SOUNDINGS

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Introduction

Plumb-line

This dissertation is an attempt to understand how design leads to different ways of interacting with nature. I have grown up in a culture that treats nature as a challenge to be overcome or a resource to be owned and exploited, and which perpetuates itself through dissociation from external realities. The values that created this world, whether or not we still agree with them, are both encoded in, and enabled by, the design of objects and systems which we have inherited. Our collective and individual actions today are harming ecosystems, societies and ourselves. Yet even as our ship is heading for catastrophe, the crew is arguing amongst itself.

In response to this, I have tried to take a level-headed look at our latent relationships with nature, and the role design plays in creating and sustaining them. I hope that this might inform a personal design philosophy that, among other things, seeks to remind us of the two-way connection we each have with nature. The distinction between humans and nature is not a clear one: rather than a line between us, there is a space to be negotiated and bridged.

Clearly, this is an almost absurdly vast and complicated topic, and conclusive answers, if they exist, cannot be developed through a single text, much less a relatively short dissertation. Instead, this work is my attempt to locate myself in the discourse, and, having been somewhat adrift until now, to build my own metaphorical ship on which to sail these seas.

> *'We make our tools, and thereafter our tools make us'*
>
> Anonymous*

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* Winston Churchill certainly said something similar with respect to buildings, but I could not find an attribution for this common quotation about 'tools'.

Bearing

Put simply, design is the act of planning and making something, or putting it into action[1]. The 'designer' first appeared as a distinct entity in the early industrial revolution[2]: since then, the activities included within 'design' have expanded far beyond form-giving or the decoration of industrial goods. Design might now include general problem-solving, and the more entrepreneurial activities concerned with defining the problem to be solved in the first place. It is the process of moving "from existing situations to preferred ones"[3].

It is worth highlighting that that "designed things are a synthesis of ideas and values"[4]: design gives form to cultural narratives and myths, and incorporates them into the application of technology[5]. Design choices also help create new narratives, by embodying a certain approach to a problem. If an object embodies a particular way of interacting with (or exploiting) nature, we might find ourselves locked into particular behaviours. For instance, the design of the car created expectations and norms that influenced the design of other objects, from the road network to suburban homes.

Debate about designers' responsibilities for what they design has been gathering pace for over a century[6]. The social and environmental arguments were brought into focus in the 1960s as part of a broader countercultural movement, and in the '70s, Victor Papanek proposed that we 'Design for Need' – addressing the concerns of the less advantaged instead of creating ephemeral goods to feed corporate consumerism[7]. The economist Fritz Schumacher, meanwhile, famously critiqued Western economic ideologies and advocated for 'appropriate' use of technology[8]. Today, these concerns are still resonant, as modern manufacturing and media allows the objects we design to proliferate across the planet faster than ever.

Even as designers might try to create their vision of the future, they remain beholden to a market: "if design moves too far ahead of what people understand, then it fails them as consumers and they stop consuming"[9]. From Wedgwood's model makers to design consultancies like IDEO today, the success of a design might best be judged by the value it creates for people. Because of this, it is still common to find examples of design that accommodate or stimulate greater demand: catering, in other words, to growth and consumption. It is less common to see design employed to reduce any kind of demand.

It is in this context that eco-design, sustainable design, cradle-to-cradle design, and their various cousins and offshoots all encourage designers to intentionally and specifically engage, in one way or another, with the 'needs of nature'. Alongside these we might place nature preservation, conservation and rewilding as types of direct interaction, or intervention, with nature and its processes[*].

Defining the 'needs of nature' in design is a matter of heated debate and much confusion. This is probably in no small part because, along with the complications caused by market forces outlined above, nature itself is poorly defined in the design discourse. In this sense, this dissertation is an exercise in charting ambiguous territories.

Reach

I propose that designed objects occupy a symbolic boundary between inner and outer spheres of human agency, and that the role of the design is to facilitate action across this boundary[†] (Figure i). In the case of a hammer, for example, the design allows a user to amplify the effect of their arm (inner) in embedding a nail in a wall (outer).

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[*] Even rewilding, which in its most modest form involves essentially doing nothing to a landscape and 'letting nature take its course', constitutes a kind of 'actively passive' engagement with nature, since it requires restricting human activity on the land.

[†] This is inspired by, but different from, Herbert Simon's formulation in creating his 'Sciences of the Artificial'. He proposed that an artefact represents an interface between an 'inner' and 'outer' environment, the inner environment being that which is designed (the object), and the outer environment being the context in which it is put to use (Herbert A. Simon, *The Sciences of the Artificial*, 2nd Edition (Cambridge, Mass: MIT Press, 1981), p. 9.). Simon introduced this "object/environment" interface as a way of treating the subjective goals and intentions of a design with more objective, 'scientific' language. In contrast, I use the interface metaphor here to denote a *boundary between spheres of influence* (user/environment) which is mediated by the object.

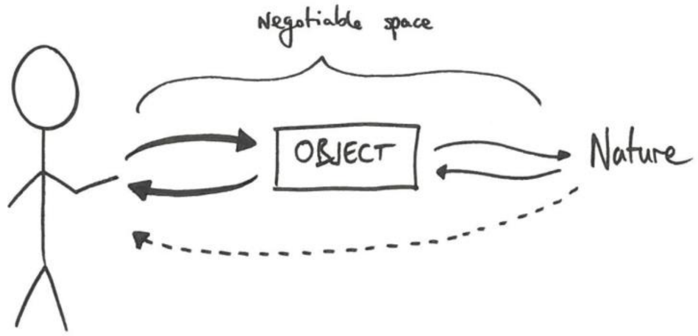

Figure i Design as an interface with nature

Critically, though, the placement of the boundary is not always an obvious operation, even if it may appear so in hindsight. Particularly when presented with a new kind of problem, it strikes me that, instead of a clean boundary between ourselves and nature, there is a much more ambiguous borderland, a space rather than a distinct line. Design is the practice of negotiating this ambiguity, and creating a path through it for others to follow. Designed objects thus mediate the relationship between us and our reality, and, in doing so, help define that reality (Figure ii), We are rooted into the natural via the artificial.

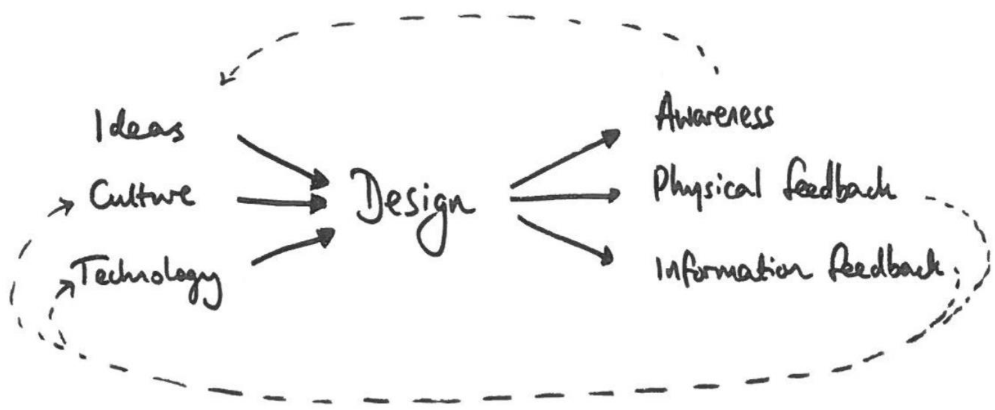

Figure ii: Design incorporates elements of our reality which are themselves products of design.

Maelstrom

Nature, like design, is a word that means many different things. Even among leading theorists, there remains a great deal of confusion and ambiguity as to the meanings of the word. For example, Herbert Simon outlined in 1981 how we might distinguish the artificial from nature, but did not actually qualify the terms nature or natural[10]. In the intervening decades, other writers, from poststructuralists to ecofeminists, have contested the "easy equation of the natural with the real"[11]. We must be wary of unqualified references to nature.

Faced with this, it is clear that I must not only find my own definition of nature to work with, but must also develop a rationale and context for this definition.

The theorist Clive Dilnot illustrates the conceptual relationship between humans, nature and the artificial in a series of diagrams, of which I have reproduced two in Figure iii.

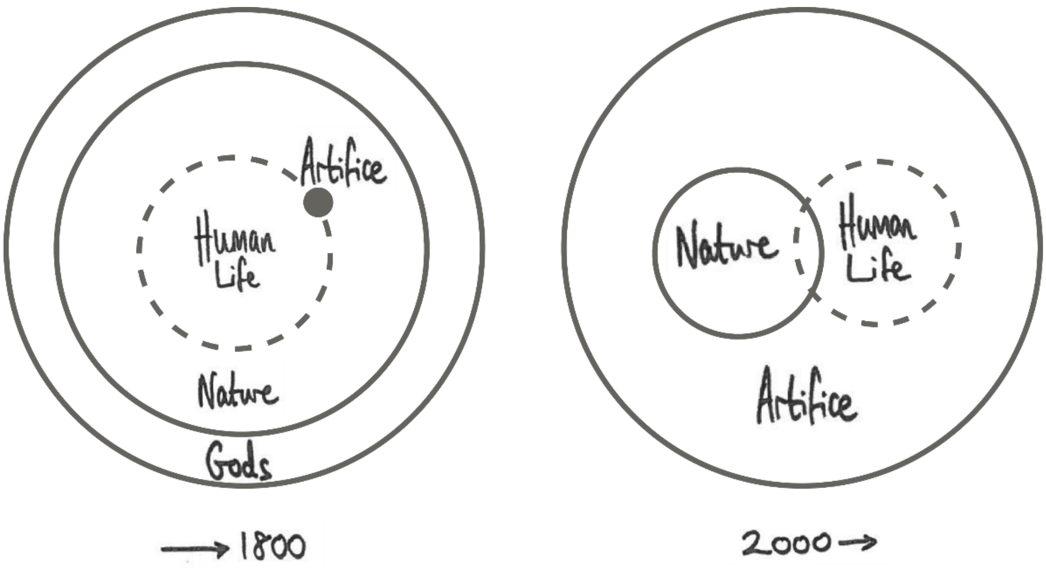

Figure iii: Nature, humans and the artificial, after Dilnot. Left: a pre-Enlightenment model, in which humans lived in a clearly delineated 'artificial' realm, whose growth was limited by the difficulty and speed of pre-industrial production. Right: our contemporary world, in which the picture is almost inverted: artifice has subsumed nature itself.

