WHERE DO CAMELS BELONG?

THE STORY AND SCIENCE OF INVASIVE SPECIES

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CHAPTER ONE

SPECIES ON THE MOVE

Species are born, and then they die. That is, they evolve by natural selection from earlier species, and eventually they go extinct. In the intervening period, which may be less than a million years, or as much as ten million years (or even more), they may do many things. But one thing they don't do is hang around in the same place. More or less by definition species evolve in one particular spot, but later they may spread to occupy a much wider range, a range that often does not include their original 'home'. The eventual range may be large or small, it may be continuous or divided into smaller patches. The variety can be bewildering. Indeed, biologists, palaeontologists and geographers have grappled for the past hundred-or-so years with the problem of explaining how species come to be where they are and (sometimes an even harder question) not where they are not.

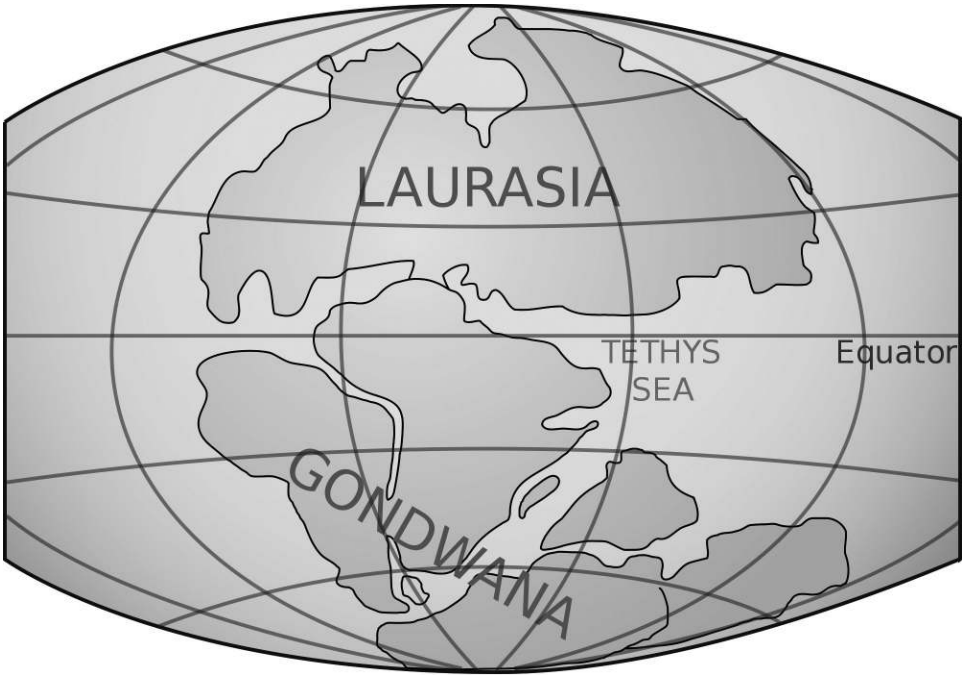
Early biogeographers were baffled by some animal and plant distributions because the history of the Earth's continents

was a mystery to them. Why are marsupial mammals and the Southern beech (*Nothofagus*) found in South America and Australia, and both also as fossils in Antarctica? Alfred Wegener proposed his theory of continental drift in 1912, but his ideas (now known as plate tectonics) were not widely accepted until the late 1950s.

SPECIES AND CONTINENTS

We now know that South America, Australia, Antarctica and Africa were once united into a single supercontinent, Gondwana, and practically all of the biogeography of the southern hemisphere can be explained by the timing of its break-up. India broke away first, soon followed by Africa, so neither acquired the early marsupials that spread throughout the rest of Gondwana. But Africa did remain attached for long enough to acquire the large, flightless ratite birds (African ostrich, South American rheas, Australian cassowaries and New Zealand kiwis and extinct moas), plus some characteristic southern hemisphere plants, such as Gunnera, the odd, rush-like restios and the Proteaceae; *Protea cynaroides* (king protea) ultimately going on to become South Africa's national flower.

