that assist with waste breakdown and nutrient cycling — I love these), and **aquarium marketing**, which often leans on vague terms like "s*ludge buster*", "*cycle enhancer*", or "*food enhancer*" without specifying strains, concentrations, or shelf life.

Even within the scientific literature, the term probiotic comes with an important caveat: not everything labelled as one has a proven benefit. The definition hinges on measurable outcomes, not intent or marketing — a distinction that is often lost once the word leaves the lab.

But enough about semantic definitions. Let's talk about Shelf Life.

Truly live microbes require a handful of things to stay alive — food, oxygen, shelter, and temperature stability. I'll keep this deliberately brief so I don't wander into **Chapter 8** before **Chapter 7** is finished. Live microbes that aren't refrigerated and have limited access to food typically have shelf lives measured in **weeks**. Refrigeration to slow them down? **Months… maybe**.

Next time you pick up a bottle, check the label. Is there a use-by date? Does it specify microbial concentration — usually expressed as CFU (Colony Forming Units), meaning individual cells capable of reproduction — per gram or per millilitre? If not, it might be bunk.

Freeze-drying is currently the most reliable method we have for preserving microbes, but it isn't perfect and doesn't work for every organism. Accepted efficacy straight from the lab is typically **around 85%**, and that number drops steadily over time. After a year or two, there's no guarantee those microbes can even wake up again. And even if they do, they still need time to establish and colonise.

That process is not instant.

This is a neat point to slide right back into **competitive exclusion**.

Once microbes establish themselves, they cling on with everything they've got. They deploy antimicrobial chemicals, build physical barriers (such as EPS — extracellular polymeric substances), buy up all the nearby real estate, and use every dirty trick available to stop competitors from setting up shop and stealing their customers.

Some microbes are particularly good at producing antimicrobial compounds. Bacteria such as *Bacillus polymyxa*, and fungi like *Penicillium* (yes — the mould we make penicillin from), are notable examples. These antimicrobial producers are widely cultivated in agriculture, aquaculture, and medicine to suppress unwanted organisms, and they're especially effective when used to support existing communities of beneficial microbes, rather than replace them outright.

Other species, including many *Pseudomonads*, excel at resource hoarding — rapidly consuming carbon, iron, and other limiting nutrients, starving newcomers before they can gain a foothold.

Fast-reproducing microbes add another layer of defence by occupying every available surface. With no space left to settle, late arrivals are forced elsewhere — or die.

Much like any ageing population, mature microbial systems resist change. (There's an *OK Boomer* joke here somewhere.) They're robust, set in their ways, and perfectly capable of ignoring most things they don't like. This is why quick chemical fixes rarely last. The microbial engine simply chugs along.

Which brings us to the next touchstone for microbial interactions: **bioaugmentation**.

In short, bioaugmentation refers to the deliberate introduction of specific microorganisms into a polluted environment in order to facilitate **bioremediation** — the cleanup of waste and toxins through biological processes. By that definition, an uncycled aquarium qualifies as a polluted system, and one that can legitimately benefit from microbial assistance.

Bearing in mind that established microbial communities are resistant to change, there are only a handful of situations where introducing new microbes makes sense:

- To assist with cycling new

Bioremediation is cool!

This isn't marketing fluff — it's a legitimate, well-established field. Wastewater treatment plants routinely rely on microbial consortia, often including members of the Bacillus group, to break down organic waste.

One of my personal favourites, *Pseudomonas fluorescens*, has even been trialled for bioremediation of oil-contaminated environments. Under the right conditions, it's capable of breaking down components of crude oil — a reminder that microbes aren't just passive recyclers, but some of the most powerful chemical engineers on the planet.

aquariums
- To aid recovery after a system crash
- To reinforce weakened systems, such as those recovering from heavy medication

Outside of these scenarios, bioaugmentation is often more trouble than it's worth — especially if the microbes aren't suited to the environment (freshwater organisms in a marine system, for example), if there's no available food, or if competition from an established community is already too intense.

By the time a biofilm reaches its later maturation phases, it stops behaving like a loose collection of "we have little choice but to play nice" and starts operating as a cohesive, coordinated system. As we discussed back in Chapter 3, several collective behaviours become dominant:

Quorum sensing:
Microbes release and detect signalling molecules that gauge population density and local conditions. Once enough information is available, behaviour changes collectively to suit. It's absolute microbial democracy — everyone votes with chemistry, and nothing happens until there's consensus.

Gene sharing:
Microbes aren't precious about intellectual property. Through horizontal gene transfer, useful traits — stress tolerance, metabolic shortcuts, resistance mechanisms — can be shared between related strains, strengthening overall community resilience.

Metabolic zoning:
Different microbes cluster based on energy needs and waste production. Some thrive where oxygen is plentiful, others where it's scarce. By arranging themselves spatially throughout the biofilm and substrates, the colony minimises conflict and maximises efficiency, with one group's waste often fuelling another.

At this stage, biofilm isn't just everywhere — it's organised, and it's working together. Teamwork makes the dream work, and cooperative biofilms are far more resilient, harder to disrupt, and far less likely to panic when conditions suddenly change.

Chapter 8: Microbial Magic… Or Marketing Mush?

A Brief Disclosure (Before We Begin)

Before we go any further, I should be upfront about one thing. I run a company called Niskai Aquatics. We make natural, holistic fish foods and microbial supplements — and yes, we make claims about them. I use my own products exclusively, and I test everything I reasonably can on some very expensive shrimp colonies. My rule is simple: **if I won't use it myself, I have no business suggesting anyone else should**.

This chapter is not here to sell you anything. If you've made it this far, you'll have noticed I've gone out of my way not to do that — and I intend to keep it that way.

Where relevant, I will also call out the shortcomings of my own products. No formulation is perfect. Every product involves trade-offs, compromises, and assumptions about how it will be used. Pretending otherwise is marketing, not ecology.

Out of professional courtesy, I won't name or directly target other brands. That's not the point of this chapter. What I *will* do is describe concepts, claims, and patterns that recur across the industry. If something I describe sounds suspiciously like a popular product you recognise…well — that part's between you and them.

Now to the meat of the topic. This chapter is effectively a **Buyer's Guide to Invisible Promises**.

I'm not here to tell you which brands are best, or which products work and which are scams. My aim is to educate you on common misconceptions, misdirections, marketing

buzzwords, and outright bullshit non-statements.
What I will tell you is what questions to ask — because ask you should. As mentioned back in **Chapter 4**, there's no such thing as a stupid question.

If something sounds too good to be true, it probably is. There's no such thing as a "*one capful fixes all*", and if you disagree… **I have a bridge to sell you**.

When I first started marketing my own products, I had to cover a few bases.
First and foremost: **you cannot make a claim that cannot be proven**. That means you cannot state a specific time-frame unless it is guaranteed.

For example, the phrase "*clears your water in one hour*" cannot be used unless it can be demonstrated unequivocally, every time. If one person times it and it takes one hour and one minute, that's a potential lawsuit. **I'm not exaggerating**.

This applies just as strongly to nutritional and medicinal claims. You cannot say "*your fish will become red if they eat my food*" because that claim cannot be reliably backed up. You can, however, say "*improves fish colouration*" — because there is no defined baseline. Improved compared to what? According to whom? How is "improved" being measured?

