UNNATURAL

The Heretical Idea of Making People

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Introduction
It's Not Natural

We know, of course, how to make people. Millions do it every day, and if they don't always succeed, my impression is that on the whole they enjoy trying. Needless to say, this book is not about *that* method – or rather, it is about where that method ends, and about what lies beyond it. And how, or whether, we can know where the boundary lies.

We can say with some confidence that the historical alternatives for making people – fashioning them from clay, from putrescent matter, from scavenged body parts – do not work. What is intriguing is that a consensus about the futility of these methods is relatively recent. That we did not notice their failure, or at least were not sure of it, for a long time tells us something interesting, and, I contend, something important.

First, it tells us that a belief in the possibility of making artificial humans, like all beliefs that lack a basis in objective fact – astrology, predestination, a heaven-and-hell afterlife – expresses deep-seated desires and anxieties. Second, the belief is wrong not trivially but in rather complex ways that are not just the result of ignorance – and in a particular sense it may not be wrong at all. Third, the mere fact that it is mistaken to think people can be made by these means does not banish the influence of that notion on our customs, assumptions, actions and judgements, and might sometimes perversely amplify it.

The idea of artificial procreation has never been more relevant than it is today. An allusion to the 'old' myths – to the alchemical homunculus, Faust, Frankenstein, *Brave New World* – is almost de rigueur in public discussions of assisted conception, 'designer babies', genetic modification, embryo research and cloning. Usually this is

nothing more than a knee-jerk reflex, made with scant regard to what precisely those words are supposed to invoke. Yet however lazy and unconsidered such journalistic references to Frankenstein are, they convey *something*. We think we know what they're getting at. And it is not something good.

Scientists engaged in new ways of 'making people' – what I here call 'anthropoeia', which condenses that phrase into its Greek equivalent – in modern times, such as those researching *in vitro* fertilization and cloning, often resent and lament these intrusions of myth and legend into their field of work. Here we are, the scientists will say, trying to improve medicine and to relieve man's estate – trying to *do good* – and all the rest of the world can see are Gothic ghouls and mad inventors. 'Whatever today's embryologists may do, Frankenstein or Faust or Jekyll will have foreshadowed, looming over every biological debate', said Robert Edwards, a pioneer of IVF, in 1989 at the height of the debate about research on the human embryos that IVF had suddenly made available. Edwards was impatient with the way, in his view, science-fiction narratives were shaping the discussion: 'The necessity or otherwise for experiments on human embryos sparks the most intense argument, as fears arise about tailor-made babies, or clones, or cyborgs, or some other nightmarish fancy.'

'The trouble really started way back in the 1930s, by courtesy of the brilliant Aldous Huxley', Edwards asserted. But he was wrong about that. Aldous Huxley did not conceive a tale that subsequently shaped thinking about embryo research, any more than did Mary Shelley, Robert Louis Stevenson or Goethe. Rather, they and other writers gave particular embodiments to pre-existing myths and legends that would have exerted their influence come what may. Edwards might well have wished that *Brave New World* had never been written, but as we shall see, Huxley's authorship of that novel was almost incidental; the ideas were firmly bedded down before he put pen to paper.

Edwards also failed to perceive the true role of fictional tropes of anthropoeia. It is not simply the case that there happen to be stories and legends that create inconvenient and misleading stereotypes. In the stories we tell about artificial people – how they are made, and what we assume they are like – we reveal some of our most profound feelings about what is natural and what is not, and about what this distinction implies in moral terms. For making people has always

been cause for moral judgement, which is at root a judgement about naturalness. As molecular biologist Lee Silver puts it, 'Nearly every literate person perceives *natural* as a synonym for good, whereas the opposite idea – unnatural, artificial, or synthetic – evokes a reflexive negative reaction.' As a result, he says, 'all naturalistic arguments against biotechnology are actually spiritual arguments in disguise'.

This connotation of the natural is, as we shall see, a historical construction. The German prefix 'un-' was attached in the early modern period to connote acts that were deemed reprehensible because they were *contra naturam*, against nature. As historian Helmut Puff says:

> Un-natural is not simply non-natural, the opposite of natural. By sheer weight of the rhetorical tradition and frequent usage in moralizing contexts, 'un-' words take on additional connotations, the other side of the norm. From the point of view of the speaker, 'un-natural' articulates a polemical stance. 'Un-' enunciations condemn that which is expressed, declare it as dangerous, treacherous ground . . . It is a word that polices the dangerous boundary between the normative and the non-normative, the pure and the impure . . . Un-natural connotes a wretched state that ought to bring about the most vocal condemnation. It is meant to activate, though the precise nature of the implied action remains undefined. Yet the emotional response solicited from the listener/reader by means of this wording is clear: horror.

Old stories and brave new worlds

Robert Edwards had ample reason to complain about the way his work was framed for public debate. When the UK government's provisional framework for regulating embryo research was released in late 1987, the *Today* newspaper covered it under the headline 'Clamp on Frankenstein scientists', while the *Sun* accompanied its report with a still from a Frankenstein movie. *The Times* spoke of 'creating babies from the dead', and even the *Independent on Sunday*, which was broadly supportive of embryo research, could not resist reporting on the Human Fertilization and Embryology Act of 1990 with a piece called 'Brave new embryos'. Opponents of the research worried that, to quote one British Member of Parliament, 'The ultimate goal may be to produce a child entirely *in vitro* or to produce genetically identical individuals by cloning.'

But the real story behind these headlines is complicated. The temptation for pro-research lobbies to present it as a case of benighted superstition and paranoia pitched against rational attempts to understand nature and improve the human lot – a rerun, if you will, of Galileo's persecution – has been undermined many times by scientists themselves. Indeed, in pronouncements of this sort, even the scientists were unconsciously drawing on old myths.

And it is quite wrong, perhaps dangerously so, to suppose as Edwards did that the public and the media have simply been hoodwinked by the stories of Huxley and Shelley. These, after all, are not the sources that induced Pope John Paul II to condemn IVF in 2004 by calling it 'a technology that wants to substitute true paternity and maternity and therefore that does harm to the dignity of parents and children alike', and to complain that the conjugal act 'cannot be substituted by a mere technological procedure which is devoid of human value and subject to the dictates of science and technology'. Yet in order to understand what truly motivates objections like these, we need to appreciate that they stem from the same tradition that created the science-fiction tales of artificial procreation – a tradition that predates the Christian Church itself.

