1 What is an animal?

What image first comes into your mind when you hear the word *animal*? A lion – 'the king of the beasts' – perhaps? Or, if you're good at mental multitasking, maybe a whole array of different creatures? The reason why one or more images will immediately flash into existence is because we all think we know what an animal is. But do we? If so, do we also have an understanding of what the animal kingdom is? Over the years, I have tried to approach these questions by doing an experiment with students, as follows. In small-group tutorials, typically taking the form of five or six students and me sitting around a table for an hour or so, asking and answering questions, an opening question I often pose, since the students are specializing in zoology, is: can you give me an example of an animal?

The reaction to this question is usually one of bewilderment. It seems too simple: is it some sort of trick? After reassurance on my part that no trick is being played, and a little clarification that I just want a common name, not a Latin one, the answers flow fast. Here is what I usually get: tiger, dolphin, elephant, cow, wolf. Of course, I don't mean that I usually get exactly those five names. So here is another example of the same kind of answer: leopard, giraffe, sheep, bat, whale.

The point I am trying to make should now be emerging. A typical response to the request to name an animal, asked of five zoology undergraduates, consists of the names of five *mammals*. It's not always the case. But it's overwhelmingly common.

There are at least three reasons for this typical kind of response. First, many students are more interested in mammals than they are in other kinds of animal. Second, my students have been mainly Irish, and the Irish countryside is scattered with domestic animals, almost all of which are mammals: hence the cows and sheep embedded in the above tutorial responses. Third, I'm convinced that the similarity of the words *animal* and *mammal* has the effect of making many people inappropriately equate them. It's only a superficial similarity, of course: the origins of the words are quite different. But it seems enough of a similarity of sound to have an effect. How many times have you heard the phrase 'birds and animals'? I've heard it far too often.

Cambridge University Press
978-1-107-04963-5 - Evolving Animals: The Story of Our Kingdom
Wallace Arthur
Excerpt
More information

The all-mammal response to my 'name an animal' request is particularly inappropriate from the perspective of numbers of species. There are about 1.5 million named and described animal species in the world. The actual number of species is a lot higher, though it's hard to know by how much. Various biologists have contemplated this issue and have come up with guesstimated actual numbers of animal species anywhere from 3 million to 30 million. Herein I'll take the pragmatic approach of giving the approximate *known* number of species for each animal group – but it's always worth recalling that any such number is a minimum. The number of known mammal species is just over 5000. So, mammals collectively represent less than 0.5% of all animal species.

What you might call old-fashioned zoology was – and sometimes still is – taught in two parts: vertebrate and invertebrate zoology. When non-mammal species creep into my tutorial groups' responses, they are, more often than not, vertebrates. In terms of relationship with relative species numbers, an all-vertebrate response is better than an all-mammal one, but not by much. There are just over 50,000 known species of vertebrates – a composite figure including the mammals and the four other traditionally recognized vertebrate groups – birds, reptiles, amphibians and fish. So the vertebrates constitute less than 5% of animals – still just a small minority (Figure 1.1).

The old-fashioned split of the subject is itself interesting. Why divide the animal kingdom so asymmetrically for the purpose of study? I suppose the answer to that question lies in the importance of zoological studies to human and veterinary medicine; also to agriculture and aquaculture. Although the latter includes some economically important invertebrates, such as oysters, they are dwarfed, in financial terms, by fish, including farmed salmon. The former – agriculture – is almost exclusively vertebrate. It extends beyond mammals, but not much. Hens are routinely farmed, and some other birds such as ostriches are increasingly farmed too.

So, not only mammals, and not only vertebrates, are animals. All species in the animal kingdom – of which invertebrates make up the huge majority – are animals. However, that's one of those vacuous circular statements that we call tautologies. If we want to *define* animals it won't do at all. But do we need a definition? Don't all biologists, and indeed many other people too, know what an animal is, and aren't they able to draw a clear line between animals and all other life-forms? Well, actually, no.

