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Animals Like Us

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FOREWORD

HUMANS, ANIMALS, AND SYSTEMATICS

WHO AM I?

We have all asked ourselves this question. We start to think about it when our hormones first kick in and start to reorganize the neural pathways in our brains long before puberty itself begins. This happens while we are becoming people in our own right and no longer take the world of childhood for granted. Wondering about our own self and our nature is the quintessentially existential question.

It is also a uniquely human question. As far as we know, we are the only species on our planet to ask ourselves this. In many ways, we can say that the point of most artistic, cultural, and scientific endeavour is to find answers for this very problem.

In the natural sciences, we solve such existential conundrums by asking similar questions and seeing whether they can be answered. Once you've answered enough similar questions, you sometimes find the answer to the original one. When it comes to questions about who we humans are, the scientific method is to ask who all the other species are. Is there something about the way we humans live that is akin to other organisms? What is typical of all animals? Or us and our closest relatives? What is typical of our species?

This book is a deep dive into the world of animals, which seeks to answer the question of who we humans are.

WHAT ARE ANIMALS?

When we hear the word "animal," most of us think of mammals like horses, cows, lions, foxes and deer, but the animal kingdom consists of far more than just that. Birds are one kind of animal, as are fish, insects, earthworms and jellyfish. The animal kingdom encompasses all multicellular organisms that must move around to get their food, unlike plants, which mostly stand still and make their own food through photosynthesis.

Plants use energy from sunlight to split both carbon dioxide and water molecules. They need carbon from the first and hydrogen from the second to build long chains of hydrocarbons—the molecules that form the bulk of the plant. The waste product (luckily for us) is oxygen. Animals also need carbon and hydrogen, but cannot photosynthesize. Instead, they have to move about to get the building materials and nutrition they need, by killing and eating other organisms (plants or other animals).

Many single-celled organisms, like amoeba, live by eating others. In previous times, single-celled organisms were divided into single-celled animals and single-celled plants, depending on whether or not they photosynthesized. The problem is that single-celled plants sometimes lose their ability to photosynthesize and become "animals" instead, and vice versa: single-celled animals get their hands on some chlorophyll from a single-celled plant and turn into "plants" themselves. True animals like you, me, foxes and earthworms are multicellular. We are not just a collection of cells that live and work together; our cells also share out the work between them. We have special cells for skin, hair, muscles, blood, fat and nerves. A neuron cannot do the job of a fat cell or vice versa. For fairly complicated animals like us, with a whole heap of different cell types, this is pretty obvious, but if we move to the outer border of the animal kingdom, things aren't so straightforward.

Sponges skirt the boundary between multicellular and single-celled organisms. They have only one type of cell with a special task: the sex cell. All the other cells do all the other jobs. If a sponge is forced through a fine-mesh cloth that shreds it into single cells, any cells that survive could live on. Give them a few quiet days in an aquarium, and the single cells will gather into clumps and form tiny little sponges. Some animals can survive being cut into two, three, or four parts, but only sponges can be taken fully apart and still survive. All they have in common with more advanced animals is that they catch their food by moving about (in this case, each cell has a single *flagellum*—a bit like the tail of a sperm cell—which it beats to create a current through the sponge). Sponges and everything that is more complicated than them therefore make up the animal kingdom.

What's Out There?

Before explorers began to cross the oceans of the world, the people of Europe mostly had dealings only with their local flora and fauna. Very few indeed were remotely interested in insects, earthworms and the other creepy-crawlies around them. As a result, the people of the Middle Ages had only a handful of species to keep track of.

In colonial times, when sailing ships brought back new species from far and wide, and as the first microscopes showed that mosquitoes and gnats were far from the smallest organisms, the number of known species began to rise dramatically. It dawned on the priests and naturalists of the day (they were often one and the same person) that they would need a cataloguing system to keep everything in order. This is where Carl Linnaeus (1707–1778), the son of a Swedish physician, came into the picture.

Linnaeus was very much a child of the 18th century. Not only was he aware of the huge numbers of new and unknown species that were being brought to Europe; as a physician's son, he also had an uncommonly good grasp of the local flora. Plants were the basis for medicine back then, and Linnaeus knew how important it was not to make mistakes when preparing infusions for sick patients. He needed a reliable and straightforward system for classifying medicinal plants.