So for the sake of a clear, honest and humane debate about how we allow, enable and assist people to come into being, it is time to bring these myths out into the open, and examine what they tell us about our fears, fantasies and fetishes concerning the idea of making people.

1 Art Versus Nature?

So, over that art
Which you say adds to nature, is an art
That nature makes.
William Shakespeare, *The Winter's Tale* (*c.*1611)

All Nature is but Art, unknown to thee,
All Chance, Direction, which thou canst not see.
Alexander Pope, *Essay on Man* (1733–4)

In our dealings with nature we cannot avoid thinking in metaphors of religious origin.
J. B. S. Haldane, *What Is Life?* (1949)

Making people artificially is a form of technology.

And that, some will say, is precisely what is wrong with it. For isn't technology, for all its undoubted conveniences, a cold, impersonal thing which should have nothing to do with the wonder of human procreation? Indeed, some would argue that to make reproduction a technological process is to divorce it from humanity entirely. 'Would not the laboratory production of human beings no longer be *human* procreation?' asked bioethicist Leon Kass in the wake of early reports on successful *in vitro* fertilization.

Quite what Kass meant by 'laboratory production' was not clear, but if, as one might suppose, a reasonable definition embraces the mixing of human ova and sperm in a Petri dish until they unite, or the injection of a spermatozoon into the ovum through a tiny syringe,

then his implication that people alive today as a result of such procedures are not the result of human procreation seems absurd and positively insulting. But of course, the matter of technological intervention reaches far beyond the techniques of IVF, for there are few pregnancies and births in the developed world that do not involve it to some degree. While that is not to the unalloyed advantage of mother and child, it does mean that the death or impairment of either of them is far less likely than in the days when procreation was a more 'natural' affair.

But why would Kass then say such a thing? Clearly, it has something to do with how he feels about the character of *technical* or *artificial* intervention in 'nature'. Now, my opening statement above is arguably little more than a tautology, for the root of 'art', *ars*, is only the Latin equivalent of the Greek root of 'technology', *techne*. Our instinctive aversion to the image supplied by this phrase focuses on the single concept embodied in those two words, artifice and technology: the concept of *art*, of human-made productions.

Yet what could possibly be wrong with *art*? The contemporary meaning we assign to this word embodies all that we deem noble in the human spirit: its creativity, imagination, capacity for wonder. Isn't the link between the works of Bach, Rembrandt and Goethe and the shuddering, oil-mired engines of industrial technology just an etymological curiosity?

Maybe that's how it seems to us now, but it is not at all how it appeared in the ancient and medieval world. For what literature and painting have in common with machines and synthetic materials is that they are all human-made: they are things that *do not exist in nature*. They are, in the literal sense, unnatural.

There we have it. What provokes us about the idea of 'making people artificially', of 'the laboratory production of human beings', is that it is unnatural. The logical absurdity of Kass's statement (and its illogic goes deeper, as we will see later) is illustrative of how instinctive feelings about what is and is not 'natural' trump any attempt to think the matter through.

I aim in this chapter to lay the ground for thinking the matter through. The distinctions that have been drawn in earlier ages between the natural and the artificial were in many ways subtler and more sophisticated than those we colloquially recognize today. We can show

now beyond question that the positions of the atoms in insulin or vitamin C made artificially – by industrial chemical synthesis – are identical to those in the same substances harvested from natural sources. Yet some people still prefer their drugs and food ingredients to come from the latter direction. This is not attributable merely to ignorance (although let's not deny that this may play a part), but stems unwittingly from old associations of the natural and the artificial that pervade the cultural atmosphere. In the ancient and early modern worlds these preconceptions were often more explicit, and therefore more productively explored.

Man the maker

Even the most ardent technophobe has to concede that making things – the skill of *techne* – is a part of what makes us human: we are as much *Homo faciens* as we are *Homo sapiens*. The debate about whether all technology should therefore be deemed 'natural' is, however, apt quickly to become arid. The better question, long discussed by the ancients, is how exactly our artefacts differ from the substances and objects we find in nature.

If one insists that there *must* be a difference, there is little left to discuss: art and nature simply yield distinct classes of things. But such a distinction was challenged by the discipline of alchemy. Historians of science are widely agreed now that alchemy was never primarily an esoteric, mystical quest to make gold, but was instead a practical technology used to create all the artificial substances that early cultures needed or desired: dyes, drugs, metals, soap, glass. All the same, alchemists *did* claim to be making gold – and that is what brought the art/nature distinction into focus.

The first alchemists, working in Egypt and Hellenistic Greece before about 200 BC, admitted that they were just mimicking gold, generally for decorative purposes such as gilding and painting. The methods and materials of this tradition are revealed in a pair of manuscripts called the Leiden and Stockholm papyri, thought to be fragments of a workshop manual written by an Egyptian artisan around the third century AD but compiling recipes from earlier sources. Among them are prescriptions for imitating gold, such as 'Giving objects of copper the appearance of gold'. There are hints that these procedures may

have had deceptive intent: this particular recipe, for example, assures the reader that metalsmiths will find it hard to detect the difference, while another set of instructions involving the alloying of gold with iron is called 'Fraud of gold'. But that is precisely the point: the author recognizes that he is making a kind of fake gold, which mimics the real thing in appearance only. Even when he suggests that the result might be better than what it mimics, that is no different from the sort of sales pitch made for modern synthetic replicas of natural materials.

Around 100 BC, this began to change. Now alchemists started to suggest they were actually replicating, and not just simulating, the precious metal. It was no coincidence that at the same time alchemy began to acquire a theoretical and mystical content, for the bold claim to be changing the fundamental nature of matter demanded philosophical justification. In the view of Zosimos of Panopolis, an early Christian Egyptian who lived around AD 300 and whose alchemical writings imply that the sole aim of this art is now transmutation to gold, metals consist of two parts: a 'body' (*soma*) and a 'spirit' (*pneuma*). It is in the *pneuma* that the defining characteristics of a particular metal reside, while the *soma* is apparently the same for all metals (Zosimos hints that it may be equivalent to the metal mercury). The *pneuma* can be evaporated from one metal – the 'freeing' of the metal's spirit – distilled, and united with another. Transmutation thus becomes equated with processes – the 'death' of a metal and its reanimation by transmigration of spirit – that were more commonly associated with living organisms, and especially with humankind. The notion of a spirit that can be liberated from one kind of matter and united with another also lay behind the ritualistic animation of statues, an aspect of the discipline known as theurgy. Such practices were deemed to give the animated matter special powers, so that statues might become oracles. They were also likely to be seen as dabbling with phenomena that once had been the preserve of the gods.