It's impractical to define — and that is precisely why marketing departments love phrases like "*supports*", "*boosts*", "*enhances*", and "*detoxifies*". These words establish no expected outcome and require precisely zero supporting documentation. They don't promise anything measurable. They just… exist.

Biology, however, does not care about flowery writing or poetic licence. It cares about measurable outcomes: growth rates, redox shifts, mineralisation, respiration, digestion speed, and similar parameters.

Products with genuine scientific backing tend to make very different kinds of statements — the sort that a discerning hobbyist can actually interrogate. These often include (but are not limited to) viable CFU and strain counts, active ingredient concentrations, and clear, transparent labelling.
They also tend to have a single focus.

Jack of all trades, master of none. If a product claims to "*do everything*", it probably does all of it **poorly**.

When a product starts to age and sales slow, the first response for most companies is not to redesign it. Redesign costs money — real money. Time, research, trials, reformulation, regulatory review. Done properly, **redevelopment can cost millions**, and it also carries the risk of alienating existing customers who were perfectly happy with the original product.

So the more common solution is far simpler: the product is handed to marketing for a re-brand. Often this amounts to little more than a label change. The contents stay the same, but the product is now "*new*", "*improved*", or "*enhanced*" — frequently accompanied by a price increase justified by whatever language is currently fashionable.

A good example emerged around **2022–2023**, when interest in probiotics and prebiotics in fish food began to rise. Adding live microbes to dried foods is technically difficult (and yes, I'm speaking from experience), so attention shifted to prebiotics — substrates that gut microbes can metabolise. In practice, this usually means some form of digestible fibre.

Several manufacturers responded by adding prominent "*Added Prebiotics*" claims to updated packaging, often alongside price increases of **20–25%**. However, when the "*new and improved*" versions were compared directly with the previous packaging, the ingredient lists were identical. No formulation change had occurred. Only the framing had.

Nothing new had been added. Something old had simply been re-described.

There is another category of mislabelling that most people will recognise: broad, sweeping claims applied to very simple products — the **WD-40** approach to aquarium solutions.

Technically speaking, some clay-based flocculants can bind certain compounds, assist with water clarification, reduce odours, and even suppress specific pathogens under the right conditions. That much is not controversial.

What is controversial is the implication that these effects occur meaningfully at the doses and application methods typically recommended — for example, **a single capful per X litres**, added directly to the water column. In practice, the kinetics simply don't support that interpretation.

Results observed under laboratory or highly controlled conditions do not automatically translate to functional outcomes in complex, open systems like aquariums. I like to joke about how a single drop of water kills cancer *in a petri dish*. Demonstrating an effect in isolation is not the same as delivering it reliably at scale.

This is particularly frustrating because many of these products do have legitimate and highly effective niche applications. Their usefulness is undermined not by what they are, but by how broadly they are marketed.

Continuing on from that soliloquy, we come to what I'll call the *mystical hand-waving* category of claims.

If a product relies on unspecified microbes, proprietary blends with no clarification, or vaguely defined "synergistic" effects that cannot be isolated or tested independently, that should raise questions. If a company cannot tell you what something is, they usually cannot tell you how it works either.

This does not mean a product must reveal trade secrets or provide a **DIY** recipe to be trustworthy. Listing ingredients does not give away the secret to baking a cake — it simply explains why the cake tastes like bananas.

Transparency matters because it enables predictability. **I control what goes into my systems precisely so I can anticipate how they will behave**.

Knowing what a product contains allows me to predict outcomes with a high degree of certainty. When "*magic*" products are broken down into their component parts, they often become far less mysterious — though not always in the way the marketing suggests.

Chlorine neutralisers are a good example. They work, and they're useful — but understanding why they work explains both their limitations and some of their quirks. The characteristic sulphur smell found in many dechlorinators comes from sodium thiosulphate, which is the active ingredient in most formulations. This is normal.

Where confusion arises is in the additional claim that these products "remove ammonia". In reality, sodium thiosulfate has a very narrow interaction with ammonia chemistry:

- Free ammonia: it does nothing to it. However, it does interfere with standard salicylate-based ammonia tests, causing artificially low readings.
- Chloramine: it removes the chlorine component, converting chloramine into free ammonia.

That is the full extent of its interaction. No binding, no detoxification, no removal — just chemistry behaving exactly as expected.

Even where chemicals can be used to temporarily restrict the effects of ammonia — as is the case with certain aldehydes — their action is inherently unstable and short-lived. These compounds do not persist, do not remove ammonia from the system, and should only ever be considered a stop-gap measure.

If such treatments truly worked indefinitely, the entire aquarium hobby would look very different. Biological filtration would be largely obsolete. There would be no reason to wait for cycles to establish, no emphasis on microbial stability, and far fewer dead fish along the way.

That this has not happened tells you everything you need to know. If a cheap, simple chemical solution existed, it would already dominate the hobby — because if there's one thing aquarists are better at than being patient, it's being cost-conscious.

On the subject of economics, it's worth briefly addressing a category of products that circulate heavily through social media advertising. These are rare cases where the claims are not merely exaggerated or vague, but so extreme in scope that they have little grounding in reality at all.

The format is usually familiar. A short video shows a filthy, green-water aquarium with no visible filtration, no plants, and far too many goldfish. A small black cube is dropped into the tank. It appears to fizz in an exaggerated fashion. The video cuts. Time is implied to have passed.

Suddenly the water is crystal clear, the glass spotless, and the **fish appear not only healthier but somehow gainfully employed**. We are told that a single cube can "fix everything."

It cannot.

Out of curiosity — and to demonstrate the point to a friend who was struggling with their own tank — I bought one. The product itself turned out to be little more than activated carbon.

Carbon can improve water clarity and remove certain dissolved compounds, but only when used correctly, typically within a filter, with sufficient contact time and flow.

It does not polish glass. It does not compensate for overstocking. It does not replace filtration, plants, or maintenance. And it certainly does not perform miracles when dropped loose into the water column.

It should also be noted that Activated Carbon is inert and cannot react with water.

The problem here is not that the underlying material is useless — it's that the claims bear no resemblance to what the material is actually capable of doing.

Theatrical Exaggeration

If you've ever watched these videos closely, you'll notice the cube doesn't just fizz — it puts on a full theatrical performance.

In reality, activated carbon is inert. It does not effervesce. It does not react with water. Any dramatic bubbling is not the product "working"; it is there to suggest activity where none exists.

I'll spare you the more colourful analogies that came to mind while watching it, but suffice it to say: if a demonstration relies on spectacle rather than mechanism, the spectacle is the point. And if a block of carbon appears to release more bubbles than an industrial air pump, it's reasonable to start asking some pointed questions. My editor has advised me to be precise with my language here for legal reasons. I trust readers to infer the rest.

The Spectacle Test

This whole saga highlights an important distinction. Products that use hyperbole to draw attention to ease of use are not automatically useless.

Ads where a cleaning product is sprayed onto a filthy surface and then cut to it being magically shiny do not suggest that no mechanical effort occurred — they simply skip over it to imply speed, convenience, or to save time and attention. The theatrics neither add to nor detract from the product; they tell a story. Problems arise when spectacle replaces explanation.