In the same essay, Dilnot points out that the artificial does not just include technology, but also the human symbolic realm and all of the ways that "we" have altered "nature". For him, "neither nature nor the artificial nor the human are today pure"[12]. Yet as with Herbert Simon, Dilnot does not qualify the human/nature dualism. Further, his (again unqualified) mention of 'purity' hints at moral judgment, or at best reinforces a prelapsarian fiction, obscuring the messy ambiguity and interconnectedness of the living systems from which humans emerged.

It is true that most of the Earth is now affected in some way by human activity, so the entire planet falls within some definition of the artificial. Yet influence is not the same as control. Despite the human footprint, natural biological processes such as reproduction, growth and death still continue. Plants continue to photosynthesise. Bees pollinate flowers and produce honey. AIDS exists.

Thanks in part to a scientific training, my own definition of nature tends to the objective: something like 'the totality of space, substance and processes in the Universe'. 'Nature' thereby includes the artificial, since humans (and human creations) are the product of processes which are in some sense natural and spontaneous. Thus, the *laws of nature* are assumed consistent throughout time and space[*], and the *natural sciences* are the disciplines dedicated to analysing and understanding those laws.[†] Translating this into a Dilnot-style diagram, we have

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[*] The position of the sciences with respect to the laws of nature is a little like that we might have to a machine for which we have lost the operating manual. Only by assuming that there are rules that govern the system can we make any headway in the sciences. We can never know whether our formulation of the 'laws of nature' really do hold universally, and this is why science cannot be 'finished'. (I remember getting chills when I realised that we can never verify this assumption – Hume's "principle of the uniformity of nature", otherwise known as the problem of induction.)

[†]It seems that, over the last 500 years, "nature" has gone from being a collection of phenomena ('natural history, natural philosophy') to being subject to an organised scientific approach. Scientific language can be used as a means of marking territories, as

Figure iv. A part of the human experience is within the artificial realm, but everything is subject to the all-encompassing 'nature'.

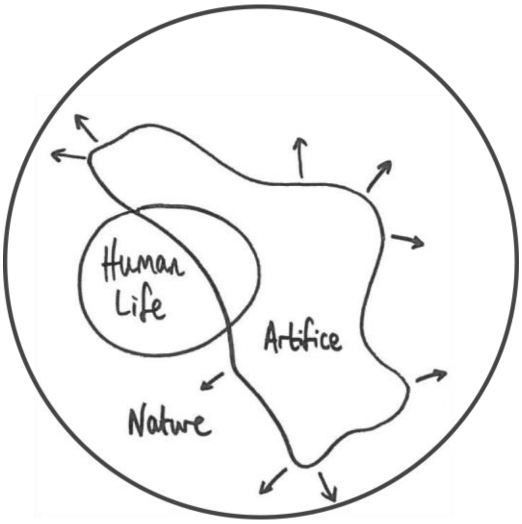

Figure iv: The author's own interpretation of the extent of the artificial today, in response to Dilnot (see Figure iii)

When describing an object, space or process, I note that the words 'natural' or 'artificial' imply a judgment by the speaker of two things: first, whether the thing in question has been subjected to human agency, and second, to what extent that agency produced its present state. This helps explain how a thing can be both natural and artificial, depending on observer and context. For example, in the UK, certain aspects of a landscape may be protected by official designations*. These designations exist to preserve 'nature', but they are designed: the 'nature' they recognise is subject to human judgment. Protected wilderness becomes a kind of hyper-reality: National Parks are giant simulacra, curated by a society according to its idea of what nature should be. Conversely, in predominantly 'artificial' built

when topics are "legitimised" by association with the sciences (serving to implicitly delegitimise non-scientific voices).

* Such as National Parks, Green Belts, Areas of Outstanding Natural Beauty, Sites of Special Scientific Interest and so on.

environments, we fight the biological in its out-of-place opportunism: instead of an ecosystem of plants, insects, mammals and birds, we see weeds, pests and vermin.

If nature is a social construct, why have I been preoccupied with our relationship with it? Because, as the ecological movement has been fond of telling us, and as experimental evidence is now revealing, all of life on Earth forms a single community, with innumerable connections and interactions between its constituents. To paraphrase the ecofeminist Donna Haraway: we exist in a hybrid ('cyborg') reality, interdependent on our companion species and our technology.[13] Our relationship with nature is really about our relationship with ourselves.

I. Liminal

The sewer is the conscience of the city. Everything there converges and confronts everything else. In that livid spot there are shades, but there are no longer any secrets.

Victor Hugo, Les Miserables

When I take a shower in my flat, I stand for a moment between a river and the sea. The system which allows this magic to happen is a work of human engineering intricately woven into, and a product of, social expectations, narratives and judgments. The sewers maintain a kind of homeostasis in the city above, well-drained and clean-flushed. They have become an intermediary between ourselves and nature, between the human world within the city and the landscape – and seascape – surrounding it.

In this chapter I examine sewers – particularly that of London – from a variety of perspectives, and illustrate how they encode a particular way of thinking and acting with respect to nature.

Subcutaneous

In this age of digital topographies, it is remarkable that tunnels, bound by the same laws of physics that we experience on the surface, can still modify our perceptions of place. Their design changes the landscape of our imaginations, and thus our physical experience. This is perhaps most evident from looking at the tube map: a comparison with the 'physically accurate' map (Figure v) serves to illustrate the distortion of scale that is normal, even cherished, for Londoners.

The sewers, on the other hand, are all but invisible to the populace of London, though their effect is no less evident. A map illustrating the network in the style of the Tube (Figure vi) helps put the scale of the system in context, even if it omits most of the detail. It has been called one of the wonders of the industrial world, and it became the model for many similar systems elsewhere. Much of the system remains in use today. The system's unsung status as 'the other Underground' draws a certain civic pride among historians[14] and bloggers[15] alike. I find it intriguing that a largely invisible feature of the landscape should be considered with such fondness.

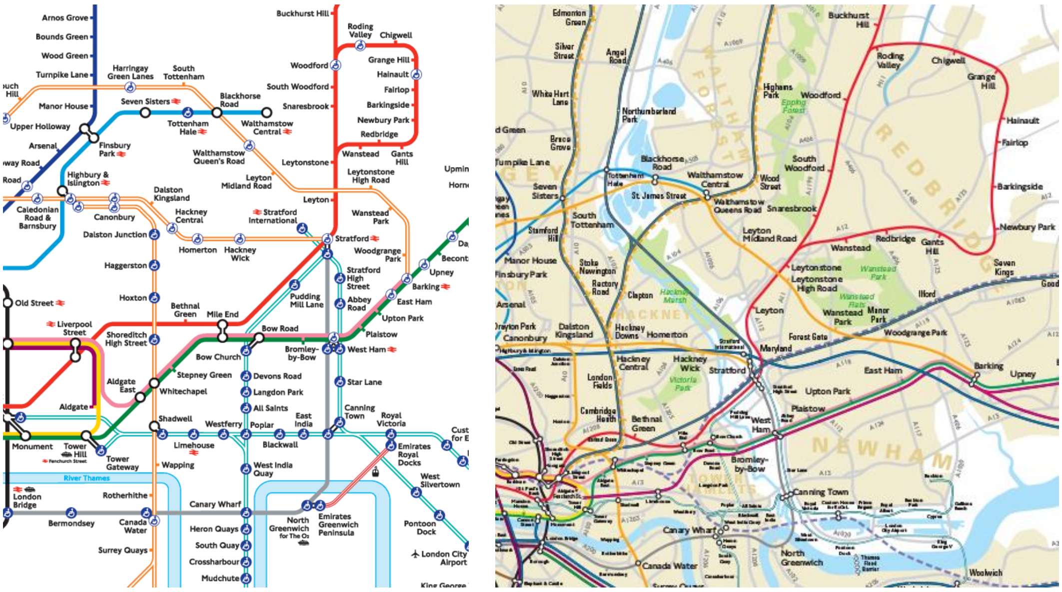

Figure v: The famous TfL tube map[16], alongside its more physically accurate counterpart[17], illustrating the convenient myth of the schematic map for the purposes of planning a journey.

Figure vi: 'London's lost rivers', a map showing some of London's underground features including rivers and sewers, in the style of the tube map. Originally published in Heritage magazine.[18]

Tunnel vision

The story of the construction of London's sewers is well known. In 1865, the demons of cholera and the Great Stink were swept away by the unstoppable march of Progress.* The system designed by Joseph Bazalgette was comprehensive and

* For much of the 19th century, London, the largest port in the world, centre of an expanding empire, stank. The city did have sewers, built in a piecemeal fashion around the tributaries of the Thames – the Effra, the Fleet and the Tyburn – which flowed under the streets, discharging directly into the tideway. By the middle of the century, with the population rising rapidly, the Thames was receiving more effluent than it could carry away, and the ebb and flow of the tides made things worse. The banks were coated in a thickening layer of sludge. London was hitting its environmental limits.

ambitious, but had a simple goal: to intercept the sewage before it reaches the Thames, and carry it away from the city. High, mid and low-level sewers on each side of the Thames follow the contours of the land, allowing gravity to carry the sewage. At the eastern terminus of each set of pipes, the sewage flowed into a tank, to be pumped into the estuary at the turn of the high tide by a set of vast steam engines. In this way, London's sewage bypassed the 'natural' Thames drainage basin, flushing directly and efficiently into the North Sea.

