

ing to say the number of digits doesn't matter, is functionally neutral. I doubt that. My tentative guess is that in those early times the different species really did benefit from their respective numbers of toes. They really were more efficient than other numbers would have been, for swimming or walking. Later, the tetrapod limb design hardened at five digits, probably because some internal embryological process came to rely upon that number. In the adult, the number is frequently reduced from the embryonic number — in extreme cases such as modern horses, to just one, the middle toe.

The fish group from which the amphibians sprang is the one known as the lobefins. The only surviving lobefins are the lungfish and the coelacanths,* and we shall meet them at Rendezvous 18 and 19 respectively. In Devonian times, lobefins were much more prominent in both the marine and freshwater faunas. The tetrapods probably evolved from an otherwise extinct group of lobefins called the osteolepiforms. Among osteolepiforms are *Eusthenopteron* and *Panderichthys*, both dating from the late Devonian, about the time when the first tetrapods were starting to emerge onto the land.

Why did fish first develop the changes that permitted the move out of water onto the land? Lungs, for example? And fins that you could walk on rather than, or as well as, swim with? It wasn't that they were trying to initiate the next big chapter in evolution! For years, the favoured answer to the question was one that the eminent American palaeontologist Alfred Sherwood Romer derived from the geologist Joseph Barrell. The idea was that if these fish were trying to do anything it was to get back to water. In times of drought, fish can easily become stranded in drying pools. Individuals capable of walking and of breathing air have the enormous advantage that they can forsake a doomed, drying pond and set out for a deeper one elsewhere.

This admirable theory has become unfashionable but not, I think, for uniformly good reasons. Unfortunately, Romer quoted the prevailing belief of his day that the Devonian was a time of drought, a belief that has more recently been called into question. But I don't think Romer needed his Devonian desiccated. Even at times of no particular drought, there will always be some ponds shallow enough to be in danger of becoming too shallow for some particular kind of fish. If ponds three feet deep would have been at risk under severe drought conditions, mild drought

* The name lobefin is not used with universal agreement. Some authors exclude the lungfish and say that coelacanths are the only surviving lobefins. I follow the terminology of Professor Robert Carroll's *Vertebrate Palaeontology and Evolution* and include lungfish as lobefins.

conditions will render ponds one foot deep at risk. It is sufficient for the Romer hypothesis that there are some ponds that dry up, and therefore some fish that could save their lives by migrating. Even if the world of the late Devonian was positively waterlogged, one could say this simply increases the number of ponds available to dry up, thereby increasing opportunities for saving the life of walking fish and the Romer theory. Nevertheless, it is my duty to record that the theory is now unfashionable. A further point against the theory is that modern fish that venture onto land do so in humid, wet areas — that is, when conditions on land are 'good' for water animals, not poor as in the Romer hypothesis.

And, to be sure, there are plenty of other good reasons for a fish to emerge, temporarily or permanently, onto land. Streams and ponds can become unusable for reasons other than drying up. They can become choked with weeds, in which case, again, a fish that can migrate over land to deeper water might benefit. If, as has been suggested *contra* Romer, we are talking Devonian swamps rather than Devonian droughts, swamps provide plenty of opportunities for a fish to benefit by walking, or slithering or flip-flopping or otherwise travelling through the marshy vegetation, in search of deep water or, indeed, food. This still retains the essential Romer idea that our ancestors left the water, not at first to colonise land, but to return to water.

The group of lobefins from which we tetrapods are derived, are today reduced to a pitiful four genera, but they once dominated the seas almost as the teleost fish do today. We are not due to meet the teleosts until Rendezvous 20, but they will help our discussion because some of them breathe air, at least occasionally, and a few even come out of the water and walk on land. A little further into our pilgrimage, we shall hear from one of them, the mudskipper, whose tale is a tale of independent, more recent encroachment onto the land.

