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THE SHOOT

I'm sitting in my office with seven books on the desk in front of me. All have identical, old-fashioned binding. Their leather spines are adorned with gilt borders and lettering, and their cardboard covers are decorated with an indeterminate pattern in brown and blue. They are slightly darker along the edges, marked by the many hands that have held them, leafed through them. They may look a bit boring, these books, compared with the bright and colourful academic texts that fill the rest of the shelves.

But you shouldn't judge a book by its cover. These worn volumes contain a time capsule; a glimpse of the natural world as people saw it more than two hundred years ago, of a perception of nature very different from that of our own age. The volumes on my desk are one of Scandinavia's foremost botanical works, a flora called *Swedish Botany*, published in 1803. Filled with many hundreds of coloured copperplates and accompanying descriptions, the flora's ambition was to illustrate and describe every plant native to Sweden. After the union between Sweden and Norway in 1814, Norwegian plants were also included: "to give this work a certain value for our new fellow-citizens as well," as the foreword to a later edition benevolently puts it.

The illustrations are incredibly beautiful, but the descriptions are at least as fascinating – because they focus just as much on the plants' applications as their appearance. It's like an insight into the challenges of the age: the need to relieve disease and ailments, and to secure enough food for yourself and your livestock in times of hardship. Mezereum is good for rubbing on your face if you are gaunt and pale, coltsfoot can be smoked like tobacco as a cure for a cough, bog myrtle sets bedbugs and fleas to flight, and famine bread can be made out of pretty much anything. In the index, you'll find "rabid dog, bitten by" alongside "*Ranunculus*" (buttercup and its relatives) and "Reindeer moss".

There's something else about this flora, though. It's an heirloom, a family treasure. And now, in a way, it has come home. Because roughly 160 years ago, in another building in the university district, other hands leafed through these pages. The hands of my great-great-grandfather, Fredrik August Dahl. Or "Old Man Dahl," as he was known to his friends – for despite his fierce-looking moustache, my great-great-grandfather is said to have been an amiable if peremptory man, with a warm personality.

My Swedish forebear was summoned to Ås when the Norwegian parliament approved the establishment of an institute of higher education in agriculture in 1854. Four years later, he was appointed the first-ever director of the Higher Agricultural College in Aas, now known as The Norwegian University of Life Sciences, NMBU – which is my own workplace today.

Some years after that, my great-great-grandfather was given this flora by his older brother, who penned a neat oak gall ink message on the flyleaf of the first volume: "This work, which was considered by our siblings to be mine, is hereby dedicated as a token of gratitude to my youngest brother, Fredrik August Dahl, Director of the Higher Agricultural College in Ås."

Overleaf, I find more dedications. The volumes have been passed down through the family from hand to hand over five generations: from the director to his son, then to his grandchild, his great-grandchild

and his great-great-grandchild. Oak gall ink and fountain pens have given way to a modern blue ballpoint pen by the final line, in which the great-great-grandchild, Marianne, sends the book sideways in the family tree to her second cousin. Me.

After leafing past the dedications, I come to the very first entry in the flora: twinflower (*Linnea borealis*). It was chosen to open this multi-volume work in homage to the great Swedish botanist and taxonomist, Carl Linnaeus, after whom the subshrub was named, because he loved this delicate evergreen plant, with its paired, pinkish-white flowers, bell-shaped and almond-scented.

Twinflower spreads across the forest floor via a creeping stalk. At regular intervals, a shoot sprouts into the air and flowers. When its day is done, the flowering shoot withers, but the creeping stem stretches onward, forward in time. Like the passage of generations.

The illustration of the twinflower in the flora depicts five such annual shoots. Like the five generations between my great-great-grandfather and me.

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This is a book about the habitat of the twinflower, the forest. About transformation and admiration and awe. About time.

I have spent thirty years working with forests and the fascinating life they contain. That's a long time measured in human terms, but brief compared to the lifetime of an oak. My great-great-grandfather's flora set my thoughts in a whirl: what has changed between his age and mine, I thought, and what is still the same? Both out there beneath the tree canopies and in our perceptions of nature?