It is perhaps unsurprising that the Victorians would opt for a massive piece of infrastructure to solve London's sewerage problem: with his bold engineering solution, Bazalgette joined the pantheon of revered engineers alongside Telford, Stephenson, Brunel and the other Men Who Built Britain. Such was the status of the project, indicative of the great 'public works[*]' of the time, that the pumping stations at Abbey Mills and Crossness were richly ornamented, looking more like cathedrals than industrial buildings (Figure vii).

This narrative of 'unstoppable progress' takes for granted the many decisions, assumptions and social factors which led to the mighty engineering solution. To understand where it came from, how things might be organised differently, and what this means for our relationships with nature, we need to look deeper into the

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After years of worsening conditions and cholera epidemics in the East End, the Great Stink of 1858, caused by an unseasonably hot spell, finally brought Parliament to its (olfactory) senses, and work began on a city-wide sanitation scheme. Within a few years, London had a vastly improved sewer system, which has more or less served the city well for a century and a half. (Paul Bryers, *Seven Wonders of the Industrial World, Episode 4: The Sewer King* (BBC, 2003); Peter Ackroyd, *London under: The Secret History beneath the Streets*, 1st United States ed (New York: Nan A. Talese, 2011).)

[*] A recent episode of the podcast "99 Percent Invisible", discussed the difference between the terms 'public works' and its modern equivalent, 'infrastructure', and suggested that we reintroduce the former term – "we as a nation need to become more invested in our infrastructure, financially and emotionally. Perhaps it is time to reclaim the term "public works" as a reminder to politicians and citizens alike that these projects are undertaken by and for the people." ('Public Works: Rethinking America's Transportation Infrastructure', *99% Invisible* <http://99percentinvisible.org/episode/public-works-rethinking-americas-transportation-infrastructure/> [accessed 5 October 2016].)

murk and understand how the problem was defined. To do this, we must examine Victorian culture and its values – and its fears.

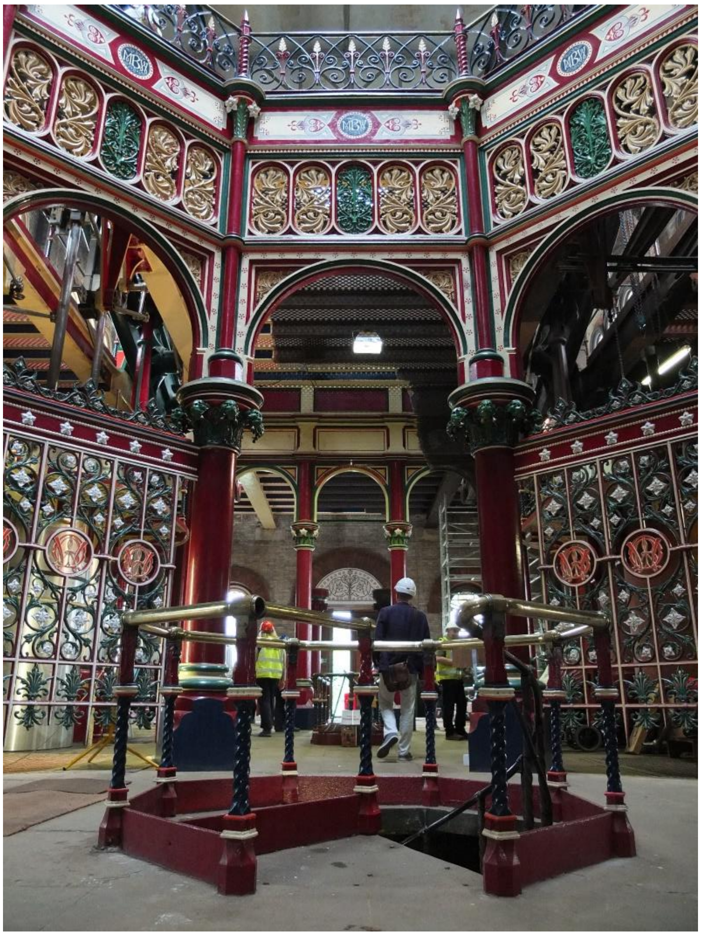

Figure vii The Crossness pumping station, one of two such facilities stations built by the Metropolitan Board of Works to pump sewage from the holding tanks out into the estuary at high tide. The building was opened by the Prince of Wales in 1865, with Lord Mayor of London and the Archbishop of Canterbury in attendance. (photograph by the author)

Excernere

Dirt, like beauty, is in the eye of the beholder. Before 1800, even kings and queens rarely, if ever, bathed. Fifty years later, the scientific understanding of disease had advanced, and a public health movement was in full flow. Activists such as Thomas Southwood Smith (1788-1861), and Edwin Chadwick (1800-1890)[19], brought hygiene and cleanliness to the top of the agenda. Before long, “the condition of total cleanliness was comparable to a state of religious grace, and just as unattainable."[20]

At the point of crisis – the Great Stink of 1858 – the ostensible reason for building the sewer was to alleviate the smell of excrement. Doing so, it was believed, would help to reduce the incidence of diseases such as cholera which were devastating the poorer parts of London. According to the dominant miasma theory, to which even Florence Nightingale was an adherent, smell alone was thought to transmit disease.[21][*] That the sewer really did reduce the transmission of disease, by removing sources of water contamination, was a happy coincidence.

For centuries, Europeans had been getting rid of their excrement by throwing it out of their homes into the streets below. The very word 'excrement' comes from the latin *excernere*, to separate out.[22] This, according to anthropologist Mary Douglas, the taboos we have about excrement derive from the fact that it was once part of the body, and is now separate: it has crossed an intimate boundary. Is it part of us or not? Ambiguity and liminality like this is treated with suspicion or disgust, and is avoided or ignored where possible.[23]

In the West, the separation of excrement from humanity takes place on different length-scales all at once: just as the waste is expelled from the body, so too is it expelled from the home, and the city. We work hard to make the act and the product of excretion more invisible. This inclination found expression in the mid-nineteenth-century through specially-designed rooms served by elaborate plumbing: bathrooms and water-closets.[24]

London's sewers had been – and effectively still are – a way of facilitating a natural drainage process. London's sanitation crisis in the 1860s was therefore a problem framed by an existing solution. Few of the implicit assumptions were challenged – first and foremost that the new solution might simply be a better version of the old

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[*] This was in spite of work by Dr. John Snow to link cholera to contaminated water in 1854, which was largely ignored until after his death.

one, but also, for example, that it would remove the waste, rather than reducing or avoiding it.

In East Asia at the time, the approach to human waste was somewhat different. In Japan and China, 'night soil' was a valuable commodity and was collected from urban and rural homes for hundreds of years. A complex economy once existed to collect and transport human faeces for use on farms. Rich people's excrement contained more nutrients and was worth more than that of the poor. One proverb tells us to "treasure night-soil as if it were gold"[25]. Remarkably, this system was well-entrenched in Japan for most of the 20th century, ending in the 1980s with a shifted to a more "American-style" consumer lifestyle[26].

In 1860, the Metropolitan Board of Works invited suggestions for how to resolve London's sewerage crisis through an advert in the Times. Among the 137 replies, one reportedly suggested collecting the solid waste, loading it onto trains and carting it out of the city to spread on fields.[27] When we consider contemporaneous practices in East Asia, which nonetheless kept contamination and disease to a minimum, this is a less absurd proposal that it might at first seem.

London's sewer system, then, was a big engineering solution, built at a time that favoured big engineering solutions. The Victorians' fetish for engineering and new technology was accompanied by a macho intent to control nature and subdue landscapes. This is particularly true of colonial landscapes, invariably constructed as female – to be conquered by the male European[28]. At home, the great 'public works' of railways, bridges and boulevards brought order to chaos – rationalising, controlling, perhaps accelerating a natural process. They helped the city keep pace with a time of great social upheaval.