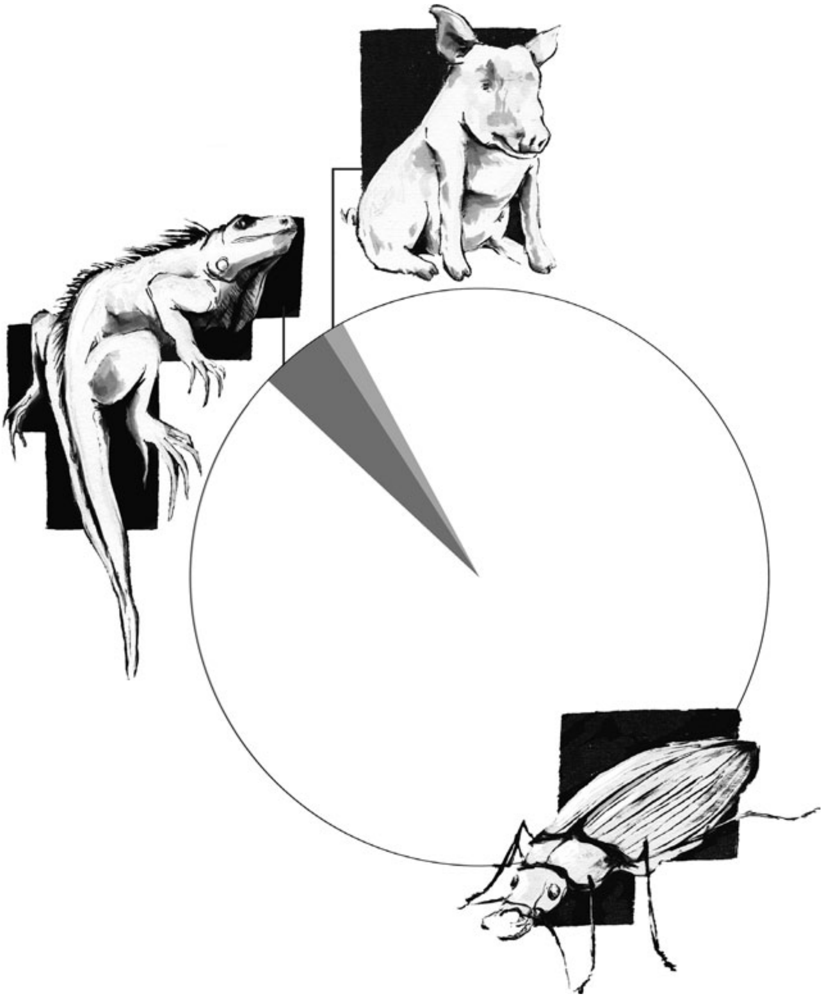

FIGURE 1.1 Pie-chart of the animal kingdom, based on approximate numbers of known species. The mammals, represented by a pig, make up less than 0.5% of animals. Taken together with the rest of the vertebrates, represented by an iguana, we have 50,000 or so species, but these still comprise less than 5% of animals. The other 95%-plus are invertebrates, represented here by a beetle.

Let's jump back in time to the eighteenth century, when the Swedish scientist Carl Linnaeus wrote his magnum opus, *Systema Naturae*, the first edition of which appeared in 1735. Linnaeus was attempting, in this book, to compile a hierarchical classification of life-forms – and indeed of other natural objects too, such as rocks, though his 'mineral kingdom' is no longer used.

With regard to his kingdoms of life, Linnaeus was so successful in his approach that we still use it today, albeit in modified and expanded form. His system of 'groups within groups' (a phrase often used by Darwin) extended from kingdoms all the way down to species, with a series of intermediates such as families. It is from Linnaeus that we get the system of formal Latin names for particular species, such as our own *Homo sapiens*. Many are inscrutable to those with no education in Latin, but others translate remarkably simply. Our own species name is simple enough, though whether we merit the *sapiens* is debatable. The Canadian lynx is among the most straightforward: *Lynx canadensis*.