Every age has its notions of how we humans should best use the forest. Coexist with the forest. And every age is convinced of its own rightness, convinced that its particular perspective is the only correct one.

Then new knowledge comes. New ideas break through, commitment builds, and attitudes are changed. Often in the face of considerable resistance from those who benefit from maintaining the status quo.

I so want more people to get to know the forest, in all its leaf- and needle-green breadth; with all its small, slimy, shell-covered, sprouting, multi-legged, marvellous organisms; as a landscape framing much of humanity's culture and economy, myths and ideas. For forests are magical, myriad and useful, and run like a deep-green warp thread through the entire tapestry of our history.

This, then, is a book about the rich species diversity of the forest, about trees and people. A book about surprising interactions and peculiar species, about how knowledge and perceptions of nature have changed from generation to generation. About where we come from and where we stand today.

Great-great-grandfather's flora serves as a framework for this book. Each chapter is named after one of the species in *Swedish Botany* and contains the corresponding illustration, although the topics covered in the chapters go well beyond the species themselves.

You will read about timber for sailing ships and bark bread and beavers that bite off their balls (or so people thought); about August Cappelen's primeval forest and Yggdrasil and fungi that can (maybe) talk; about felling and self-mummification and rare species and eco-grief; about forest fires and amber and tar-burning and Asterix and hair ice and a subterranean forest beneath Norway's National Theatre. About why I love old dead pine trees. And much, much more.

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The story extends over time and space: from the little life of an insect beneath a scrap of bark, over in a matter of weeks or months, to the vast forest landscapes where trees live out their slow existence. For the sprouting of the seed and the moment when the log lies prostrate beneath the moss are separated by hundreds of years, possibly dozens of human lifespans.

The forest is home to a host of tiny anonymous species that rarely get their day in the sun. Here, in my narrative, I make room for them: mycorrhizal threads that silently weave their way through the soil, braiding themselves into the fractals of the tree roots; the rapid wingbeats of insects among the greenery; creatures concealed within the wood; lives that end after a single summer.

The forest does something to you. The great soughing in the canopies speaks to you; it has sung through the forests for millions of years, ever since the Carboniferous period. Because forests are ripe with time. Trees are heirlooms from an age gone by, an age you have never experienced.

Forests are also sensations: the shift between light and dark, shades of brown and green. Soft moss beneath your shoes, the rough bark of the pine. Seeds that dance in spirals from the treetops. Forests are strong trunks and the deep-green stamina conferred by conifers, the scent of birch leaves, life force, new buds that herald yet another spring.

In Norway, we have extracted resources from the forest for millennia, and forestry is still an important industry. An industry that has a tremendous impact on the ecosystem and the species that inhabit it, as well as the other ecosystem services of the forest. The ecological conditions in Norwegian forests are considerably poorer than they are in intact, primeval forests. We are in the process of converting much of our forestland from a well-functioning ecosystem to a landscape devoted to timber production.

But forests are so much more than timber. What I want this book to do is contribute to a broader narrative about forests. A narrative in which forestry is just one aspect among many. Because forests must also be preserved as a home for species diversity and threatened species, as a carbon store, and as a source of fascination, inspiration and rich encounters with nature.

The more pressure we place on forestland, the more important it becomes to ensure that many people – preferably all people – are knowledgeable about the state of the forest and the choices we are making there. Only thus can we engage in a broad and democratic debate about how we are to coexist with the forest in our own age.

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Aspen – On conflict and interactions in the forest

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WHEN THE MEAL BECOMES A MURDERER

The oyster mushroom is not alone. There are several hundred species of fungi that wouldn't say no to the fungus kingdom's equivalent of a "rare steak," in the form of a roundworm, a springtail, a water bear or a little bacteria colony. The trapping methods vary; some fungi, for example, produce snares that tighten around any unwitting bug that happens to creep through the noose, or offshoots covered in sticky "bug-glue," not to mention fungi that produce tiny spiked balls with a remarkable resemblance to the morning star – the weapon not the celestial body. There is, incidentally, a fun scientific article that compares "fungal weapons" with other such mediaeval weapons.