THE SALAMANDER'S TALE

NAMES ARE A MENACE in evolutionary history. It is no secret that palaeontology is a controversial subject in which there are even some personal enmities. At least eight books called *Bones of Contention* are in print. And if you look at what two palaeontologists are quarrelling about, as often as not it turns out to be a name. Is this fossil *Homo erectus*, or is it an archaic *Homo sapiens*? Is this one an early *Homo habilis* or a late *Australopithecus*? People evidently feel strongly about such questions, but they often turn out to be splitting hairs. Indeed, they resemble

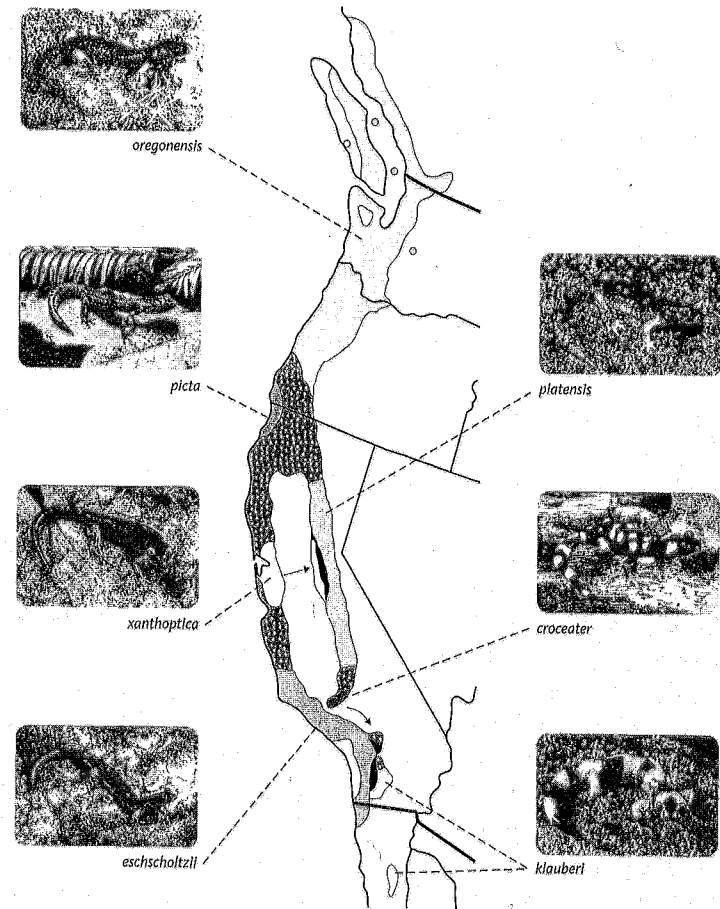
theological questions, which I suppose gives a clue to why they arouse such passionate disagreements. The obsession with discrete names is an example of what I call the tyranny of the discontinuous mind. The Salamander's Tale strikes a blow against the discontinuous mind.

The Central Valley runs much of the length of California, bounded by the Coastal Range to the west and by the Sierra Nevada to the east. These long mountain ranges link up at the north and the south ends of the valley, which is therefore surrounded by high ground. Throughout this high ground lives a genus of salamanders called *Ensatina*. The Central Valley itself, about 40 miles wide, is not friendly to salamanders, and they are not found there. They can move all round the valley but normally not across it, in an elongated ring of more or less continuous population. In practice any one salamander's short legs in its short lifetime don't carry it far from its birthplace. But genes, persisting through a longer timescale, are another matter. Individual salamanders can interbreed with neighbours whose parents may have interbred with neighbours further round the ring, and so on. There is therefore potentially gene flow all around the ring. Potentially. What happens in practice has been elegantly worked out by the research of my old colleagues at the University of California at Berkeley, initiated by Robert Stebbins and continued by David Wake.

In a study area called Camp Wolahi, in the mountains to the south of the valley, there are two clearly distinct species of *Ensatina* which do not interbreed. One is conspicuously marked with yellow and black blotches. The other is a uniform light brown with no blotches. Camp Wolahi is in a zone of overlap, but wider sampling shows that the blotched species is typical of the eastern side of the Central Valley which, here in Southern California, is known as the San Joaquin Valley. The light brown species, on the contrary, is typically found on the western side of the San Joaquin.