The system he worked out was based on characteristics of the plants that could be precisely counted and measured. All flowers with ten stamens were placed in one group, and those with twelve in another. The characteristics were calculated based on, say, whether the flower simultaneously had male and female parts and so on. Once all the plants had been sorted in this way, it became easier to whittle it down to precise species. Linnaeus's system was so successful that he later tried to set up an equivalent one for animals. His goal was to build a comprehensive system within which animals and plants (and even stones) could be placed and classified as they were described.

Linnaeus's *Systema naturae* (1735) was neither the only nor necessarily the best system of his day (his stone systematics, for example, was rejected). Linnaeus was shrewd, though. He made sure that large parts of his collection and his scientific works ended up in England, where the star of the British Empire was on the ascent. The upshot of it is that Linnaeus's system remains in use to this day, whereas the many competing systems proposed by Frenchmen, Germans or Dutchmen have all faded into oblivion.

Linnaeus was also a sharp observer and cleared up many old misconceptions. While revising his *Systema naturae*, he moved whales out of the fish category (like Aristotle, he first classified them as "live-bearing fish," along with sharks) and into mammals. He was also one of the first people to point out that bats are most definitely not birds and established, quite rightly, that they belonged among the mammals.

THE GREAT DIVERSITY

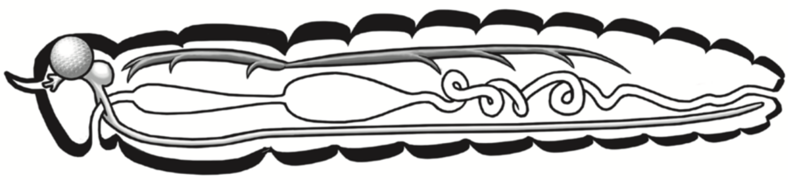
When we think of everything that flies, creeps, crawls and swims, or simply lets itself drift on the currents, it soon becomes obvious that there are huge numbers of animal species. We know, for example, of five-and-a-half thousand mammal species alone, and almost twice as many bird species. If we turn to small animals, the numbers are even more staggering: thirty-five thousand crustacean species and around a million different insect species have been named. In all, science has described just under two million animal species. How many there *really* are, no one knows; guestimates range between two and five times as many species as have already been described—in other words, from four to ten million. For comparison, there are somewhat fewer than 300,000 described species in the plant kingdom. Here, too, the real number is certainly higher, but at any rate, this shows that the animal kingdom is far more complex than the plant kingdom.

The reason why animal species far outnumber plant species is that animals have many, *many* more ways of living. A plant generally stands around sucking up water and carbon dioxide, and there’s a limit to how many ways that can happen. Because animals move around and have to eat other living things, they have a far wider choice of ecological niches. Measured by weight, plants are in the absolute majority, but measured by number of species, animals are the out-and-out winners.

SNAP, CRUNCH, AND SQUISH

There are many ways of dividing up the two million animal species, but one perfectly good, if rough, way to classify them is based on the noises the animals make if you happen to step on them. That may not sound very scientific, but the "step method" reveals the very principle of the animal's make-up.

Some animals will go "snap," some will go "crunch" and others will go "squish." In most cases, a swift glance at the victim will tell us what kind of noise we would get without having to actually step on them. A beetle would obviously make a crunching sound, as would a crab. Both animals have hard skeletons on the outside and are soft on the inside—the diametrical opposite of how we are built: soft on the outside with a hard skeleton inside.



Schematic diagram of an arthropod. The black outline is the skeleton, the central nervous system (pale grey) is below the gut, the circulation system—blood vessels and heart (dark grey)–is above.

The hollow skeleton structure of the "crunch animals" has a few advantages. Perhaps the most important one is that the skeleton serves as armour while at the same time making the animal immune in practical terms to attacks from all kinds of smaller critters. What's more, roughly three-quarters of all known animal species are "crunch animals." It's an incredibly successful construction. Because the joints on the legs are so conspicuous (think crabs or lobsters), they are called arthropods, from the Latin word *Arthropoda*, meaning "those with jointed feet." Arthropods include large groups like insects, crustaceans, and spiders, as well as some smaller groups like millipedes and centipedes. Arthropods can be found *everywhere* in the world.

