MERLIN SHELDRAKE

Entangled Life

How Fungi Make Our Worlds, Change Our Minds, and Shape Our Futures

VINTAGE

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A Lure

Who's pimping who?

Prince

A heap of Piedmont white truffles, *Tuber magnatum*, sat on the scales on a check-patterned rag. They were scruffy, like unwashed stones; irregular, like potatoes; socketed, like skulls. Two kilograms: €12,000. Their sweet funk filled the room, and in this aroma was their value. It was unabashed and quite unlike anything else: a lure, thick and confusing enough to get lost in.

It was early November, the height of truffle season, and I had travelled to Italy to join two truffle hunters working out of the hills around Bologna. I was lucky. A friend of a friend knew a man who dealt truffles. The dealer had agreed to set me up with his two best hunters, who in turn had consented to let me go out with them. White-truffle hunters are famously secretive. These fungi have never been domesticated and can only be found in the wild.

Truffles are the underground fruiting bodies of several types of mycorrhizal fungi. For most of the year, truffle fungi exist as mycelial networks, sustained in part by the nutrients they obtain from the soil and also by the sugars they draw from plant roots. However, their subterranean habitat confronts them with a basic problem. Truffles are spore-producing organs,

analogous to the seed-producing fruit of a plant. Spores evolved to allow fungi to disperse themselves, but underground their spores can't be caught by air currents, and are invisible to the eyes of animals.[1]

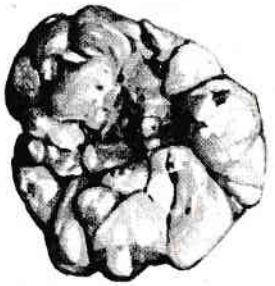
Their solution is to smell. But to smell above the olfactory racket of a forest is no small task. Forests are criss-crossed with smells, each a potential fascination or distraction to an animal nose. Truffles must be pungent enough for their scent to penetrate the layers of soil and enter the air, distinctive enough for an animal to take note amid the ambient smellscape, and delicious enough for that animal to seek it out, dig it up and eat it. Every visual disadvantage that truffles face – being entombed in the soil, difficult to spot once unearthed, and visually unappealing once spotted – they make up for with smell.

Once eaten, a truffle's job is done: an animal has been lured into exploring the soil and recruited to carry the fungus's spores off to a new place and deposit them in its faeces. A truffle's allure is thus the outcome of hundreds of thousands of years of evolutionary entanglement with animal tastes. Natural selection will favour truffle fungi that match the preferences of their finest spore dispersers. Truffles with better 'chemistry' will attract animals more successfully than those with worse. Like the orchids that mimic the appearance of sexually receptive female bees, truffles provide a depiction of animal tastes – an evolutionary portrait-in-scent of animal fascination.

I was in Italy because I wanted to be drawn underground by a fungus into the chemical world in which it lived. We are ill-equipped to participate in the chemical lives of fungi, but ripe truffles speak a language so piercing and simple that even we can understand it. In doing so, these fungi include us for a moment within their chemical ecology. How should we think about the torrents of interaction that occur between organisms underground? How should we understand these spheres of more-than-human communication? Perhaps running after a dog hot on the trail of a truffle and burying my face in the soil was as close as I could get to the chemical tug and promise that fungi use to conduct so many aspects of their lives.

The human sense of smell is extraordinary. Our eyes can distinguish several million colours, our ears can distinguish half a million tones, but our noses can distinguish well over a trillion different odours. Humans can detect virtually all volatile chemicals ever tested. We outperform rodents and dogs in detecting certain odours, and we can follow scent trails. Smells feature in our choice of sexual partners and in our ability to detect fear, anxiety or aggression in others. And smell is woven into the fabric of our memories; it is common for people suffering from post-traumatic stress disorder to have olfactory flashbacks.[2]

Noses are finely tuned instruments. Your olfactory sense can split complex mixtures into their constituent chemicals, just as a prism can split white light into its constituent colours. To do this, it must detect the precise arrangement of atoms within a molecule. Mustard smells mustardy because of bonds between



Piedmont white truffle, *Tuber magnatum*

nitrogen, carbon and sulphur. Fish smell fishy because of bonds between nitrogen and hydrogen. Bonds between carbon and nitrogen smell metallic and oily.[3]