If a demonstration relies on visual drama, time jumps, before/after cuts, or exaggerated sensory cues (smoke, bubbles, colour flashes, and similar effects), pause and ask:

- What mechanism is being shown?
- What is consuming energy — what is actually happening?
- What would stop this from working?

If the advertisement cannot answer these questions, it is selling the video, not the product. This applies just as readily to posters, websites, and flashy labels. If the pitch does not clarify the mechanism at work, or relies on vague, non-specific statements about "*effects*", it warrants a second look.

The real problem with this kind of marketing is not just wasted money. Inflated claims teach bad mental models. They replace understanding with buzzwords, discourage learning how systems actually function, and — in a hobby involving living organisms — can lead directly to mismanagement and harm.

And here's a good segue to a popular product that almost functions as a lie — but for a reason I wish was better understood.

Glutaraldehyde. Marketed as "*Liquid Carbon*" or "*Liquid* CO_2", and frequently misused by well-meaning hobbyists who believe CO_2 is rocket science (it isn't — it's just expensive. See **Chapter 4**).

Glutaraldehyde is highly toxic. It is classified as a broad-spectrum biocide due to its non-selective protein cross-linking action (indiscriminate life-ending, effectively). It is used to sterilise heat-sensitive medical equipment, preserve tissue, and disinfect surfaces where microbial life is not desired.

It is not gentle chemistry.

And yet, people dose it weekly. So why? And why is it marketed as a carbon supplement when it clearly isn't one in any functional sense?

The answer is regulation. In most jurisdictions, products marketed as medications, antimicrobials, or disease treatments for pets fall under strict veterinary oversight. Manufacturers must demonstrate safety, efficacy, and acceptable margins of harm. Glutaraldehyde does not discriminate. It affects microbes, algae, plants, and animals alike. That makes it difficult to market honestly as a treatment. However, glutaraldehyde does contain carbon. It is an organic carbon compound (**$C_5H_8O_2$**), and it will eventually decompose into carbon-containing by-products, including CO_2.

From a purely technical standpoint, this satisfies the criteria required to label it as a "*carbon source*". And so, it is not sold as a biocide.

It is sold as a fertiliser.
Different category. Different regulatory framework. Different standards. And thus, it slips through. This does not make it magical, benign, or equivalent to CO_2 injection. It makes it chemically aggressive, biologically blunt, and frequently misunderstood. This is also not illegal, even if it is a bit cheeky.

Whilst we're in the category of misclassification, let's talk microbial products.

There are four broad categories of microbial supplements commonly sold in the hobby. Each functions differently, and each applies to different situations. We'll walk through the classifications first, then discuss how and when these products actually make sense.

The aim here isn't to sell anything or slag anyone off — it's simply to explain what these terms mean, how the products function, and why their applications differ.

Prebiotics

Despite the name, prebiotics are not microbes in any sense.
They are the food microbes consume.
Sugars, carbohydrates, oligosaccharides, and indigestible fibres can all act as prebiotics. The unifying feature is that they provide a usable carbon and energy source for microbes. Some are fast-acting, some are slow, and some favour certain microbial groups over others.
That's it.
They are bug fuel.

Probiotics

Probiotics are living microorganisms. In practice, the term is used very loosely.
As discussed in Chapter 7, legal and commercial definitions of "probiotic" do not require a demonstrated benefit — only that the organisms are not harmful. That means many products

labelled probiotic are better described as microbial inoculants rather than targeted treatments.
Whether they provide benefit depends entirely on:

- species and strain
- viability
- concentration
- and whether they survive long enough to do anything useful

Synbiotics
Any product combining prebiotics and probiotics is referred to as a synbiotic.
In theory, this pairing can be useful. In practice, it only works if both components function as intended. Otherwise, it's just two buzzwords sharing a label.

Postbiotics
The least commonly discussed category is postbiotics.
Postbiotics are not living organisms, but biologically active compounds produced by microbes — including metabolites, enzymes, and cell fragments. Dead microbes can still provide benefit through these compounds.
Brewer's yeast, Vegemite, and even leavened breads all contain postbiotic components. Nothing is alive — but something is still doing work.

To be blunt, most forms of carbohydrate can function as prebiotics to some degree. Wheat flour, spirulina, starches, fibrous vegetables — all broadly fall into this category. A product that upsells these functions without specificity is usually just being trendy.

Some formulations include additional FOS (fermentable oligosaccharides) such as inulin. These are almost exclusively used as prebiotics because they preferentially feed slower-growing microbial populations, which can help limit blooms of fast-acting microbes that cause instability. That said, if you're paying significantly more for a fish food solely because it contains inulin, take a second look. Inulin is inexpensive, and at meaningful concentrations it can dilute nutritional value.

Probiotics are a fun one. In fish food, many add minimal practical benefit. Cheap foods do not magically become better because a probiotic has been sprinkled on top. Digestive microbes can't extract nutrition that isn't there to begin with. Manufacturing matters here. Most flake and pellet foods are flash-baked at high temperatures because it's cheaper and more consistent. This kills any microbes added before cooking. Spray-coating freeze-dried microbes after cooling is technically viable, but it limits how much can be applied — and is largely ineffective with flake.

Higher-quality feeds may be cold-processed or slowly dehydrated, which opens more viable pathways for microbial inclusion. Even then, freeze-dried microbes do not have unlimited shelf lives. Even robust spore-forming organisms such as *Bacillus subtilis* degrade over time. If a food claims to "contain probiotics" but lists no realistic shelf life — or carries a use-by date stretching beyond two years — it's worth being sceptical. If probiotic inclusion is the sole reason to buy that product, it's probably not worth paying extra. In most cases, the concentrations involved are simply too low to matter.

That said, there are powdered microbial feeds that work. These are typically synbiotic blends of sugars, yeasts, and *Lactobacillus*, sometimes paired with *Bacillus subtilis*. They're often marketed as fry foods, but usually require additional dietary supplementation because their intrinsic nutritional value is low. They're also relatively expensive in Australia, and prone to overuse. High concentrations of fast-acting microbes can bloom easily if overdosed, so care is required.

Then there's the other side of this space: the less food-focused, more structural products. These are often labelled as "*sludge busters*", "*cycle accelerators*", or "*biofilm generators*". This category typically combines fast- and slow-release prebiotics with selected probiotics to accelerate EPS production, smooth nutrient cycling, and support microbial diversity.

These products are not magic fairy dust. They do not fix poorly designed systems, replace nitrogen cycles, or teach your fish to do algebra. They simply smooth rough edges — and, importantly, they have a shelf life.

Sludge busters should not be necessary in a properly maintained system. They're best reserved for cleaning your septic tank.

As before, if a product does not clearly list its ingredients or microbial species, is sold as a liquid requiring no refrigeration, or lacks a realistic use-by date, it's unlikely to perform as advertised. Prebiotics may be stable, but you're paying for the bugs — not the rice bran and sugar.
Postbiotics are relatively rare in aquarium products. At the time of writing, the most common and obvious example that

comes to mind is brewer's yeast — widely used, well understood, and rich in biologically active compounds despite containing no live microbes.