But for now we will stick with the high end of Linnaeus's system: kingdoms. He introduced just two kingdoms of life: animals and plants. The number of kingdoms recognized has risen since Linnaeus's time, especially in the last half-century or so. It is now at least eight. Some of the extra ones are well known – such as fungi, which Linnaeus had considered to be plants – while others are not. Also, our neo-Linnaean scheme includes a category of life-forms *above* that of kingdoms – the domain. See Figure 1.2 for the relationship between domains and kingdoms.

Our domain – Eukarya, or Eukaryota – includes all those organisms that are composed of cells in which the genetic material is found in membrane-bound organelles, primarily nuclei. This type of cell (eukaryotic) differs from the simpler cells of bacteria (prokaryotic), whose genetic material is not partitioned from the rest of the cell by a membrane. The more complex structure of the eukaryotic cell renders it a better building block for making big multicellular organisms. Although some bacteria are quasi-multicellular – forming strings or mats of cells – all the truly multicellular creatures belong to the six (or so) kingdoms of the Eukarya. Here, I'll restrict attention to just one of these – Animalia, of course.

As far as we know, the animal kingdom had a single origin in the realm of eukaryotic unicells – more on this in Chapter 2. From this single origin – or stem – radiated out, during the course of evolution, the million-plus animal species of today, together with the many other animal species that have become extinct at various points in time, and so are known only from the fossils they left behind.

Now, back to the issue of defining an animal. We can see from the above that animals are multicellular (at least for most of their life-cycle)

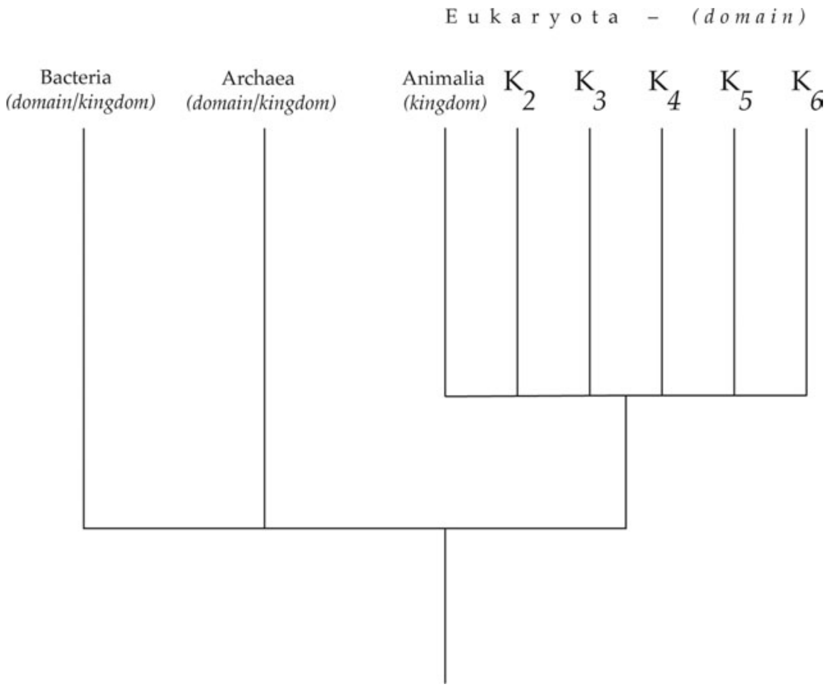

FIGURE 1.2 Domains and kingdoms of the living world, shown in simplified form. Animals belong to the domain Eukaryota (or Eukarya), which includes all those creatures made up of complex cells that have a membrane-bound nucleus and organelles. Other eukaryotic kingdoms are just labelled K2 to K6. The exact number of these is open to debate, especially as there is no clear definition of kingdom. Plants and fungi are two of them. One of the others is the kingdom containing the brown algae (most familiar seaweeds belong here; strangely, these are not plants). One name for this kingdom is Chromalveolata; an alternative name is Chromista.

and that their constituent cells are of the more complex (eukaryotic) kind. That's fine as far as it goes, and it certainly distinguishes animals from bacteria. But if we use only those two features we cannot distinguish animals from plants. So we need a third, and it's not hard to find: photosynthesis. Most plants make their own food from light and inorganic nutrients by photosynthesizing. This is something that animals cannot do.