The history of the northern hemisphere has been quite different, and also quite complicated, but the basic fact to remember is that the northern hemisphere continents have generally been more joined up, and until more recently, than the southern. In fact the waters of the Bering Strait are relatively shallow and have been repeatedly exposed as dry land when sea level has been lower during the several recent glacial episodes. These connections have allowed animals and plants that evolved in Asia to spread to North America and vice versa. As a result, there is a certain uniformity about northern



Pangaea, which contained all the world's land, began to break up around 200 million years ago into northern (Laurasia) and southern (Gondwana) supercontinents.

hemisphere floras and faunas. Indeed there's a large group of plants that are distributed more or less right round the globe at Arctic or cool temperate latitudes. Familiar examples, all found on hills or mountains in the UK, are mountain avens, moss campion and cowberry. Few mammal species do exactly the same (the brown bear is an exception), but in almost every case the North American and Eurasian species are either very closely related species, or sometimes only subspecies, for example, bison, red fox, otter, beaver and lynx. Sometimes we give them different names, such as moose and caribou in North America and elk and reindeer respectively in Eurasia, but they're still essentially the same.

Throughout most of prehistory, connections between the northern and southern hemispheres were few, but when they occurred they led to some of the most spectacular animal migrations the world has ever seen. The best documented came with the (relatively recent) establishment of the central American land bridge between North and South America. Ever since the break-up of Gondwana, South America had existed in almost complete isolation, developing a fauna at least as odd and unique as that of Australia. A few intrepid island-hoppers made the jump from one continent to the other (in both directions) before the continuous land bridge developed, but the main exchange, usually referred to as the Great American Interchange, occurred only three million years ago, towards the end of the Pliocene.

At first, large numbers of different kinds of animals migrated in both directions, and some of the southern kinds were initially highly successful. The ground sloth *Megalonyx*, weighing up to a tonne, made it as far as Alaska. South America did not have any advanced mammalian carnivores, so many of its top predators were birds, including the so-called 'terror birds', large flightless carnivores. Terror birds stood up to three metres tall and had the largest bird skulls known, with huge curved beaks; they were also fast runners, perhaps achieving speeds of close to 50 km an hour. One of the larger species spread as far north as Florida and Texas. Ultimately, however, all the larger southern colonists became extinct, and the only major mark the Interchange has left on the mammal fauna of North America is porcupines, anteaters, opossums and armadillos. Some smaller birds were also highly successful in the north: humming birds started out in South America but now extend as far north as Canada.

In contrast, most North American colonists of the south were ultimately far more successful, including canids (dogs,

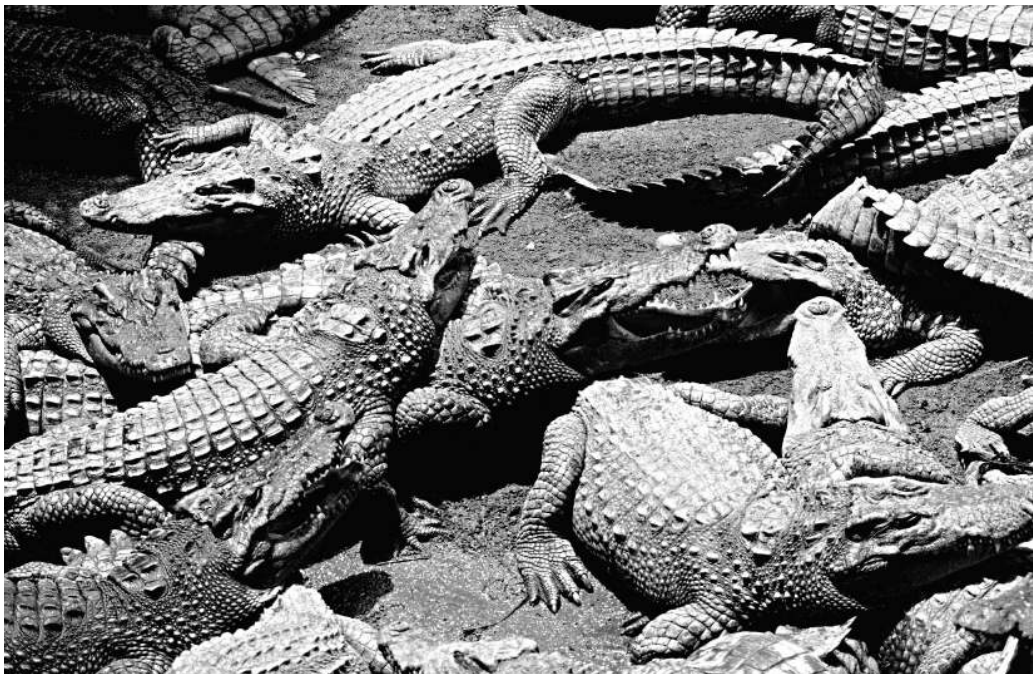
wolves and foxes), llamas, horses and (especially) rodents; nowadays, 85 per cent of modern South American mammals are of North American origin. We began this book by talking about camels, but horses show remarkable parallels. Again they arose in North America; 50 million years ago, the earliest horse ancestors were small, forest-dwelling browsers. Horse evolution is closely linked to changing climate and the spread of grasslands across North America, as over time they gradually became larger and leggier, with tougher teeth, adaptations to running in open grasslands and eating grasses. North American horses were diverse, with several coexisting species. Just like camelids, horses spread to the Old World and also to South America, before becoming extinct in North America about 8,000 years ago. But in the case of the horse, the South American species, a pony-sized animal that probably looked a bit like a donkey, also became extinct at about the same time.