If there's a single key takeaway from this chapter, it's this: Products, marketing, and advertising aren't inherently evil — misunderstanding is. Sometimes that misunderstanding is accidental; sometimes it's encouraged to help spruik sludge. Most bad products survive not because they're clever, but because people don't ask enough questions.

Once you understand what questions to ask, the junk tends to expose itself. So don't stop asking. Ask the shop staff. Ask the reps. Ask the manufacturers. Ask each other.

And if no one can give you a straight answer, you already have one.

Chapter 9: A Test Kit By Any Other Name...

Before we even start dissecting the twisted logic of "water testing is essential but also kinda… not", we need to step back and clarify what, exactly, we're testing for.

(Those of you with a firm grasp of water chemistry can skip ahead. The rest of you? Pay attention. This bit matters.)

As we've already established in **Chapters 2, 3**, and **4**, you can't just plonk tap water into a glass box and throw fish at it. Not unless your goal is a short, educational tragedy.

Aquariums don't run on water alone. They run on a web of microbial infrastructure — biofilms, decomposers, nutrient cyclers, and all the invisible glue that holds the system together. That machinery has to be built, fed, and given time to stabilise.

But here's the part that catches people out:
Even with all the right biological tools in place, a system can still fail if the water chemistry itself is hostile.

Author's Aside

I didn't particularly want to write this chapter.

Unfortunately, the sheer volume of terrible advice circulating online made that decision for me. So here we are. Adding a chapter on test kits to a book that's supposed to be about ecology. But it's all linked, so y'know.

This is Greg putting on yet another hat, sacrificing another tranche of sleep, because his ego — or perhaps his conscience — refuses to let him rest while people are still yelling at test kits and wondering why their tanks keep imploding.

Yes — it's never quite as simple as I make it sound.
And somehow, it still is.

The tier of water chemistry we actually care about isn't especially complicated once you stop treating it like arcane wizardry. You don’t need to understand every molecular interaction or memorise reaction pathways.

You don’t need to know how it works.
You just need to understand **what the numbers represent, what influences them, and what they allow — or prevent — biology from doing.**
Think of it like microbes.

You don’t micromanage every bacterium. You manipulate the environment and let the system sort itself out. Water chemistry works the same way — just with fewer living opinions and slightly less guesswork.

There’s a whole laundry list of parameters that can be tested for. We’re going to ignore most of them and focus on the **key dozen or so that actually matter**.

Note: Everything here is freshwater-focused. For marine-specific chemistry, please consult someone who enjoys salt creep and calcium reactors.

- **pH — Potential of Hydrogen (ions)**
  A measure of how acidic, neutral, or alkaline the water is.
- **KH — Carbonate Hardness (Alkalinity)**
  Determines how resistant the system is to pH change; effectively your buffering capacity.
- **GH — General Hardness**
  A measure of dissolved calcium and magnesium ions; critical for osmoregulation, plant health, and long-term biological function.

- **NH_3 / NH_4^+ — Ammonia / Ammonium**
  Toxic byproducts of decomposition. Relative toxicity depends strongly on pH and temperature.
- **NO_2^- — Nitrite**
  A toxic intermediate stage of the nitrogen cycle.
- **NO_3^- — Nitrate**
  The end product of aerobic nitrification. Low acute toxicity, but biologically active and not consequence-free.
- **PO_3 / PO_4 — Phosphate**
  Mineral and organic phosphorus sources. Essential for biological processes and commonly supplied via food and fertilisers. Can be used deliberately in engineered buffering systems, but primarily expresses itself biologically.
- **Cl — Chlorine**
  An antimicrobial disinfectant added to tap water. Highly toxic to aquatic life. Rarely tested directly.
- **TDS — Total Dissolved Solids**
  An aggregate measure of dissolved inorganic material. Largely meaningless without context; best used only for tracking change over time.
- EC — Electrical Conductivity
  A direct measure of total ionic strength in the water. TDS values are typically derived from EC using an assumed conversion factor.

Before we start on water parameters, one thing needs to be said.
I can’t stress this any further without becoming unpleasant, so I’ll keep it simple: test your source water.
If you use tap water, test your tap.
If you use RO, rainwater, bore water, or anything else — test that.

Test it regularly. Monthly is a good baseline.

This does two things. First, it tells you when your foundation has shifted — because if your source water changes, everything downstream changes with it. Second, it establishes a baseline for any adjustments you make later: T**DS, GH, KH, remineralisation, dilution, and buffering all depend on knowing where you started.**

Without that baseline, you're not managing chemistry — *you're guessing*.

pH

If you've coasted through life without ever learning the very basics of pH, I'm impressed. I aspire to be that blissfully unencumbered.

In any case: pH is a scale from **0 to 14.**

Lower numbers are more acidic. Higher numbers are more basic.

At the extreme ends:

- **pH 0** is about as acidic as it gets. This is not ideal for fish.
- **pH 14** is aggressively basic — think drain cleaner. You can usually find it in line at Starbucks ordering a *Pumpkin Spice Latte, venti, low-fat whip.* Also not ideal for fish.
- **pH 7** is neutral. Like the Swiss.

Conveniently, it also sits squarely in the overlap zone tolerated by most freshwater species.

Testing pH

pH tests generally come in three flavours:

- Liquid drops
- Test strips

- Digital pens

Drops and strips aren't perfectly precise — expect accuracy somewhere around ±0.5 pH units. For the overwhelming majority of fish, this is completely fine. Unless, of course, you're keeping the universe's most emotionally delicate species.

Digital pens can offer better resolution, but only if they're calibrated, maintained, and not treated like a magic wand. (More on that later.)

pH Ranges (Not Magic Numbers)
Fish live within a range of pH.
Anyone who insists a fish — or shrimp — must live at an exact value (say precisely 6.2, but not 6.1 or 6.3) is delusional. What harms fish isn't a slightly different number — it's **rapid change**.
Fish adapt to numbers.
They do not adapt to chaos.

pH Stability
Pure water (such as RO/DI) has no pH stability. It should have:

- **KH** ≈ 0
- **GH** ≈ 0
- **TDS** ≈ 0 ppm
- **EC** ≈ 0 µS/cm

Freshly produced, it often reads **pH 7.0** — but this is fleeting. The moment it's exposed to air, it absorbs CO_2, forming carbonic acid and becoming acidic. As a result, "pure-adjacent" water typically settles somewhere between **pH 5.5** and **6.6**, depending on exposure and contamination.

Any mineral influence shifts this behaviour further — which brings us neatly to buffering.

KH and pH Stability

KH directly affects pH stability.
Low KH buffers weakly, allowing pH to swing easily.
Higher KH stabilises pH more aggressively — but also tends to push it alkaline.

As a very rough rule of thumb, a **KH around 6** often corresponds to a pH somewhere between **7.0 and 8.5**, depending on other inputs.

Which is why chasing pH without understanding KH is an excellent way to stay confused.

There's a whole slew of products that can affect pH. We'll cover **KH-based methods** in the next section, but aqua-soil deserves an honourable mention here.

Aqua soils lower pH primarily through **cation exchange**. They bind calcium (and magnesium) ions from the water and release hydrogen ions (H^+) in return. More hydrogen ions in solution means lower pH — because chemistry, and because nature enjoys being inconvenient.

