THE BOOK *of* BARELY IMAGINED BEINGS

As centuries pass by, the mass of works grows endlessly, and one can foresee a time when it will be almost as difficult to educate oneself in a library, as in the universe, and almost as fast to seek a truth subsisting in nature, as lost among an immense number of books.

Denis Diderot, *Encyclopédie*, 1755

In our gradually shrinking world, everyone is in need of all the others. We must look for man wherever we can find him. When on his way to Thebes Oedipus encountered the Sphinx, his answer to its riddle was: 'Man'. That simple word destroyed the monster. We have many monsters to destroy. Let us think of the answer of Oedipus.

George Seferis, Nobel Prize speech, 1963

THE BOOK *of* BARELY IMAGINED BEINGS

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A serious and good philosophical work could
be written consisting entirely of jokes.
Ludwig Wittgenstein

The world is full of magical things patiently
waiting for our wits to grow sharper.
Bertrand Russell

The true measure of a mountain's greatness
is not its height but whether it is charming
enough to attract dragons.
from a Chinese poem

The most barbarous of our maladies is
to despise our being.
Michel de Montaigne

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INTRODUCTION

On a bright afternoon in early summer a few years ago, my wife and I took our tiny new daughter out on a picnic. The air was so clear that everything seemed like a hyper-real version of itself. We sat down next to a bubbling stream on grass that glowed in the sunlight. After a feed our daughter fell asleep. I turned to a bag of books, magazines and papers which I tended to carry about in those pre-tablet days and which always contained far more than I had time to read on topics like ecological degradation, nuclear proliferation and the latest concessions made to torturers and criminals: the funnies.

Also in the bag that day was a copy of *The Book of Imaginary Beings* – a bestiary, or book of beasts, by the Argentine writer Jorge Luis Borges, first published in 1967. I had last looked at it almost twenty years before and had thrown it in as an afterthought. But as soon as I started to read I was riveted. There's Humbaba, the guardian of the cedar forest in *Gilgamesh*, the world's oldest known poem, who is described as having the paws of a lion, a body covered with horny scales, the claws of a vulture, the horns of a wild bull and a tail and penis both ending in snake's heads. There's an animal imagined by Franz Kafka which has a body like that of a kangaroo but a flat, almost human face; only its teeth have the power of expression and Kafka has the feeling it is trying to tame him.

There is the Strong Toad of Chilean folklore, which has a shell like a turtle, glows in the dark like a firefly and is so tough that the only way to kill it is to reduce it to ashes; the great power of its stare attracts or repels whatever is in its range. Each of these – and many others from myths and fables from all over the world as well as several from the author's own imagination – is described in vignettes that are charming, weird, disturbing or comic, and sometimes all four. The book is a bravura display of human imagination responding to and remaking reality. As I say, I was riveted – until I dozed off in the sunshine.

'All the creatures in this world have dimensions that cannot be calculated.' (Zhuangzi c.300 BC)

I woke with the thought that many real animals are stranger than imaginary ones, and it is our knowledge and understanding that are too cramped and fragmentary to accommodate them: we have *barely imagined* them. And in a time that we are now learning to call the Anthropocene, a time of extinctions and transformations as momentous as any in the history of life, this needs attention. I should, said this niggling thought, look more deeply into unfamiliar ways of being in the world of which I had only an inkling. And I should map those explorations in a Book of Barely Imagined Beings.

The present geological epoch used to be called the Holocene (derived from ὅλος – *holos* – whole or entire, and καινός – *kainos* – new) and referred to the 10,000 years or so since the end of the last Ice Age. In 2008 geologists agreed a new term, the Anthropocene, to acknowledge that humans are now the largest single influence on the Earth system. Typically, the new epoch is said to have begun with the large-scale combustion of fossil fuels

Normally I would shrug off such a half-formed idea pretty quickly. But this one refused to go away, and over the months that followed it became an obsession to the point where I could no longer avoid doing some actual work. The result is what you are holding in your hands: explorations and sketches towards a twenty-first-century bestiary.

We typically think of bestiaries, if we think of them at all, as creations of the medieval mind: delightful for their bizarre and beautiful images illuminated in gold and precious pigments from far-off lands. The Ashmole Bestiary, a thirteenth-century manuscript in the Bodleian Library in Oxford, is a good example. In one picture, a man dressed in red is watching a pot on a fire he has made on a small island in the sea, unaware that the island is actually the back of a huge whale. Meanwhile, a high-castled ship sails by, silhouetted against a sky entirely of gold. In another picture, barnacle geese, depicted in black, hang by their beaks from what look

like green, red and blue Art Deco trumpets but are supposed to be flowers on a tree. The text is often as entrancing as the pictures. The asp is an animal that blocks its ear with its tail so as not to hear the snake charmer. The panther is a gentle, multicoloured beast whose only enemy is the dragon. And the swordfish uses its pointed beak to sink ships.

But there is more to bestiaries than this. Along with zany pictures, bizarre zoology and religious parables, they contain gems of acute observation: attempts to understand and convey how things actually are. Undaunted by (and unaware of) the limits of the knowledge of their time, they celebrate the beauty of being and of beings.

A full account of the inspirations and origins of the great illuminated bestiaries of the High Middle Ages would refer to the great scientific works of the ancients, especially Aristotle's *History of Animals* written in the fourth century BC and Pliny's *Natural History* of 77 AD. And it would record how, via a text called *The Physiologus* and through the turbulent years after the sack of Rome (which included a plague that may have killed as much as half the population of Europe), extracts from these and other sources were combined with Bible stories and Christian teaching and shoehorned into compendia of natural history and spiritual teaching. (It might, along the way, allude to masterpieces of the Dark Ages such as the Lindisfarne Gospels, decorated on the Northumbrian coast around 700 AD with braided animal figures from the pagan north as well as mandala-like designs from the sunlit eastern Mediterranean.) But I want to trace something else: an older and more enduring phenomenon – one that predates even images such as the scenes of abundant bird life and dancing dolphins painted in, respectively, Egypt and Crete more than a thousand years before Aristotle was born.

At around 30,000 years old, the paintings in Chauvet Cave in France are among the oldest known. These images of bison, stags, lions, rhinos, ibex, horses, mammoths and other animals were made by artists as skilful as any working today. We will never know exactly what they meant for their creators, but

Lions in the Chauvet cave.

we can see that these artists had studied their subjects with great care. They knew, for instance, how the animals changed over the seasons of the year. As the paleoanthropologist Ian Tattersall writes, 'depictions sometimes show bison in summer molting pelage, stags baying in the autumn rut, woolly rhinoceroses displaying the skin fold that was visible only in summer, or salmon with the curious spur on the lower jaw that males develop in the spawning season. Indeed, we know things about the anatomy of now-extinct animals that we could only know through [their] art.' And we know from handprints stamped or silhouetted on the cave walls that people of both sexes and all ages, including babies, took some part in at least some of whatever took place here. We can see that the animals *mattered* to these people. The same species recur, but there are no images of landscape; no clouds, earth, sun, moon, rivers or plant life, and only rarely is there a horizon or a human or partly human figure.

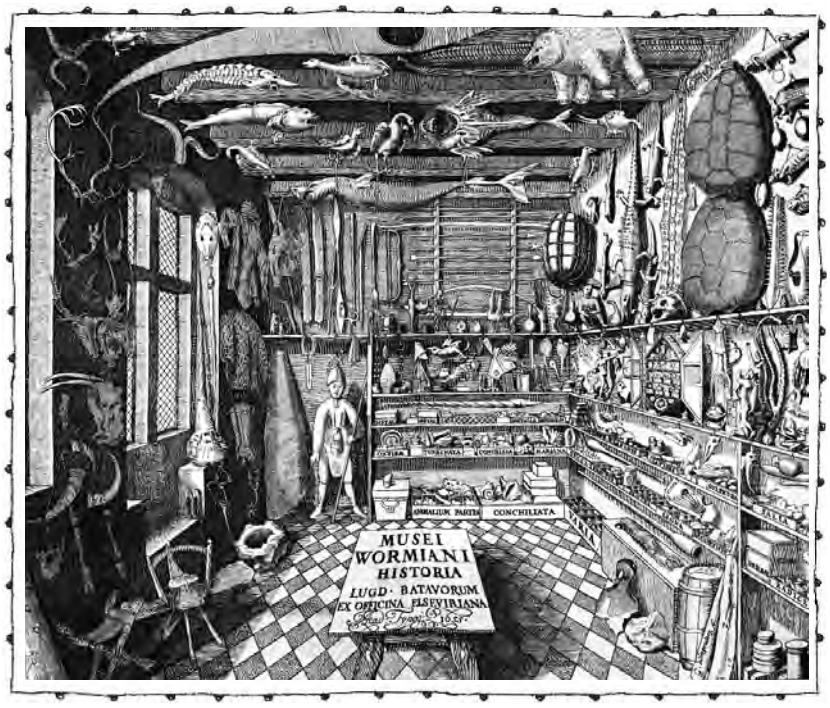
Perhaps, contrary to Plato's allegory of the cave, we sometimes only see the real once we have seen its shadow in art.