Schematic diagram of a vertebrate. Spine/spinal cord in the middle (black), central nervous system (pale grey) above, circulation system (heart/main arteries) below the gut.

Meanwhile, animals with skeletons on the *inside* will make a nasty "snap" if you step on them. All of them are based on the same design: a strut made of cartilage or bone runs through the whole animal from its head to the tip of its tail. The strut is (more or less) divided into a series of vertebrae (made of bone or cartilage), which is why these animals are called *vertebrates*. In the figure, the gut lies below the vertebrae and a spinal cord above them. Keen readers will recognize this structure from our own anatomy. We belong among the vertebrates—and anyone who is in any doubt about that can place a hand on their back and feel the tips of the series of hard bony arcs that run down it, covering and protecting the spinal nerve. The entire vertebrate is built on the principle that its muscles and skin lie around some form of strut: this is what makes the "snap" when animals like these are stepped on.

Vertebrates include fish, amphibians, reptiles, birds and mammals. Surprisingly, vertebrates account for no more than one per cent of all known animal species. The reason for the low number of species is that vertebrates are pretty large animals—on land, they range from matchbox size upwards. Big animals need a lot of food and a lot of space. There simply isn't room for there to be as many different species of vertebrates as there are small arthropods.

Despite the benefits of skeletons, a surprisingly large number of animals get by fine without them. Worms and slugs are good examples of animals without skeletons that are known to most of us. If you step on these animals, they don't go "crunch" or "snap" but make a gurgling little "squish." Some of these animals have a hard outer shell precisely so they won't get squashed—snails, for example. However, the animal itself doesn't have a skeleton.

Many of these animals are really tiny, often just a few hundred cells in size. Creatures like these can live in microscopic habitats, such as the space between grains of damp sand. As a result, there can be incredibly numerous: on a beach, many tons of microscopic animals may lie hidden in the sand—exceeding the combined weight of the holidaymakers above them. If we sorted all the world's animals into three big piles, a snap, crunch and squish pile, the last of these would be the biggest by a long stretch—maybe ten times bigger than the two other piles put together.

The squish pile contains many sometimes very different animals, like sponges, jellyfish, flatworms, different groups of worms and hordes of more or less microscopic critters of the kind that live between grains of sand. There are actually only two groups that stand out in this crowd. One of them is *molluscs*, which include slugs, snails, mussels, octopuses, squids and a few other small groups. Although most are small and harmless (like common mussels and periwinkles), this group also contains giant squids, the only truly large and active animals that are not vertebrates. The other notable group among the squish animals is the *echinoderms*: sea lilies, starfish, brittle stars, sea urchins and sea cucumbers. These rather odd animals consist of thin membranes of tissue distributed in and around a skeleton of hard calcium plates and spikes. Strictly speaking, we'd be more likely to say "ouch" than they would be to go "squish" if we happened to carry out a step test.

In Linnaeus's day, most of the squish animals were lumped together into a group called "vermes," which means "worms" in Latin. Much of the systematics since the beginning of the 19th century has involved gaining an understanding of who is actually related to whom among these animals. In broad-brush terms, the classification of the animal kingdom was already mapped by the mid-20th century, but the details are still being worked out. This means that the diagram of the animal kingdom's family tree at the beginning of the book should not be seen as the last word on the matter. Even though I can't imagine any major changes, the diagram is intended as a reference for any readers who might be feeling a bit at sea as we get to grips with the world of animals.

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ANIMALS IN DREAMLAND

The Evolutionary History of Sleep

We humans spend a fair amount of our allotted time on Earth asleep. Sleep is a part of our biology, just like body temperature, the digestive system, and the sensory apparatus. But *why* do we sleep? What's the point of spending up to a third of our life in dreamland? To answer this question, we're going to take a closer look at the sleeping habits of the rest of the animal kingdom, and look at the sleeping patterns of animals as diverse as lynxes, budgerigars, sharks, bees and—last but not least—jellyfish.