"Re-ambiguation"

A counter-example to sewerage systems in the modern era might look something like the Microbial Home (Figure ix). This work by the Philips Design-Led Innovation team in 2011, led by Jack Mama and Clive van Heerden, consists of a series of interconnected stations in which each function's output is another's

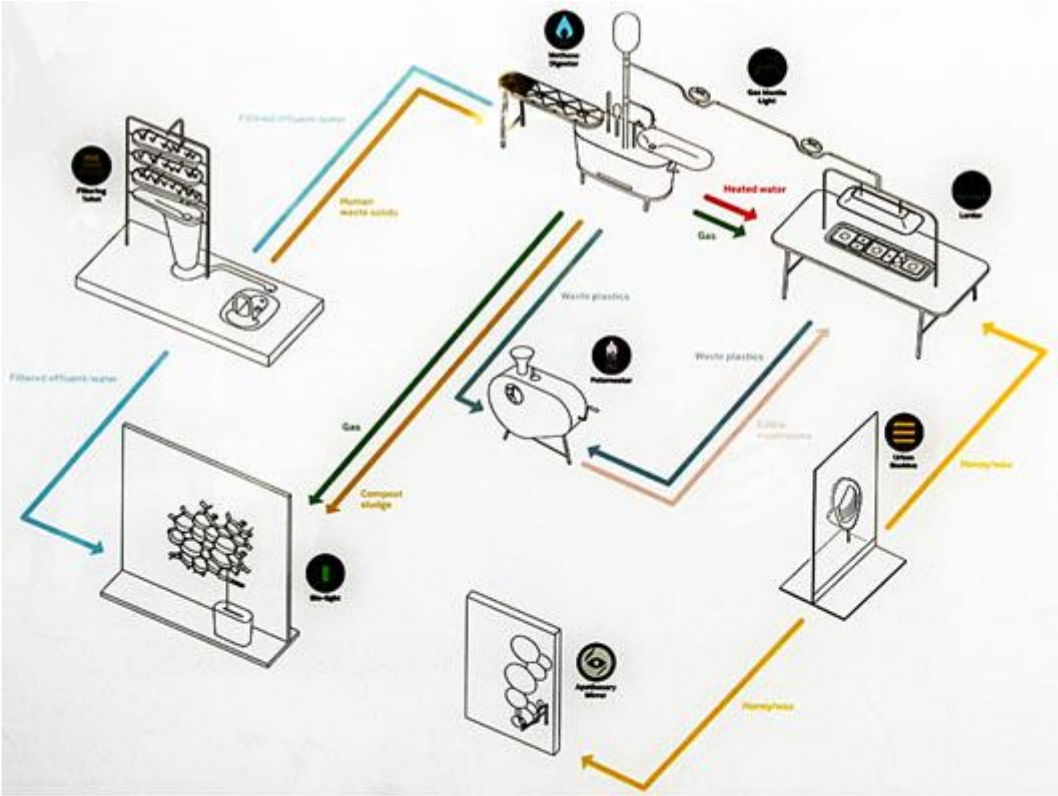

Figure viii The Microbial Home: schematic showing the flows of nutrients, energy and other services between the stations, helping the home become a kind of human-centred ecosystem.

input[29]. The design allows ecosystems of bacteria and other organisms to exist in symbiosis with humans, thereby bringing the functions of sewage treatment and food production into the home. The work confronts our germ-phobias and critiques our superstitions and rituals surrounding cleanliness and sterilisation of our living environments[*]. It also poses an interesting question, namely: how can we incorporate our species more purposefully into a nutrient cycle so as to limit the damage we might do to other habitats? The work proposes handing a certain amount of freedom back to the user. It questions taboos about cleanliness and,

[*] It is interesting to note that the word hygiene comes from the name of the ancient Greek goddess of health, Hygeia, whose name has since come to stand for sterility. (Theoi, 'Hygeia - Greek Goddess of Good Health (Roman Salus)' <http://www.theoi.com/Ouranios/AsklepiasHygeia.html> [accessed 5 October 2016].)

through a visual language invoking familiar bathroom furniture with a futuristic twist, reframes them. It helps us question a set of otherwise well-established domestic rituals.

*Figure ix: The squat-toilet station of the Microbial Home, incorporating a methane bio-digester to generate energy from excrement; urine is sent through a system incorporating plants, which it fertilises while it is filtered.**

Innovation, design, engineering?

Throughout this chapter, I have mentioned engineering, but this term needs qualifying. For me the difference between design and engineering is the difference between first- and second-order cybernetics[30], which is to say that engineering is about optimising for a desired outcome, whereas design includes decisions about what outcome is desired. Innovation in engineering concerns solutions ('how do we do this?'). Innovation in design must first ask 'what should we do?'.

A given problem might have two sets of solutions. The engineering solutions will take certain goals and parameters as invariate, and optimise the outcome.

Engineering solutions are characterised by physical modifications to the world, especially those that remove ambiguity or choice from users and participants. Safety features on aircraft are good examples of where this is essential. Design solutions, on the other hand, will tend to challenge and redefine the problem itself, perhaps by subverting a behaviour or exploiting a behavioural instinct.

Much infrastructure depends on engineering, especially if it expands or augments an existing system[*]. It could easily be said that engineering makes much of life possible in the modern world.

Sometimes the 'engineering solution' becomes the only option because the obvious alternatives are too difficult or too expensive to implement. For example, the Thames Barrier prevents flooding in the city by literally holding back the tide (King Canute would no doubt be impressed). Large centralised systems permit economies of scale. Compared to the cost of installing tidal flood defences throughout the city, or indeed allowing London to be flooded, the case for a barrier became evident.[†]

However, this kind of 'progress' can limit freedoms, explicitly or implicitly. Once sewers exist, you can't easily avoid using them. Thames Water sends a bill to all of London's households on the reasonable assumption that they are using the services of the sewer. It is cognitively and physically difficult to do anything else with your waste, since the sewerage solution is both a 'sunk cost' and vastly more convenient than alternatives.

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[*] An intriguing counter-example to this is the 2012 redesign of Exhibition Road and Kensington High Street. The removal of barriers between pedestrians and vehicles introduced ambiguity into the scene, making drivers more vigilant and giving pedestrians more control over the street. ('Shared Space Is the Future for London's Roads', *Evening Standard*, 2012 <http://www.standard.co.uk/comment/comment/shared-space-is-the-future-for-londons-roads-7313484.html> [accessed 2 October 2016].)

[†] Such a centralised solution can, however, introduce weak points. If the Thames Barrier fails, or is overtopped, London would be defenceless against a tidal surge.

Neo-Victorian

Bazalgette's lower outfall sewers, running beside the Thames, have an overflow mechanism to ensure that the system doesn't 'back up' across London in the case of a blockage or heavy rain. This overflow works by simply diverting the excess into the Thames. Thanks to the growth of the city and the changing habits of its residents, about 10,000 tonnes of untreated sewage is now entering the Thames every year.

To address this problem, construction has started this year on the Thames Tideway Tunnel. The object of the TTT is to divert and contain the sewage that overflows from the present system, plunging it once again below the surface – this time further than ever before, into a subterranean twin of the Thames, 50 metres below ground. This project seems like an extrapolation *ad absurdum* of Bazalgette's work. Where he tamed the submerged the rivers of London, the Tideway Tunnel ensures that the Thames above will always be a curated, cleansed version of itself, like some fluvial Dorian Gray whose ghastly picture lies far below.

The project's website claims that it will 'reconnect London with the Thames'[31] by preventing almost all urban sewage from entering the river – in other words, by selectively *dis*-connecting the city and the river.

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We will always need to implement a mix of engineering and design approaches – the bigger and cleverer solutions on the one hand, and those confronting and adjusting our values on the other. Engineering approaches seem to reduce or postpone those uncomfortable moments of ambiguity in which we are forced to reassess our priorities. They have the satisfying sense of 'getting things done'. On the other hand, design solutions present risk and upheaval. This accounts for why many institutions, public and private, seem to have a bias towards engineering-type solutions within their respective mould. But if we ignore the alternatives, we narrow our realities.

In the next chapter I will explore how this has put modern society in the strange position of being utterly dependent on certain aspects of nature, yet completely out of touch with it.

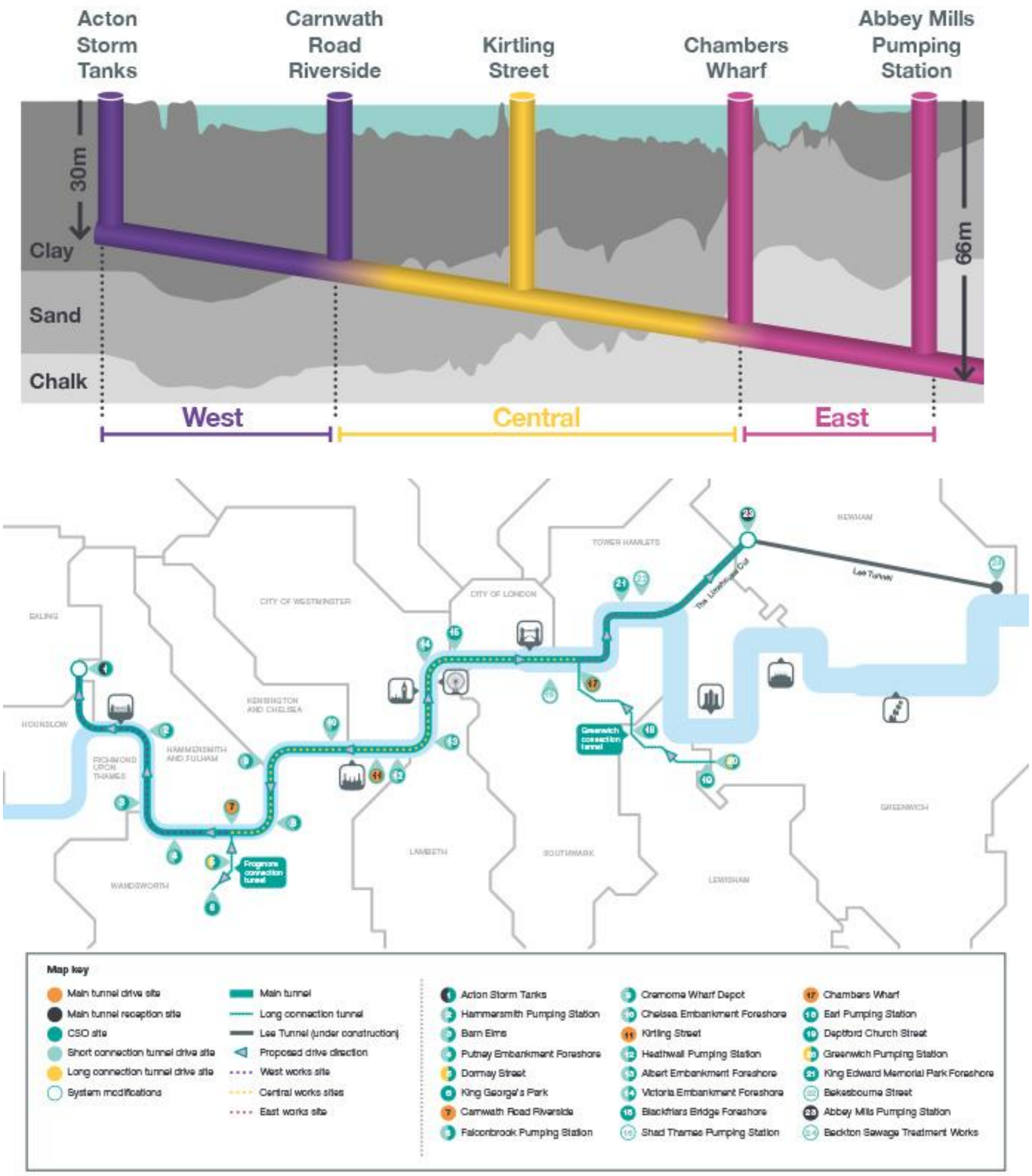

Figure x: The Thames Tideway Tunnel: depth (top) and route (bottom) diagrams.[32]