All this points to something obvious but which is, I think, so important that it is hard to overstate. And that is that for much of human history attempts to understand and define ourselves have been closely linked to how we see and represent other animals. Methods of representation may change but a fascination with other

modes of being remains. The cabinets of curiosities of the sixteenth and seventeenth centuries, for example, are in obvious respects quite different from the bestiaries of the medieval period. Bringing together actual specimens and fragments of exotic animals, plants and rocks, they helped pave the way for more systematic study of the natural world in the eighteenth century when the taxonomic system that we still use today came into being. But, like the bestiaries, these cabinets still had the power to enchant, as their German name, *Wunderkammern* ('cabinets of wonders'), attests. Today our fondness for curiosities and wonders is no less. From the *Wunderkammer* to the Internet is a small step, and the latter – containing virtually everything – is both the servant of science and an everyday electronic bestiary. From giant squid to two-faced cats, what we know about animals and what we don't, the amazing things they can do and the things they can't, the ways they never stop being strange or surprising, feature constantly among the most shared articles and video clips on the web.

The following seems to be true: our attention is often momentary or disorganized, but fascination with other ways of being, including that of animals, is seldom far from our minds, and gushes up like spring water from within dark rock in every human culture. We may be shameless voyeurs, passionate conservationists or simply curious, but we are seldom indifferent. Like our ancestors, we are continually asking ourselves, consciously or unconsciously, 'what has this got to do with me, my physical existence, the things I hope for and the things I fear?'

The selection of animals in these pages is not intended to be representative of what there is in the world. Still less is this book an attempt at a comprehensive work of natural history. And while I have made every attempt to get the facts right, I have not tried to produce a systematic overview of each animal but have, rather, focused on aspects that are (to my mind, at least) beautiful and intriguing about them, and the qualities, phenomena and issues that they embody, reflect or raise. In some respects, the arrangement resembles the one in a Chinese encyclopedia called the



Ole Worm's cabinet of curiosities, circa 1655.

Celestial Emporium of Benevolent Knowledge imagined by Borges:

> In its distant pages it is written that animals are divided into (a) those that belong to the emperor; (b) embalmed ones; (c) those that are trained; (d) suckling pigs; (e) mermaids; (f) fabulous ones; (g) stray dogs; (h) those that are included in this classification; (i) those that tremble as if they were mad; (j) innumerable ones; (k) those drawn with a very fine camel's-hair brush; (l) etcetera; (m) those that have just broken the flower vase; (n) those that at a distance resemble flies.

This book is envisaged as an 'aletheiagoria' – a new coinage so far as I know, which alludes to phantasmagoria (a light-projected ghost show from the era before cinema) but uses the word 'aletheia', the Greek

for 'truth' or 'revealing'. It suggests (to me, at least) flickering 'real' images of a greater reality. I have tried to look at a few ways of being from different angles and, through 'a wealth of unexpected juxtapositions', explore both how they are like and unlike humans (or how we imagine ourselves to be) and also how their differences from and similarities to us cast light on human capabilities and human concerns. The results are a little strange in places and, indeed, a little strained. Some of the analogies and digressions I have followed have little to do with the animals themselves. They are deliberate attempts to use the animals to think with, but not to think only about the animals. And, for all the digression, there are themes or strands that weave the book together.

Italo Calvino uses the phrase 'wealth of unexpected juxtapositions' to describe Pliny's *Natural History*, which divides (for example) fish into: 'Fish that have a pebble in their heads; Fish that hide in winter; Fish that feel the influence of stars; Extraordinary prices paid for certain fish.' And so it is in the essays (in Samuel Johnson's definition: loose sallies of the mind, irregular indigested pieces) in this book.

One theme of the book is how evolutionary biology (and the scientific method of which it is part) give us a richer and more rewarding sense of the nature of existence than a view informed by myth and tradition alone. Not only is it the case that, in Theodosius Dobzhansky's phrase, 'nothing makes sense except in the light of evolution'; it's also true that astonishment and celebration flourish when rooted in an appreciation of what can be explained. As Robert Pogue Harrison puts it, 'imagination discovers its real freedom in the measured finitude of what is the case'; it was Henry David Thoreau, a radical political activist as well as environmental visionary, who actually measured the depth of Walden Pond with a plumb line, not the 'practical' folk around him who said the pond was bottomless. In the words of Richard Feynman, 'Our imagination is stretched to the utmost not, as in fiction, to imagine things which are not really there, but just to comprehend those things which *are* there.' Thanks to evolutionary theory, the world becomes a transparent surface through which one can see the whole history of life.

Another theme is the sea. About two-thirds of the creatures headlining the chapters are marine. There are several reasons why this is so. For one, the world ocean is our distant origin and by far the largest environment on Earth, covering more than seven-tenths of its surface and comprising more than 95 per cent of its habitable

zone. (Recall Ambrose Bierce's definition: 'Ocean, n. A body of water occupying about two-thirds of a world made for Man – who has no gills.') And yet this great realm is far less known to us than is the land. It is our 'job' to know it better. As Bill Bryson has observed, nothing speaks more clearly of our psychological remoteness from the seas, at least until comparatively recently, than that the main expressed goal of oceanographers during the International Geophysical Year of 1957–8 was to study 'the use of the ocean depths as the dumping ground of radioactive wastes.' Only quite recently have we gone from seeing the world ocean as peripheral to beginning to understand that it plays a central role in the Earth system, including its climate and biodiversity, and so in our fate. And only recently have we begun to learn that the seas are rich with real rather than mythical beings that are strange and sometimes delightful in ways we would never have imagined – that there are, for example, creatures as tall as men which have no internal organs and thrive in waters that would scald us to death in moments, that there is a vast world of cold darkness in which almost all creatures glow with light, or that there are intelligent, aware animals that can squeeze their bodies through a space the width of one of their eyeballs.

The scale of human impacts on the ocean, the gravity of the consequences and an agenda for hope and practical action can be found in *Ocean of Life* by Callum Roberts.

Yet another strand running through the book concerns consequences of human behaviour. A few years ago I found myself in a snowstorm on a beach in the Arctic staring at a pile of fat, farting walruses. I was an afterthought, almost a stowaway, on an expedition of artists, musicians and scientists come by sailboat to the Svalbard archipelago (commonly known in English as Spitsbergen) to see for ourselves some signs of the momentous changes under way in the region, and to contemplate what's at stake. (The Arctic is warming more rapidly than anywhere else on Earth. The evidence overwhelmingly points to human activity as the cause.)

Walruses – bulky and comical on land but exquisitely agile and sensitive in the water – are among my favourite animals. Indeed, my daughter may owe them her existence because it was with a drawing of a walrus on a napkin that I first beguiled her mother. I am not alone in my inordinate fondness for these

beasts if the many films on the Internet of walruses performing aerobic manoeuvres in synchrony with trainers, playing the tuba and making very rude sounds are anything to go by. Nor is delight at walrus appreciation especially new. In 1611 a young one was displayed at the English court,

> where the kinge and many honourable personages beheld it with admiration for the strangenesse of the same, the like whereof had never been seene alive in England. As the beast in shape is very strange, so it is of a strange docilitie, and apt to be taught.