DORMICE AND NIGHTJARS

All animals may sleep, but this doesn't mean that they all do it the same way, nor that they all sleep as much or as little as each other. Herbivores like cows, sheep and zebras don't sleep a great deal. Grass is an extremely nutrient-poor food and it is spread over large areas. As a result the animal takes a long time to gather the food it needs. A cow that goes out to graze at sun-up won't lie down to chew the cud until it is too dark to graze efficiently. She dozes, but doesn't enter dreamland. When animals are on the menu for other species, as herbivores are, sleeping can be fatal, so the cow can only treat herself to short, half-hour spells of sleep. What's more, her daily haul of grass has to be ruminated. The same is true of her wild relatives, like antelopes and buffaloes. As a result, they are among the mammals that sleep the least, often just a few hours out of twenty-four.

At the other end of the spectrum lie the carnivores. Lynxes, lions and the other big cats are almost pure meat-eaters and therefore live off extremely nutrient-rich food. Animal cells don't have cell walls, so it is much easier for the stomach juices to break them down and give the digestive system access to the good stuff than it is with plant cells. They also contain far more useful nutrients. If a lynx makes a big catch (a roe deer, say), it has enough food for several days. That's why predators can sleep a lot more than herbivores. Predators that live in groups and don't need to worry too much about trouble from other animals sleep for an especially long time. A male lion often sleeps twenty hours out of twenty-four, versus the cow's four. Omnivores lie somewhere in between, depending somewhat on the species and their access to food. In fact, we can make a pretty good guess at where on the food chain an animal is by looking at its need for sleep. We humans, with our eight hours, are obviously omnivores, and need roughly the same amount of sleep as foxes and badgers.

The time of day or night when animals sleep varies a great deal depending on what they get up to in their waking hours. Birds need their sight to fly around the forest. Consequently, they, like us, sleep at night when they can't see anyway. The exception to this rule is owls, which hunt for small rodents. The rodents spend the day in their burrows precisely to avoid being spotted by birds of prey, and if the owls are to get any food they need to be up when their prey is out and scurrying about—and at night they don't have to compete with hawks and buzzards. Predators like lions wake up at dusk when the herbivores they hunt have their bellies full of food and can no longer see as well as in the daytime. They see better at night than zebras and buffaloes, but in the darkest hours, the predators also give up: Hunting animals that can run away or put up a fight is not best done in the dark.

Small mammals like shrews live life in high gear and are constantly having to take naps. They can't wait until nightfall. They catch a few winks–ten minutes here and half an hour there–then carry on hunting for the little beetles and worms they live off. Unlike lions, they hunt at night too. Given their extremely fast-paced lifestyle, even a few hours without food will take a toll on their health. They have long whiskers to help them find their way in the pitch black of the forest floor, and they can also navigate using the echo of their own squeaks, just like bats.

A Comfortable Sleeping Position

Sleeping is pretty easy for animals as small as this. They don't have large swathes of flesh, fat and bones weighing on their lungs and blood vessels. Their blood pressure isn't as high either. As a result, it doesn't really matter how they lie when it's time for them to relax. Warm-blooded animals often curl up to retain their body heat, but many cold-blooded animals, like frogs and insects, simply stop in their tracks, right where they are, crawling onward when they're done sleeping.

Bigger animals have a harder time of it when they need to find a good sleeping position. Once you get up into the weight class of humans, the extra pounds start making it difficult to lie still for long. Big animals are structured as frames to support muscles and intestines. The bigger an animal is, the less flexible its skeleton and muscles are, and the more rigid its joints and blood vessels. The nerves are adapted to work best when the animal is standing or walking. Curling up like a mouse is out of the question: the spine is too stiff and something will get pinched, causing pins and needles, and poor blood circulation. Many of the large bovids simply sleep standing up, and if they have to lie down, they actually "kneel" on their knees and elbows, to ensure that their stomach, with its enormous ruminant system, isn't upset. By comparison, we humans may feel stiff and uncomfortable after a night on a hard surface, but we really don't have all that much to complain about.

The weight problem is also the reason why humans and gorillas are the only primates that don't sleep in trees. If you weigh 90 pounds or less, you can lie down and sleep on a reasonably large branch; but it's hard for an adult human to find a comfortable position. We'd probably manage to get up into the tree with a bit of effort, but we certainly wouldn't get much sleep. The same of course applies to gorillas, which are even heavier than us. Chimpanzees are right on the cusp, but solve the problem by building a kind of nest for the night out of leaves and branches. Gorillas do the same thing, only on the ground. In other words, we aren't the only ones among our close relatives who go to bed at night.