II. Manual

> *Before any plank was put into place, MacAlpine and Tom [...] held a consultation over it. First they examined it very carefully, and then they bent it, tapped it, listened to it, and, as I live by bread, I swear that once, at least, I saw MacAlpine tasting it. At any rate he applied his tongue to the wood, and then went through all the motions of an expert tea-taster – even to that final feat of expectorating through the clenched teeth with precision and gusto.*

From *The Southseaman*, Weston Martyr (1885-1966)
(quoted in JE Gordon, the New Science of Strong Materials[33])

On a sailing boat, you cannot help but feel the sea and the wind through the ropes, the tiller and the movements of the deck. You feel exposed, vulnerable even, but also closely connected to the forces of nature. The boat acts as a kind of vector for the connection, conveying tactile information to you so that you can act on it.

This chapter focuses on materials and sensory experience, particularly touch, as key parts of the designed 'interface' between humans and nature. Through this interface, our sense of connectedness with things outside ourselves – whether human or nonhuman – may be brought closer or pushed further away, or even totally dissociated. A wooden ship will be profoundly different to sail compared to a modern fibre-glass yacht with aluminium mast, while a large steel cruise ship is designed to eliminate the sensations of the sea for its passengers.

Overlaid on this are the physical, social and chemical relationships that materials have with their surroundings. The use of a material may have psychological and cultural connotations; its production may require an entire industrial sector. It may continue to exist long after the object has been discarded. Material choices are not immaterial.

As a touchstone for many of these issues, I turn to the smartphone, with its touchscreen and electronic innards dependent on metals from far-flung parts of the world. In this chapter I will explore how smartphones (and their sister devices, tablets) may be affecting human experience and cognition, and furthering a trend of disconnection from nature. I will also explore how the sense of touch and an awareness of materials can help to bridge that same divide.

Only connect?

Touch appears in metaphors for communication, understanding, connection or control. We might, for example, tell someone to 'get in touch' with us, or help them 'grasp a concept', or tell them to 'get a hold on' themselves. Across cultures, one of the first and last things people might do when they see each other is to physically touch: a handshake, a hug or a kiss serve to make the ensuing interaction more real and honest, or a farewell more meaningful. Touch can help build trust, but can also be dangerous, associated with disease and the unclean. All in all, it is an important part of being human.

Touch offers a literal and immediate connection with an entity or environment outside our bodies, through which we can send and receive different types of information. The reciprocal nature of touch, whereby if I am touching you, you must be touching me, contrasts with the other ways we have of communicating with the world: if I speak to you, you are not necessarily speaking to me. (You might not even be listening to me.) This immediacy and reciprocity makes touch one of the fundamental conduits through which we converse with, and feel 'connected to', the world around us.

The history of design reveals our changing relationship with touch, and especially the avoidance of touch. Society has long manifested its anxieties into a fear of touching[34] and this is particularly evident in the design of bathrooms, kitchens and medical spaces, where germ theory has contributed to a considerable evolution in design in the last century[35]. Touch is impure, unclean and carnal –

unlike 'pure' thought and theory, for example, as we find in those 'clean' subjects like philosophy and mathematics – or indeed the so-called pure sciences*.

Yet touch is essential for neurological development, and for our perception and manipulation of space. In *The Craftsman,* Richard Sennett puts forward the idea that the hand and the brain work as one, quoting Kant's saying that 'the hand is the window on to the mind'[36]. Neurologist Frank Wilson expresses a similar view, stating his dissatisfaction with the 'cephalocentric' (brain-centred) view of intelligence which sidelines the role of the hands and touch. For him, the interaction of brain and hand "marks the fusion of what is physical, cognitive, emotional, and spiritual in us". He later says "if the hand and brain learn to speak to each other intimately and harmoniously, something that humans seem to prize greatly, which we call autonomy, begins to take shape."[37]

What, then, comes of disengaging the head from the hand, separating visual and tactile cultures from each other? Three years ago, one newspaper headline decried the inability of primary schoolchildren to hold a pen: "Playing with touch-screen devices means youngsters are struggling to learn basic motor skills"[38]. But if Wilson and Sennett are to be believed, this could be only the beginning of a deeper dissociation.

Disembodied users

We are spending more of our lives interacting with the world through touch-screens. Compare a café in a major city today with one five years ago and you would have a general sense of this, but the statistics are striking and incontrovertible. Last year, smartphones overtook laptops as the most popular device for accessing the internet in the UK, and over half of households were

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* By comparison, we rarely hear people talk about 'pure engineering' – indeed Oxford University names its undergraduate course "engineering sciences", perhaps in an attempt to elevate it above mere practical pursuits.

found to own a tablet, up from 2% since 2011. Over the same interval, the average amount of time people spent online each week doubled, from 10 to 20 hours.[39]

As a technology and as a communications medium, the touch-screen has opened up a world of opportunities for interaction design. Because the layout and meaning of an interface can be determined by software, we can now have much more dynamic interactions between human and computer. Yet when the 2D surface of a touch-screen becomes such a dominant way of interacting with the world, we become inured to the sense of touch. Instead of touching objects, working with them, we are merely pressing fingers to a window in our palm. The world becomes like the art gallery in which 'you can look but you can't touch', and while we might be able to 'keep in touch' with more people, our text-based communications are no more intimate than slipping notes through the wall of a prison cell.

Through touch-screens we become immersed in a vast world of information, but what do we give in exchange? In order to navigate complexity, our online behaviours are channelled through scripted interactions. People become 'traffic' and the role of the User Experience (UX) designer is to direct the flows through intuitive interfaces.

In *The Craftsman*, again, Richard Sennett argues that one of the most important ways that we learn about the world is by encountering, and then overcoming or working with, resistance[40]. Most of us begin to do this at a very early age when we play with toys, or first encounter social boundaries: we try to do something, and the resistance we meet forces us to reassess the situation. By being confronted with a world that doesn't work the way we want or expect it to, we may build up a tolerance to ambiguity.

By contrast, 'good design' (according to advocates of the user-centred approach such as Don Norman[41]) is usually that which is 'intuitive' to use, and creates the least frustration in the user.

When every interaction is designed to be intuitive, what is there left to think about? Where, and how, do we learn through resistance?[42]

Interaction design seems to be about working with and exploiting psychological and cognitive biases, producing an intuitive experience for users – and a friction-free path for them to spend money as consumers. The touch-screen can bring almost anything in the world into your personal sphere through a few prods of a phone. In this sense, distance has become meaningless.

But if we now consider the touchscreen as an interface between humans and nature, it feels restrictive. Never before have we been able to access so much of the world from a place of such apparent safety – but we are imprisoned by the glass of the touch-screen. The 'touch' here is ironic: the only surface we do touch is made from a material – glass – known for being featureless and ageless[43], in other words, with nothing to sense. Never before have we been able to interact with so much freedom, but with so little engagement.

Bilateral

"Engineers like their materials to be consistent and are not too deeply interested in reasons, so they encouraged the idea that each material has a characteristic strength which could be determined accurately, once for all, if only one did enough tests. Materials laboratories [in the early 20th century] filled a great many notebooks with testing data but learnt very little about the strength of materials."[44]

As a materials scientist for four years, my training revolved around the acquisition of scientific understanding a little like that described by J. E. Gordon in the quote above. Here, a material is translated into symbols and specifications that we can communicate and manipulate 'objectively', such as its yield stress[*] or refractive index[†]. Today, our knowledge of materials is somewhat better than it seems to

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[*] A measure of the strength of the material, related to the maximum load that it can carry before it fails (yields).
[†] An optical property of a material, derived from measuring its interaction with light at an interface with air.

have been in Gordon's day: for instance, we know not just the strength of steel, but why some steels are stronger than others, why and how they break, and how to tailor them to a particular task. Still, the principles behind the scientific understanding of materials remain the same: we convert materials into a series of specifications, models and analogies, the better to be applied in the service of humanity.

I was dimly aware that artists and designers approach material differently from this, but only once I had embarked on a design education did I begin to understand those differences. By experiencing a material – working with it, touching it, manipulating it, forming it – one gains a kind of implicit knowledge which cannot easily be translated into symbolic representation and language, as it resides in objects and is conveyed by sensory experience.[*] As such it is also partly subjective. Experiential knowledge may also, like theory, be informed by experiment, which can still be highly methodical. Building up this experience-based knowledge of materials has emerged as one of the goals of my own design education, to complement the theoretical foundation I possess.