But all this amusement hides an uglier reality. For most of the last four hundred years Europeans laughed at walruses and then killed them – for fun, but mainly for profit – driving many populations (though not the species as a whole) to extinction. In their first encounter, in 1604, English sailors quickly learnt that walruses were not only harmless but rich in oil and furnished with splendid tusks, and both fetched good money. In 1605 ships of the London Muscovy Company returned to Spitsbergen to spend the entire summer killing walruses, boiling down the blubber for soap and extracting tusks. By the 1606 season they were so experienced that they killed between 600 and 700 full-grown animals within six hours of landing.

We twenty-first-century visitors, prancing about with caring-sharing environmental sensitivity, meant no harm, we most truly did not. But we had to get photos, so photos we got. And in our excitement, each wanting to get closer, we panicked the animals and sent them tumbling for the sea. The ship's captain was furious: walruses need their rest, and we were ruining it. Individually well-meaning (or so we believed), we were, collectively, small-time vandals. Writing in 1575, Michel de Montaigne asked:

> Who hath perswaded [man] that this admirable moving of heavens vaults, that the eternal light of these lampes so fiercely rowling over his head, that the horror-moving and continuall motion of this infinite vaste ocean were established, and continue

There's a larger point here, encapsulated by the novelist Ian McEwan in his account (reported in a newspaper article and then included in his novel *Solar*) of a scene of chaos on an expedition like ours that he joined the following year. The ship's boot room, a store for gear against the harsh conditions outside, quickly descended into chaos as people grabbed what they wanted without regard to who it belonged to. If, McEwan asks, people widely regarded as sensitive, intelligent and talented can't even manage a boot room, what hope do they have of saving the planet? As the philosopher Raymond Geuss puts it, 'don't look just at what [people] say, think, believe, but at what they actually do, and what actually happens as a result.'

> so many ages for his commoditie and service? Is it possible to imagine anything so ridiculous as this miserable and wretched creature, which is not so much as master of himselfe, exposed and subject to offences of all things, and yet dareth call himselfe Master and Emperour of this Universe?

This passage, which clearly influenced *Hamlet*, often comes to mind when I think of our experience with the walruses and other expeditions and experiments I have seen and participated in. It is a reminder of how thoughtless we can be of the consequences of our actions, but it also relates to another strand in the book.

Humans have much more powerful senses than we often realize. A young, healthy person can see a candle flame in the dark thirty miles away, and the human ear can hear down to the threshold of Brownian motion, which is caused by the movement of individual molecules. Still, other creatures have powers of perception – vision, hearing, smell and so on – that vastly exceed our own. In some ways their awareness of the world is superior to ours. And yet in at least one respect – consciousness – all (or virtually all) other animals seem to be greatly our inferiors. Not surprisingly we make a big deal out of human consciousness and identity. But a greater appreciation of the evolutionary inheritance and capacities we share with other animals – and of how, in some ways they surpass us – can contribute to better ways of thinking about the nature of being human and being otherwise.

Douglas Hofstadter suggests the 'I' is actually 'a hallucination hallucinated by a hallucination'. Spinoza thought that 'The ocean stands for God or nature, the sole substance, and individual beings are like waves – which are modes of the sea.' At the level of quantum mechanics, at least, Spinoza's intuition may be strictly true: 'The connections to all the things around you literally define who you are,' says the physicist Aaron O'Connell.

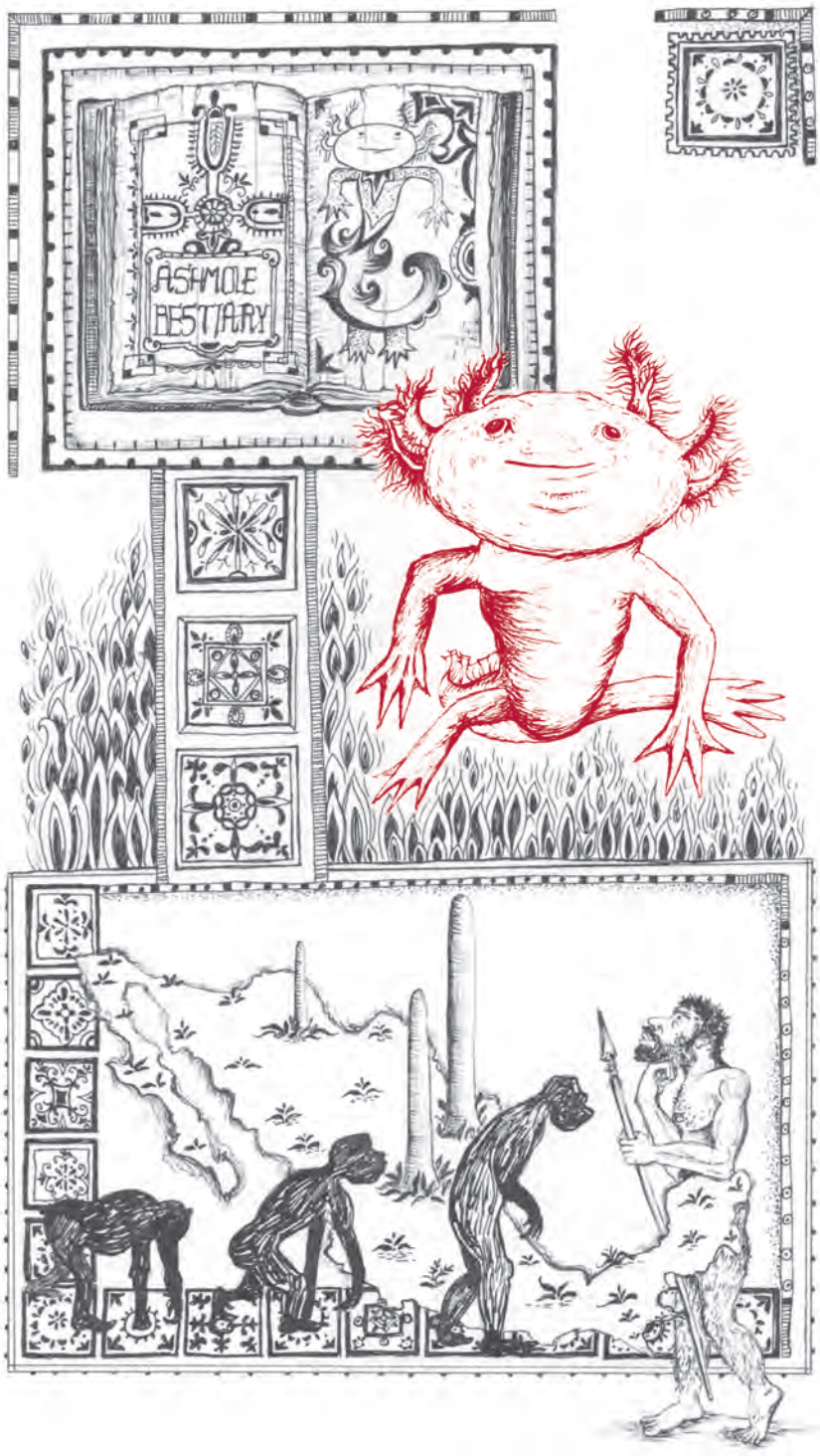
All these strands mentioned here, and others, including the question of how we perceive time and value over time, connect to a central question: what are our responsibilities as citizens of the Anthropocene to present and future generations? Medieval bestiaries described both real and what we now know to be imaginary animals. They were full of allegory and symbol because for the medieval mind every creature was a manifestation of a religious or moral lesson. Since at least Hume and Darwin many of us no longer believe this. But as we increasingly reshape Creation through science and technology, not to mention our sheer numbers, the creatures that do thrive and evolve are, increasingly, corollaries of

our values and concerns. The Enlightenment and the scientific method will, therefore, have made possible the creation of a world that really will be allegorical because we will have remade it in the shadow of our values and priorities. Perhaps the philosopher John Gray is right when he says that the only genuine historical law is a law of irony. This book – a stab at a bestiary for the Anthropocene, in which all the animals are real, evolving and in many cases threatened with imminent extinction – asks what we should value, why we fail to value and how we might change.