It's an inverse relationship: as hardness ions are removed, acidity increases. Simply put, more H^+ ions means lower pH. This is why aqua soils soften water, reduce KH over time, and naturally push systems toward acidic conditions — especially in the early life of the substrate.

Note: Higher-quality (and usually more expensive) aqua-soils tend to have greater buffering capacity and more robust cation exchange sites. Some will actively consume carbonate as quickly as it's introduced, making a measurable KH effectively impossible.

In these systems, the soil itself becomes the dominant buffer. As long as it's still chemically active and not exhausted, pH will remain remarkably stable — regardless of what your KH test kit insists on telling you.
When that buffering capacity fades, the numbers start moving again. That's your cue.

kH:

Carbonates (CO_3^{2-}) and and bicarbonates (HCO_3^-) that are present in water. Through a small amount of chemical shitfuckery, KH buffers - or prevents - pH from swinging.

For simplicity, we'll refer to the whole suite of KH as "carbonates". **Sue me, I'm lazy**.

Carbonates do not "*lock*" pH. They work by reacting with acids to neutralise them and slow pH drops.

This reaction consumes the available carbonates, meaning KH is gradually depleted over time. Monitoring KH is important, and maintaining KH stability is a key part of balancing a system.

When you look at the parameters listed for a fish, the KH value is best understood as shorthand for the type of system that species evolved in. Low-KH environments tend to be acidic, experience rapid pulses in biology and dissolved organics, and often support fewer species at lower densities. Fish from these environments typically have narrower physiological tolerances, slower metabolisms, and handle rapid change poorly.

Fish from higher-KH systems are adapted to more chemically stable conditions: higher pH, smaller or negligible parameter swings, and greater mineral availability.

KH also influences nitrification rates, the structure and activity of microbial communities, plant nutrient availability, and **CO_2** behaviour within the system.

In essence, KH requirements in nature govern overall system momentum and stability. This tells us more about expected species behaviour than almost any number on a test kit, short of direct observation. It is also why chasing specific KH values is rarely critical — and why attempting to force carbonate hardness upward can cause more harm than keeping fish in water with lower-than-recommended KH.

GH

GH — or General Hardness — is a measure of the calcium and magnesium present in a system. These two ions form the backbone of most biological mineral processes in freshwater environments. Most aquarium GH salts maintain a calcium-to-magnesium ratio of roughly **3–4:1**, while tap water can vary wildly. Standard GH tests measure total hardness and do not distinguish between the two individually.

Most fish species — including shrimp and snails — benefit from this general balance.

Aquarium GH salts also commonly include trace elements such as iron, manganese, zinc, and selenium. Alongside calcium and magnesium, these minerals are biologically essential. They support enzyme function, tissue development, shell and bone formation, and a wide range of metabolic processes.

Supplying them is not optimisation — it is meeting baseline biological requirements.

Osmoregulation is a term I use a lot, because it does a lot of heavy lifting. In simple terms, fish require a certain level of dissolved minerals in the surrounding water to regulate fluids across cell membranes. Without sufficient mineral availability, **cells dehydrate or collapse**, **organs and skeletal structures fail to develop** properly, d**igestive and enzymatic processes falter**, and **immune resilience drops**. **Shells and carapaces become thin and weak**, giving pathogens and parasites an easy foothold.

On the other end of the spectrum, excessive GH can be just as harmful. When mineral concentrations climb too high, chemical processes are disrupted, skeletal growth becomes abnormal, and shells or carapaces can harden to the point where movement and moulting are impaired.

In short: don't chase GH past the point of sufficiency. Overdoing it can be every bit as damaging as running too low. GH is about providing the minerals life needs to function —

not about pushing numbers higher in the hope that more is better.

Ammonia

Ammonia (**NH_3**) and Ammonium (**NH^+_4**) are highly toxic by-products of the decomposition cycle. Granted, Ammonium is marginally safer under certain conditions, but this is functionally irrelevant for aquariums and the fish that live in them. **Slightly less toxic is still lethal, even if it takes an hour longer to kill your fish.**

There isn't much more to be said about ammonia here, except this: any detectable reading is too much. **Ammonia should read 0 ppm at all times**. If it doesn't, your fish are being actively harmed — whether you can see it yet or not.

Nitrites:

Nitrite (NO^-_2) is the intermediate stage of the nitrogen cycle. While less immediately toxic than ammonia, they are still harmful to fish.

Any detectable nitrite reading indicates that the nitrogen cycle is incomplete, and the aquarium is not yet safe for fish.

Fish-in Cycles:

As a hobbyist, a professional, and a person, I vehemently oppose fish-in cycling.During my years as a retail-facing professional, I have seen firsthand the damage ammonia exposure can inflict on fish. Blackened tissue. Open lesions. Skin and scales sloughing away. These injuries are only the visible part of the problem.Ammonia causes chemical burns. Fish gills are among the most delicate, highly vascularised tissues in the animal kingdom — thin membranes designed for gas and ion exchange, not chemical assault. I can only imagine the damage being done where we cannot see it.As a paramedic, I have seen what chemical burns do to a human being. If ammonia can permanently injure a grown adult, it requires no leap of imagination to understand what it does to an animal that weighs a few grams and breathes through exposed tissue.A fish-in cycle does not guarantee harm — but it always carries the risk of it. And that risk is borne entirely by the animal, not the keeper. Saving a week of time is a poor justification for exposing a living creature to avoidable injury.

Nitrates:
Nitrate (NO^-_3) is the end stage of the aquarium nitrogen cycle. Unlike ammonia and nitrite, nitrates are **not acutely toxic at low concentrations**, but they are not biologically neutral either .In most freshwater systems, nitrate levels are generally kept below ~40 ppm, with more sensitive species — including Caridina shrimp — often requiring levels closer to 20 ppm or lower for long-term comfort and stability.

Phosphates:
Phosphates (PO_4^{3-}) are a source of enormous misinformation in the aquarium hobby. We covered this fairly comprehensively in **Chapter 4**, so I won't rehash the phosphate-versus-algae argument here (my budget thanks you for your understanding).

Phosphate is one of the three primary, or "macro", nutrients required for plant growth — the others being nitrogen and potassium. In aquariums, phosphate commonly exists in two broad forms, which standard hobby test kits are unable to distinguish.

Mineral phosphates are inorganic and often bound to substrates, minerals, or salts. They are less immediately bioavailable and typically require biological activity or acidic conditions before being released into forms plants can use. Mineral phosphates are sometimes included in buffering products to influence pH behaviour. They are usually introduced intentionally, rather than appearing on their own.

Organic phosphates, or organophosphates, are most often produced through the decomposition of organic material —

food, waste, plant matter, and biofilm. These forms tend to appear naturally in aquariums as a result of bio-load and maintenance practices. While organophosphates can influence water chemistry, their effect on pH is generally minor compared to mineral buffering systems.

Phosphate levels tolerated by aquariums vary widely depending on plant mass, lighting, and overall system balance.

In densely planted systems, concentrations in the single-digit ppm range — and sometimes higher — are commonly observed without issue. As with most parameters, context matters far more than chasing a specific number.