Non-interbreeding is the recognised criterion for whether two populations deserve distinct species names. It therefore should be straightforward to use the name *Ensatina eschscholtzii* for the plain western species, and *Ensatina klauberi* for the blotched eastern species — straightforward but for one remarkable circumstance, which is the nub of the tale.

If you go up to the mountains that bound the north end of the Central Valley, which up there is called the Sacramento Valley, you'll find only one species of *Ensatina*. Its appearance is intermediate between the blotched and the plain species: mostly brown, with rather indistinct blotches. It is not a hybrid between the two: that is the wrong way to look at it. To discover the right way, make two expeditions south, sampling the salamander populations as they fork to west and east on either side of



Strikes a blow against the discontinuous mind. *Ensatina* populations around the Central Valley, California. Stippled areas indicate zones of transition. Map adapted from Stebbins (2003).

the Central Valley. On the east side, they become progressively more blotched until they reach the extreme of *klauberi* in the far south. On the west side, the salamanders become progressively more like the plain *eschscholtzii* that we met in the zone of overlap at Camp Wolahi.

This is why it is hard to treat *Ensatina eschscholtzii* and *Ensatina klauberi* with confidence as separate species. They constitute a 'ring species'. You'll recognise them as separate species if you only sample in the south. Move north, however, and they gradually turn into each other. Zoologists normally follow Stebbins's lead and place them all in the same

species, *Ensatina eschscholtzii*, but give them a range of subspecies names. Starting in the far south with *Ensatina eschscholtzii eschscholtzii*, the plain brown form, we move up the west side of the valley through *Ensatina eschscholtzii xanthoptica* and *Ensatina eschscholtzii oregonensis* which, as its name suggests, is also found further north in Oregon and Washington. At the north end of California's Central Valley is *Ensatina eschscholtzii picta*, the semi-blotched form mentioned before. Moving on round the ring and down the east side of the valley, we pass through *Ensatina eschscholtzii platensis* which is a bit more blotched than *picta*, then *Ensatina eschscholtzii croceater* until we reach *Ensatina eschscholtzii klauberi* (which is the very blotched one that we previously called *Ensatina klauberi* when we were considering it to be a separate species).

Stebbins believes that the ancestors of *Ensatina* arrived at the north end of the Central Valley and evolved gradually down the two sides of the valley, diverging as they went. An alternative possibility is that they started in the south as, say, *Ensatina eschscholtzii eschscholtzii*, then evolved their way up the west side of the valley, round the top and down the other side, ending up as *Ensatina eschscholtzii klauberi* at the other end of the ring. Whatever the history, what happens today is that there is hybridization all round the ring, except where the two ends of the line meet, in the far south of California.

As a complication, it seems that the Central Valley is not a total barrier to gene flow. Occasionally, salamanders seem to have made it across, for there are populations of, for example, *xanthoptica*, one of the western subspecies, on the eastern side of the valley, where they hybridise with the eastern subspecies, *platensis*. Yet another complication is that there is a small break near the south end of the ring, where there seem to be no salamanders at all. Presumably they used to be there, but have died out. Or maybe they are still there but have not been found: I am told that the mountains in this area are rugged and hard to search. The ring is complicated, but a ring of continuous gene flow is, nevertheless, the predominant pattern in this genus, as it is with the better-known case of herring gulls and lesser black-backed gulls around the Arctic Circle.

In Britain the herring gull and the lesser black-backed gull are clearly distinct species. Anybody can tell the difference, most easily by the colour of the wing backs. Herring gulls have silver-grey wing backs, lesser black-backs, dark grey, almost black. More to the point, the birds themselves can tell the difference too, for they don't hybridise although they often meet and sometimes even breed alongside one another in mixed colonies. Zoologists therefore feel fully justified in giving them different names, *Larus argentatus* and *Larus fuscus*.