So efforts to justify and explain the alchemical claim to be *reproducing* nature, rather than simply simulating it, led very quickly to suggestions that the alchemists could manipulate and perhaps even induce life. According to the great thirteenth-century German scholar Albertus Magnus, alchemists act towards metals as doctors do towards

their patients. The idea that both are guiding their subjects towards a more 'perfect' state clearly extended beyond the realm of mere metaphor.

Makers or deceivers?

In the ancient and medieval Western world, Christian, Muslim and pagan alike deferred to the learning of the Greek philosophers, particularly Aristotle and Plato, on matters concerning the natural world. What did those writers have to say about the distinctions between art and nature, and the possibility of transcending them?

The central issue is deftly summarized by historians of science Bernadette Bensaude-Vincent and William Newman: 'Is *techne* a continuation of nature's activity, a rebellion against nature, or a challenge to nature?' In the first of these interpretations the technologist is simply helping along a process that occurs in nature anyway, and towards the same goal. In the second, he is performing something that cannot occur in nature, while in the third he is claiming to be able to make something superior to that which nature may produce. In either of these latter two views, one can say that the activity is or results in something that is *unnatural*.

In his *Republic*, Plato deplores the imitative feats of poetry and painting because of their deceptive character. Anyone, he scoffs, can replicate 'the sun and the heavens, and the earth and yourself, and other animals and plants, and all the other things', simply by holding up a mirror to them. But that would be to make the 'appearances only': a feeble feat of mimicry. There are three types of makers, says Plato. The highest is the divine Creator, who makes not actual things but the archetypes of things. Take a bed, for example. The Creator has made only one bed, what we might call the essence of a bed or, as we'd now say, the Platonic ideal of 'bed'. Then there is the carpenter, who makes individual instances of this ideal: an inferior sort of making, but nevertheless worthy and important, for this is after all an actual bed on which one might rest. The third 'maker' is the painter, who, however, does not truly make anything at all, but only the appearance of something. What good is that when you need a bed to lie on? Besides, it is only a single appearance: the bed made by a carpenter can be seen in the round, from any angle, but the painter can show

us only one view of a bed. He does not even have to know that it is a bed, or what beds are for. 'A painter', says Plato, 'will paint a cobbler, carpenter, or any other artist, though he knows nothing of their arts.' In short, the painter is a wizard, a shallow deceiver whose productions are not to be trusted. We venerate Homer, Plato says, and yet for what? All he gave us was a story, an illusion of the world, lacking in truth, wisdom and virtue:

> Had he in his lifetime friends who loved to associate with him, and who handed down to posterity an Homeric way of life, such as was established by Pythagoras who was so greatly beloved for his wisdom, and whose followers are to this day quite celebrated for the order which was named after him? Nothing of the kind is recorded of him . . . But can you imagine that if Homer had really been able to educate and improve mankind – if he had possessed knowledge and not been a mere imitator – can you imagine, I say, that he would not have had many followers, and been honoured and loved by them?

This astonishing attack on imitative art – 'an inferior who marries an inferior, and has inferior offspring', as Plato puts it – seems to reflect a common attitude in the ancient world, whereby mimesis was seen as a form of deception.

So much the worse for the fine arts. But some technological arts were also deemed to possess an unnatural character. In a book called *Mechanica* (*Mechanical Problems*), falsely attributed to Aristotle but probably written by another ancient Greek scholar,* mechanical machines are said to act 'against nature' because they can, for example, oppose the natural tendency of heavy objects to fall to the ground, instead lifting them aloft and thereby coercing them into a new, 'contra-natural' behaviour. Today, 'against nature' has a pejorative ring to it, and that connotation was not absent in ancient times. According to William Newman, 'the very term *mechanomai*, the verbal form of the Greek word for machine, was often used in a negative sense, to mean the act of deceitful contrivance'. Among the most notorious of such deceits were the moving statues and automata attributed to Daedalus (see p. 33).

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* Some think the author was the Pythagorean scholar Archytas of Tarentum, active in the fourth century BC, who was an acquaintance of Plato.

Not everyone took such a dim view of art. Indeed, on the whole the Greeks tended to regard *techne* as something intrinsically beneficial, and even Pseudo-Aristotle's *Mechanical Problems*, for all its talk of contravention, celebrates the triumph over nature that machines afford. To Aeschylus, the bestowing of technologies on humankind by Prometheus (examined in the next chapter) was an act of liberation. The Athenian poet Antiphon says that art enables humans to supersede nature where otherwise we would be subservient to it. From around the time that he expressed these sentiments in the late fifth century BC, Greek philosophers began to portray *techne* as a means of coercing nature, by force or even by 'torture', so as to gain mastery over it and transgress its boundaries. This was seen as a praiseworthy goal, or at least a useful one.

Aristotle himself was silent on the propriety of such coercion. He did, however, agree that art had its benefits. He said that it could act as a kind of handmaid to nature, correcting its mistakes as one artisan might correct those of another, and helping to bring it to a state of greater perfection. Here, nature and art necessarily act both in the same direction and towards the same end, because in Aristotle's teleological world nature was itself guided as if by intelligent agency towards making things as well designed as they could be: 'nature is a cause,' he said, 'a cause that operates for a purpose'. And so:

> if a house, e.g. had been a thing made by nature, it would have been made in the same way as it is now by art; and if things made by nature were made also by art, they would come to be in the same way as by nature. Each step then in the series is for the sake of the next; and generally art partly completes what nature cannot bring to a finish, and partly imitates her. If, therefore, artificial products are for the sake of an end, so clearly also are natural products. The relation of the later to the earlier terms of the series is the same in both.