In *The Book of Imaginary Beings*, Borges describes the A Bao A Qu, a creature something like a squid or cuttlefish, which only stirs each time a human enters the dark tower in which it lives with the intention of making the arduous climb to the top:

> . . . only when it starts up the spiral stairs is the A Bao A Qu brought to consciousness, and then it sticks close to the visitor's heels, keeping to the outside of the turning steps where they are most worn by generations of pilgrims. At each level the creature's colour become more intense, its shape approaches perfection, and the bluish light it gives off is more brilliant. But it achieves its ultimate form only at the topmost step, when the climber is a person who has attained Nirvana and whose acts cast no shadows. Otherwise, the A Bao A Qu hangs back before reaching the top, as if paralysed, its body incomplete, its blue growing pale, its glow hesitant. The creature suffers when it cannot come to completion, and its moan is a barely audible sound, something like the rustling of silk. Its span of life is brief, since as soon as the traveler climbs down, the A Bao A Qu wheels and tumbles to the first steps, where, worn out and almost shapeless, it waits for the next visitor.

One can interpret Borges's strange story in many ways or not at all. Here I'll call it an allegory, and stick my own crude meaning on it: unless we enlarge our imaginations to better take account of the realities of other forms of being as well as our own, we miss our main task.


ASHMOLE
BESTIARY

AXOLOTL

Ambystoma mexicanum

Phylum: Chordata
Class: Amphibia
Order: Caudata
Conservation status:
Critically Endangered

. . . the Salamander, which feedeth upon ashes as bread, and whose joy is at the mouth of the furnace.
Christopher Smart

The history of the errors of mankind . . . is more valuable and interesting than that of their discoveries. Truth is uniform and narrow . . . but error is endlessly diversified [and] in this field, the soul has room enough to expand herself to display all her boundless faculties and all of her beautiful and interesting extravagancies and absurdities.
Benjamin Franklin

The first time you see an axolotl it is hard to look away. The lidless, beady eyes, the gills branching like soft coral from its neck, and the lizard-like body kitted out with dainty arms and legs, fingers and toes, together with a tadpole-like tail make this creature seem quite alien. At the same time the large head, fixed smile and flesh-pink skin give it a disconcertingly human appearance. Combined, such contradictory traits are fascinating. It's easy to see why one of the first European names for this creature translates as 'ludicrous fish'. The Argentine writer Julio Cortázar imagines a character gazing at an axolotl for so long and so intently that he *becomes* one.

A distant relation of the axolotl known as the Olm, or Proteus, also has pale pink, (European) human-like skin and external gills. It lives in streams in the limestone caves of Slovenia and is known as the 'Human fish'.

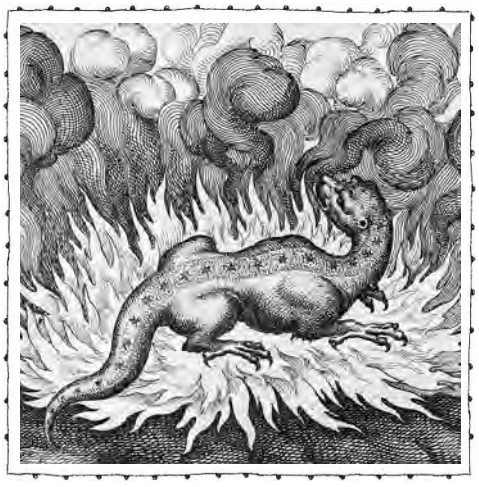
The comparatively sober findings of scientific research provide another reason to marvel. Along with its newt cousins, the axolotl is able to regenerate entire severed limbs. Some specialists in regenerative medicine believe that it may be possible one day to restore human limbs and even organs in ways derived at least in part from what we have learned from these creatures. If this does prove to be the case – and even if the potential for axolotl-like regeneration in humans is not as great as hoped – much will have been learned along the way about the workings of cells, which are perhaps the most complex objects in the universe apart from the human brain. And the knowledge

gained will be another step in the emergence of unequivocally better ways of understanding life and the relation of the human to the non-human.

But before trying to address such matters, this chapter will digress into what humans have believed about the order of animals to which the axolotl belongs, the actual role that the ancestors of that order played in evolution, and some of the errors people have made in interpreting the past and the present.

The axolotl is a kind of salamander, one of about five hundred species alive today. For thousands of years people believed that salamanders had a special relationship with fire. The *Ashmole Bestiary*, an illuminated book of beasts made in England in the High Middle Ages, mirrors this: 'The salamander lives in the midst of flames without pain and without being consumed; not only does it not burn, but it puts out flames.'

Few medieval authors or readers would have thought to test this claim. They wouldn't have seen the need. They already knew that every beast in Creation was a lesson in God's plan – or several lessons at once. In the case of the salamander, St



A mythical fire-salamander.

Augustine had, early in the Christian era, cited its fire-hardiness to bolster the case for the physical reality of damnation. 'The salamander', he wrote, 'is a sufficiently convincing example that everything which burns is not consumed, as the souls in hell are not.' Later commentators, by contrast, saw the animal's supposed non-combustibility as a symbol of righteousness: like the salamander, the chosen would withstand fire just as Shadrach, Meshach and Abednego had withstood the fiery furnace.

Zoroastrians do not worship fire itself. Rather, fire (along with water) is seen as an agent of purity: an individual who has passed the fiery test has attained physical and spiritual strength, wisdom, truth and love with serenity.

The union of salamander and fire actually predates Christianity and perhaps Judaism. 'Sam andaran' means 'fire within' in Persian, the language of Zoroastrians – early monotheists for whom fire was an important symbol of the divine. But there was more to the salamander in ancient and medieval minds than fire. According to the *Ashmole Bestiary*, it is also an animal of mass destruction:

> It is the most poisonous of all poisonous creatures. Others kill one at a time; this creature kills several at once. For if it crawls into a tree all the apples are infected with its poison, and those that eat them die. In the same way, if it falls in a well, the water will poison those who drink it.

'This Salemandre berithe wulle, of which is made cloth and gyrdles that may not brenne in the fyre.' (William Caxton, 1481)

These various attributes – fire creature, symbol of virtue, or poison – sit alongside each other in medieval European bestiaries. By the Renaissance, however, the connection with fire had come to dominate. An unburnable cloth from India is 'salamander wool' (this is probably an early mention of asbestos). For Paracelsus and other European alchemists, the salamander was the 'fire elemental', the essence of one of the four fundamental substances of the universe, which could be summoned to the practitioner's aid. A salamander amid flames also became a piece of branding for a king: a Nike swoosh for Francois I of France competing with Henry VIII of England at the Field of the Cloth of Gold. In the following centuries, storytellers from Cyrano de Bergerac to J. K. Rowling have rejoiced in the fantastic qualities of the fire-living salamander. For some it is entirely make-believe. For

others it is definitely real but extremely rare, like – say – the snow leopard today. The Renaissance artist, sexual predator and murderer Benvenuto Cellini provides a good example of this second view:

> When I was about five years of age, my father happening to be in a little room in which they had been washing, and where there was a good fire of oak burning, looked into the flames and saw a little animal resembling a lizard, which could live in the hottest part of that element. Instantly perceiving what it was he called for my sister and me, and after he had shown us the creature, he gave me a box on the ear. I fell a crying, while he, soothing me with caresses, spoke these words: 'My dear child, I do not give you that blow for any fault you have committed, but that you may recollect that the little creature you see in the fire is a salamander; such a one as never was beheld before to my knowledge.' So saying he embraced me, and gave me some money.

It's easy to see that if your only knowledge of the salamander came from bestiaries and the stories they inspired then a real sighting such as the one Cellini recalls would seem to confirm it. The actual explanation – that they like to sleep in cool, damp places such as piles of logs, get carried along when the wood is taken in for burning and, far from sporting in the flames, are writhing in their death throes – would seem dull and unconvincing.

The ancient Greeks and Romans had been more empirical, if not always right, in their claims. When Aristotle refers to a salamander in his *History of Animals*, written in about 340 BC, he makes it clear that he is relying only on hearsay in claiming that they walk through fire and in doing so put the fire out. And in the *Natural History*, written more than four hundred years later, Pliny distinguishes the salamander (an amphibian) from lizards (which are reptiles), describing 'an animal like a lizard in shape and with a body starred all over; it never comes out except during heavy showers and disappears the moment the weather becomes clear.' This is a good description of the golden Alpine salamander

and of some subspecies of the fire salamander. But Pliny also writes – in a passage that inspired later bestiaries – that a salamander is 'so cold that it puts out fire on contact' and that it can be toxic.