But now here's the interesting observation, and the point of resemblance to the salamanders. If you follow the population of herring gulls westward to North America, then on around the world across Siberia and back to Europe again, you notice a curious fact. The 'herring gulls', as you move round the pole, gradually become less and less like herring gulls and more and more like lesser black-backed gulls until it turns out that our Western European lesser black-backed gulls actually are the other end of a ring-shaped continuum which started with herring gulls. At every stage around the ring, the birds are sufficiently similar to their immediate neighbours in the ring to interbreed with them. Until, that is, the ends of the continuum are reached, and the ring bites itself in the tail. The herring gull and the lesser black-backed gull in Europe never interbreed, although they are linked by a continuous series of interbreeding colleagues all the way round the other side of the world.

Ring species like the salamanders and the gulls are only showing us in the spatial dimension something that must always happen in the time dimension. Suppose we humans, and the chimpanzees, were a ring species. It could have happened: a ring perhaps moving up one side of the Rift Valley, and down the other side, with two completely separate species co-existing at the southern end of the ring, but an unbroken continuum of interbreeding all the way up and back round the other side. If this were true, what would it do to our attitudes to other species? To apparent discontinuities generally?

Many of our legal and ethical principles depend on the separation between *Homo sapiens* and all other species. Of the people who regard abortion as a sin, including the minority who go to the lengths of assassinating doctors and blowing up abortion clinics, many are unthinking meat-eaters, and have no worries about chimpanzees being imprisoned in zoos and sacrificed in laboratories. Would they think again, if we could lay out a living continuum of intermediates between ourselves and chimpanzees, linked in an unbroken chain of interbreeders like the Californian salamanders? Surely they would. Yet it is the merest accident that the intermediates all happen to be dead. It is only because of this accident that we can comfortably and easily imagine a huge gulf between our two species — or between any two species, for that matter.

I have previously recounted the case of the puzzled lawyer who questioned me after a public lecture. He brought the full weight of his legal acumen to bear on the following nice point. If species A evolves into species B, he reasoned closely, there must come a point when a child belongs to the new species B but his parents still belong to the old species A. Members of different species cannot, by definition, interbreed with one

another, yet surely a child would not be so different from its parents as to be incapable of interbreeding with their kind. Doesn't this, he wound up, wagging his metaphorical finger in the special way that lawyers, at least in courtroom dramas, have perfected as their own, undermine the whole idea of evolution?

That is like saying, 'When you heat a kettle of cold water, there is no particular moment when the water ceases to be cold and becomes hot, therefore it is impossible to make a cup of tea.' Since I always try to turn questions in a constructive direction, I told my lawyer about the herring gulls, and I think he was interested. He had insisted on placing individuals firmly in this species or that. He didn't allow for the possibility that an individual might lie half way between two species, or a tenth of the way from species A to species B. Exactly the same limitation of thought hamstringing the endless debates about exactly when in the development of an embryo it becomes human (and when, by implication, abortion should be regarded as tantamount to murder). It is no use saying to these people that, depending upon the human characteristic that interests you, a foetus can be 'half human' or 'a hundredth human'. 'Human', to the qualitative, absolutist mind, is like 'diamond'. There are no halfway houses. Absolutist minds can be a menace. They cause real misery, human misery. This is what I call the tyranny of the discontinuous mind, and it leads me to develop the moral of the Salamander's Tale.

For certain purposes names, and discontinuous categories, are exactly what we need. Indeed, lawyers need them all the time. Children are not allowed to drive; adults are. The law needs to impose a threshold, for example the seventeenth birthday. Revealingly, insurance companies take a very different view of the proper threshold age.