The ability to detect and respond to chemicals is a primordial sensory ability. Most organisms use their chemical senses to explore and make sense of their environment. Plants, fungi and animals all use similar types of receptors to detect chemicals. When molecules bind to these receptors, they trigger a signalling cascade: one molecule triggers a cellular change, which triggers a bigger change, and so on. In this way, small causes can ripple into large effects: human noses can detect some compounds at as low a concentration as 34,000 molecules in one cubic centimetre, the equivalent of a single drop of water in 20,000 Olympic swimming pools.[4]

For an animal to experience a smell, a molecule must land on their olfactory epithelium. In humans, this is a membrane up and behind the nose. The molecule binds to a receptor, and nerves fire. The brain gets involved as chemicals are identified, or trigger thoughts and emotional responses. Fungi are equipped with different kinds of bodies. They don't have noses or brains. Instead, their entire surface behaves like an olfactory epithelium. A mycelial network is one large chemically sensitive membrane: a molecule can bind to a receptor anywhere on its surface and trigger a signalling cascade that alters fungal behaviour.

Fungi live their lives bathed in a rich field of chemical information. Truffle fungi use chemicals to communicate to animals their readiness to be eaten; they also use chemicals to communicate with plants, animals, other fungi – and themselves. It isn't possible to understand fungi without exploring these sensory worlds, but they are hard for us to interpret. Perhaps it doesn't matter. Like fungi, we spend much of our lives being drawn towards things. We know what it is to be attracted or repelled. Through smell, we can participate in the molecular discourse fungi use to organise much of their existence.

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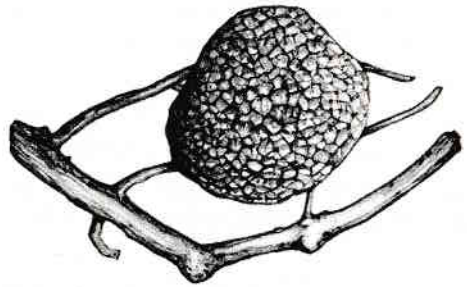
In human history, truffles have long been associated with sex. The word for truffle in many languages translates to 'testicle', as in the old Castilian *turmas de tierra*, or Earth's testicles. Truffle fungi have evolved to make animals giddy because their lives depend on it. As I spoke with Charles Lefevre, a truffle scientist and cultivator in Oregon, about his work with the Périgord black truffle, he broke off: 'Funny – as I'm saying this I am "bathing" in the virtual aroma of *Tuber melanosporum*. It's as if a cloud of it is filling my office, but there are currently no truffles here. These olfactory flashbacks are common with truffles in my experience. They can even include visual and emotional memories.'[5]

In France, Saint Anthony – the patron saint of lost objects – is regarded as the patron saint of truffles, and truffle masses are celebrated in his honour. Prayers do little to stop the skulduggery. Cheap truffles are stained or flavoured to pass them off as their more valuable cousins. Prized truffle forests are targeted by truffle poachers. Expertly trained dogs worth thousands of euros are stolen. Poisoned meat is strewn around woods to kill the dogs of rival hunters. In 2010, in a crime of passion, a French truffle farmer, Laurent Rambaud, shot dead a truffle thief he encountered while patrolling his truffle



Périgord black truffle, *Tuber melanosporum*

orchards during the night. Following his arrest, 250 supporters marched in support of Rambaud's right to defend his crop, angry at the rise in thefts of both truffles and truffle dogs. The deputy head of the Tricastin truffle growers' union told *La Provence* newspaper that he had advised fellow producers never to patrol their fields with a gun because 'the temptation is too high'. Lefevre put it well. 'Truffles bring out the dark side of people. It's like money lying on the ground, but it's perishable and mercurial.'[6]

Truffles are not the only fungi to attract animal attention. On the west coast of North America, bears upend logs and dig out ditches looking for the prized matsutake mushroom. Oregon mushroom hunters have reported elk with noses bloodied in their hunt for matsutake in sharp pumice soils. Some species of tropical rainforest orchid have evolved to mimic the smell, shape and colour of mushrooms to attract mushroom-loving flies. Mushrooms and other fruit bodies are fungi at their most conspicuous, but mycelium, too, can be a lure. A friend of mine who studies tropical insects showed me a video of orchid bees crowding around a crater in a rotting log. Male orchid bees collect scents from the world and amass them into a cocktail which they use to court females. They are perfume makers. Mating takes seconds, but gathering and blending their scents takes their entire adult lives. Although he hadn't yet tested the hypothesis, my friend had a strong hunch that the bees were harvesting fungal compounds to add to their bouquets. Orchid bees are known to have a taste for complex aromatic chemicals, many of which are produced by fungi that break down wood.[7]