Pliny's *History* is full of things that seem fantastical and bizarre to our eyes. In Ethiopia, he writes, there are winged horses with horns, manticores, which have the face of a man, the body of a lion and the tail of a scorpion, and something called a catoblepas, which kills you if you look into its eyes. Even creatures we know to be real become fantastical. The porcupine, for example, can shoot its quills like spears. If a shrew runs across a wheel-rut it dies. Frogs melt away into slime in the autumn and coalesce into frogs again in the spring. The anthiae, a kind of fish, rescue their hooked companions by cutting fishing lines with their fins.

But while Pliny accepts, or reports, many claims that are plainly false to us, he is not entirely gullible. He is for example scathing about astrology and the afterlife, which are items of faith for vast numbers of people today. And when he realizes he doesn't know something, he says so plainly. In the case of the salamander he does at least start from observed reality. Salamanders are indeed 'cold-blooded' – more precisely, ectotherms, which means they take their temperature from their surroundings – so if found in a cool damp place they are indeed cool to human touch. You'd be ill-advised to lick a salamander, but it would be an exaggeration to call it more than mildly toxic. Fire salamanders, which are common on forested hillsides in southern and central Europe, extrude secretions onto their skin containing a neurotoxic alkaloid, Samandarin, when they think they are under attack. This can cause muscle convulsions, high-blood pressure and hyperventilation in small vertebrates. Perhaps this is their real 'fire within'.

For all the knowledge he compiled, Pliny concluded that 'among all things, this alone is certain: that nothing is certain, and that there is nothing more proud or more wretched than man'.

The *Natural History* is a remarkable attempt, perhaps the first in the West, to compile all knowledge. Still, Thomas Browne, the seventeenth-century English physician, is pretty unforgiving of what Pliny actually achieved: 'there is scarce a popular error passant in our days', he writes, 'which is not either directly expressed, or deductively contained in [it].' He tried

to put the record straight with the *Pseudodoxia Epidemica*, or *Vulgar Errors* (the *Bad Science* of its day, it ran to six editions between 1646 and 1672). Browne identifies the causes of popular delusions as, variously, 'erroneous disposition, credulity, supinity, obstinate adherence to antiquity' and 'the endeavours of Satan', but most of his energy goes on demolishing the delusions themselves. The myth of the salamander is one of 'fallacious enlargement', and is easily demolished by a bit of solid English empiricism: 'We have found by [our own] experience, that it is so far from quenching hot coals, that it dieth immediately therein.'

Browne was a practical man but he was also fascinated by symbols and mysteries. His *Garden of Cyrus* is an exuberant vision of the interconnection of art, nature and the universe. For Browne, God is a universal geometer, who places the quincunx (the X shape formed by five points arranged like the five spots on dice) everywhere in living and non-living forms. As W.G. Sebald notes, Browne identifies the quincunx everywhere: in crystalline forms, in starfish and sea urchins, in the vertebrae of mammals and the backbones of birds and fish and in the skins of various species of snake; in the sunflower and the Caledonian pine, within young oak shoots or the stem of the horsetail; and in the creations of mankind, in the pyramids of Egypt and in the garden of King Solomon, which was planted with mathematical precision with pomegranate trees and white lilies. Examples might be multiplied without end.

Given sufficient enthusiasm one can find the quincunx almost anywhere, including the salamander. As the 'fire elemental', it can be connected to the tetrahedron, the perfect form which Plato believed was the element that constituted fire. The tetrahedron is a 3-simplex whose 4-simplex analog is the pentachoron, a four-dimensional body which can be orphographically projected onto a quincunx (as well as a pentagram and other shapes). You could almost do the same for the code of life itself if you look no further than Rosalind Franklin's 'Photograph 51', which shows DNA in cross section as something like a quincunx.

The salamander reappears in a riddle unearthed more than fifty years after Browne's death when the Swiss physician and naturalist Johann Scheuchzer found a fossil of a creature whose large skull resembled that of a human child, he declared it to be *Homo diluvii testis*, or man, witness to the Great Flood: 'a rare relic of the accursed race of the primitive world'. And this judgement stood for another hundred years until the French comparative anatomist Georges Cuvier examined it. The fossil, he declared in 1812, was definitely not human. A positive identification, however, wasn't made until 1831: *Diluvii testis* was a giant salamander of a type now extinct but related to

the enormous creatures that are still found in a few Chinese and Japanese rivers.

Cuvier and others showed that many species that had once roamed the Earth were now extinct, and it was increasingly apparent that there had been vast periods of time before humans appeared. What, then, was our true place and role in Creation? For James McCosh, a philosopher in the once influential but now little remembered Scottish School of Common Sense, the answer was clear: man was the culmination of a process that had produced the ideal form in nature. 'Long ages had yet to roll on before the consummation of the vertebrate type,' McCosh wrote in 1857; 'the preparations for Man's appearance were not yet completed. Nevertheless, in this fossil of Scheuchzer's there was a prefiguration of the more perfect type which Man's bony framework presents.'

Words and phrases like 'consummation' and 'perfect type' are out of fashion today. 'Prefiguration' less so. Amphibian fossils *do* prefigure much of what we see in modern vertebrates, ourselves included. The bodies of salamanders alive today (not to mention those of geckos, grebes and gibbons) share a lot with ours. Salamander limbs may be smaller and slimier than those of most people, but they have essential similarities: they are encased in skin and contain a bony skeleton, muscles, ligaments, tendons, nerves and blood vessels. There are big differences of course – their hearts, for example, have three chambers rather than the four found in reptiles and mammals – but what's a ventricle between friends?

The palaeontologist Richard Owen, a contemporary of both James McCosh and Charles Darwin, thought such similarities, or homologies as he called them, were evidence of 'transcendental anatomy', of a divine plan, with God as a carpenter running off creatures on his workbench as variations of archetypal themes. (He called this the 'axiom of the continuous operation of the ordained becoming of living things'.) But, Owen insisted, each species was separate: one did not evolve into another, and man stood outside as a unique creation. Darwin, by contrast, argued that the similarities seen in so many living creatures,

including man, were better explained by descent with modification from a common ancestor.

Most of us now accept that humans are continuous in an evolutionary sense but we continue to insist that there are essential differences in our way of being. As the anthropologist Loren Eiseley wrote in the 1950s, man is a 'creature of dream [who] has created an invisible world of ideas, beliefs, habits and customs which buttress him about and replace for him the precise instincts of lower creatures'. Eiseley thought that 'a profound shock at the leap from animal to human status is echoing still in the depths of our subconscious minds'.

What could account for our apparently unique ability to be the carriers of such dreams in a way that creatures with superficially similar anatomy – like the salamander – are not? The answer pieced together by paleobiologists and geneticists over that last hundred years is, of course, that after diverging from a common ancestor with our nearest ape cousins, our hominid ancestors acquired much larger brains in a series of evolutionary spurts, notably in the last two million years, until they reached a form very close to ours less than 200,000 years ago. But there is a problem with such an account – at least I have stated it here.

The problem is not that this account is in any way misleading – it is not – but that it is too matter-of-fact; it fails to convey how singular it is that, after so many hundreds of millions of years of vertebrate life – much of it, as we shall see, filled with strange creatures resembling the axolotl – something as marvellous as the human brain evolved in such a comparatively short period of time.

People have looked for all kinds of ways to get around this counterintuitive truth. Among those that claim to be scientific here are two of the most delightfully absurd. In 1919 a distinguished English physical anthropologist named F. Wood Jones argued that large-brained proto-humans were actually tens of millions of years old and 'utterly unlike the slouching, hairy ape-men of which some have dreamed'. They were, rather, 'small active animals' resembling tarsiers,

'If you know how to look, our body becomes a time capsule that, when opened, tells of critical moments in the history of our planet and of a distant past in oceans, streams and forests. Changes in the ancient atmosphere are reflected in the molecules that allow our cells to cooperate to make bodies. The environment of ancient streams shaped the basic anatomy of our limbs. Our colour vision and sense of smell has been molded by life in ancient forests and plains.' (Neil Shubin, 2008)

A Tarsier.