Some discontinuities are real, by any standards. You are a person and I am another person and our names are discontinuous labels that correctly signal our separateness. Carbon monoxide really is distinct from carbon dioxide. There is no overlap. A molecule consists of a carbon and one oxygen, or a carbon and two oxygens. None has a carbon and 1.5 oxygens. One gas is deadly poisonous, the other is needed by plants to make the organic substances that we all depend upon. Gold really is distinct from silver. Diamond crystals really are different from graphite crystals. Both are made of carbon, but the carbon atoms naturally arrange themselves in two quite distinct ways. There are no intermediates.

But discontinuities are often far from so clear. My newspaper carried the following item during a recent flu epidemic. Or was it an epidemic? That question was the burden of the article.

Official statistics show there are 144 people in every 100,000 suffering from flu, said a spokeswoman for the Department of Health. As the usual gauge of an epidemic is 400 in every 100,000, it is not being officially treated as an epidemic by the Government. But the spokeswoman added: 'Professor Donaldson is happy to stick by his version that this is an epidemic. He believes it is many more than 144 per 100,000. It is very confusing and it depends on which definition you choose. Professor Donaldson has looked at his graph and said it is a serious epidemic.'

What we know is that some particular number of people are suffering from flu. Doesn't that, in itself, tell us what we want to know? Yet for the spokeswoman, the important question is whether this counts as an 'epidemic'. Has the proportion of sufferers crossed the rubicon of 400 per 100,000? This is the great decision which Professor Donaldson had to make, as he pored over his graph. You'd think he might have been better employed trying to do something about it, whether or not it counted officially as an epidemic.

As it happens, in the case of epidemics, for once there really is a natural rubicon: a critical mass of infections above which the virus, or bacterium, suddenly 'takes off' and dramatically increases its rate of spreading. This is why public health officials try so hard to vaccinate more than a threshold proportion of the population against, say, whooping cough. The purpose is not just to protect the individuals vaccinated. It is also to deprive the pathogens of the opportunity to reach their own critical mass for 'take-off'. In the case of our flu epidemic, what should really worry the spokeswoman for the Ministry of Health is whether the flu virus has yet crossed its rubicon for take-off, and leapt abruptly into high gear in its spread through the population. This should be decided by some means other than reference to magic numbers like 400 per 100,000. Concern with magic numbers is a mark of the discontinuous mind, or qualitative mind. The funny thing is that, in this case, the discontinuous mind overlooks a genuine discontinuity, the take-off point for an epidemic. Usually there isn't a genuine discontinuity to overlook.

Many Western countries at present are suffering what is described as an epidemic of obesity. I seem to see evidence of this all around me, but I am not impressed by the preferred way of turning it into numbers. A percentage of the population is described as 'clinically obese'. Once again, the discontinuous mind insists on separating people out into the obese on one side of a line, the non-obese on the other. That is not the way real

life works. Obesity is continuously distributed. You can measure how obese each individual is, and you can compute group statistics from such measurements. Counts of numbers of people who lie above some arbitrarily defined threshold of obesity are not illuminating, if only because they immediately prompt a demand for the threshold to be specified and maybe redefined.

The same discontinuous mind also lurks behind all those official figures detailing the numbers of people 'below the poverty line'. You can meaningfully express a family's poverty by telling us their income, preferably expressed in real terms of what they can buy. Or you can say 'X is as poor as a church mouse' or 'Y is as rich as Croesus' and everybody will know what you mean. But spuriously precise counts or percentages of people said to fall above or below some arbitrarily defined poverty *line* are pernicious. They are pernicious because the precision implied by the percentage is instantly belied by the meaningless artificiality of the 'line'. Lines are impositions of the discontinuous mind. Even more politically sensitive is the label 'black', as opposed to 'white', in the context of modern society — especially American society. This is the central issue in the Grasshopper's Tale, and I'll leave it for now, except to say that I believe race is yet another of the many cases where we don't need discontinuous categories, and where we should do without them unless an extremely strong case in their favour is made.