Carnivorous fungi challenge our understanding of the interactions in the forest. What happens, for example, when mycorrhizal fungi, which use nitrogen as a medium of exchange to obtain sugar from tree roots, become meat-hungry and send the nitrogen onward into the trees themselves?

Several years ago, two biologists in Canada set up a colony of springtails in their lab to study them. Springtails are small, sweet, wingless creatures that are closely related to insects. The food given to the springtails included the fresh living parts of bicoloured deceiver mushroom, a cap fungus that grows in woods.

When they returned to the lab, the biologists were surprised to find that, rather than the springtails eating the fungus, the opposite had happened: the fungus had actually devoured the springtails! It's as if you'd served pizza to the children, gone out for a bit and come back to find that the pizza had eaten up the kids….

What's more, the springtails that had been fed fungus other than the bicoloured deceiver were well-fed and in the best of health.

The biologists' curiosity was piqued. They planted small pine shoots with a mycorrhizal mantle of bicoloured deceiver on their roots in flowerpots (using Weymouth pine, a North American tree species that is also planted in some places in Europe). Then they placed living springtails in the soil in the flowerpots. They made sure that the "meat" only came into contact with the mycorrhizal threads and not the pine roots. Prior to this, they had labelled the nitrogen in the springtails, so that they could follow it through the food chain.

In this way, the scientists were able to track the nitrogen from the meat. Not just into the fungus – when, as expected, the springtails were eaten once again – but also further up into the trees! It turned out that up to a quarter of the trees' nitrogen stemmed from living springtails that the bicoloured deceiver mushroom had dispatched and digested.

In other words, the pine tree can – indirectly – kill and eat little critters that live around its roots aided by its fungal partners. Carnivorous pine trees – how crazy is that? It's hard to disagree with Merlin Sheldrake, the biologist and author of *Entangled Life* when he says, "the more we learn about fungi, the less makes sense without them."

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Other times, bugs get the better of the fungi: not only do many insects live off fungi – one obvious example being the larvae we find in the mushrooms we pick; some actively cultivate fungus as food. Numerous insects that live in fresh, nutrient-poor dead wood bring "grain" along with them – more accurately fungal spores that they can cultivate when they fly to a new tree.

In 1836, a monk called Josef Schmidberger diligently studied his apple trees and discovered a white coating in the tunnel systems of the bark beetles. He saw that the beetles were eating this white substance and thought it must be a structure that the tree produced to provide nourishment for the beetles. The monk called this white substance "ambrosia" – after the divine food of the Greek gods.

Later, though, scientists discovered that this white coating was a fungus that the beetles themselves brought with them in special pouches on their bodies, but the name lingered. To this day, biologists refer to "ambrosia fungus" and "ambrosia beetles." There are several species in both groups.

The wood-boring beetle mother carries the ambrosia fungus in a special storage space in her own body. When she reaches a tree where she wants to set up a nursery, she gnaws her way into the wood, cutting across the growth rings, and lays her eggs inside there. At the same time, she plants fungus in the nurseries that she chews out inside the wood, and this fungus grows along the tunnels, causing a dark discolouration. The wood-borer beetle mum and dad both stick around to tend the kitchen garden and the kids, there among the growth rings.

From a forester's point of view, this ambrosia interaction is far from divine. The quality of the timber is diminished by both the perforations and discolouration of the wood. That's why it's important to transport freshly felled material out of the forest before the beetles swarm in spring and, ideally, to wet-store it at the sawmill to prevent the beetles from moving in.

But for fungus and beetles, this is a useful collaboration, which benefits both. Because fungus is much better than insects at extracting nutrients from the wood, it is easier for the beetle babies to gain access to nitrogen by eating the fungus. At the same time, the fungus benefits from being transported to new accommodation.