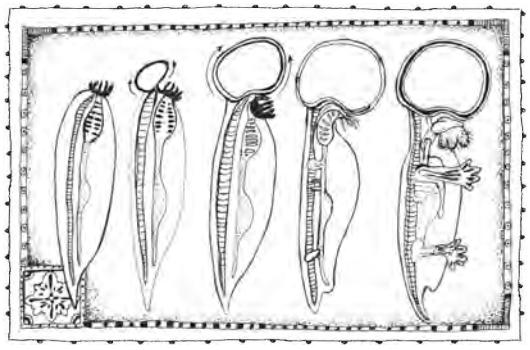
already endowed with legs longer than arms, small jaws and a greatly enlarged cranium.

Even at the time he advanced it, Wood Jones's hypothesis was at the outer edge of plausibility which is a pity, given how cute tarsiers are. Wilder still is the theory of initial bipedalism advanced by François de Sarre, which posits that human-like forms preceded not only all other apes but all tetrapods (that is, land animals with backbones: amphibians, reptiles, mammals and birds) and even fish. This homunculus, says this theory, actually evolved directly from an aquatic 'pre-vertebrate' that looked a bit like a lancelet, or amphioxus (a creature alive today that looks like a small and simple fish with a nerve chord but no brain or spine). Humans, therefore, have retained the most primitive body shape of all terrestrial vertebrates, and all the others – stegosaurus, snake and salamander, cow, capybara and coati – have evolved from it: we are the archetype from which all other vertebrates have arisen.

The coati, also known as the hog-nosed coon, the snookum bear or the Brazilian aardvark, is a kind of raccoon.

The theory of initial bipedalism claims that our lancelet-like ancestors evolved a bubble-like, gas-filled floating organ that helped control buoyancy.

At first, this acted as a float, allowing the little creatures to float like champagne corks with their bodies suspended vertically in the water. Two pairs of limbs and a little tail evolved to help the animals steer themselves in the water and they began to look like vertically-poised floating embryos, with axolotl-like branched gills sticking out of the neck. The globular head, meanwhile, allowed space for a big brain to develop. This aquatic homunculus then evolved endothermy (warm-bloodedness), body hair, ears, prehensile hands and live birth, and became the first animal to colonize the land.



Early stages in the development of the aquatic homunculus.

If this theory is absurd it is at least splendidly and originally so. And the *actual* shapes of our proto-amphibian ancestors are no less strange and fascinating.

Many scientists used to think that the first vertebrates to venture onto land were something like coelacanths – ancient fish with stubby fins – and that they wriggled out of the water *before* they evolved legs as we think of them, or lungs. The model in mind was probably the 'walking fish' such as the mudskippers we see today. This is now known to be wrong (although mere wrongness doesn't stop it from being the basis for an inventive and funny beer advertisement, *noitulovE*). Lungs and limbs came first, but the creatures that evolved them were still wholly aquatic.

Our, and the salamanders', ancestors, the first tetrapods (four-limbed vertebrates), evolved in the Devonian geological period, roughly 365 million years ago. They lived in slow-moving, shallow waters of estuaries or coastal swamps, rich in food and places to hide. In these conditions, 'fishapods', able to do push-ups on proto-limbs to gulp fresh air from just above its river habitat, would have had an edge over those relying only on gills to extract meagre oxygen from the murky water. Flexible necks and multiple digits – sometimes seven or eight on each 'hand' or 'foot' – evolved to help a body twist, finger and pick through the weeds and rotting logs.

What would their world have been like? Imagine yourself thrown back in time and washed up on the edge of a Devonian river mouth. It's warm, and you feel a little light-headed because the oxygen concentration in the air, at around 15 per cent, is lower than you're used to. But the water flows and the waves lap just as they always do, and this is reassuring. Looking at the sand beneath your feet, you half recognize something scuttling along the shallow lip of the water: it's a small version of the horseshoe crabs we know today. (Out to sea are placoderms – heavily armoured fish, some of them more than six metres (twenty feet) long and equipped with massive, powerful jaws. But they're out of sight so they don't trouble your glance.)

Moving inland, the vegetation on the riverbanks is bewildering. Nearby is something like a tree trunk: a tall round cylinder about eight metres (twenty-five feet) high with smooth sides and a rounded top. It vaguely resembles a saguaro cactus but without the spikes. This is the fruiting body of *Prototaxites*, the 'humungous fungus'. A little further away is a thicket of … well … nearly-trees, sporting ferns fronds rather then needles or leaves, arranged in odd, symmetrical umbrella-shapes. There are also stumpy things that look like green traffic bollards in various stages of emerging from the ground. And there are shrub-sized clubmosses, their stems close-packed with green scales, looking like bendy policeman's truncheons. You see some strange insects on the ground

and the plant stems, but there are none buzzing in the air – flying insects will not evolve for another sixty millions years. And there's no birdsong, of course: there won't be any for another three hundred million years.

Insect flight evolved less than 300 million years ago, in the Permian. Songbirds evolved in the early Eocene, less than 56 million years ago.

The meandering river mouth is a patchwork of weeds and deep pools. And there, through murky water, you glimpse something about the size of a ten-year-old child, poised delicately on short limbs that end in seven webbed digits. It has a tail rather like a newt's and a face somewhere between fish and frog. You are looking at *Ichthyostega,* and this species, or something very like it, may be our, and the salamander's, direct ancestor. This particular individual saw you coming, however, and quickly swims away: a ripple, then silence.

Three or four thousand years ago in Mesopotamia people imagined that a being called Oannes, half-man and half-fish, rose from the sea to teach wisdom to mankind. *Icthyostega* is emphatically not a supernatural being; it is just a tetrapod from the almost unimaginably remote past. And unlike Oannes, it does not 'teach' us anything in any direct sense. But if we allow it to exist on the water's edge of our conscious minds we may allow ourselves to learn more, feel more deeply about our own rootedness in antiquity and in the strange transformations that have unfolded deep in our past.

A primordial being that looks like a fish may seem a little silly but consider that until two or three thousand years ago giant carp and sturgeon, many of them larger than a man and weighing a tonne or more, were not uncommon in many Asian and European rivers. They must have been impressive presences, and would surely have set people to wondering. A few species of giant fish have hung onto existence in the Mekong and some remote rivers until very recently. Not all river-dwelling mythical beings are benign: the Nhang of Armenian lore, for example, is a river-dwelling serpent-monster with shape-shifting abilities that can lure a man by transforming itself into a woman, or changing into a seal and dragging him down to drown to drink his blood. Following the 2003 invasion of Iraq, river carp were said to be growing to the size of men on all the dead bodies thrown into the Tigris and Euphrates.

After *Icthyostega* there is a break in the fossil record of about twenty million years before there is evidence of amphibians that were completely at home on land.

Ichthyostega

Fossilization is rare in nature. Bill Bryson estimates that the entire fossil legacy of the approximately 300 million Americans alive, with 206 bones each, would amount to about fifty bones, or less than a quarter of one complete skeleton.

This gap may be filled one day. Whatever the precise details turn out to be, this transition was momentous: coming onto land from an environment where animals are essentially weightless was at least as great a challenge as the one an astronaut endures returning to gravity after a long time in space.

For over a hundred million years through the Carboniferous and Permian periods – five hundred times as long as anatomically modern humans have existed – amphibians were top predators on land. *Cacops* looked like a foreshortened crocodile crossed with a really big frog. *Eryops* resembled a monstrous salamander. *Prionosuchus* was, superficially, a dead ringer for a crocodile, only it was nine metres (thirty-three feet) long – much bigger than the largest saltwater crocodiles today. Other species kept the external gills of their larval stage into adulthood, like axolotls but well over twice the size. And at least one, *Diplocaulus*, had a head shaped like a large boomerang.

Amniotes – creatures whose eggs have protective membranes that prevent them from drying out on land – first evolved quite early in the Carboniferous. And, over time, descendants of the first amniotes evolved into reptiles (including the dinosaurs and later their descendants, the birds) and the beasts that eventually became mammals. Ultimately these new kinds of land-adapted vertebrates displaced amphibians in many niches on land, which is probably why this book was not written by a large frog. But it took a long time and there were bumps along the way. A little over 254 million years ago, for example, the greatest catastrophe in the history of life so far killed-off more than two thirds of all terrestrial vertebrates and 97 per cent of all marine life. Amphibians suffered even more than the amniotes. Even so, some survived. And, having ceded much of the ground to reptiles and protomammals, the ancestors of modern amphibians made a virtue of life in the niches remaining available to them. They exploded again (over geological time) into a diversity of beings stranger than anything you'll find in a medieval bestiary.