Most architects and designers have some awareness of materiality, though I find myself especially drawn to those whose work is directly informed by a process of two-way engagement with materials. This process, which we might call "material-led design" [45], is exemplified by some of Thomas Heatherwick's early work (Figure xi) and experiments (Figure xii), in which he has a kind of conversation with materials through form.[†]

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[*] This is not to be confused with Don Norman's 'knowledge in the world', the idea that designers can place cues (thus 'knowledge') in the form of an object, to help the user. Donald A. Norman, *The Design of Everyday Things*, Revised and expanded edition (New York, New York: Basic Books, 2013), p. 75.
[†] The Eameses also famously pursued this kind of material experimentation in creating their lounge chair designs. The first outing of their moulded plywood chair was at MoMA in 1940, but the pair kept experimenting and modifying the design for decades, working with furniture makers and aircraft engineers to push the material's capabilities.

Figure xi: Thomas Heatherwick: extruded chair [46]

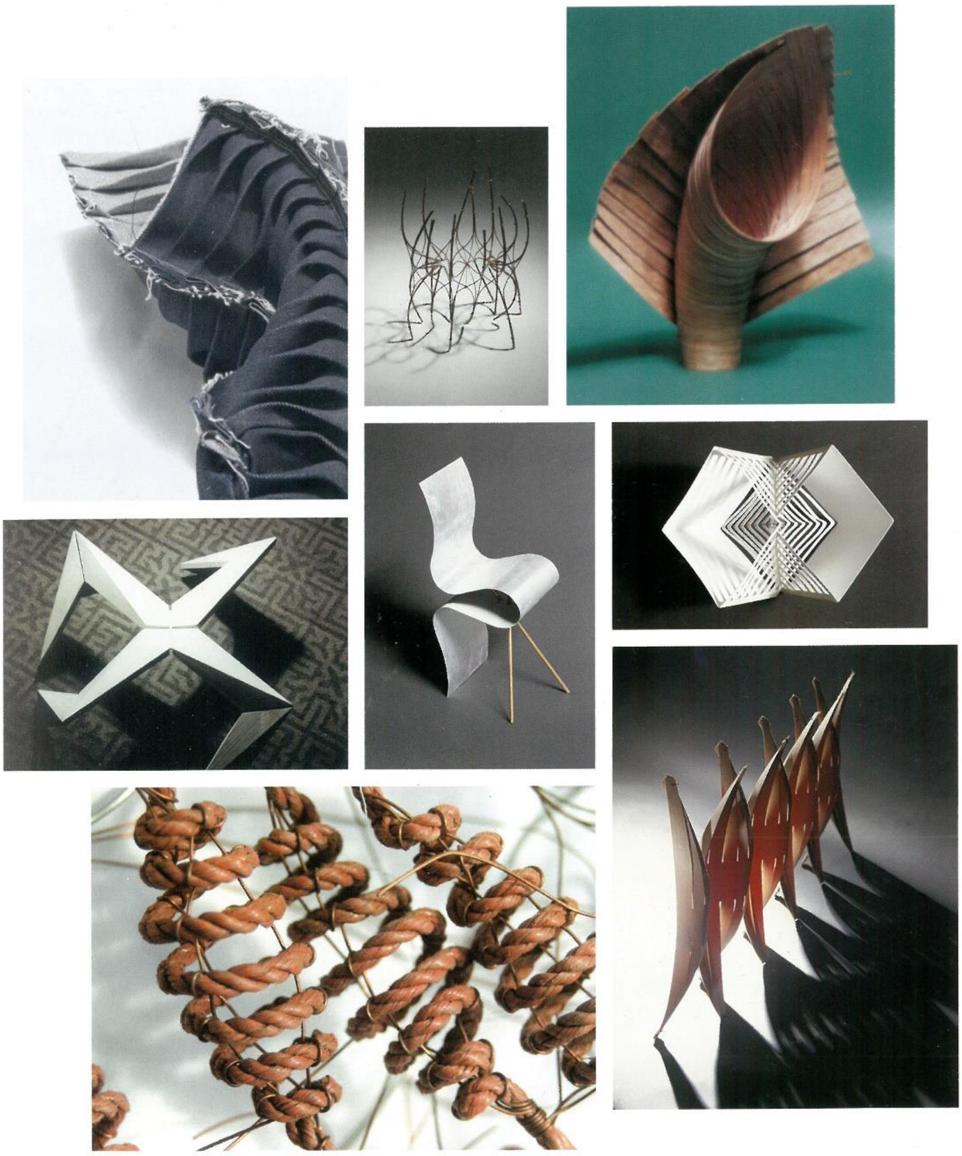

Figure xii: Thomas Heatherwick's material-based experiments[47]

The cybernetician Gordon Pask developed a theory of conversations as a "process of coming to know", in which one "cognitive system" interacts with another and comes to understand its "knowledge"[48]. A material is not by any stretch a "cognitive system" but if we treat it as something not entirely inanimate, that contains a kind of basic elemental 'knowledge' in its physical properties, then the experience of a material could fit into this definition of a conversation.

This idea of conversation reminds me of the suggestion by designer Stuart Walker (paraphrasing Martin Buber in the early 20th century) that, when it comes to nature in the abstract, we replace the instrumental 'I-It' relationship with the more reciprocal 'I-You'. As Walker explains, this results in a reframing of how we interact with the world through design: "An 'It' is known in terms of specifications [...]; a 'You' is known directly."[49] The 'encounter with' replaces the 'experience of' nature.[*] We allow ourselves to be changed.

Another parallel can be drawn with the position of anthropologist and sociologist of science Bruno Latour, when he proposes a philosophical framework, 'political ecology', at whose core is an 'equality of speech' between human and nonhuman entities[50†].

This leads me to the question: what kinds of designs, and design processes, are oriented towards conversations, rather than direct control?

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* In practical terms, then, given that nature is a social construct, we should be mindful of the rationale we use to apply the concept of "user needs" to nonhuman actors. It could be that all we are really doing is 'rerouting' our own values – either in order to serve our own interests directly, or because we otherwise lack a way of choosing between ourselves and nonhumans.

† In short order, Latour demolishes most of the attempts made so far to incorporate ecology and the interests of the nonhuman into human politics. Deep Ecology, for example, he mocks as "a movement with vague contours that claims to be reforming the politics of humans in the name of the 'higher equilibria of nature'". He proposes that, rather than having humans and nature situated in two worlds, with the sciences having the role of "breaking with society to achieve objectivity, of rendering mute things assimilable by human language, and finally, of coming back "to earth" to organize society according to the ideal models supplied by reason.", humans and nature would instead part of a single collective, characterised by association and "in the process of expanding". We do not do away with objective external reality, but acknowledge the importance of the history of the sciences and the mediation of the scientific disciplines.

Plastic

At the MIT Media Lab, the Tangible Media Group, headed by Hiroshi Ishii, explores the possibilities of using technology for haptic interaction. Projects such as Materiable (Figure xiii) propose one such method of interacting with digital data through a spatial and tactile interface. In this example, a field of actuators in a square array are able to rise or fall according to the user or computer input, while visual information is projected from above. While this prototype has its limitations, it represents a dynamic medium for human-computer interaction that incorporates both touch and vision.

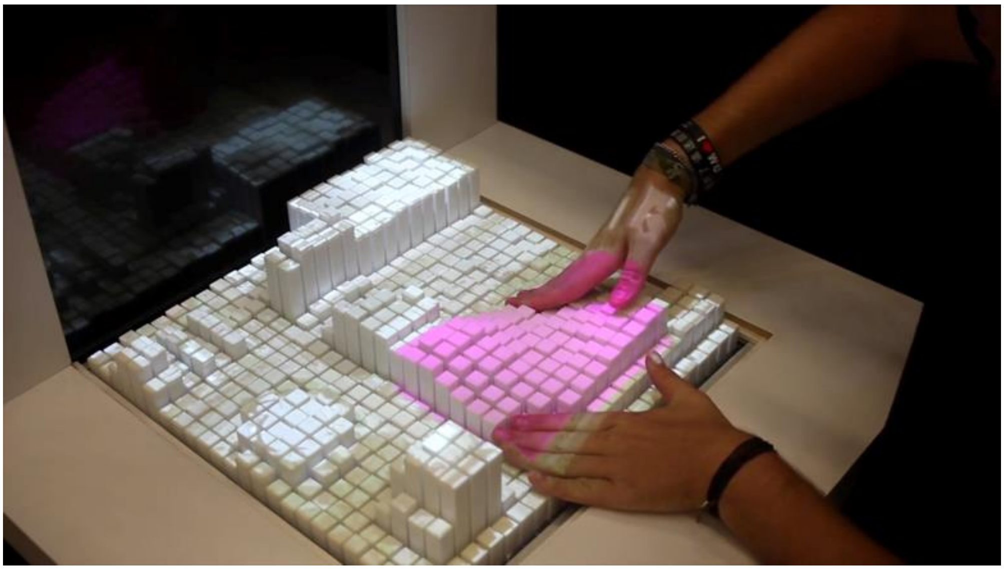

Figure xiii Materiable, by the MIT Tangible Media Group[51]

How does this compare with "real" embodied interactions? Contemporary digital design rarely takes into account the fact that our bodies are made of materials, and that by virtue of existing we affect the world. If an interaction takes place through a system of digital intermediation, can we still be in touch with the world?[*]

This comparison reminds me of the difference between acoustic and electric musical instruments. When playing an acoustic piano, I am physically in touch

[*] Further, by opening touch to the copy-and-paste replicability of the digital, we risk commodifying it, just as visual media have become commodified.

with the music I am making, through the keys and the complex system of levers, hammers and strings behind them. The action provides mechanical feedback through the instrument. This touch feedback is as important as sound for moderating the music – it is part of my conversation with the music through the instrument. By contrast, an electric keyboard is dissociated from the sound it produces: touch is more like a one-way instruction. While the instrument has other advantages, a player is no longer connected to the music in the same way.