Charles Darwin, while on the *Beagle* expedition, famously found a fossil horse tooth in Patagonia, thus becoming the first person to realise that horses had existed in the Americas long before they were (re)introduced by the Spanish. The discovery had a powerful effect on Darwin's ideas about extinction, as he wrote in *The Origin of Species*:

> *No one I think can have marvelled more at the extinction of species, than I have done. When I found in La Plata the tooth of a horse embedded with the remains of Mastodon, Megatherium, Toxodon, and other extinct monsters, which all co-existed with still living shells at a very late geological period, I was filled with astonishment; for seeing that the horse, since its introduction by the Spaniards into South America, has run wild over the whole country and has increased in numbers at an unparalleled rate, I asked myself what could so recently have exterminated the former horse under conditions of life apparently so favourable.*

RELICTS, REFUGIA AND ICE AGES

It's clear that the movement of continents, and the migration of species across and between continents, all against a background of evolution of new species and extinction of older ones, have drastically rearranged the Earth's biota (its total collection of organisms) on numerous occasions. Some gaps in distributions, sometimes very large ones, are the result of dispersal, while others arise from the extinction of intervening populations by changes in climate. Nile crocodiles are (or were) ubiquitous from South Africa to the Nile Delta and across to Senegal. But what are they doing in the Tibesti Mountains in northern Chad, one of the most remote places on Earth and surrounded in every direction by hundreds of miles of Saharan desert?



Nile crocodiles – ubiquitous across a huge swathe of Africa.

Migration across that desert is clearly impossible for a wetland species, so the only possible explanation is that the climate was once much wetter, allowing crocodiles to extend much further north and west of their present continuous distribution. Plenty of other evidence points in the same direction, including geomorphological signs of former rivers and cave paintings of elephants and giraffe (both now absent) in the Tibesti. In fact we now know that the Sahara has rarely been as dry as it is right now.

Similar climatic relicts turn up almost anywhere you care to look. Crocodiles are an example of a wide contiguous distribution with a few odd outliers, but often an entire distribution will consist of isolated patches, with no obvious large centre of distribution. *Rhododendron ponticum*, familiar now to gardeners, is an example of a species with a formerly wide distribution in previous interglacial warm periods, but now reduced to a few isolated remnants. Its largest native territory is in the Pontic region, around the southern and eastern shores of the Black Sea, but it also occurs in western Turkey, in a few tiny areas of western Spain and Portugal and in the mountains of Lebanon. Alpine species, widely distributed in cold periods but restricted to mountains in warmer times, are particularly likely to show relict distributions. For example *Rhododendron ferrugineum* (alpenrose), another of Europe's few surviving rhododendrons, now survives only in the Alps, Pyrenees, Jura, northern Apennines and the Dinaric Alps in Croatia.

Nowhere is the ebb and flow of species quite so clear, or so well documented, as in the expansion and contraction of species' ranges in response to the Pleistocene glaciations in Europe and North America. Throughout the whole history of the Earth, glaciations ('ice ages') have been relatively rare, but the whole of the Pleistocene (the last 2.58 million years) has technically been an 'ice age', with a permanent ice sheet throughout that

time in Antarctica and most likely in Greenland too. Periodically the ice sheets have expanded (glaciations), extending as far south as London, Seattle and New York at their greatest extent, and contracted (interglacials). We are currently about 10,000 years into an interglacial. These huge fluctuations in temperature have caused warmth-loving species to retreat to southern refugia during the glaciations, and then rapidly expand their ranges during the warm periods. These retreats and advances demonstrate both how fast species can migrate when conditions allow, and also how much chance is involved in how far they manage to advance, exactly where they retreat to, and indeed whether they manage to survive at all.