Nests like the ones gorillas, bears and us humans make won't be any help to animals heavier than 450 pounds. If large animals lie on their sides, as we can throughout the night, they risk not being able to get up again. A large horse will be suffocated by its own weight if it can't get its legs underneath it and relieve the pressure on its lungs. Big animals don't have to hide from the world around them, but they still struggle to get any rest. Large predatory dinosaurs like *Tyrannosaurus* had pubis bones that jutted out to form a kind of chair beneath their belly, which they could use if they needed to sleep (or just rest their leg muscles). How the great long-necked dinosaurs slept is still a mystery to this day.

Sleep as Energy Conservation

Even in warm-blooded animals like lions, body temperature often sinks a degree or two during sleep. The same applies to us. When our body is getting itself ready for lower night-time temperatures, we feel too warm. This is why many of us feel clammy and kick off the covers even when we're lying in a bedroom at a regular indoor temperature. When morning comes, the opposite happens: it suddenly feels lovely and warm under the covers but far too cold in the surrounding room. This shift in the body's thermostat between sleeping and waking phases saves us masses of energy, on both movement and body heat. Animals also use sleep as a way of conserving energy.

Some animals need to save more energy than others. The sloth eats the leaves of the *Cecropia* tree—which no other animals can live off. The leaves are poisonous, but the sloth's digestive system can (just about) deal with the poison. We see the same phenomenon in in koala bears, which live off eucalyptus leaves. Eucalyptus is in fact poisonous too. We are familiar with it as an additive in cough medicines and throat lozenges, but if you tried to live off these lozenges, you'd soon find out that the substance is no good for your stomach. Despite the fact that they are herbivores, koalas and sloths sleep 15–18 hours, while their livers work at full steam to process the poison in their food. Sloths are so slow and need so much rest that they sleep hanging from the branches wherever they happen to be.

Sleeping with Half Your Brain

Some animals face much greater challenges than sloths, which can sleep off the poison high above the ground. Migratory birds, for example, also have to sleep. Some of them fly around the clock. This means that they have to nap on the wing. The problem with flying and sleeping at the same time is that sleep knocks out the body's control systems. It's one thing to sleep safely on a twig, quite another to snooze hundreds of feet above the surface of a cold ocean or a harsh rocky outcrop!

That's why migratory birds have to sleep with half their brain at a time. One half sleeps while the other keeps track of balance and wingbeats. When one half has rested, the other one switches into sleep mode while the first half takes control again. This is how albatrosses manage to glide across the waves for weeks on end, and thrushes land safely on terra firma after a night flight across the Channel.

We see the same phenomenon among numerous marine mammals. Dolphins have an especially hard time because their big brain needs constant oxygen; and, unlike seals, they don't have the option of waddling ashore for a nap. They therefore sleep with one half of their brain while the other allows them to rise to the surface and grab some oxygen from time to time. When seals aren't sleeping on land but are out at sea and need to nod off, they do it the dolphin way: with half of their brain at a time.

Sleeping with half a brain lets animals be asleep and awake at the same time, but it's hardly an ideal sleeping method. Given the choice, most mammals would sleep with the whole of their brain at the same time. Sperm whales, the species that served as the model for Moby-Dick in the book (and films) of the same name, have the biggest brain in the animal kingdom, and they sleep with the whole of their brain once they enter the Land of

Nod. The large oily mass in their nose that gives these whales their distinctive appearance is lighter than the water around it and allows the whale to float freely in the water, dangling by its nose. It's a very odd sight: a school of sperm whales hanging still and vertical in the water—and they don't do it often either. They sleep perhaps three or four hours out of twenty-four, in periods of fifteen minutes. Sea otters also float as they sleep, often anchoring themselves to seaweed or each other, so that they won't drift off while they're snatching forty winks.