However, nature is always messy; this makes it hard for us to catalogue it with neat categories and definitions. Not only do some plants, such as the Venus fly-trap, supplement their diet by trapping and eating insects, but others have become parasitic (usually on other plants) and have lost the ability to photosynthesize altogether. Also, some animals harbour symbiotic algae that photosynthesize. In some cases, such as certain corals, the amount of food that the animal gets in this way can constitute a considerable proportion of its total energy intake.

So far so good. We can distinguish animals from bacteria. And, with a few exceptions, we can distinguish them from plants. But our evolving definition of an animal (eukaryotic, multicellular and 'eating') would, if not refined further, include many fungi. How do we prevent it from doing so? Perhaps the obvious feature to bring in at this stage – indeed, you may wonder why I haven't brought it in already – is movement.

Generally, animals move; plants and fungi don't. But again, the effects of nature's messiness on our attempts to generalize should never be underestimated. Two of the most common invertebrates of rocky seashores are limpets and barnacles. On a casual visit to a stretch of coast we may easily observe many of each. They seem to be welded to the rock. In a sense barnacles are – they use a kind of glue or bioadhesive. But limpets are mobile – they're just rather slow and take long rests. Time-lapse photography would readily reveal this difference: over a 24-hour period, an individual limpet will move quite a bit – perhaps a few metres. But an individual barnacle will not shift its position on the rock at all.

Although *adult* plants don't move from place to place, other, non-adult stages of plant life-cycles can be very mobile indeed, as those of us who get hay fever are only too well aware. Pollen blows long distances in the wind. Also, after fertilization, seeds can move long distances too. And if we turn to the fungal kingdom, we see that although fungi do not have pollen or seeds, they have mobile spores.

The American biologist John Tyler Bonner remarked, in 1974, that organisms do not *have* life-cycles; rather, they *are* life-cycles. Taking this enlightened four-dimensional view of animals, plants and fungi, they all move. (Even barnacles move from one bit of coast to another – this is done by mobile larvae.) So is our attempt to define animals doomed? Well, actually no: movement in animals is undertaken by life-stages, whether larval or adult, that generally are able to provide their own power, albeit they may also make use of other forces, such as water currents. In contrast, the stages in the life-cycles of plants and fungi that move are usually completely dependent on external forces, such as the wind or insects in the case of pollination.

Cambridge University Press
978-1-107-04963-5 - Evolving Animals: The Story of Our Kingdom
Wallace Arthur
Excerpt
More information

Finally, we have a definition of animals that separates them tolerably well from organisms belonging to all the other kingdoms of life. An animal is an organism with the following characteristics: its cells are eukaryotic; it is multicellular, at least for most of its life-cycle; it obtains much of its food by eating rather than photosynthesizing; and it has at least one self-powered mobile stage in its life-cycle. To these features we might add that animal cells are not enclosed within cellulose cell-walls; this not only strengthens the separation of animals from plants, but also helps us to separate them from some strange creatures called slime moulds.

So, the use of just a few criteria can form the basis for a pragmatic definition of an animal. Not only that, but animals thus defined correspond to the evolutionary radiation of forms that we noted earlier grew from a single stem in the realm of unicells. Thus the animal kingdom is what is sometimes called a 'natural' category of life-forms: one that includes all the descendants of a particular (in this case ancient) ancestor. The technical name for this kind of group is *monophyletic*. Some long-recognized groups, notably reptiles, are *not* monophyletic groups, which is why they are no longer used 'in the trade' (more on this in Chapters 6 and 7) – though of course they are still very much used in everyday language.