Humans wear perfumes produced by other organisms and it is not uncommon for fungal aromas to be incorporated into our own sexual rituals. Agarwood, or *oudh*, is a fungal infection of *Aquilaria* trees found in India and south-east Asia and one of the most valuable raw materials in the world. It is used to make a scent – dank nuts, dark honey, rich wood – and has been coveted at least since the time of the ancient Greek physician Dioscorides. The best *oudh* is worth more, gram for gram, than gold or platinum – as much as $100,000 per kilogram – and the destructive harvest of *Aquilaria* trees has driven them to near extinction in the wild.[8]

The eighteenth-century French physician Théophile de Bordeu asserted that each organism 'does not fail to spread exhalations, an odour, emanations around itself … These emanations have taken on its style and its demeanour; they are, in fact, genuine parts of itself.' A truffle's fragrance and an orchid bee's perfume may circulate beyond the flesh of each organism, but these fields of odour make up a part of their chemical bodies which overlap with one another like ghosts at a disco.[9]

I spent several minutes in the truffle weighing room, lost in the aroma. My reverie was interrupted when my host Tony, the truffle dealer, bustled in with one of his clients. He closed the door behind him, sealing in the smell. The client inspected the heap of truffles on the scales and cast an eye over the bowls of unsorted and uncleaned specimens ranged across a grubby work bench. He nodded to Tony, who tied up the corners of the rag. They walked out into the yard, shook hands, and the client drove off in a smart black car.

It had been a dry summer, which had resulted in a poor truffle harvest. Their price reflected their scarcity. Bought directly from Tony, a kilogram would set you back €2,000. The same kilogram purchased at a market or restaurant would cost as much as €6,000. In 2007, a single 1.5-kilogram truffle was sold at auction for £165,000 – like diamonds, the price of truffles increases non-linearly with their size.[10]

Tony had a warm manner and a dealer's bravado. He seemed surprised that I would want to join his hunters, and didn't get my hopes up about our chances of finding any truffles. 'You can go out with my guys, but you probably won't find anything. And it's hard work. Up and down. Through bushes. Through mud. Through streams. Are those the only shoes you have?' I assured him I didn't mind.

Truffle hunters have their turf, sometimes legal, sometimes not. When I arrived, both truffle hunters – Daniele and Paride – were wearing camouflage. I asked whether it helped them to sneak up on the truffles, and they responded in earnest. It allowed them to hunt for truffles without being followed by other truffle hunters. Truffle hunters are in the business of knowing where to look. Their knowledge has value and, like truffles themselves, can be stolen.

Paride was the friendlier of the two, and met me outside with Kika, his favourite truffle dog. He had five dogs, of various ages and states of training, each a specialist in either black or white truffles. Kika was charming, and Paride introduced her proudly. 'My dog is very clever, but I am more clever.' Kika's breed – the Lagotto Romagnolo – is one of the most commonly used for truffle-hunting. She was knee-height and, with hair that fell over her eyes in shaggy ringlets, she resembled a truffle. Indeed, after a morning smelling truffles, meeting a litter of truffle dog puppies, talking truffles, witnessing truffle deals, and eating truffles, even the rounded rocky hills had started to look like truffles. Paride spoke about the subtle cues he and Kika used to communicate with each other. They had learned to read and interpret the tiniest shifts in the other's behaviour and could co-ordinate their movements in near total silence. Truffles had evolved to communicate to animals their readiness to be eaten. Humans and dogs had developed ways to communicate with one another about truffles' chemical propositions.

A truffle's aroma is a complex trait, and seems to emerge out of the relationships the truffle maintains with its community of microbes, and the soil and climate it lives within – its *terroir*. Truffle fruiting bodies house thriving communities of bacteria and yeasts – between a million and a billion bacteria per gram of dry weight. Many members of truffles' microbiomes are able to produce the distinctive volatile compounds that contribute to truffles' aromas, and it is likely that the cocktail

of chemicals that reaches your nose is the work of more than a single organism.[11]