Chlorine:

Most hobbyists don't routinely test for chlorine, but standard pool and drinking water test kits usually include a chlorine (Cl_2/free chlorine) test. Chlorine used for disinfection is often referred to as "free chlorine", which describes the reactive chlorine species present in water after chlorine gas has been added. However it's labelled, **any detectable free chlorine is toxic to fish and invertebrates**.

Test kits:

Test kits are not gospel.

A test result tells you that something chemistry-related is happening. It does not tell you why. Results should always be interpreted within context, and compared over time as a trend — not treated as a final verdict on the health of a system.A single reading is a snapshot, not a story.

Take TDS as an example. If your TDS creeps upward week after week and nothing else has changed, that increase is likely just the slow accumulation of food inputs, waste, dissolved organics — or even simple evaporation. That doesn't mean something is "wrong." It means the system is behaving normally. If that pattern is consistent, there's no reason to panic every time the number moves.

Sudden changes are different.

If a test suddenly shows ammonia, that's obviously bad — but the test still hasn't told you the cause. It's reporting a symptom, not a diagnosis. In a correctly "cycled" system, **Ammonia doesn't appear spontaneously.**

Something upstream failed. It's no different to running a fever. The thermometer tells you that you're sick, not why. Treating the number without addressing the underlying cause doesn't fix the problem — it just masks it.

Not All Test Kits Are Equal

(And Why I Use Strips for Day-to-Day Monitoring)
Not all test kits are created equal — and more importantly, they are not designed for the same job.

Drop tests, titration kits, digital probes, laboratory photometers — all of these exist for a reason. They offer precision, repeatability, and tighter resolution. When you need to know exactly where a parameter sits, they're the right tools for the job.But here's the part that often gets missed: Most day-to-day aquarium decisions do not require laboratory precision.

They require trend awareness.

For routine monitoring — the casual, frequent "is anything drifting?" check — I use test strips. Not because they're perfect, but because they're fast, consistent, and easy to repeat often. A test that gets used regularly is more valuable than a perfect test that only comes out when something is already wrong.

Strips trade precision for speed and accessibility. They usually resolve parameters in broad bands rather than exact numbers. **That's a limitation — but it's also the point**. Most fish and plants don't care whether nitrate is 18 ppm or 22 ppm.

They care whether it's low, moderate, high, or rising rapidly.

Strips are very good at answering those questions.When something looks off — a value jumps, a trend breaks, or behaviour changes — that's when I reach for higher-resolution tools. Drops, meters, or targeted tests are confirmation tools, not first responders.This is the mistake people make: They use high-precision tests as everyday reassurance tools, and low-precision tests as diagnostic tools — when it should be the other way around.Test strips are for:

- frequent checks
- spotting drift
- confirming stability
- catching problems early

Drop tests and meters are for:

- investigating a problem
- confirming a suspicion
- dialling in a specific adjustment

Neither is “better” in isolation. They’re complementary.And like everything else in this hobby, the best tool is the one that matches the question you’re actually asking.

A quick addendum on pH, TDS and EC pens/probes.

These are brilliant, but:

- Require regular calibration
- Require proper storage in liquid solutions
- Require replacement batteries or recharge
- Are expensive (for the ones worth buying, anyway)
- Are delicate. Don’t drop them.

For most hobbyists, that’s a lot of maintenance for information you don’t actually need day to day.

Chapter 10: Closing Thoughts and Microbial Mindfulness

It's been a long road, getting from there to here. It's been a long time, and my time is finally near.

I'm not just quoting Faith of the Heart here. (Good song. Go listen to it and let it live rent free forever). My life has been a busy one, and I sometimes feel I've crammed several lifetimes into the past year, let alone the last decade. But I still have a long journey ahead - and more learning to do. As I write this closing chapter (at 11:50pm on the 31st December 2025), I'm waiting for my new microscope to arrive so I can get started on my next project - The Moss Manual. It'll be a load of fun, and definitely a different thing to the Layman's Guide.

Addendum: After writing this, I had a conversation with a person (who knows who they are, and why this is their fault) and had to add **Chapter 9** on Chemistry. A scientist’s job is seldom done. But I digress.

I'll never stop learning new things. I'll never stop asking questions. And neither should you. If you've made it this far, you're probably driven by as much curiosity as I am (or I'm paying you very well to proof-read this. Either way). But seriously. Never lose that drive. You never know... Maybe in 10 years, you'll be writing a guide to why that Niskai guy was full of shit - and I'd love to read it!

I guess what I'm, trying to say is this: knowledge and passion are the keys to life. I've... Never been happier than when I've been doing this stuff. Understanding how the world around us functions has been the biggest eye-opener I've ever experienced, and I would do it all again in a heartbeat. And I'll be honest - if I'd had a copy of this 10 years ago? I'd be very dangerous today.

So go forth, armed with the knowledge needed to kick-start an ecosystem, and remember: "*Your tank should be as alive as you are*"

Appendix A: Not-so-common terms

(As used within the Guide)

This appendix exists so you don't have to reread three chapters and a joke just to remind yourself what a word meant.

Aerobic / Aerobe
Refers to processes or organisms that require oxygen to function. Most surface-level biology in aquariums and soils is aerobic.

Algae
A broad, informal term covering many unrelated photosynthetic organisms. Some algae are microscopic, some are plant-like, and some behave more like biofilm residents than plants. Algae are not automatically bad; they are part of most healthy systems.

Ammonia / Ammonium
Two forms of the same nitrogen compound. Ammonia is more toxic, while ammonium is less harmful and more easily handled by biology. The balance between them depends on pH and temperature.

Anaerobic
An environment with little or no oxygen. Some useful processes happen here, but uncontrolled anaerobic zones cause problems fast.

Anoxic
Describes an environment with no free oxygen available. Anoxic zones support specialised microbial processes and are not inherently dangerous, but become problematic when they expand beyond their intended or natural boundaries.

Aquarist (see You)
The person reading this guide. Keeper of glass boxes, negotiator with biology, and occasional cause of their own problems.

Aquarium
A fully aquatic system designed to keep organisms submerged in water. Most biological processes here are driven by water chemistry, flow, oxygen availability, and submerged biofilms.

Aquatic
Describes organisms or processes adapted to living fully submerged in water.

Aufwuchs (also called the Grazer's Pantry)
The living coating that forms on hard surfaces underwater: algae, microbes, fungi, and tiny animals all tangled together. This layer is built on biofilm and becomes the primary natural food source for shrimp and many grazing fish. When this layer is healthy, grazing animals thrive. When it's absent, food chains collapse.

Bioavailable
Present and usable by living organisms. Test kits detect presence — biology cares about access.

Biofilm
A living layer made up of microbes, slime (EPS), trapped nutrients, and microscopic life. Biofilm is where most useful biological work happens in aquariums and soils. It is not dirt. It is not waste. It is the engine room.

Biopolymer (see EPS)
A large biological molecule produced by living organisms. In this guide, the most important biopolymers are extracellular polysaccharides (EPS), which form the physical structure of biofilm.

Blackwater
Water systems dominated by organic compounds and tannins, with very low mineral content. Biology behaves differently here than in mineral-rich systems.

Capillary
The movement of water through very small spaces without the need for pumps or pressure. Capillary action explains how moisture moves through substrates, soils, and biofilms.