The last common ancestor of frogs, toads, salamanders and newts is the Elderly Frog of Dr Nicholas Hotton III, or *Gerobatrachus hottoni*. This amphibian Abraham, aka the frogamander, lived during the early Permian but was only discovered in 2007, a fossil in Don's Dump Fish Quarry in Baylor County, Texas. The frog/salamander lineage split during the next 100 million years, before the break-up of the supercontinent Pangea. Ancient frogs and toads became better jumpers, while salamanders specialized in slithering.

Consider *Beelzebufo*, a warty 'toad from hell' of Miltonic resonance as big as a super-size pizza. Behold *Nasikabatrachus sahyadrensis,* a rare purple frog as squishy as a bag full of jelly but tough enough to survive almost unchanged for 150 million years. Lo, the crab-eating frog, which lives in mangrove swamps and marshes, and is the only known modern amphibian which can tolerate salt water. Hail the Southern Gastric Brooding Frog, which – until it recently became extinct – swallowed its fertilised eggs and allowed the young frogs to develop into tadpoles and then froglets in the safety of its stomach before disgorging them on an eager world. *Ave*, the caecilians, an entire order which are neither frog, toad, nor salamander but, like the pelican of story, feed their young with their own flesh. And let Earth rejoice in the salamanders, wondrous in their more than five hundred kinds.

. . Princely counsel in his face yet shon,
Majestic though in ruin: sage he stood
With Atlantean shoulders fit to bear
The weight of mightiest Monarchies; his look
Drew audience and attention still as Night

The idea that the pelican feeds its young with its own flesh and blood was popular in medieval Europe, and the birds feature in bestiaries as a sign of piety and sacrifice and as a symbol of Christ himself. Caecilians do something similar for real. The young nibble fatty deposits on their mother's skin using special teeth unknown in other modern amphibians. The skin is so nutritious that the young can increase their weight up to ten times in the week after birth. It is the only known case of dermatotrophy – the deriving of necessary nutrients from the consumption of skin – in the animal kingdom.

It would take another Christopher Smart – the English poet best known for the *Jubilate Agno*, a paean to all creation (but most especially his cat Jeoffrey) – to celebrate all these beings: to write a *Jubiliate Amphibio*. And it would take another William Dunbar – the Scots author of the *Lament for the Makars*, a roll call of poets and friends taken by death – to lament the passing of so many in what, on current trends, looks likely to be the greatest amphibian extinction since the Permian.

The axolotl is a member of the Mole salamanders, a genus found only in North America, and one of a handful of species found only in the highland lakes of Mexico. There are two explanations for its name. One connects it to Xolotl, the Aztec god of fire, guide of the dead, and sometime bringer of bad luck. In a story associated with the legend of the Five Suns, Xolotl (who has backwards feet and the head of a dog) transforms into an axolotl. A second explanation says the name comes from *atl* and *xolotl*, the words for 'water' and 'dog' in the Nahuatl, the language of the Aztecs. As the popular names of other species of salamander, such as snot otter and mud puppy, testify, the larger salamanders can look a little like dogs underwater. This would be all the

more the case if your idea of a dog is of the 'hairless' breed common in Mexico.

The axolotl makes at least two entrances into the theatre of European taxonomy. The first is via the pen of Francisco Hernandez, a sixteenth-century Spanish naturalist who recorded its native Nahuatl name and came up with *piscis ludicrous* – the ludicrous fish. The second is in 1789 when the English zoologist George Shaw, who was also the first European scientist to examine a platypus, assigned it a place in the Linnaean firmament. In 1800 the German naturalist Alexander von Humboldt shipped two live axolotls, along with fossilized giant elephant bones and other goodies, to Georges Cuvier – he of the giant primeval swamp salamander – in Paris. Cuvier decided axolotls were the larval form of an unknown air-breathing species, and seems to have left it at that. It was not until sixty years later that scientists, also in France (and benefiting from their country's attempted conquest of Mexico), first studied one of the axolotl's most remarkable features: the fact that it was a reproducing adult even though it looked like a 'tadpole' – that is, a juvenile – but that it could also, mysteriously, transform itself into what looked like another species altogether.

When a new species evolves which has traits as an adult that were previously seen only in juveniles the phenomenon is known as 'neoteny'. It can be observed in a variety of animals. Adult ostriches, for instance, have tufty wee wings similar in proportion and appearance to those of the baby chicks of their ancestors. Humans are reckoned to have as many as twenty neotenic traits, including a small jaw and large head that make us look more like baby gorillas or chimps than 'proper' adult apes. But staying 'immature' doesn't mean you have to be small or sexually dormant. The ostrich is the biggest living bird, and humans are not exactly unsuccessful breeders.

One of the most conspicuous differences between humans and other apes – brain size – is more accurately described as the result of heterochrony rather than neoteny. Brain and head growth in the chimpanzee fetus starts at about the same developmental stage and presents a growth rate similar to that of humans, but ends soon after birth. In humans, rapid brain and head growth continues for several years after birth.

The phenomenon of neoteny has been pressed into service to explain or connect all kinds of things, but it has not always been clear where science ends and where metaphors begin. Aldous Huxley, the

author of *Brave New World* (1932), toyed with the increasingly fashionable idea that humans were neotenic apes and that if human life were extended indefinitely we would become like other apes – hunched, hairy and sitting in our own mess on the floor. His inspiration, at least in part, was actual experimental work on axolotls undertaken by his older brother Julian, one of the leading evolutionary biologists of the first half of the twentieth century, who turned them into something that looked very like their relatives the Mexican tiger salamanders by injecting them with a hormone.

Aldous Huxley was wrong about what would happen if humans were able to live indefinitely, but his theory was, perhaps, no less grounded in reality than another idea popular in his time and still influential today: recapitulation theory. This notion, first put forward in 1866 by the German naturalist Ernst Haeckel, and popularly known as 'ontogeny repeats phylogeny', holds that each creature replays the history of life in the course of its individual development up to the point at which its particular species first appeared. Humans, for example, start out at conception as tiny cells just like the first life, and progress via embryonic stages in which they are fish-like, complete with gills, through a mammal-like stage, complete with a tail, before finally emerging as the 'advanced' beings we are today.

Recapitulation theory also seemed to fit with the idea of progress popular in nineteenth- and early twentieth-century Europe and as such was extended to support 'scientific' racism and imperial expansion: the children of the 'advanced' European race, it was believed, were on the same level as the adults of indigenous populations, especially those in Africa who, in Kipling's now notorious phrase, were 'half devil and half child'. And the swarthy natives were (supposedly) very like the apish proto-men of the distant past. White children passed through these stages on their way to becoming the most advanced form of human being.

Many of the most astute minds of the age bought into this theory. Sigmund Freud added a new parallel:

Some scientists think that chordates, the phylum including all vertebrates, evolved as the result of neoteny. Among the nearest living relatives of chordates are sea squirts, or tunicates – sack-like marine filter feeders that superficially resemble sponges. As a larva, the sea squirt swims about, wriggling by means of a notochord, a rod-shaped body made of cells from the mesoderm that resembles a primitive backbone similar to the one in chordate embryos. Maturing, they stick onto rock and lose the notochord. The geneticist Steve Jones compares this life cycle of a sea squirt to that of an academic given tenure: after an active life, it settles on the sea floor and absorbs its brain.

a healthy European child was going through the 'primitive' stage in which non-European adults and early man had got 'stuck' (as, he believed, had neurotic European adults). And an adult from a 'primitive' (non-European) culture and early man were, he said, like a normal modern child: they were 'trapped' in early stages of the unfolding. It inspired Freud's colleague, the Hungarian psychiatrist Sándor Ferenczi, to write a book called *Thalassa: A Theory of Genitality* (1924), in which he argued that that much of human psychology is explained by our unconscious yearning to regress to the comforting confines of the womb-as-sea. Ferenczi saw the full sequence of human life – from the coitus of parents to the final death of the offspring – as a recapitulation of the gigantic tableau of our entire evolutionary past. Impregnation recapitulates the dawn of life. The fetus, in the womb of its symbolic ocean, then passes through all ancestral stages from the primal amoeba to a fully formed human. Birth recapitulates the colonization of land by amphibians and reptiles, while the period of latency, following youthful sexuality and before full maturation, repeats the torpor induced by ice ages.