The chemical basis of truffles' allure remains uncertain. In 1981, a study published by German researchers found that both Piedmont white truffles (*Tuber magnatum*) and Périgord black truffles (*Tuber melanosporum*) produced androstenol – a steroid with a musky scent – in non-negligible quantities. In pigs, androstenol functions as a sex hormone. It is produced by males and prompts the mating posture in sows. This finding triggered speculation that androstenol might explain the impressive abilities of sows to find truffles buried deep underground. A study published nine years later cast doubt on this possibility. Researchers buried black truffles, a synthetic truffle flavouring and androstenol five centimetres underground, and challenged a pig and five dogs – including the champion of the local county truffle dog contest – to find the samples. All the animals detected the real truffles and the synthetic truffle flavouring. None detected the androstenol.[12]

In a series of further tests, the researchers narrowed truffles' allure down to a single molecule, dimethyl sulphide. It was a neat study, but unlikely to be the whole truth. The smell of a truffle is made up of a flock of different molecules drifting in formation – more than a hundred in white truffles, and around fifty in the other most popular species. These elaborate bouquets are energetically costly and are unlikely to have evolved unless they served some purpose. What's more, animal tastes are diverse. Certainly, not all truffle species are attractive to humans and some are even mildly poisonous. Of the thousand-odd species of truffle in North America, only a handful are of culinary interest. Even these aren't of interest to everyone. As Lefevre explained, a large number of people are offended by the aroma of the otherwise prized species. Some species smell outright repulsive. He told me about *Gautieria*, a genus that produces truffles with a foulsome stench – like 'sewer gas' or 'baby diarrhoea'. His dogs love them,

but his wife won't let him bring any into the house, even for taxonomic purposes.[13]

However they do it, truffles create nested layers of attraction around themselves: humans train dogs to find truffles because pigs are so attracted to them that they devour the truffles they find rather than turn them over to their minders. Restaurateurs from New York and Tokyo travel to Italy to build relationships with truffle dealers. Exporters have developed sophisticated chilled packing systems to maintain truffles at optimal conditions as they are washed, packed, hand-delivered to the airport, flown around the world, collected from the airport, carried through customs, repacked and distributed to consumers – all within forty-eight hours. Truffles, like matsutake mushrooms, must arrive fresh on a plate within two to three days of harvest. Truffles' aromas are made in an active process by living, metabolising cells. A truffle's odour increases as its spores develop, and its aroma ceases when its cells die. You can't dry a truffle and expect to taste it later, as you can with some types of mushroom. They are chemically loquacious, vociferous even. Stop the metabolism, and you stop the smell. For this reason, in many restaurants, fresh truffles are grated onto your food before your eyes. Few other organisms are so good at persuading humans to disperse them with such urgency.[14]

Truffle spore

We piled into Paride's car and drove up a valley on a narrow country road, through the damp yellows and browns of the oak woods that covered the hills. Paride talked about the weather, and cracked jokes about dog-training and the pros and cons of working with a 'bandit' like Daniele. After a few minutes, we turned down a track and pulled over. Kika jumped out of the boot, and we walked along a meadow and into a wood. Daniele had already arrived and was hovering furtively with his dog. There was another truffle hunter nearby, he explained, and we had to be quiet. Daniele's dog was tousled and unkempt and had twigs caught in its curls. It didn't have a name, although Paride said he had heard Daniele call it Diavolo (Devil) earlier that morning. Unlike Kika, who was affectionate and friendly, Diavolo had a tendency to snap and snarl. Paride explained why. Whereas he trained his dogs to hunt for truffles as if it were a game, Daniele trained his by hunger. 'Look' – Paride pointed at Diavolo – 'it's desperate, it's eating acorns.' They bantered for a while. Daniele argued that his dogs were more effective truffle hunters than Paride's well-fed and well-loved 'pets'. Paride stuck up for the reformed school of truffle dog training, summing it up neatly. 'Daniele hunts truffles at night, and I hunt them in the day. He is nervous and I am not. His dog bites, and mine is friendly. His dog is slim, and mine is not slim. He is bad, and I am good.'

All of a sudden, Diavolo darted off. We followed him, Paride providing a commentary as we scrambled along. 'There may be a truffle. Or a mouse. Either way the dog's happy.' We found Diavolo digging and snorting halfway up a muddy bank. Daniele caught up and cleared away the brambles. At this point, Paride explained, the truffle hunter had to read the dog's body language closely. A wagging tail promised truffles, a still tail suggested otherwise. A two-pawed dig indicated white truffles, a one-pawed dig black. The signs looked good, and Daniele began to loosen the soil with a blunt, flat-tipped tool like a giant screwdriver, smelling pinches of soil as he got deeper. He and the dog took it in turns, though he was careful