Here's another example. Universities in Britain award degrees that are classified into three distinct classes, First, Second and Third Class. Universities in other countries do something equivalent, if under different names, like A, B, C etc. Now, my point is this. Students do not really separate neatly into good, middling and poor. There are not discrete and distinct classes of ability or diligence. Examiners go to some trouble to assess students on a finely continuous numerical scale, awarding marks or points that are designed to be added to other such marks, or otherwise manipulated in mathematically continuous ways. The score on such a continuous numerical scale conveys far more information than classification into one of three categories. Nevertheless, only the discontinuous categories are published.

In a very large sample of students, the distribution of ability and prowess would normally be a bell curve with few doing very well, few doing very badly and many in between. It might not actually be a symmetrical bell like the picture, but it would certainly be smoothly continuous, and it would become smoother as more and more students are added in.

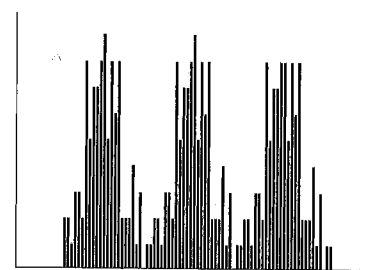
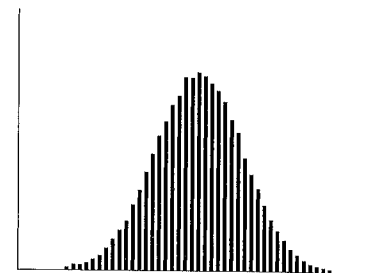
A few examiners (especially, I hope I'll be forgiven for adding, in non-scientific subjects) seem actually to believe that there really is a discrete

entity called the First-Class Mind, or the 'alpha' mind, and a student either definitely has it or definitely hasn't. The task of the examiner is to sort out the Firsts from the Seconds and the Seconds from the Thirds, just as one might sort sheep from goats. The likelihood that in reality there is a smooth continuum, sliding from pure sheepiness through all intermediates to pure goatiness, is a difficult one for some kinds of mind to grasp.

If, against all my expectations, it should turn out that the more students you add in, the more the distribution of exam marks approximates to a discontinuous distribution with three peaks, it would be a fascinating result. The awarding of First, Second and Third Class degrees might then actually be justifiable.

But there is certainly no evidence for this, and it would be very surprising given everything we know about human variation. As things are, it is clearly unfair: there is far more difference between the top of one class and the bottom of the same class, than there is between the bottom of one class and the top of the next class. It would be fairer to publish the actual marks obtained, or a rank order based upon those marks. But the discontinuous or qualitative mind insists on forcing people into one or other discrete category.

Returning to our topic of evolution, what about sheep and goats themselves? Are there sharp discontinuities between species, or do they merge into each other like first-class and second-class exam performances? If we look only at surviving animals, the answer is normally yes, there are sharp discontinuities. Exceptions like the gulls and the Californian salamanders are rare, but revealing because they translate into the spatial domain the continuity which is normally found only in the temporal domain. People and chimpanzees are certainly linked via a continuous chain of intermediates and a shared ancestor, but the intermediates are extinct: what remains is a discontinuous distribution. The same is true of people and monkeys, and of people and kangaroos, except that the extinct intermediates lived longer ago. Because the intermediates are nearly always extinct, we can usually get away with assuming that there is a sharp discontinuity between every species and every other. But in this



book we are concerned with evolutionary history, with the dead as well as the living. When we are talking about all the animals that have ever lived, not just those that are living now, evolution tells us there are lines of gradual continuity linking literally every species to every other. When we are talking history, even apparently discontinuous modern species like sheep and dogs are linked, via their common ancestor, in unbroken lines of smooth continuity.

Ernst Mayr, distinguished elder statesman of twentieth-century evolution, has blamed the delusion of discontinuity — under its philosophical name of Essentialism — as the main reason why evolutionary understanding came so late in human history. Plato, whose philosophy can be seen as the inspiration for Essentialism, believed that actual things are imperfect versions of an ideal archetype of their kind. Hanging somewhere in ideal space is an essential, perfect rabbit, which bears the same relation to a real rabbit as a mathematician's perfect circle bears to a circle drawn in the dust. To this day many people are deeply imbued with the idea that sheep are sheep and goats are goats, and no species can ever give rise to another because to do so they'd have to change their 'essence'.