We humans can also do something akin to what seals and dolphins do. When we're afraid or are sleeping in a new and unfamiliar place, we sleep lightly. At even the faintest sound, our eyes will pop open and we'll find ourselves wide awake. We may not achieve full sleep with half our brain like the dolphins, but this is similar. The activity in one half of the brain subsides. When we talk about "sleeping with one eye open," that actually isn't far from the physiological truth.

Further Down the Family Tree

It is easy to see when mammals and birds are sleeping. They have eyelids they can shut and they lie down in a very recognizable way. The further away from ourselves we get on the family tree and the more different the anatomy becomes, the harder it is for us to work out what is going on. Reptiles and amphibians can shut their eyes too, but reptiles, which can let their body temperature fall further to save energy, have a kind of dozing state that we mammals lack. We see the same thing in amphibians. Perhaps it's a bit like our "one eye open" sleep, described above. Yet they also have sleep as we know it: a state in which they lie still with their eyes closed until someone pokes them and wakes them up. If we put electrodes on their head that picks up their brain activity, we can see that it comes in waves that rise and fall in a steady pattern, like the wave patterns familiar to us from mammals in deep sleep.

If we use these kinds of electrodes on fish, we can see that they too have clear periods of sleep. They have no eyelids to shut, but their brainwaves are unmistakeable. Primitive fish such as sharks also have periods of sleep. The species that live on the ocean bed, like nurse sharks, often lie in the shallows where they are out of reach of their foes. A diver can actually lift one of these sharks all the way up to the surface without waking it.

Once we leave the ranks of the vertebrates, the reference points become fewer and further between. We have no idea what starfish, earthworms, and mussels get up to, even though they too have periods when they just lie still. We do know that roundworms, the type of worms to which we sometimes play unwilling hosts, sleep. Their brains are quite unlike ours, so no one has tried to work out just how different their sleep is. All we know is that there is a clear difference between these animals' brain phases when they are active, and when they are inactive and not responding to external stimuli. Even jellyfish have to sleep now and then, despite the fact that they don't have a proper brain, but get by instead with a nerve net spread over the surface of their body. Sometimes, they will stop fluttering their bell and slowly sink into the depths. They are affected by melatonin, just like us humans.

Melatonin is found in many living species, even in plants and single-celled organisms. In the larvae of some segmented worms that live as plankton in the sea, melatonin will be produced when the larvae are exposed to daylight. Once they have built up enough melatonin, they will stop swimming and sink into the depths. The melatonin breaks down at a steady rate and when it is used up, the larvae "wake up" and start to swim again. In this way the day and night cycle is regulated, placing the larvae at a suitable level in the water.

WHAT'S THE POINT OF SLEEP?

Knowing, as we do, that so many members of the animal kingdom do in fact sleep, we can deduce that all species more advanced than sponges do so too. But *why*? The simplest way to find an answer to that question is to look at what happens if we *don't* sleep. You can, for example, keep jellyfish awake by giving them a small electric shock every time they fall asleep. If you keep that up for a while, they have problems responding to the world around them; the elegant fluttering of their bells gets jerkier and in the end they can't even eat. If you continue to keep them awake, they will die. If you let them sleep, they become their old selves again after a while. Sleeping is necessary for normal nerve function and it seems to be something all animals with a nervous system need to do.

There is a terrible disease that proves beyond a shadow of a doubt what happens to the brain if we cannot get sleep. *Fatal familial insomnia* is a hereditary disease in humans that only strikes in middle age. As the name suggests, patients have persistent sleeping difficulties, no matter how tired they are. The result is that they get confused, stop responding to the world around them and, in the end, lose significant parts of their brain function, as if they were suffering from very advanced Alzheimer's. The disease is always fatal. Like jellyfish, humans will end up dying if they don't get sleep.

The best theory we have about sleep is that it cleans up the nervous system. Thinking is a very energy-intensive process. Neurons require something like 10–15 times as much energy as the other cells in the body, and a surprising amount of the body's energy is used in the nerves themselves. As a result, a degradation product called adenosine (an amino acid the body uses as an energy transmitter) builds up, especially in the central nervous system. Consequently, the brain has to be cleaned up and aired out—and this happens while we are in deep sleep. If we don't get to sleep, adenosine levels will rise until our brain can no longer function properly. When we get tired, what we feel is the concentration of adenosine. Caffeine will block the system that registers adenosine, so a cup of coffee makes us *feel* awake, but it won't actually make our nervous system work any better. Even jellyfish, which don't have a central nervous system, need a break now and then to clean up their little nerve net. This indicates that sleep is the result of having a nervous system. The only animals that do not sleep are sponges, but they don't have any neurons at all.