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Ash – On the cultural understorey

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REVERENCE AND ECO-GRIEF

If it's difficult to describe the powerful emotions I often feel in the forest, it's even more challenging to talk about how the *loss* of the forest affects me. I'm talking about the despair I sometimes feel over how hard it is to effect change, and to get other people, politicians, to understand the scientific arguments. But there's also the personal grief I feel when I see a forest near me changing; when a sylvan space filled with nurse

logs and matted moss that once murmured of a species-rich interior suddenly becomes an exposed vacuum in the terrain, where all that remains is the silent, scarred speech of the stumps.

Ecological grief or eco-grief is a neologism, as is its synonym, solastalgia, formed of *solacium*, meaning comfort, and *algia*, meaning pain. Both describe the sorrow we can feel in the face of the climate and environmental crises. Some describe this grief as feeling homesick even though you are still at home – a grief and longing that springs from the fact that your home or *okios* (the Greek word that is the root of the word ecology) is so changed.

For when forests vanish, are developed or degraded, you don't just lose a place, but something more: a link that ran back through cultural time. Forests do something to you and this "something" is lost with the disappearance of the forest. Eco-grief is the yearning for a forest that is no longer a place, but only a memory. Like the imprint left on a bed where a loved one previously lay.

Once upon a time, nature's rhythm dictated our days, but it is a long time since humans have lived as hunter gatherers, following the forest's clock and calendar. With the agricultural revolution and the industrial revolution that came after it, we gradually distanced ourselves from the forest, from nature. Even agriculture is partly detached from natural conditions these days through artificial irrigation, fertilisation, the use of heated greenhouses. Today, more than half of the world's population lives in urban areas. We buy our blueberries at the supermarket, our timber at building supply outlets and our firewood at petrol stations.

Gradually we have become alienated from nature. A new lifestyle, as urban consumers, imposed new demands on us to be "streetwise". And when our contact with nature vanished, we also lost knowledge, the intimate understanding, the words we need to speak about the details and interconnections in the forest.

With the arrival of modernity and science, we gradually lost our reverence for nature. A reverence composed of both respect and fear.

This duality made perfect sense two or three centuries back. We needed the forest – for boats and buildings, firewood and pastureland, food and more or less effective medicines – but nature was still unruly and far beyond our control.

In my flora, which was begun in the early 19th century, this kind of reverence for a sacred Creation still shines through in the more scientific explanations. Like when the author, describing porcini, expresses frustration over the incomprehensible place fungi occupy in the scientific order, exclaiming: "… how the Originator of the natural world has set the seal of his wisdom and power upon every point, every part and every whole of the objects that surround us;… if we search everywhere for the more or less visible traces of the all-knowing Originator, our investigations are constantly interrupted by reverence, rapture and wonder."

But there is little room for wonder and admiration in a forest where the felling machine works around the clock. No wood nymph could live in a clear cut. In a society driven by intellect and rationality, nature is no longer mythical but mechanical.

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AMBER AND THE DREAM OF A DINOSAUR

From a transparent golden lump the size of a small grape, two large compound eyes gaze out at the world. The insect in whose head these eyes are set is instantly recognisable as a horsefly, one of those bugs that will happily take a chunk out of you on a hot summer's day beside a forest tarn. But this particular pair of eyes has beheld landscapes and a species diversity we can only dream of, for its little life played out between 25 and 40 million years ago, on a planet of lush forests awash with mammals whose blood it could suck. Until its life came to an abrupt end in resinous gum, which turned into amber over the millennia that followed.