Chelators / Chelation
Compounds that bind nutrients (especially metals like iron) and keep them soluble. A nutrient can be present and chelated without being usable by everything in the system.

Chlorine
A disinfectant commonly added to tap water. Chlorine kills microbes indiscriminately, which is why untreated tap water is dangerous to biofilms and aquatic life.

Competitive Exclusion
The tendency for one organism or group to outcompete others when they occupy the same niche. In balanced systems, diversity limits competitive exclusion.

Cross-Feeding
A process where the waste or by-products of one organism become food for another. Cross-feeding is common in biofilms and is a major reason diverse microbial communities are more stable.

Cyanobacteria / Blue-Green "Algae"
Photosynthetic bacteria often mistaken for algae. Cyanobacteria form slimy sheets, can fix atmospheric nitrogen, and commonly appear when nutrient balance and oxygen dynamics are off. Despite the name, they are bacteria, not algae.

Cycled
A casual term used to describe a system that has developed sufficient biological capacity to process waste reliably. A system can be cycled without being mature or stable.

Cycling
The ongoing biological processes that convert, store, and move nutrients through different forms and organisms. Cycling is continuous, not a one-time event.

Dead Zone
An area with little to no effective flow. Dead zones often accumulate waste, develop low-oxygen conditions, and become hotspots for imbalance if left unmanaged.

Denitrifiers
Microbes that operate in low-oxygen areas and convert nitrate into nitrogen gas or ammonia. They help close nutrient loops

but are easy to misunderstand and mismanage.

Detritivores
Small animals like springtails, worms, and isopods that physically break down dead material so microbes can finish the job.

Detritus (see Mulm)
Dead and decaying organic material such as plant matter, waste, and microbial remains. In aquariums, detritus often becomes mulm once broken down.

Diatom
A type of microscopic algae with silica-based shells. Diatoms commonly appear in young or changing systems and are often a normal stage of development.

Emersed / Emergent
Refers to plants or growth forms where roots or lower structures are underwater, but leaves or stems grow above the waterline.

Enzyme
A biological catalyst produced by living organisms that speeds up chemical reactions. Enzymes allow microbes and fungi to break down complex materials into usable forms.

Extracellular polysaccharides / Exopolysaccharides (EPS)
Sticky substances produced by microbes that hold biofilm together. EPS acts like glue, scaffolding, and pantry all at once

— trapping nutrients, holding moisture, and giving other organisms somewhere to live.

Facultative Anaerobe
A microorganism that can switch between using oxygen and functioning without it, depending on conditions. Many microbes in aquariums and soils fall into this category, which is why biology adapts so quickly to change.

Fish-In Cycle
Cycling a system with fish present. This method relies on careful control to minimise stress and harm, and is actively discouraged in this guide.

Fishless Cycle
A method of establishing biological capacity in a system without fish present. This approach avoids animal stress and allows biology to develop safely.

Flow
The movement of water or air through a system, influencing oxygen delivery, nutrient distribution, and waste removal. Flow shapes biology more than most people realise.

Forum-Based Advice
Advice sourced from online forums and comment sections. Quality ranges from excellent to catastrophically bad. Treat with caution, verify claims, and apply context.
Exceptions exist. If the name Tom Barr keeps coming up, you are likely dealing with someone who actually understands the system they're talking about.

All other advice is best taken with a grain of salt — or, if you prefer, a wedge of lime and a shot of tequila.

Functional Redundancy
The presence of multiple organisms capable of performing similar roles. Functional redundancy increases resilience and helps systems recover from disturbance.

Greg: Tired
The author. Made the mistakes first so you don't have to. Results may vary.

Hair Algae
Filamentous algae that grow in strands or tufts. Often associated with excess light, unstable nutrient availability, or immature biofilms. Hair algae are more symptom than cause.

Hair-tearium
A tongue-in-cheek term for what happens when humidity, biology, and neglect conspire to grow things where you did not intend them to grow. Usually observed on glass, hardscape, tubing, or anywhere you swore you cleaned last week.

Heterotrophic Bacteria
Bacteria that obtain energy and carbon by consuming organic matter rather than light. These microbes drive decomposition, biofilm growth, and much of the nutrient cycling discussed in this guide.

Hobbyist (see You)
A broader label often applied to aquarists, terrarium keepers, and anyone else who willingly maintains tiny ecosystems for fun. Enthusiasm varies. Learning is optional but recommended.

Hydrophilic
Describes a surface or material that attracts and holds water. In this guide, hydrophilic conditions support moisture retention, gas exchange, nutrient movement, and active biology. Hydrophilic states are typical of healthy, functioning biofilms and substrates.

Hydrophobic
Describes a surface or material that repels water. Hydrophobic states restrict moisture movement, gas exchange, and nutrient flow, and often indicate imbalance, compaction, or degraded biofilm structure.

Hyphae / Fungal Hyphae
Thread-like filaments produced by fungi. Hyphae spread through soil, substrate, and organic matter, breaking down material and moving nutrients. Large fungal networks are made up of many hyphae woven together.

Hypoxic
Describes an environment with low oxygen, but not zero. Hypoxic zones are common inside biofilms, substrates, and filters, and are often where some of the most useful microbial processes occur.

Ionic Charge
The electrical charge carried by an atom or molecule. In simple terms, ionic charge affects how nutrients dissolve, move, and interact with biology in water.

Lean System
A system run with deliberately low nutrient availability. Lean systems rely heavily on efficient cycling, biofilm function, and biological balance rather than excess inputs.

Low-Oxygen Zone (see Hypoxic)
An area where oxygen is present but limited. Many microbes function best here, and low-oxygen zones are common inside biofilms, substrates, and filters.

Mature
Describes a system with established biofilms, functional redundancy, and predictable biological behaviour. Maturity develops with time and stability, not just completion of cycling.

Microbial Guild
A loose group of microbes defined by what they do, not what they're called. Guilds overlap, cooperate, and compete. One microbe can belong to multiple guilds depending on conditions.

Microorganism
A living organism too small to be seen clearly without magnification. This includes bacteria, fungi, protozoa, and micro-algae.

Micro-Predators
Microscopic organisms that feed on bacteria, algae, and fungi. They keep microbial populations in check and form a key food source for fry and small animals.
Mulm
Fine, dark organic debris made up of decomposed plant matter, waste, microbes, and biofilm fragments. Mulm is biologically active and often beneficial in moderation, particularly in substrates and filters.

Mutualism
A relationship where two organisms benefit from each other. Many plant–microbe relationships in this guide are mutualistic.

New Tank Syndrome
A collection of problems common in newly set up systems, caused by immature biofilms and unstable biology. Symptoms often resolve with time and proper management.

Nitrate
A more stable nitrogen compound produced from nitrite. Nitrate is less toxic and can be used by plants and microbes, but still accumulates if unmanaged.

Nitrite
An intermediate nitrogen compound produced during nitrification. Nitrite is toxic to fish and indicates incomplete or overwhelmed cycling.

Nitrogen Cycle
A simplified teaching model used to describe how nitrogen moves through systems. In reality, it is not a closed cycle, a loop, or a neat web, but a collection of overlapping processes, shortcuts, storage pathways, and losses. Useful as a concept, misleading when taken literally.