Now that we know how to distinguish animals from all other life-forms, it's time to look at why our favourite organisms are given their name. Where does 'animal' come from? Its root is from the Latin *anima*, meaning soul (well, actually meaning all of the following: breath, life-giving breath, mind and soul). This raises many interesting philosophical questions, some of which will be dealt with later (especially in Chapter 30). But let's deal with one of them now.

A long time ago, I attended the inaugural professorial lecture of Peter Harvey, a man well known in his academic field: Buddhist studies. He had just been appointed to a chair in this field at the University of Sunderland (England, not Massachusetts) and, as tradition dictates, he was giving a formal lecture of about an hour's duration to a mixed audience of academics and students from many disciplines. Appropriately, he kept his lecture broad, and for the most part I and other non-Buddhism-students were able to follow it well. Among other things, he covered the idea of rebirth, or reincarnation.

At question time, I asked him how far down the evolutionary scale reincarnation would apply. For example, could a human be reborn only as a vertebrate? Or might it be possible to be reborn as a worm? If reincarnation extended into invertebrates, could a human be reborn as a sponge? I received a diplomatic and intelligent, but not very enlightening, answer: that it wasn't clear.

Not everyone realizes that sponges are animals. In western society we usually first come upon them in the bath. Although some bath-sponges are indeed the skeletons of real sponges that have died, many – especially now – are synthetic substitutes. A living sponge has flesh, albeit of a rather primitive sort, covering, and supported by, the skeleton – which is itself made of many little bits called spicules and/or a sort of tough proteinaceous matrix. The flesh of a sponge is covered in holes. Water flows in via lots of small holes and out via others or, in many cases, via a single large hole (Figure 1.3). In the intervening period, small creatures suspended in the water are 'eaten'. It seems a strange word, because sponges have no jaws or teeth; the eating consists of the sponge using enzymes to digest and assimilate its tiny prey.

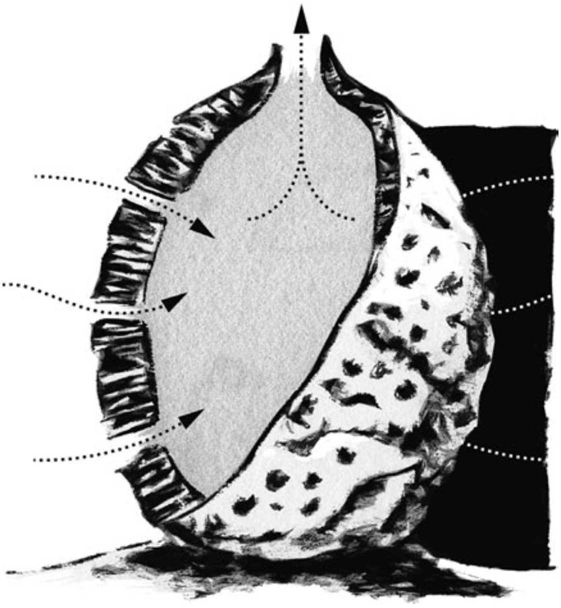

FIGURE 1.3 A sponge, shown with part of the body cut away and arrows to indicate the direction of water flow through the animal. In the example shown, water flows in through lots of small holes and out through a single large one. However, there are many variations on this theme, as might be expected for a group of more than 8000 species.

Cambridge University Press
978-1-107-04963-5 - Evolving Animals: The Story of Our Kingdom
Wallace Arthur
Excerpt
More information

I doubt if sponges have souls. But then again do humans or any other animals have souls in the sense of spirits that transcend their bodily deaths? It's interesting that a career in evolutionary biology does not seem to narrow the spectrum of views on that question. Nor does it narrow the spectrum of views on whether there is a God (or gods). In the public at large there are theists, agnostics and atheists. Among evolutionary biologists the same three stances can be found – though it's probably true that their relative frequency is different.