Amber is a time capsule, a three-dimensional glimpse into ecosystems of time gone by. Trapped inside fossilised resin, tiny details of the past may be preserved: a little wasp, caught in the process of being devoured by a young spider 100 million years ago, is frozen in time and space, like a never-ending nightmare – even the silk of the spider's web is still clearly visible. But we also find documentation of primordial motherly care in a lump of amber that contains a scale insect mother carrying her eggs and newly hatched nymphs in a sac on her abdomen. This, too, is a slice of life from an ordinary day almost 100 million years ago. And because the insects are small enough to fit into a lump of amber, and their exoskeletons robust enough to be preserved intact, it all looks so very lifelike.

The premise of Jurassic Park (1983) also rests on a tiny insect trapped in amber. For anyone who has suppressed all memory of this hyperactive fantasy film, it all starts when a scientist finds a mosquito preserved in amber. Encapsulated within its belly is a drop of dinosaur blood, and the genetic material in the dinosaur blood is used to bring the monsters of the past back to life in all their terrifying beauty.

Sadly, although the film did much to introduce the then relatively unknown concept of gene technology to the general public, the underlying premise doesn't hold water. DNA decomposes over time and it has been far too long since Tyrannosaurus & co. were stomping around on Earth. Even in amber samples from a mere 10,000 years ago, scientists have been unable to find any genetic material from the trapped insects. Unfortunately, then, or perhaps fortunately – depending on who you ask – we must abandon the dream of a dinosaur theme park.

Amber has been known and prized for a long time. As far back as the days of the Egyptian pharaohs, people were transporting amber from as far afield as the Baltic Sea. There was much, often creative, speculation about the origin of these golden lumps – ranging from petrified lynx urine via desiccated sunlight to birds' tears.

We also find this tear motif in Greek mythology, in a story of youthful arrogance reminiscent of the tale of winged Icarus: a young boy called Phaethon was very full of himself and loved to boast that he was the son of Helios, the sun god. When his friends cast doubt on the story, he went straight back home to his father and demanded proof of paternity. Helios promised that he would grant his offspring any wish that his heart might desire, but regretted it immediately when Phaethon demanded to drive the chariot that drew the sun across the sky for a day. But a promise is a promise, so Phaethon took the reins of the chariot of the sun – and things turned out just as badly as you might expect: The horses bolted and charged away (to this day, you can see the trail they left as they careered through the heavens: the band

of the Milky Way across the night sky...) and when the brat tried to correct his course, he came so close to the earth that forests and cities caught fire. Zeus, the mightiest of the gods, had to step in. He cast a thunderbolt that sent the chariot of the sun crashing into the River Po, where Phaethon also ended his days. His sisters stood on the riverbank weeping until the gods (in what strikes me as a very odd kind of consolation) took pity on them and transformed them into poplars – and their tears into… you guessed it: amber.

Of course amber isn't trees' tears. If you want to compare it to anything at all, it would make more sense to call it trees' blood. You need go no further than your nearest coniferous forest to grasp the principle: when a conifer is damaged – a branch is snapped, say, or an insect gnaws through its bark – yellow resin trickles out and over the site of the injury, and after it comes into contact with the air, it hardens into a resinous gum.

Resin is part of the tree's immune system: both its consistency and the chemical substances it contains prevent fungal spores or insects from taking up residence and damaging the tree. Many conifers (and other plants) produce resinous gum. It often has a powerful scent owing to all the aromatic substances, which evaporate easily; this is why there are different types of resin in incense and myrrh.

But the transformation into amber doesn't happen overnight, and only a tiny fraction of the resin of the past has ever ended up as amber. Very special conditions are required for that to happen: the resin must end up in an airless place – in practice, in sediments on the ocean bed. It must lie there slumbering for many millions of years, under high pressure and at high temperatures. Most of the amber we know of is between 30 and 90 million years old and originated in the Baltic, although the very oldest piece was formed more than 300 million years ago.

It's hardly surprising that gazing into the eyes of a horsefly trapped in amber can set your thoughts in a whirl. Minutes and hours of a human life, indeed the entirety of a modern human existence, are an insignificant trifle in the context of deep time. Perhaps we are in need of such reminders of how irrelevant our reckoning of time is when measured against the complete chronology of living life.

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