This teleological aspect of nature, Aristotle said, was revealed by the 'design' of non-human artefacts and forms, such as the way animals seemed shaped and disposed for their natural role – an expression of 'purpose' that continued to baffle and confuse scientists until Darwin furnished an explanation of how it might arise in the absence of a designer. As Aristotle wrote:

> This is most obvious in the animals other than man: they make things neither by art nor after inquiry or deliberation. Wherefore people discuss whether it is by intelligence or by some other faculty that these creatures work, spiders, ants, and the like. By gradual advance in this direction we come to see clearly that in plants too that is produced which is conducive to the end – leaves, e.g. grow to provide shade for the fruit. If then it is both by nature and for an end that the swallow makes its nest and the spider its web, and plants grow leaves for the sake of the fruit and send their roots down (not up) for the sake of nourishment, it is plain that this kind of cause is operative in things which come to be and are by nature.

This is, then, why art must either imitate nature or supplement it, and in either case it acts in parallel. For Aristotle, and for many others who came after, *techne* was therefore not only a mimic of nature but actually provided a model for understanding how nature works: as in 'art', so in nature. For the Alexandrian anatomist Erastistratus in the third century BC, we might comprehend the heart's mechanism by reference to the bellows pump. By the same token, nature had many tricks to teach the technologist – a belief now very much back in vogue in the scientific field known as biomimetics. The Greek historian Diodorus Siculus claimed that Talos, the nephew of the great inventor Daedalus, invented the saw by copying in iron the shape of a snake's jawbone, which he found would cut through wood.* And echoing Aristotle's comment about 'houses' built in nature, the Roman architect and technologist Marcus Vitruvius Pollio asserted that the first houses built by men imitated the nests of swallows. In this view, how could technology be anything other than benign?

This correspondence between art and nature justified the way Aristotle used the terminology of technology to describe processes in nature. In his *Meteorology* he speaks of 'boiling' and 'roasting' – terms derived from cookery – in the context of natural phenomena, and equates such processes in nature explicitly with the methods of art:

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* In his *Natural History*, Pliny attributes Daedalus himself with the invention of carpentry. Daedalus is said to have murdered Talos, partly out of jealousy because his nephew's skills exceeded his own. For this crime he was exiled to Knossos, where he entered into the service of King Minos of Crete – a story that I pick up in the next chapter.

This, then, is what is called concoction by boiling: and it makes no difference whether it takes place in an artificial or a natural vessel, for the cause is the same in all cases.

Here, art and nature are placed on equal footing: artisans imitate nature when they carry out these processes in the kitchen or the workshop, and their vocabulary can be imported back into the natural world. This correspondence became a central theme in medieval alchemy, whose practitioners considered that their laboratory procedures represented in microcosm the transactions of macrocosmic nature, to the extent that alchemical transformation became the explicatory principle of all natural events: the circulation of water between sky and ocean, say, was a form of alchemical evaporation and condensation.

Inevitably, this two-way exchange blurred the boundary itself: art and nature began to look seamless. Even an apparently synthetic procedure such as glass-making might be called 'natural', because it uses natural materials – sand and soda, the latter for example as the mineral called natron – and processes them using extreme heat, which also occurs in nature – for example in volcanic regions. How, then, could the product be anything other than natural itself? After all, a kind of natural glass *did* sometimes turn up at volcanic sites where the earth's heat had melted sand.

Aristotle therefore allows the possibility that, by mimicking nature's processes, the artist might produce not merely an imitation of its products but something that genuinely warrants the description 'natural'. In his *Theorica et practica*, the thirteenth-century Italian writer Paul of Taranto offered an ambitious attempt to defend alchemy by aligning it with the natural philosophy of medieval scholasticism, and with Aristotelianism in particular. According to Aristotle, all substances are comprised of matter and form, and Paul remarked that art does nothing more or less than impress a new form into a natural substance. Yet he drew the Aristotelian distinction between incidental, superficial form – appearance, one might say – and intrinsic, substantial form. Sometimes art manipulates only the former, as in painting and sculpture, but other kinds of art bring about a fundamental change, working on what Paul calls the 'form of nature'. So there are certainly fraudulent and ignorant alchemists

who merely reproduce the appearance of gold – they are 'painters of metals' – but there are also genuine ones who transform a metal's essence.

There is something of Aristotle's viewpoint in the comments of Francis Bacon on the art–nature distinction in the seventeenth century. Bacon insisted that the emerging scientific enterprise needed experiments that led to practical outcomes: to artefacts, new substances and forms, novel technologies. For Bacon, true scientists are like bees, which extract the goodness from nature and use it to make valuable things. These included medicines, 'artificial metals', fabrics and machines – and also engineered life. In Bacon's utopian fable *The New Atlantis* (1627), the scientist-priests who rule the fictional land of Bensalem say that:

> We make, by art . . . trees and flowers to come earlier or later than their seasons; and to come up and bear more speedily than by their natural course they do . . . We have also means to make divers plants rise by mixtures of earths without seeds; and likewise to make divers new plants, differing from the vulgar; and to make one tree or plant turn into another. We have also parts and enclosures of all sorts of beasts and birds . . . By art likewise, we make them greater or taller than their kind is; and contrariwise dwarf them, and stay their growth: we make them more fruitful and bearing than their kind is; and contrariwise barren and not generative. Also we make them differ in colour, shape, activity, many ways . . . Neither do we this by chance, but by what we know beforehand, of what matter and commixture what kind of those creatures will arise.

Bacon has been credited with overthrowing entirely the old distinctions between art and nature. But he didn't completely deny that there was a difference, saying only that art may compel nature 'to do that which without art would not be done'. Like Aristotle, he says that art can help natural processes to go further than they would otherwise. Yet he insists that a production may be deemed artificial only because of the way it was made, and not because of what it is. Lamenting 'the fashion to talk as if art were something different from nature, so that things artificial should be separated from things natural, as differing totally in kind', he insisted that 'men ought on the contrary to have a settled conviction, that things artificial differ from things

natural not in form or essence, but only in the efficient' – that is, in the way they have been made.*

Until the seventeenth century, these issues were debated with the greatest heat and contention in regard to alchemy. Many historians of science have been tempted to pose the central battle of alchemy as an argument between those who believed that base metals can be transmuted to gold and those who did not. Recent scholarship has introduced more subtlety by showing that even renowned 'doubters', such as the seventeenth-century Anglo-Irish scientist Robert Boyle, were generally more concerned to draw a distinction between those who knew the 'true art' and the charlatans and bunglers who merely claimed to. But now we see that there is another facet to the disputes too: it wasn't necessarily a matter of whether or not you believed that gold could be made, but whether you thought the alchemists' gold was as good as that in nature. After all, it was almost universally thought that metals form in the earth by a process of maturation in which the lesser passes gradually to the greater: lead to iron to gold. The alchemist simply claimed to be inducing this 'natural' process at a faster rate in the laboratory. To the fourteenth-century Muslim polymath Ibn Khaldun, that was a crucial distinction: he argued that alchemical metals cannot be as good as natural ones because they are made too quickly. The maturation of metals cannot be speeded up without compromising it, he said, because 'Nature always takes the shortest way in what it does.' The falsehood of alchemists then lay not in passing one thing off as another, but in trafficking inferior goods.