To Sleep, Perchance to Dream?

Humanity's attempts to understand sleep are older than science, and a great deal of attention has been paid to dreams. From antiquity we hear how a restless night of bad dreams was reason enough for prince and pauper alike to reconsider their plans. The interpretation of dreams was one of the fundamental skills of priests and soothsayers. Yet even though the interpretation of dreams has been and remains a popular activity, it is hard to find any genuine connection between our dreams and the lives we lead in our waking hours. So why do we dream? Which other creatures dream? Do all species that dream have something in common with each other that they do not share with the non-dreaming species?

It is no surprise to anyone that dogs and cats dream. For as long as we have kept domestic animals, we have seen their whiskers and legs twitch in sleep. The same goes for birds. Chickens, geese, and budgerigars move their eyes beneath their eyelids, and sometimes twitch their wings and claws. Yet snakes and lizards do not seem to dream and neither do fish. When they are not swimming, it can be hard to tell whether fish are in a sleeping or waking state.

If we put electrodes on the head of a sleeping dog or cat, we can see that they have the same sleep phases as us humans. When a leg twitches, parts of the brain behave as if it were awake, but the body (with the except of the twitch) is paralysed. The animal's eyes move rapidly back and forth beneath the eyelids. This kind of dream sleep is called the Rapid Eye Movement (REM) phase. Other times, animals sleep soundly: the electrodes show the steady stream of two or three waves per second that is typical in heavy sleep.

Mammals evolved from a group known as mammal-like reptiles at around the same time as the dinosaurs made their appearance. It is not entirely clear what sleep was like for these species, but we do have some points of reference. The spiny anteater, a mammal so primitive that it lays eggs and is close to being a reptile, was long thought not to dream. It showed none of the classic signs of REM sleep—neither eye movements nor the characteristic brain waves. However, the spiny anteater's assumed lack of dreams proved to be a case of looking in the wrong place. This animal actually *does* dream; it just doesn't dream with its forebrain the way we do. The typical REM signals only showed up when scientists looked a bit further back in the brain, among the more basal parts. The spiny anteater dreams, but it is possible that the consciousness in the frontal part of the brain is not aware of it.

When we search in the more primitive parts of vertebrates' brain architecture, we find that certain reptiles also dream. It is difficult to imagine what a dream in the midbrain and the brain stem would look like. Perhaps it may be a bit like what humans experience when they dream in deep sleep. When people are woken up during this phase, they are usually too confused to be able to tell you about their dreams before they forget them; but the few who have managed to remember, speak of simple dreams: a colour, a taste, a feeling.

If we follow the branches of the animal kingdom's family tree further down, things don't get any simpler. We know that birds dream. Birds and mammals aren't especially closely related, having evolved from separate groups of reptiles. Not all reptiles dream, though; does that mean that birds and mammals evolved their capacity to dream separately? We have little oversight of amphibians, which are in the borderland between land animals and fish. Their brains are simply too small for us to get any sense out of them. And besides, it's hard to fix electrodes to wet skin.

The Meaning of Dreams

The interpretation of dreams has been common in most cultures. Although the idea that dreams were communications from the hereafter was long go relegated to the realm of superstition, both Freud and Jung had well-developed theories about dreams. For many years, people thought we dreamed in order to process the day's impressions; that this was the brain's way of transferring important impressions to the long-term memory. Nowadays, we know that isn't true. Transferral to the long-term memory happens during deep sleep, not when we are dreaming, whether the dreamer is a human, mouse, canary, or a bee.

Since the prevailing theory about sleep is that it helps clean up the brain, dreaming sounds like a terribly bad idea. When we dream, after all, our brain is active, and masses of adenosine is created. Indeed, the most active dreaming during the REM phase is given low priority when the brain really needs sleep. Both people and animals that have been awake for several days in a row will fall into a deep and apparently dreamless sleep the first chance they get. Whatever function dreams may have, deep sleep is more important.