For the radical environmentalist philosopher Paul Shepard (1982), contemporary Americans were childish adults suffering from ontogenetic crippling – culturally induced neoteny gone wrong.

Haeckel's theory and the enthusiastic application of it in politics and psychology as well as in biology arose at the high point of European global expansion and conquest. The axolotl was present at a key time and place of that expansion's beginning: the Spanish conquest of Mexico. And though devastated by the consequences, it has survived as a captive (the axolotl reproduces very well in the lab and the aquarium) to play an unwitting role in the development of a more sophisticated world view which, we may hope, promises something better for both humans and salamanders.

Hernán Cortés and his men entered the great central valley of Mexico in November 1519. The chronicler records:

> When we saw all those towns and villages built in the water, and other great towns on dry land, and that straight and level causeway leading to [the city of] Mexico, we were astounded. These great

> towns . . . and buildings rising from the water, all made of stone, seemed like an enchanted vision . . . Indeed some of our soldiers asked whether it was not all a dream . . . It was all so wonderful that I do not know how to describe this first glimpse of things never heard of, seen, or dreamed of before.

It must have looked a little like Venice, only with the twin cities, or *altepetls*, of Tenochtitlán and Tlatelolco dominating Lake Texcoco, the largest of five shallow bodies of water in a broad valley surrounded by volcanic mountains rather than a marsh and lagoon on the edge of the sea. Tenochtitlán (which the Spanish called Mexico), Tlatlolco and the cities on the other lakes fascinated the Spanish with their rich markets, huge public buildings, hanging gardens, not to mention the prostitutes who painted their teeth black to enhance their allure.

The wealth of the cities, and their ability to muster armies numbering tens and possibly hundreds of thousands, depended on highly productive agriculture. *Chinampas* – sometimes called 'floating gardens' but actually artificial islands in the lakes – played a key part in this, supplying maize, beans, squash, amaranth, tomatoes and chilies in abundance. The waters surrounding them were rich in fish and other edible creatures, not least axolotls, which the locals ate with gusto.

The valley of Mexico is endorheic, which means it has no natural outlet to the sea. At a glance it looks flat but, like the bottom of a bathtub, one end is actually slightly higher than the other. The lakes that once covered much of it are all but gone, but when they did exist those at the higher end – Chalco, Xochimilco (both spring-fed) and Tlcopan – had the sweetest water. Downstream, the larger lakes and marshes of Texcoco, Xaltocan and Zumpango became saltier as water evaporated away.

The most productive agriculture needed the sweetest water, and this was also the favoured home of the axolotls (like almost all extant amphibians, they abhor salty water). Indeed Chalco and Xochimilco are their

only recorded habitat, and they appear to have thrived there even with a substantial human presence.

The Spanish conquest is one of the most dramatic events in recorded history: Cortés and a few hundred men defeated an apparently mighty empire able to muster tens of thousands of troops. Cunning, audacity, speed and ruthlessness were key; but (as Napoleon Bonaparte would have appreciated) Cortés was also *lucky*. Yes, he had horses, steel swords and guns (quite unknown in the New World). And yes, crucially, he had the help of many local enemies of the Aztecs. But even more importantly he had something on his side that no one had yet learned to control: smallpox. The indigenous people had no immunity to the disease and died in enormous numbers. (Just how many has been disputed, but it may have been as many as four out of ten people in a matter of weeks.) The toll included a lot of the best leaders and soldiers, and those who survived were often terribly weakened. Agriculture all but collapsed, and those who escaped the worst effects of the disease starved – or, if they survived, were deeply traumatized. To amalgamate Paul of Tarsus and Jared Diamond, 'So abideth these three: guns, germs and steel; but the greatest of these is germs.'

Contemporary accounts are harrowing. A Spanish monk wrote: 'as the Indians did not know the remedy of the disease they died in heaps, like bedbugs. In many places everyone in a house died and, as it was impossible to bury the great number of dead, they pulled down the houses over them so that their homes become their tombs.' When Cortés finally defeated the Aztecs in the last battle for Tenochtitlán, it was said the Spaniards could not walk through the streets without stepping on the bodies of smallpox victims.

Smallpox causes a painful rash on the skin and for the Aztecs the disease was *huey ahuizotl*, the great rash. *Ahuizotl* was also the name of a legendary lake creature that liked to eat human flesh – something like axolotl's horrible twin. It was said to look something like a dog or an otter, with human hands and an additional hand on its tail which it used to snatch prey and drag it beneath the water.

Fear, mystery and an ambiguous border between life and death have a long history in these lands. The Tlatilco culture, which occupied the western shore of Lake Texcoco and the eastern shore of Lake Chalco from about 1200 to 200 BC, left behind some extraordinary, beautiful and haunting artefacts, including figurines that are two-headed or otherwise deformed. The name 'Tlatilco' was given to this culture by Nahuatl speakers, who arrived long after it had disappeared. It means 'the place of hidden things'.

Ahuizotl

Mexico City has long since metastasized into a sprawling, heavily polluted megalopolis with more than twenty million inhabitants. This transformation would not have been possible without one of the largest drainage programmes ever undertaken. The diminution of Lake Chalco, the axolotl's stronghold, began in colonial times (already, in one of the key battles of the conquest, the Spaniards had demolished a great causeway that had separated sweet and brackish water) and it finally gurgled away like water down a plughole through massive artificial tunnels in the twentieth century. A remnant of Lake Xochimilco, the animal's other home, survived a little longer; it was serviceable for the rowing and canoeing events of the 1968 Olympics. But now all that remains of it are a few polluted canals and reservoirs in which a small and critically endangered population remains.

The neoteny of axolotls and other gilled salamanders may once have been an excellent survival strategy: the ability of breeding adults to continue to live underwater in the highland lakes may have given them an advantage over cousins that matured to the land-dwelling stage. Now it is a disadvantage: the lakes are drained, polluted or subject to other human pressures that are driving these animals to extinction in the wild. Their continued survival is probably down to their appeal and their usefulness to human beings.

Axolotls have this advantage over many other species in a human-dominated world: many people

find them cute. With strange, childlike faces and a resemblance to homunculi they are popular for the home aquarium trade. As for other uses, there are or have been two: food and scientific research. For centuries, axolotls were a valued part of local diets in Mexico. Whether or not they were once harvested sustainably, however, this is clearly no longer the case. As for their value to science, the picture seems more promising. The axolotl and other salamanders (and newts) are probably unique among vertebrates in being able to regrow a fully functioning arm or leg after an amputation. And they can do this repeatedly, regardless of how many times the part is amputated, and without a scar (sometimes, two will grow where one was before). They can even regrow parts of internal organs, including eyes and parts of the brain. Axolotls have the good fortune to be the easiest salamanders to breed, maintain and study in lab conditions. These properties, and others, make them ideal for the study of vertebrate limb development but, more than that, they have played a valuable role in the development of regenerative biology.

If a human loses a limb and survives long enough to heal, he or she will have a stump covered in scar tissue where the limb used to be. That makes us much like most other vertebrates. Salamanders (and particularly the axolotls on whom experiments are most often performed) are an exception. They somehow 'know' how much of a limb is missing and needs to be regrown. It happens something like this. Blood vessels in the remaining stump contract quickly and limit bleeding. Then, during the first few days, the wound transforms into a layer of signalling cells (called the 'apical epithelial cap'), while fibroblasts – cells that hold internal tissues together and give shape to a shape – break free from the connective tissue meshwork and migrate across the amputation surface to meet at the centre of the wound. The fibroplasts then proliferate to form a blastema – an aggregation of stem-like cells that become progenitors for the new limb.

The reconstruction of a limb by the blastema is similar to the formation that took place during the animal's original embryonic development, but with a

difference. In an embryo, the sequence of events in limb development always begins with formation of the base of the limb (the shoulder or hip) and is followed by progressive building of more distal structures until the process terminates with the making of fingers or toes. But in the case of the axolotl, the site of amputation can be anywhere along the limb and regardless of where the wound is located, only those parts of the limb that were amputated regrow.

For thousands of years people believed that salamanders knew the secret of fire. This is not true, of course. But these strange creatures – and most especially the axolotl – may hold clues to the flame of life. For this alone they surely deserve a place in a contemporary bestiary.