There is no such thing as essence.

No evolutionist thinks that modern species change into other modern species. Cats don't turn into dogs or vice versa. Rather, cats and dogs have evolved from a common ancestor, who lived tens of millions of years ago. If only all the intermediates were still alive, attempting to separate cats from dogs would be a doomed enterprise, as it is with the salamanders and the gulls. Far from being a question of ideal essences, separating cats from dogs turns out to be possible only because of the lucky (from the point of view of the essentialist) fact that the intermediates happen to be dead. Plato might find it ironic to learn that it is actually an imperfection — the sporadic ill-fortune of death — that makes the separation of any one species from another possible. This of course applies to the separation of human beings from our nearest relatives — and, indeed, from our more distant relatives too. In a world of perfect and complete information, fossil information as well as recent, discrete names for animals would become impossible. Instead of discrete names we would need sliding scales, just as the words hot, warm, cool and cold are better replaced by a sliding scale such as Celsius or Fahrenheit.

Evolution is now universally accepted as a fact by thinking people, so one might have hoped that essentialist intuitions in biology would have been finally overcome. Alas, this hasn't happened. Essentialism refuses to lie down. In practice, it is usually not a problem. Everyone agrees that

Homo sapiens is a different species (and most would say a different genus) from *Pan troglodytes*, the chimpanzee. But everyone also agrees that if you follow human ancestry backward to the shared ancestor and then forward to chimpanzees, the intermediates all along the way will form a gradual continuum in which every generation would have been capable of mating with its parent or child of the opposite sex.

By the interbreeding criterion every individual is a member of the same species as its parents. This is an unsurprising, not to say platonically obvious conclusion, until you realise that it raises an intolerable paradox in the essentialist mind. Most of our ancestors throughout evolutionary history have belonged to different species from us by any criterion, and we certainly couldn't have interbred with them. In the Devonian Period our direct ancestors were fish. Yet, although we couldn't interbreed with them, we are linked by an unbroken chain of ancestral generations, every one of which could have interbred with their immediate predecessors and immediate successors in the chain.

In the light of this, see how empty are most of those passionate arguments about the naming of particular hominid fossils. *Homo ergaster* is widely recognised as the predecessor species that gave rise to *Homo sapiens*, so I'll play along with that for what follows. To call *Homo ergaster* a separate species from *Homo sapiens* could have a precise meaning in principle, even if it is impossible to test in practice. It means that if we could go back in our time machine and meet our *Homo ergaster* ancestors, we could not interbreed with them.* But suppose that, instead of zooming directly to the time of *Homo ergaster*, or indeed any other extinct species in our ancestral lineage, we stopped our time machine every thousand years along the way and picked up a young and fertile passenger. We transport this passenger back to the next thousand-year stop and release her (or him: let's take a female and a male at alternate stops). Provided our one-stop time traveller could accommodate to local social and linguistic customs (quite a tall order) there would be no biological barrier to her interbreeding with a member of the opposite sex from 1,000 years earlier. Now we pick up a new passenger, say a male this time, and transport him back another 1,000 years. Once again, he too would be biologically capable of fertilising a female from 1,000 years before his native time. The daisy chain would continue on back to when our ancestors were swimming in the sea. It could go back without a break, to the fishes,

* I am not asserting that as a fact. I don't know if it is a fact, although I suspect that it is. It is an implication of our plausibly agreeing to give *Homo ergaster* a different species name.

and it would still be true that each and every passenger transported 1,000 years before its own time would be able to interbreed with its predecessors. Yet at some point, which might be a million years back but might be longer or shorter, there would come a time when we moderns could not interbreed with an ancestor, even though our latest one-stop passenger could. At this point we could say that we have travelled back to a different species.