Dreams seem to be the preserve of animals with big and complex brains. Mammals dream, but the simplest mammals, which have small brains, barely dream at all. Studies of the brains of sleeping songbirds show that they dream about singing. Certain reptiles that live in groups, like the massive Komodo dragon, have slightly larger brains than most reptiles—and they also dream. Surprisingly enough, we have seen that bees dream. We have known for well over a generation that insects sleep, but it came as a surprise to find that they dream too. They have periods in which they gently twitch their antennae and flutter their wings slightly before gliding back into deep sleep. The discovery that bees dream was made when scientists were researching the transfer of memories to the long-term memory. Since the assumption back then was that the transfer happened in the dream phase, the scientists were extremely surprised to find that they could only bolster or weaken bees' memories through the use of odorants when the bees were sleeping deeply. Like us humans, bees can only transfer memories to the long-term memory in deep sleep, not in the dream phase. Even octopuses dream. They wave their tentacles around gently as little ripples of colours and structure flutter over their skin. And sometimes they have nightmares and unleash a little dash of ink. Octopuses are, in fact, the most intelligent invertebrates we know of, while bees may be the smartest of the insects. Relative to their body weight, both bees and octopuses have considerably larger brains than, for example, snakes and fish.

Large brains must be active in order to function. If we wake someone from a deep sleep, the poor person will be disorientated and often unable to coordinate their arms and legs properly for the first few seconds or minutes. If, however, we wake up right after dreaming, we may be confused, but our brain will have full control of our limbs. Since we also know that warm-blooded animals dream more, and more noticeably, than cold-blooded animals such as monitor lizards and snakes, this is probably a question of brain temperature.

We do not dream with the whole brain anyway: the frontal lobe and the language centres are not normally involved, which explains why dreams often feel like films rather than stories and can appear utterly illogical.

Dreams, the most spectacular part of the entire sleep experience, are probably nothing more than the brain churning a hodgepodge of impressions to keep its temperature up, and the dreams themselves may be the least important things that happen to us while we are asleep.

Larks and Owls

We humans have our own biology and it isn't always easy to understand. Not everyone needs the same amount of sleep and not all of us want to sleep at the same time. When it comes to sleep, we know that roughly two-thirds of us fall into the categories known as larks (or morning people) and owls (night people). To the best of our knowledge, no other single species shows such a dramatic divergence in sleeping patterns. This doesn't mean that such differences do not exist, of course, but that we have so far only found them among humans.

We have long known that lark and owl sleeping patterns are genetically determined. Funnily enough, research into Neanderthal DNA was one of the factors that set scientists on the trail. We now know that all modern humans outside Africa have a certain percentage of Neanderthal blood. This is largely found among the genes in the immune system, giving us various types of antibodies that make us better at resisting diseases in the colder parts of the world. Neanderthal genes have, however, also give us other characteristics. These include the variant of the gene that gives people the owl sleeping pattern. These genes ended up in our species through certain, somewhat dubious encounters between us and the Neanderthals in the Middle East and the Black Sea region some 65,000–70,000 years ago.

We know that Neanderthals and modern humans experienced a slightly different ecology, and the sleeping pattern supports this. Modern humans have largely been gatherers and omnivores, whereas the Neanderthals mostly lived off big game hunting. Gatherers spend a lot of time finding food and can't waste large stretches of the day on sleep. When they use their sight, as humans do, they need to be awake during the daylight hours. Predators can sleep more and will often take an afternoon nap. And they come into their own at dusk. We reckon the gene that gives people the owl sleeping pattern had the same effect on Neanderthals that it has on us, which allows us to imagine Neanderthals living a bit like lions: drowsing through the day and waking up as the sun set.

Modern humans are a hybrid species descended from several groups of early humans. Combining different genetic adaptations in a single body isn't always the best solution, but we know that owls are more common in northern regions and rarer towards the tropics. Perhaps the owl sleeping pattern has advantages in regions with long winter nights, or maybe the advantages come into play in the bright summer nights. If, dear reader, you now feel the urge to put down this book and take a power nap on the sofa, at least you can blame it on the genes passed down to you by your short, shaggy forebears.