Nitrifiers
Microbes that convert ammonia into nitrite, then nitrate. Important, but only one small part of nutrient cycling.

No-Oxygen Zone (see Anoxic)
An area with effectively no free oxygen. Certain specialised microbes operate here. These zones are not inherently dangerous, but problems arise when they expand unchecked.

Nutrient Cyclers
Microbes that convert nutrients from one form into another. They don't make nutrients disappear — they change how usable they are.

Nutrient Sink
A place where nutrients accumulate and are temporarily stored rather than immediately used or removed. Biofilm, mulm, substrates, and plant tissue can all act as nutrient sinks.

Nutrient Speciation
The chemical form a nutrient exists in. Same nutrient, different behaviour. Presence does not guarantee usability.

Nutrient Transporters
Microbes that move nutrients toward plant roots instead of transforming them. Most effective in substrates, soils, and emersed root zones.

Old Tank Syndrome
A decline in system health caused by long-term accumulation, compaction, or neglected maintenance. Often misdiagnosed as sudden failure rather than slow imbalance.

Oxygen Gradient
The gradual change in oxygen availability from one area to another, such as from open water into biofilm, substrate, or filter media. Oxygen is rarely uniform, and many biological processes depend on these gradients.

Paludarium
A hybrid system that intentionally combines aquatic and terrestrial zones. Expect wet–dry gradients, emergent roots, fluctuating moisture, and overlapping microbial guilds. These systems live or die by balance.

Pathogen
An organism capable of causing disease. Whether a pathogen causes harm depends heavily on system balance, stress, and immune health.

Periphyton (See Aufwuchs)
The scientific term for Aufwuchs. Same thing, fancier word (more HECS debt).

Phosphates
Compounds containing phosphorus. Phosphates are essential nutrients for plants and microbes, but excess availability can favour algae growth.

Porous
Describes a material with many small spaces or gaps. Porous materials provide surface area for biofilm, allow water movement, and support biological activity.

Postbiotic
Non-living microbial by-products such as enzymes, organic acids, or metabolic compounds. Postbiotics can influence biology even when the microbes that produced them are no longer active.

Prebiotic
A substance that feeds existing microbes rather than adding new ones. In aquariums, prebiotics support biofilm growth and microbial activity instead of introducing specific species.

Probiotic
A product or organism intended to add living microbes to a system. In aquariums, probiotics often struggle to establish unless conditions already support them.

Quorum Sensing
A communication process used by microbes to detect how many of their kind are nearby. When enough microbes are present, quorum sensing can trigger changes in behaviour such as biofilm formation, enzyme production, or rapid growth.

Rate Limiting
The factor that controls how fast something can happen. Adding more of anything else doesn't help until the limiting factor changes.

Rhizosphere
The zone immediately around plant roots where microbes, nutrients, and roots interact most intensely.

Scaffold / Scaffolding Microbes
Microbes that build and maintain biofilm structure by producing EPS. Without them, other microbes, algae, and grazers have nowhere to live or feed.

Scum
Floating or surface-bound accumulations of organic matter, microbes, and biofilm. Common in low-flow or poorly mixed areas. Rarely dangerous on its own, but always a useful signal.

Siderophores
Iron-binding compounds produced by microbes. Extremely effective at grabbing iron — sometimes helping plants, sometimes starving competitors.

Silt
Very fine inorganic particles such as clay or mineral dust. Silt is not biologically active by itself, but quickly becomes useful once coated in biofilm.

Slime
A visible accumulation of biofilm, EPS, microbes, and trapped particles. Slime usually indicates active biology. Whether it is helpful or problematic depends on where it forms and how quickly it builds.

Slime Algae
A casual, hobby-level term for soft, sheet-like growths that peel, smear, or lift easily. This may include algae, biofilm, cyanobacteria, or a mix of all three. The term is descriptive, not scientific.

Sloughing / Biofilm Sloughing
The natural process where sections of biofilm detach and shed from surfaces. Sloughing is normal and expected in healthy systems, especially when biofilm becomes thick or conditions change. It often looks like a sudden mess, but usually signals renewal, not failure.

Stability
Not “numbers that don’t move,” but a system’s ability to absorb change, recover from disturbance, and keep functioning over time.

Submersed / Submerged
Refers to plants, organisms, or structures that remain fully underwater.

Substrate
The material at the bottom of a system, such as soil, sand, gravel, or layered media. Substrates provide surface area, habitat, and nutrient storage for biological processes.

Sulphur & Iron Reducers
Microbes that operate in oxygen-poor zones and cycle sulphur and iron compounds. Helpful in balance, unpleasant when allowed to run wild.

Synbiotic
A combination of probiotics and prebiotics. These aim to introduce microbes while also supplying food to help them survive, with mixed results in closed systems.

TDS (Total Dissolved Solids)
A measure of all dissolved substances in water. TDS reflects overall mineral and organic load rather than specific nutrients.

Terrarium
A predominantly terrestrial enclosure with soil, leaf litter, and air as the primary medium. Moisture is present, but not continuous or submerged. Biology here relies heavily on fungi, detritivores, and soil biofilms rather than water-column processes.

The Inch-Per-Gallon (2.54 cm to 3.78541 L) Rule (see: Total Joke)
A long-standing rule of thumb suggesting fish stocking can be calculated by body length alone. This rule ignores behaviour, body mass, waste production, oxygen demand, surface area, and reality. Widely repeated, rarely useful.

Total Joke
Ideas, rules, or advice best treated with as much disdain as gum on the bottom of your shoe. Commonly repeated, rarely examined, and almost always context-free.

Vivarium
A broad catch-all term for an enclosure designed to keep living organisms. In practice, it usually refers to mixed or animal-focused systems that may include land, water, and air, without committing to a specific balance.

You: (See Awesome)
Yes, you. You're reading the appendix. That already puts you ahead of most people.

Appendix B: Recommended Reading

This list exists for readers who want to go deeper, wider, or sideways without falling straight into academic paywalls or forum arguments.

Ecology of the Planted Aquarium – Dr Diana Walstad
A foundational text that explains the fundamentals of nutrient cycling and plant–microbe interactions in aquariums. Walstad covers several topics I skimmed or skipped, largely because they didn't apply to what I wanted to teach here. Still absolutely worth reading, and written in relatively plain English compared to most academic material. I built much of my thinking from the bones of Walstad's work, so in that sense The Layman's Guide can be read as a spiritual successor rather than a replacement.

The Journeyman's Guide to Microbial Whatsits
Yes, the sequel. It's coming, and it goes harder. Expect heavier science, deeper mechanisms, and fewer safety rails. Not for the faint of heart, but very much for those who finished this book and thought, "Okay, but how does that actually work?"

AMAZONAS Magazine
A high-quality publication written for hobbyists and breeders by hobbyists and breeders. Article quality is consistently high and manages to satisfy both the scientist and the couch-potato in me. Particularly strong on South American species, with up-to-date knowledge and excellent photography.

Practical Fishkeeping (UK)
A more hobbyist-focused magazine based out of the UK. Articles are written simply and accessibly, making it ideal for readers who want practical advice and light science without diving too deep into theory.