The barrier would not come suddenly. There would never be a generation in which it made sense to say of an individual that he is *Homo sapiens* but his parents are *Homo ergaster*. You can think of it as a paradox if you like, but there is no reason to think that any child was ever a member of a different species from its parents, even though the daisy chain of parents and children stretches back from humans to fish and beyond. Actually it isn't paradoxical to anybody but a dyed-in-the-wool essentialist. It is no more paradoxical than the statement that there is never a moment when a growing child ceases to be short and becomes tall. Or a kettle ceases to be cold and becomes hot. The legal mind may find it necessary to impose a barrier between childhood and majority — the stroke of midnight on the eighteenth birthday, or whenever it is. But anyone can see that it is a (necessary for some purposes) fiction. If only more people could see that the same applies to when, say, a developing embryo becomes 'human'.

Creationists love 'gaps' in the fossil record. Little do they know, biologists have good reason to love them too. Without gaps in the fossil record, our whole system for naming species would break down. Fossils could not be given names, they'd have to be given numbers, or positions on a graph. Or instead of arguing heatedly over whether a fossil is 'really', say, an early *Homo ergaster* or a late *Homo habilis*, we might call it *habigaster*. There's a lot to be said for this. Nevertheless, perhaps because our brains evolved in a world where most things do fall into discrete categories, and in particular where most of the intermediates between living species are dead, we often feel more comfortable if we can use separate names for things when we talk about them. I am no exception and neither are you, so I shall not bend over backwards to avoid using discontinuous names for species in this book. But the Salamander's Tale explains why this is a human imposition rather than something deeply built into the natural world. Let us use names as if they really reflected a discontinuous reality, but by all means let's privately remember that, at least in the world of evolution, it is no more than a convenient fiction, a pandering to our own limitations.

THE NARROWMOUTH'S TALE

MICROHYLA (sometimes confused with *Gastrophryne*) is a genus of small frogs, the narrowmouthed frogs. There are several species, including two in North America: the eastern narrowmouth *Microhyla carolinensis*, and the Great Plains narrowmouth *Microhyla olivacea*. These two are so closely related that they occasionally hybridise in nature. The eastern narrowmouth's range extends down the east coast from the Carolinas to Florida, and west until half way across Texas and Oklahoma. The Great Plains narrowmouth extends from Baja California in the west, as far as eastern Texas and eastern Oklahoma, and as far north as northern Missouri. Its range is therefore a western mirror of the eastern narrowmouth's, and it might as well be called the western narrowmouth. The important point is that their ranges meet in the middle: there is an overlap zone running up the eastern half of Texas and into Oklahoma. As I said, hybrids are occasionally found in this overlap zone, but mostly the frogs distinguish just as well as herpetologists do. This is what justifies our calling them two different species.

As with any two species, there must have been a time when they were one. Something separated them: to use the technical term, the single ancestral species 'speciated' and became two. It is a model for what happens at every branch point in evolution. Every speciation begins with some sort of initial separation between two populations of the same species. It isn't always a geographical separation, but, as we shall see in the Cichlid's Tale, an initial separation of some kind makes it possible for the statistical distribution of genes in the two populations to move apart. This usually results in an evolutionary divergence with respect to something visible: shape or colour or behaviour. In the case of these two populations of American frogs, the western species became adapted to life in drier climates than the eastern, but the most conspicuous difference lies in their mating calls. Both are squeaky buzzes, but each buzz of the western species lasts about twice as long (2 seconds) as the eastern species, and its predominant pitch is noticeably higher: 4,000 cycles per second as against 3,000. That is to say, the predominant pitch of the western narrowmouth is about top C, the highest key on a piano, and the eastern predominant pitch is around the F# below that. These sounds are not musical, however. Both calls contain a mixture of frequencies, ranging from far below the predominant to far above. Both are buzzes, but the eastern buzz is lower. The western call, as well as being longer, begins