The Oxford-based English biologist Richard Dawkins is the most famous evolutionary atheist. His 2006 book *The God Delusion* makes his position very clear. In contrast, we have the Cambridge-based American evolutionist Robert Asher, whose broadly theistic view is embodied in the title of his book, just as Dawkins' atheism is embodied in his. Asher's book, published in 2012, is entitled *Evolution and Belief: Confessions of a Religious Paleontologist*. In between the two 'convinced' stances – perhaps 'nearly convinced' stances would be a more accurate term – is the 'don't know' stance of agnosticism. This term was coined by Thomas Henry Huxley (1825–1895), the man who acquired the nickname 'Darwin's Bulldog' from his robust public defence of Darwin's theory of evolution by natural selection. So although there have doubtless been agnostics for centuries, Huxley was the first to wear the badge. He famously declared, in a letter written in 1886: "I am too much of a sceptic to deny the possibility of anything."

Let's return from our detour into the realm of religion to the realm of animals. As we've seen, it is possible to come up with a definition of *animal* that suffices to separate animals – more or less – from all other life-forms. Yet included within this defining umbrella lie incredibly different creatures – from sponges to people. When writing – a few paragraphs back – about my question at the end of Peter Harvey's lecture, I slipped in the phrase 'evolutionary scale' to include all animals from the most primitive, like sponges, to the most advanced, like humans. But this notion of an evolutionary scale is better avoided; it carries a heavy philosophical baggage that plagued evolutionary theory for more than a century. It has now been rightly relegated to the dustbin of scientific terms that have outlived their usefulness.

Both the origin of this term and its abandonment require some explanation. The idea of a natural scale of beings pre-dates evolutionary theory. It was used by the romantic 'nature philosophers' of the eighteenth and early nineteenth centuries as a way of ordering all the different creatures then known – a vertical, linear arrangement with humans at the top. After Darwin, it was easy to replace the romantic idea with its evolutionary equivalent. Thus, to some, evolution was seen as an escalator up which creatures moved in time, progressively getting more advanced from their primitive beginnings.

While this is true of some evolutionary lineages, including our own, it is clearly not true of others. For example, among the most successful life-forms on the planet today are bacteria. Trace any living species of bacteria back a billion years and what do you find? Essentially, a long line of ancestors all of which were bacteria-like in form. Such lineages may well outnumber those in which we might say that the creatures concerned have advanced. This is why we shouldn't think of evolution as an escalator – it can be one, but it often is not. I'll develop this point further in Chapter 11.

We've strayed out of the animal kingdom to bacteria in order to make a point. But now let's return to animals for the final point of this opening chapter. The actual animal kingdom takes the form depicted in the pie-chart shown in Figure 1.1. We already noted the asymmetry of the split between vertebrates and invertebrates. But within the latter there is another major asymmetry: insects represent about 75% of all invertebrate animals. And within the insects, some types make up a disproportionate number – beetles especially. The British biologist J. B. S. Haldane is supposed to have said, when asked by a theologian what he had learned about the Creator from his studies of the animal kingdom, "an inordinate fondness for beetles". Actually, the context in which Haldane made this remark, and its exact wording, are matters of some debate, as discussed by the American palaeontologist Stephen Jay Gould in his 1995 popular science book *Dinosaur in a Haystack* (see, in particular, Gould's chapter 29, "A special fondness for beetles").

In another of his many books, *Wonderful Life*, published in 1989, Gould asked what might happen if it were possible to 'replay the tape of life'. What he meant was the following: if we could take planet Earth back to the origin of life and let evolution happen all over again, would it take the same course? He thought not. Of course, we can't give a definite answer to this question, because we can't do the replaying experiment. One possibility would be the same broad types of animal but with different individual species. A more interesting possibility