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* Robert Hooke, examining natural and artificial objects through a microscope later in the century, did adduce a more concrete distinction relating to the issue of fabrication. He found that natural objects seemed more finely wrought: thorns, for example, were always sharper and smoother than pins. Compared to the fabulous intricacy of the fly's eye, human art seemed paltry and clumsy at the microscopic scale, no matter how elegant to the naked eye. 'So unaccurate is [Art]', he wrote in his *Micrographia* (1665), 'in all its productions, even in those which seem most neat, that if we examin'd with an organ more acute then that by which they were made, the more we see of their *shape*, the less appearance will there be of their *beauty*: whereas in the works of *Nature*, the deepest Discoveries shew us the greatest Excellencies.' This, however, is a far more materialistic distinction than that which could be applied to the 'essences' of substances natural and artificial, such as gold and minerals. It merely showed that God was a superior craftsman, which no pious observer – and Hooke was certainly that – would ever have doubted.

Alchemists challenged that prejudice. An anonymous work called the *Book of Hermes* dating from around the late thirteenth century says that 'human works are variously the same as natural ones', pointing out that several salts and minerals such as 'green salt' (probably verdigris), vitriol (metal sulphate salts), tutia (zinc oxide) and sal ammoniac (ammonium chloride) 'are both artificial and natural'. Indeed, the author claims, 'the artificial are even better than the natural' – which might have been true in at least one sense, given that the laboratory-made materials might be more pure. He adds (anticipating Francis Bacon):

> Nor does art make all these things, rather it helps nature to make them. Therefore the assistance of this art does not alter the nature of things. Hence the works of man can be both natural with regard to essence and artificial with regard to mode of production.

Even the 'artificiality' of alchemical methods is open to question, given that they mimic those of nature. In the 1330s, the Italian physician and alchemist Petrus Bonus argued that bricks, for instance, are not 'unnatural', for they are not fundamentally different to clay baked in the warmth of the sun. Petrus repeats the claim that substances and objects made by human art can be even better than their 'natural' analogues: nature can be improved. This is certainly one way to interpret Aristotle's comment that art may 'partly complete what nature cannot bring to a finish'.

Spirit of life

I have dwelt at some length on the debate over the alchemical transmutation of metals and minerals because many of the same ideas carry over to early theories of life. However peculiar it might seem to us to generalize from inert to organic matter – from metals to men – this was a natural extension within a world view that was in some sense animistic, in which all of creation was imbued with vital spirits. From ancient Greece to Renaissance Europe, it was widely held that there was a steady, progressive quickening of matter from the lowliest rock to the stuff of humankind. Metals were already considered to possess in some sense more 'animation' than stones –

they were known, for example, to be able to grow in curious branching forms that resembled plants. Plants themselves were still higher on the scale, having powers of growth, nutrition and to a limited extent movement. Animals were higher still, and finally humans.

This belief was the corollary of an Aristotelian view of matter in which a fundamental, undifferentiated substance (what was called by some Greek philosophers *prote hyle*) was given specific qualities by a 'spirit', a volatile ingredient located somewhere between the physical and the metaphysical. If all organisms are composed of the same basic matter, and if the spirits that define a particular substance can be sublimed and transferred, then it is only reasonable to suppose that matter lower on the scale can acquire a greater degree of animation – that it can be, as it were, brought to life. This was the rationale for the universal belief in spontaneous generation, in which simple animals such as insects and worms, even rodents, can spring from apparently lifeless matter. It was common enough, of course, to find such life thronging in putrid organic matter such as rotten food or carcasses. That spontaneous generation must to be preceded by decay had a parallel in the alchemical idea that metals must 'die' before being 'reborn' in a higher state.

Spontaneous generation from a warm, moist, fetid matrix was the canonical scheme in Greek thought for the origin of (non-human) life. Ovid's *Metamorphoses* puts it this way:

> All other forms of life the earth brought forth,
> In diverse species, of her own accord,
> When the sun's radiance warmed the pristine moisture
> And slime and oozy marshlands swelled with heat,
> And in that pregnant soil the seeds of things,
> Nourished as in a mother's womb, gained life
> And grew and gradually assumed a shape.

This transformation even furnished a kind of primitive evolutionary theory: Anaximander of Miletus in the sixth century BC said that fish grew from warm mud, and that from them humans eventually evolved.

Aristotle concurred that spontaneous generation is a real phenomenon, saying, for example, that lice appear this way in irritated skin. Each type of spontaneously generated creature was considered to

spring from its own specific matrix: bees from the carcasses of cattle, wasps from horses or donkeys, scorpions from crabs, snakes from decomposing spinal cords. There is some sense here that like begets like, a reflection of the emphasis on *form*: the Islamic philosopher Avicenna (Ibn Sina, *c.*980–1037) claimed, for example, that snakes may be made from the hairs of women, kept in a warm, moist place.