The British Isles are particularly interesting, because sea levels fall dramatically (by about 120 m) during a glaciation, creating a land connection between Ireland, Britain and mainland Europe. As the ice melts, Ireland and Britain once again become islands, Ireland significantly earlier owing to the greater depth of the Irish Sea. So there are always species that manage to reach Britain as the climate warms, but fail to reach Ireland, which is why (with apologies to St Patrick) Ireland has no snakes in the present interglacial. Or moles or common toads, come to that. However, every interglacial is different. In our current one (the Holocene, which has persisted for the past 11,700 years), silver fir (*Abies alba*) never made it to Britain, while in the previous one it got all the way to the west coast of Ireland. Similarly, box (*Buxus sempervirens*) managed to reach Ireland in the last interglacial, but in this one it only just made it to southern England.

But where did these species survive during the cold periods? This is where the story gets really interesting, because the geography of southern Europe means that Iberia, Italy and the Balkans provide alternative warm refuges. The oaks, shrews, water voles and (now extinct) bears that live in Britain

in the present interglacial spent the glaciation in Spain, while the tawny owls, grasshoppers, newts and alder and beech trees reinvaded from the Balkans. The Alps make the use of Italy as a refuge somewhat problematical, but German and Scandinavian hedgehogs managed to make it back from there, while British hedgehogs came from Spain.

The implications of all this are profound. A crucial thing to remember is that, although we talk of animals and plants advancing and retreating as the glaciers waned and waxed, only the first part of that is literally true. Although species did spread north as the ice melted, those northern colonists generally died out when the ice returned. That is, there was no actual 'retreat', and the only populations that survived the whole cycle were those that remained in the southern refugia, mostly adjusting to rising and falling temperatures by ascending and descending the nearest mountain. So, although the English are fond of referring to their oaks as 'English oaks', the oaks that thrive in England today spent more than 99 per cent of the last two and a half million years in Iberia and are more accurately 'Spanish'. Not only that, but the refugium that provided specific colonists seems to be rather random, so English oaks in a previous interglacial may well have been Greek, or perhaps Italian.

One consequence of the repeated opening and closing of the English Channel is that there were always species that were capable of living in Britain but nevertheless failed to migrate fast enough and so were left behind in mainland Europe, and every now and then one of these failed colonists finally arrives. For example several bumblebees are found in Europe, but not in Britain, and one that many naturalists always thought 'should' be here is the tree bumblebee, *Bombus hypnorum*. The tree bumblebee is found throughout much of Europe as far north as the Arctic Circle, and it also seems to like gardens, so it generally became more abundant during the twentieth century. So it was

no great surprise among the bee cognoscenti when a specimen was captured in southern England in 2001. Since then, the tree bumblebee has spread rapidly, and I saw one for the first time in my own garden in Sheffield in 2010.

Tree bumblebees were always present just across the English Channel, so their eventual colonisation of Britain is scarcely a surprise, although the fact that they took so long to arrive is. A much more remarkable colonist is the collared dove, a bird occurring originally across Asia from Turkey to China. Collared doves began to spread west in the nineteenth century, reaching the Balkans around 1900, Germany in 1945 and Britain by 1953 (where they were recorded in Norfolk as a breeding bird in 1955). Since then their spread has been remarkable, taking only two years to reach Scotland and a further two to reach Ireland. During the last quarter of the twentieth century numbers in Britain increased fivefold, but have been relatively stable since then.

MIGRATIONS, OCEAN DISPERSAL AND ISLANDS

There's no difficulty in explaining how tree bumblebees and collared doves reached Britain – both can fly and the English Channel is only a narrow waterway. Equally it's easy to see how horses and camels travelled from Kansas to Africa: they simply walked. On the other hand, species of all kinds are capable of migrations that are not always easily explained, and some of these take place quite routinely. Aphids, once they get high enough to be carried by the faster winds that occur further from the ground, can travel long distances. Hop aphids frequently turn up more than 100 km from the centres of hop production in southern England. Black bean aphids overwinter in Britain on the shrub spindle, which has a strongly southern distribution. Nevertheless, from this southern base they go on