What might all this mean for our understanding of our place in the world, and our sense of autonomy, agency and ingenuity? If we want to be able to interact with a second-person nature ('I-you', as opposed to 'I-it'), we must seek fields of conversation rather than instruction. We must find ways to sense resistance.

Terroir

The capacitive touch-screen has transformed the iPhone from a mobile phone into a smartphone. As I mentioned at the beginning of this chapter, regardless of the sense of connection with nature that an object might provide, it represents, through its own materials, a way of interacting or conversing with nature. Let us therefore consider the *terroir* of an iPhone.

As Thomas Thwaites' *Toaster Project* illustrated[52], it is all but impossible to live in modern society without buying into a global economy. This is a somewhat worn sentiment, but it is profound. Even apparently simple devices (in Thwaites's case, a bottom-of-the-range toaster) can consist of hundreds of parts, made from over a hundred materials, mined and processed in dozens of countries, many of which are in the developing world and many of which are associated with less than salubrious practices.

Since the launch of the 'magical' iPhone in 2007[53], there has been a huge rise in demand for rare elements that are used in the latest electronics. These metals – dysprosium, tantalum, gallium, indium, hafnium and dozens of others – have particular properties, many revealed only through trial-and-error lab experiments in the last few decades. They have enabled our devices to become smaller, lighter, more reliable and faster. The eclectic mix of materials in a smartphone means that we now carry around half the periodic table in our pockets.[54]

The demand for these elements bears no relation to their abundance in the earth's crust, nor to their ease of extraction. In many cases, much of the world's supply comes from a single country – as for the so-called 'rare earth' metals*, 95% of which originate in one mining facility in China[55]. Tantalum, on the other hand, which is necessary for high-performance capacitors, is mined on the war-torn Rwanda/Congo border.

It is ironic that part of the reason for the sudden surge in demand for these elements, alongside the popularity of smartphones, is their use in 'sustainable' technologies, such as wind turbines and smart meters. Our dependence on these minerals is having alarming effects on societies and natural systems all over the planet.

Manufacturers of smartphones have come under pressure to 'clean up' their supply chains[56], and the start-up Fairphone is attempting to create devices free of 'conflict minerals'[57]. Yet even Fairphone's strategy director acknowledges that, given the political situation in many of the countries of origin, such a goal is not yet attainable[58]. There is not enough conflict-free material to satisfy the demand. Fairphone is trying to link consumer behaviour back to the welfare of miners, but its efforts are undermined by the appetite of the market.

It may not be an entirely fair comparison, given the very different product categories, but the complicated, sprawling supply chain of the smartphone contrasts drastically with that of the FullGrown chair. This piece of furniture is shaped, grafted and grown from a live willow tree, before being harvested, seasoned and finished. It is made in once place, from a single material, and each one has a unique form that results from the interplay between the tree and its environment.[59] Wooden ships were once created in a similar way, in a

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* Such as neodymium and dysprosium, used in optical coatings and in magnets.

manufacturing process that started decades before the first tree was felled. Larches were grown for masts by surrounding the tree with fast-growing species, forcing it to grow straight and tall.

Is there hope for the smartphone to be more like the willow chair, or the larch mast? Perhaps that is the wrong question. Perhaps by the time we can grow ingredients for a smartphone, we won't be interested in smartphones any more. In the next century, it seems likely that many of the materials we will be using will be biological in origin. It is this new world of social and ethical considerations to which I now turn.

III. Vital

"This is the latest," said Crake.

What they were looking at was a large bulblike object that seemed to be covered with stippled whitish-yellow skin. Out of it came twenty thick fleshy tubes, and at the end of each tube another bulb was growing.

"What the hell is it?" said Jimmy.

"Those are chickens," said Crake. "Chicken parts. Just the breasts, on this one. They've got ones that specialize in drumsticks too, twelve to a growth unit.

"But there aren't any heads..."

"That's the head in the middle," said the woman. "There's a mouth opening at the top, they dump nutrients in there. No eyes or beak or anything, they don't need those."

– From Oryx and Crake, by Margaret Atwood [60]

The field of synthetic biology promises to transform the world in hitherto unimagined ways. The disciplines of biology, design and engineering have not converged in quite this way ever before, and the clash of disciplinary cultures has revealed a highly ambiguous undeclared space at the frontier of technology. Distinctions that were once clear – between user, maker, object, action and effect – are being blurred. This chapter is about biological systems, and how designers create and curate interactions with living matter. By analysing two main examples, one new and one ancient, I hope to begin to understand what this emerging field might have in store for design as an interface with nature.

New victims

Human agriculture has long exploited animals. Factory farming today "represents the industrial-scale application of engineering logic onto animals in order to maximise production"[61]. With the possibility of in vitro meat coming closer thanks to advances in biotechnology, the ethical (and practical) ramifications of growing tissue outside a body are now coming under scrutiny.

The ethical dilemmas of biotechnology are a favourite topic of designer-provocateur Oron Catts. His *Victimless Leather* (2008) was designed to probe our ethical and material relationships with nonhuman biology, by creating a tissue culture of skin cells in the shape of a jacket (Figure xiv). Barely a few centimetres in size, the object was in no way wearable – as such it was something of a parody of a garment, a satirical comment on the ways that garments are partly used by humans to construct their separateness from nature and from each other.

Working with Ionat Zurr in the interdisciplinary group SymbioticA, Oron Catts has produced a variety of work that examines, juxtaposes or subverts the scientific and public attitudes towards biological experiment, and Victimless Leather is no exception. Its appearance looks almost menacing or superstitious, though a close inspection of the equipment shows it to be only that which would normally be used in a lab. For instance, the red light illuminating the glassware from below is simply the indicator for the pump that circulates the nutrients.

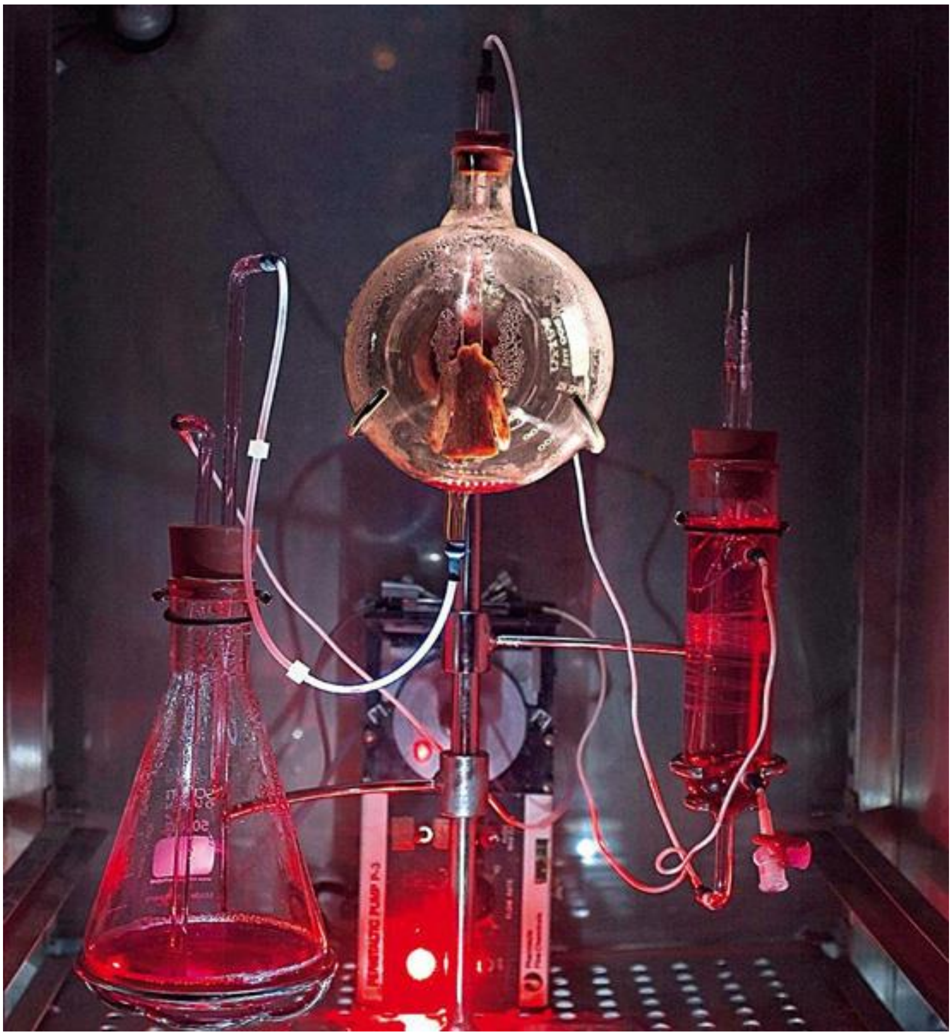

Figure xiv: Victimless Leather: A Prototype of a Stitch-less Jacket Grown in a Technoscientific 'Body', Oron Catts & Ionat Zurr (2004). The work consisted of a tissue culture in the shape of a jacket, probing the new relationships between nature and the artificial enabled by biotechnology.