And just as alchemists purported to recreate the maturation of metals, so they began to assert that they could summon life out of lifeless stuff by an artificial type of spontaneous generation. There was a respectable pedigree for such claims in holy scripture, as Thomas Aquinas pointed out: Aaron turned his wooden staff into a snake in front of the Pharaoh, and the Pharaoh's magicians did the same trick using their 'secret arts'.* There was not necessarily anything esoteric about such knowledge; for the Roman writer Virgil, spontaneous generation of bees was simply a useful form of biotechnology for the bee-keeper – a craft known as *bougonia*. He supplies a recipe, making the creation of new life sound no different from the art of making wine or bread:

> They find a two-year calf with sprouting horns
> Whose nostrils and whose mouth they stop,
> Despite his struggles; beat and pulverize
> The carcass, while they leave the skin intact.
> Here enclosed they leave him, laying sticks
> And sprays of thyme and new-cut cinnamon
> Beneath his flanks . . .
> Meanwhile, within the corpse the fluids heat, the soft bones tepefy
> [become warm],
> And creatures fashioned wonderfully appear;
> First void of limbs, but soon awhir with wings.

It is understandable that this artificial generation of life should be regarded almost casually: in contrast to the transmutation of metals, almost any fool, trickster or careless housemaid could 'generate'

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* The Pharaoh's magicians also copied Aaron's feat of conjuring up frogs, but it is not clear whether this was an act of spontaneous generation or simply of summoning. See Exodus 7:8–12.

maggots in rotten meat. But again the persistent question about artifice arises: are these creatures the *same* as 'natural' ones? Not according to Avicenna, who wrote that 'Art is weaker than nature and does not overtake it', so that art cannot make products identical to those in nature. These words appear in a document known to the Latin-speaking medieval world as *Sciant artifices* ('Let the artificers know'), part of a work on geology and minerals, *Liber de congelatione et conglutinatione lapidum* (*Book on the Congealment and Concretion of Stones*), which was for some time believed to be the work of Aristotle himself (and thus to carry his full authority). Avicenna was here speaking only of alchemy in relation to metals, but his argument was later considered to apply to any form of art.

The Muslim scholar Averroes (Ibn Rushd, 1126–98), whose writings exerted a strong influence on the natural philosophy of the European Middle Ages, took much the same position but addressed explicitly the artificial production of life. Commenting on Aristotle's *De generatione animalium* (*On the Generation of Animals*), he says that creatures such as insects or mice made by spontaneous generation (whether by art or by chance) in rotten matter are quite different from those that result from sexual reproduction, even though they look identical, because they originate from different types of matter. In particular, he says, they are *sterile*. Remember that.

The response of the medieval world to the idea of 'artificial life' was thus quite different from the horror it now typically engenders, which must suggest to us that feelings of revulsion about these 'unnatural' creations are by no means inevitable. Medieval people saw nothing intrinsically *distasteful* in creating humans and other forms of life – the problem was rather that, as Averroes said, organisms made by art were, like alchemists' gold, a kind of fake. In defending their art, alchemists were therefore compelled to make counterclaims about the status of artificial beings.

But wasn't it hubristic to imagine that God's creations could be equalled, perhaps even bettered? That accusation gained strength as the Renaissance brought fresh vigour to the art–nature debate and stimulated interest in strange transmutations. The sixteenth-century Sienese engineer Vannoccio Biringuccio argued that if alchemists could really make the philosopher's stone then they could claim to 'hold prisoner in a bottle that God which is the creator of all these things'.

Later that century, the ceramicist and philosopher Bernard Palissy said of alchemical transmutation that it is 'a rash undertaking against the glory of God to wish to usurp that which is of his estate'.

Petrus Bonus had previously rejected accusations of impiety, asserting that alchemy was given to man by God so that we might improve on the raw substance of nature. Yet this line of defence did little to prevent Church prohibitions against the practising of alchemy by clerics, beginning in the late thirteenth century. One of the most important, a bull issued by Pope John XXII in the early fourteenth century, appears to label alchemists as charlatans and forgers who 'deceive the ignorant populace as to the alchemical fire of the furnace', thereby condemning them in secular terms as deceivers. But John XXII was also concerned about the alleged links between alchemy and sorcery (he had been the intended victim of an assassination plot using black magic), and his prohibition argued that transmutation is 'not in the nature of things': that it is improper for more fundamental reasons than mere trickery. And his accusation of deception does not itself necessarily imply intentional fraud for financial gain: it was often the mere *claim* to reproduce the substances of nature that led alchemists to be called fraudulent.

Nature's errors

Questions about whether nature can be rivalled or surpassed by art must confront the matter of how perfect nature is in the first place. There was good reason to believe that not everything in the natural world was wrought with skill, foresight and precision. Here is what the English traveller John Mandeville claimed to see in the fourteenth century on the islands around a region he called Dondun, probably in the East Indies:

> In one of these isles be folk of great stature, as giants. And they be hideous for to look upon. And they have but one eye, and that is in the middle of the front . . . And in another isle toward the south dwelt folk of foul stature and of cursed kind that have no heads. And their eyes be in their shoulders. And in another isle be folk that have the face all flat, all plain, without nose and without mouth. But they have two small holes, all round, instead of their eyes, and their mouth is flat also without lips . . .

His catalogue of monstrosities continues: people with horses' feet, with ears 'that hang down to their knees', with feathers. The monsters encountered in voyages to faraway lands are a familiar trope in the Middle Ages, and all are comparably incredible. But they *were* believed, as often as not, because folk knew that the world did spawn 'monsters' of one sort or another. The Florentine writer Luca Landucci recorded one that visited his home city in 1513:

> A Spaniard came to Florence, who had with him a boy of about thirteen, a kind of monstrosity, whom he went round showing everywhere, gaining much money. He had another creature coming out of his body, who had his head inside the boy's body, with his legs and his genitals and part of his body hanging outside.

Aristotle's close analogy between nature and art made it natural to regard 'monsters' as mere mistakes, like those even the best craftsmen would occasionally make. As he put it:

> Now mistakes come to pass even in the operations of art: the grammarian makes a mistake in writing and the doctor pours out the wrong dose. Hence clearly mistakes are possible in the operations of nature also. If then in art there are cases in which what is rightly produced serves a purpose, and if where mistakes occur there was a purpose in what was attempted, only it was not attained, so must it be also in natural products, and monstrosities will be failures in the purposive effort.

To Aristotle, monsters were contrary to nature only insofar 'as it holds for the most part': they deviate from the normal course of nature, but deviations are themselves intrinsic to the way nature works. One might say that monsters are thus 'contra-natural' without being exactly unnatural.

Aristotle was not burdened by the obligation to insist on God's perfection. But Christian writers could hardly assert that monsters were divine errors, and so they decided these beings must be intentional – that they signified God's purpose. To St Augustine, writing in the fifth century, monsters serve as divine warnings about the consequences of vice and folly. This significative role of monsters is reflected in the word itself, derived either (or equally) from the Latin *monstrare*,

to show, and *monere*, to warn.* In the Middle Ages, *monstrum* (monstrous) was almost cognate with *portentum* and *ostentum* as words connoting deviations from nature with portentous import. According to Isidore of Seville in the early seventh century, monsters 'predict future things', and 'come by the divine will'. As portents, they therefore have moral connotations: in Augustine's view, the monster delivers an admonition about degeneracy.

Mandeville's bizarre races were not viewed in quite the same way as deformed individuals. Wondrous species suggested that nature was strange, even perverse, but they were considered a part of the natural order all the same. Only monsters that differed in their deformity from others of their kind were *contra naturam*, and they therefore inspired horror where dog-headed men were merely cause for amazement. Isidore explained that monstrous babies did not live long because they did not need to: they had fulfilled their role as an augury once they were born. But were they, then, human, and did this mean they should be baptised? If they were conjoined twins, was one baptism needed, or two? No one knew the answers to these questions;† more surprisingly, as we shall see later, they are questions that have never really gone away.

It fell to Thomas Aquinas to reconcile Aristotle's view of monsters as nature's errors with Augustine's insistence on monsters being portents made by divine intervention. Yet for all his ingenuity in giving Aristotelianism a Christian interpretation, Aquinas could not do much more here than force an awkward marriage: violations of the natural order, he said, can sometimes be accidental (preternatural) and sometimes divinely arranged. 'The order imposed on things by God is based on what usually occurs, in most cases, in things', he wrote, 'but not on what is always done.' The sixteenth-century French surgeon Ambroise Paré hedged his bets to an even greater degree, listing a dozen causes of monsters that included the glory, or the wrath, of God, too much or too little seed involved in the generation, hereditary or accidental illness, too narrow a womb, and the intervention of

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* The Greek equivalent is *teras*, meaning portent. The modern study of anomalies in physical development – growth defects – is called teratology, and agents known to cause such defects are known as teratogens.

† A common rule of thumb relied on a head count: the number of souls was equal to the number of heads.

witchcraft and demons. In any event, he stressed, 'monsters are things that appear outside the course of Nature'.

That was the point: in the Middle Ages and the early modern periods, monsters might not necessarily be portents but they were aberrations loaded with moral baggage. Often they were caused by deviant acts or thoughts. Birth deformities could be the fruit of warped imagination in the mother during conception and gestation, or of unnatural unions: a 'dog-headed' child indicated that the mother had coupled with a dog. As biologist François Jacob expresses it:

> Each monster is the result of iniquity and bears witness to a certain disorder: an act (or even an intention) not in conformity with the order of the world. Physical or moral, each divergence from nature produces an unnatural fruit. Nature, too, has its morality.

Although Francis Bacon was not the atheist that some have tried to make him (he considered atheism 'in all respects hateful'), he had little time for a God who was constantly intervening in the world. He considered that nature ran by its own accord, and that monsters need be given no religious interpretation. But rather than dismissing them, *pace* Aristotle, as mere useless mistakes, he regarded them as a source of creative inspiration: rather than destroying nature's order, they suggested a new way in which things might be contrived. In this view, monsters and prodigies seemed to display in nature an innate creative potential, a capacity to evade its own rules. Later in the seventeenth century, Gottfried Leibniz argued that in its inventiveness nature displayed an intelligent autonomy, which in turn implied that nature herself had a kind of soul. Any form of novelty and curiosity of shape in nature was considered to be evidence of this soul at work. This was what led John Beaumont, describing 'stone-plants' (the mineral growths now called dendrites that look tree-like and organic) to the Royal Society in the 1680s, to award minerals a 'vegetative soul' like that postulated by Aristotle.

Although Leibniz cautioned against regarding nature's soul as akin to the rational soul of humankind, nonetheless views like his seem to personify nature as an artisan, making strange objects that had about them something of the 'artificial'. In other words, not only did art mimic nature, but vice versa. Yet if nature was an intelligent agency,

where did God feature? Might nature go its own way, heedless of God's design? As historians Lorraine Daston and Katharine Park remark, 'If philosophers deprived nature of skill and autonomy, it was out of openly voiced fear that she might usurp the praise due to God.'

This reawakened troubling questions that had emerged four centuries earlier in the wake of enthusiasm for Aristotle's mechanistic, rule-bound nature. Was nature God's servant, a contrivance that unfolded of its own accord so that God was spared the indignity of keeping it daily in motion? If so, could God nonetheless alter the laws, or was nature autonomous? You could argue it either way. To the seventeenth-century English physician Walter Charleton it was demeaning to suppose that God needed servants; he was in constant personal attendance in the world. Robert Boyle also rejected God's dependency on servants, but derived the opposite conclusion that the universe must therefore be entirely mechanistic, a complex device that operated as precisely and as regularly as the famously intricate clock made for Strasbourg cathedral, with its automata that observed the hours: 'all things', he wrote,

> proceed, according to the artificer's first design, and the motions of the little statues, that at such hours perform these or those things, [and] do not require, like those of puppets, the peculiar interposing of the artificer, or any intelligent agent employed by him.

Natural law

The occurrence of 'monsters' thus led to a rather subtle consideration of what 'natural' means. One view was that nature was a fallible craftsman; another was that these aberrations were ordained by God for specific reasons. In either case, one was left with no cause to attribute 'perfection' to nature.

The wresting of purpose from nature that has characterized the scientific enterprise for the past 200 years, particularly in Darwinian biology and in cosmology, has paradoxically forced a greater insistence on an idealized nature. The theory of evolution by natural selection seems at face value to provide a mechanism for the inexorable improvement and optimization of nature, and the modern desire to mimic biological shape and form in the applied sciences sometimes invokes

and fosters the notion that 'nature knows best' – that natural products are as good as they could possibly be. Evolutionary biologists know that this is an illusion. For one thing, there is no absolute 'optimum' towards which evolution can aim: the target is constantly shifting, because both the non-living and the living environments of any organism are always in flux. But in any case, evolution need seek only a solution that is 'good enough', providing the recipient with a marginal reproductive advantage. It generates ad hoc solutions with the materials at hand, and cannot easily go back to restructure the platform on which natural selection tinkers. So the natural world is full of botched designs such as the back-to-front neural wiring of the human eye, locked into place by 'accidents' of evolutionary history. Yet no matter how often biologists point out such things, or explain some of the (to our eyes) vile and pernicious strategies that predatory organisms use on their prey, we appear now to be saddled with a reified nature.