The living nature of this work introduced additional complications and provocations. Living cells need feeding, but the only nutrient medium that can keep these particular cells alive needs to be extracted from cow foetuses, rendering the 'victimless' moniker empty and ironic. Thus the fantasy of "victimless" animal products has more the character of the disconnect we encountered in the touchscreen than that of a 'conversation with nature'.

These cells also need protecting since they have no way of protecting themselves. Tissue cultures like this are monocultures – they consist of a single kind of cell, without any immune system, and as such are extremely vulnerable to infection. As it happens, the Victimless Leather did become infected. Catts relates with glee how he had to interact with the work during the exhibition, administering antibiotics to the garment he had created in order to keep it alive. In a way nobody might have predicted or intended, the Victimless Leather grew its own layers of satire, to help its creator illustrate the limitations of synthetic biology.

Tampering

Biodesign might be defined as design in which living systems are used as a material. This gives biodesign two major distinctions from other kinds of design. First that the products of biodesign are in a state of becoming, rather than of simply being. Second, that the object itself possesses a kind of agency, expressed through survival, growth and, if it is allowed to reproduce, evolution.

Biotechnology – the means to manipulate life at the most fundamental levels – means many things to many people. To designers and engineers, the field carries great promise as a medium for making. Biological systems are programmable, self-replicating, self-healing and sustainable. As many a breathless funding application and conference headline has pointed out, biotechnology might be used to make materials or molecules, even whole functional devices. We could even turn the tools on our own bodies, and 'improve' on our evolutionary adaptations – or those of other species[*].

Yet designers and engineers are liable to take these capabilities in very different directions. Bioengineering is characterised by standardisation, certification, commodification and control. It seeks to use biotechnology to solve the problems of today: finding clean and limitless sources of fuel, for instance, or polymers, or pharmaceuticals. It presents biology as "an ideal future technology for making

[*] This has effectively already happened: there are a number of "model" species that are curated for use in experiments, from bacteria to mice, zebra fish, dogs and occasionally primates. Before testing a new drug on a mammal, for example, an analogue of the human disease may be induced in the creature by manipulating its gene code.

things"[62] – but is this technology actually well suited to meeting our current needs? Once again we encounter the distinction between engineering and design developed in chapter 1. As the technology for creating and altering life gathers pace, funded by corporate and governments, there is an urgent need to work out where we are going, and what we want to do when we get there.

For me, biodesign is a broad topic that probes the possible meanings of biotechnology. It is an intriguing field skittering back and forth between acceptable and unacceptable interference with nature – a line whose location is, of course, highly mobile, and dependent on cultural values.

Biotechnology blurs the line between the natural and artificial, creating new kinds of ambiguity and new liminal organisms, part natural, part artificial. If we discuss design as an interface with nature, biodesign portends an era of blending and splicing until the interface is invisible.

Chaotic flows

Our view of the 'balance of nature' has changed radically in the past hundred years. For much of history, there has been a pervasive idea that this balance was a given, to the point that attributes of the natural world were sometimes taken as a moral justification for social oppression[63]. The modern view, aided by the development of chaos theory[64] and cybernetics[65], and catalysed by a global man-made ecological catastrophe currently underway, is that all of nature is in a constant state of becoming, rather than being. Non-equilibrium is the norm, and what appears to be stability is really a momentary balance of competing flows[66].

Bound to our own biological frame, with our senses and our lifespan, we see the world through a narrow window in time and space. But thanks to technological progress, our view has broadened. Evidence is mounting that there are deep and uncanny connections between life-forms on this planet: we now know, for example, that tendrils of fungi called mycorrhizae link trees in a forest in a giant network, allowing nutrients to be 'banked', and information to flow between individuals[67]. We have also seen evidence of a two-way relationship between the microbes living in our gut and own biology and behaviour[68]. With each paper published, James Lovelock's Gaia hypothesis seems to move from convenient myth towards scientific reality.

Meanwhile, Oron Catts suggests that a choice is developing in our society. On one hand, we have the 'industrialisation of biology' – the current application of industrial techniques and attitudes to biological systems, resulting in 'efficient' monocultures, antibacterial resistance and ecosystem degradation. On the other hand, we have the 'biologisation of industry': smaller-scale production, which incorporates diversity, experimentation, evolution and symbiosis.[69]

Provocation/exploration

Many of the self-described 'biodesign' and 'bioart' projects we see today include elements of provocation. In this young field, designers are still exploring biological tendencies and concepts new to the design community (though not necessarily to biologists), and their social ramifications.[70] Yet I would argue that these are not intrinsic qualities of biodesign as a practice, but rather of a particular approach to the field, as the neophytes come to terms with the capabilities of the medium.

In the nineties, a group of designers started to probe the relationships and restrictions between form, function and human interaction in the case of electronic objects. Electronics have a looser relationship between the exterior appearance and inner workings than mechanical technologies that preceded them. The projects presented by Dunne and Raby in their book *Hertzian Tales* experiment with the unexpected, the unintuitive and the unhelpful, to question our cultural attachments and "explore design approaches for developing [...] aesthetic potential beyond a purely commercial context"[71]. In part, this kind of work is about using design experimentally to understand ourselves.

Yet despite the impact of these projects, it would be fair to say that most electronic objects today are not intentionally provocative. In a similar fashion, I believe that the true value of biodesign is not in the 'what if' but in the 'so what'. Like many emerging technologies, we are currently blinded by the possibilities – we are at the "peak of expectations", to borrow a phrase from Gartner[72] - after which comes the "trough of disillusionment". Technology, in other words, tends to become useful only after it has become boring.

One early, and quite simple, example of 'boring' (i.e. useful) application of biodesign might be bioconcrete. This techno-biological material contains a particular extremophile bacterial strain that remains dormant until exposed to water, whereupon it secretes calcium deposits. If and when cracks appear in the concrete, the dormant bacteria reawaken and 'heal' the material, recovering up to 90% of its strength[73]. This is an improved 'smart' version of a material that includes biological systems as part of the 'smartness'.

And yet - looked at another way, are we not co-opting another organism to do work for us? Once the bacteria have done their job, they run out of food and die. Is this a smart material, or inter-species slavery?

Ancient boundaries

Under the definition above, an English hedgerow might also be considered an example of biodesign, albeit one that does not involve a petri dish. These structures are formed from a mix of species of woodland trees, planted in a row and laid into an impenetrable barrier. Requiring some skill to create, hedges are a hybrid of craft and cultivation[74]. What can we learn about successful biodesign from hedges?

A hedge represents an alignment of interests of humans with other species. It is a symbiosis of growth and manufacture – it is both an object and a process – and its state of becoming is aligned with its function as a boundary.

Unlike the tissue culture jacket in *Victimless Leather*, a hedge consists of whole organisms, so it is resilient out in the open. Its constituents may still be subject to infection, contamination, pests and predators, but for all that, it is remarkably resilient. This is thanks to a number of factors, not least its species diversity. The form of a hedge is not a spontaneous one for its constituent species to take, and with no maintenance or intervention, the structure reverts and becomes functionally useless. Yet overbearing management is harmful[75]. The structure therefore demands a balance between design and self-determination.*

Comparing a hedge to more ‘high-tech’ examples of biodesign and bioengineering – the stuff of synthetic life and gene libraries – shows us that, if we want our creations to be usable outside sterile environments, we have to let them live. To do that, we have to be happy to give them a life of their own. This may sound dangerous (“How will we control it? What if it rebels against us?”) – the idea of not being in control may make the engineer in us deeply anxious. But to a biologist, control in this sense is a non-starter: evolution just happens. Moreover, it is not something to be feared: there is as much, if not more, cooperation in the wild than there is competition. What if, instead of attempting to control biology, our goal was to cultivate benign symbiotic relationships?

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* As a side-effect of the hedge’s structure and function as an impermeable boundary for livestock, it also becomes a haven for benign wildlife – especially species which tend to live at the edges of forests. Being made from woodland trees, and with open land on both sides, a hedge is like a forest edge without a forest.

Conclusion

Between us and nature, there is an ambiguous, negotiable territory, a richly textured and layered landscape constructed from our own culture, psychology, physicality and other factors. The more I have considered this landscape, through the examples in the three chapters of this dissertation, the more I have been drawn to the idea of conversation. Conversation suggests an exchange, a bipartisan relationship with something outside the self, both in the creation and in the use of objects. Conversation is a form of symbiosis.

At various points in history, the activity of gardening was regarded as a wholesome experience that put one in touch with the earth. In the twenty-first century, I suggest that we bring back the activity of gardening as a helpful metaphor for both designers and engineers. A garden is both an object and a process. In order to be successful and resilient, it must be planned well, and maintained (and better planning might mean less maintenance). The role of the gardener is that of cultivator, regulator and steward. The metaphor can only go so far: a real-life gardener does not create new plants to put in the garden from scratch. But it makes the point that in a garden, full control is neither possible nor desirable.

The novel Oryx and Crake is described by its author, Margaret Atwood, as a work of "speculative fiction"[76]. It draws on existing technology and social trends, extrapolating them to their logical, dark conclusions. Its world is populated by unquestioning consumers driven by 'hope and fear, desire and revulsion'[77], and its grotesque visions of supposedly victimless meat (the 'chickie-nobs' in the opening quotation of the last chapter) seem eerily prescient. To me, the world of Oryx and Crake is a world desperate to be in control, yet unwilling to come to terms with what that might mean. I am reminded of the opening line of the Whole Earth Catalog in 1968: "We are as gods and might as well get good at it"[78]. Needless to say, there is more to being a deity than technical proficiency.

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