Let's be clear: humans do have a sad aptitude for fouling up the natural world. Nature often works in a delicately balanced fashion which human activities can easily send awry. But that is not because nature is good and *techne* is bad – it is because we are frequently clumsy, misinformed or stupid. Eradicating pathogenic viruses and microbes does not seem in principle like a terrible intervention, even if in practice we may sometimes do it blunderingly. Extinction is a natural process (which has killed off just about every species that ever existed) – we are bringing it about at an alarming rate now, but it is far from clear that there is any moral obligation to preserve species that would otherwise go extinct without any push from us. Nature doesn't know best; it is just that we usually don't understand or appreciate it sufficiently to know any better.

Today nature is seen as something amenable to objective scientific study: it is what happens out there in the world when we humans do not interfere. But the 'goodness' that is popularly attributed to this nature comes from another source, which is theological and philosophical. Thus the contemporary reification of nature arises from a confusion of terms: 'nature' as a physical and biological entity, and 'nature' as a predisposition. Because in Judaic, Christian and Islamic tradition nature was under God's jurisdiction and guidance, what happened 'naturally' was the result of God's will and therefore was good by definition.

2 Work of the Gods

A Greek it was who first opposing dared
Raise mortal eyes that terror to withstand,
Whom nor the fame of Gods nor lightning's stroke
Nor threatening thunder of the ominous sky
Abashed; but rather chafed to angry zest
His dauntless heart to be the first to rend
The crossbars at the gates of Nature old.

Lucretius, *On the Nature of Things* (*c.*50 BC)

A mighty lesson we inherit:
Thou art a symbol and a sign
To Mortals of their fate and force;
Like thee, Man is in part divine

Lord Byron, 'Prometheus' (1816)

The engineer is usually a humble fellow, narrowly goal-oriented, content to tinker with stolid diligence until he (it is usually he) gets the bridge built or the machine running. But when he abandons his humility, when he attempts to soar, to exceed the limits that his skill and judgement ought properly to impose, then he becomes mythical. Then he becomes a Prometheus.

To be Promethean is not, as some dictionaries imply, merely to be bold, original and creative, but also to be transgressive and hubristic. That is undoubtedly what Pope John Paul II had in mind when, alluding to the goals (as he perceived them) of modern biomedical research, he spoke of the 'Promethean ambitions' of science. But others find

Friend of man

Who made humans? That is usually regarded as the work of the gods. Many creation myths insist that the first people were fashioned from clay, mud, dirt: primal matter given a life-soul by supernatural means. The Egyptian god Khnum made humankind this way from the clay of the Nile basin; the goddess Nuwa formed the Chinese people from yellow earth. In the Book of Genesis, the Judaeo-Christian God 'created man of the dust of the ground'.

These creation myths insist on a continuum, or at least a negotiable boundary, between animate and inanimate matter. That continuity is also demanded by any purely scientific theory of life's origins on earth, but in myth this usually takes the form of a kind of animism in which life is immanent in all matter. Ovid's *Metamorphoses* describes all manner of such transitions between life and lifeless substance. He says that Prometheus' son Deucalion, the Greek equivalent of Noah, and his wife Pyrrha repopulated the world after the Deluge by making people from rocks thrown over their shoulders. The rocks are called 'the bones of your mother' by the oracle at Themis – meaning the 'bones' of the earth goddess Gaia, but imputing to them already a kind of latent vitality.

Plato says that, while humans were made by the gods 'out of earth and fire', Prometheus was instructed to equip them for the world:

> He found that the other animals were suitably furnished, but that man alone was naked and shoeless, and had neither bed nor arms of defence. The appointed hour was approaching when man in his turn was to go forth into the light of day; and Prometheus, not knowing how he could devise his salvation, stole the mechanical arts of Hephaestus and Athene, and fire with them (they could neither have been acquired nor used without fire), and gave them to man. And in this way man was supplied with the means of life.

Prometheus is usually identified as one of the Titans, the ancient race of deities whose battle with the Olympian gods is most probably a mythical retelling of the struggle between rival theologies in the ancient world. Prometheus saw which way that battle was turning

and threw in his lot with Zeus and the Olympians. He acquired architecture, medicine, metallurgy and other practical arts from Athene – whether by theft or study is not clear – and passed them on to humankind, making Zeus increasingly uneasy about the growing powers of men. In one account, Zeus decides to withhold fire from humanity because he is angry at how Prometheus tricks him into choosing the least appetizing parts of a sacrificial bull that is to be divided between the gods and men. But Prometheus steals fire and gives it to humankind, and in retribution Zeus condemns Prometheus to his terrible punishment in chains in the Caucasian mountains, eviscerated forever by a great eagle.

Later versions of the Prometheus myth by Aesop and Ovid make his role even more profound: he becomes not only the agent of humankind's ability to use fire, but the maker of humanity itself, whom he fashions from earth and water. This amplifies both the nature of Prometheus' defiance of the Olympian's authority and his role as friend of the human race. His very name makes him an omen of future knowledge: it comes from *promathein*, loosely meaning to think ahead or to understand in advance.

Fire and earth

The view of life as a union of base matter and spirit or soul – of life breathed into earth – finds echoes in Greek natural philosophy. There was no single 'theory of life' in ancient Greece, but many – and they are not always easy to distinguish or even to understand, because the philosophers were no more agreed than we are today on what life is or where it resides. Is it a kind of substance, or a property of matter? If the latter, is that property immanent within matter or imposed upon it?

There are at least two ancient Greek words that can be translated as 'life', reflecting an ambivalence about whether it should be defined empirically – by what we can see – or from first principles. To wit, *zoe* (the root of zoology and protozoa) refers to the sorts of behaviours associated with life (among which self-determined movement was seen to be crucial), while *psyche* refers to the intrinsic property of being alive, what we might call 'life-as-soul'. But underpinning all these ideas is the fact that the Greeks, and the Western world until

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