Introduction

Two of Barcelona's architectural masterpieces are as different as different could be. The Church of the Holy Family, designed by Antoni Gaudí (1852–1926), is only a few miles from the German Pavilion, built by Mies van der Rohe (1886–1969). Gaudí's church is flamboyant, complex, and irregular. Mies's pavilion is tranquil, simple, and rectilinear. Mies, the apostle of minimalist architecture, used the slogan "less is more" to express what he was after.[1] Gaudí never said "more is more," but his buildings suggest that this is what he had in mind.

One reaction to the contrast between Mies and Gaudí is to choose sides based on a conviction concerning what all art should be like. If all art should be simple or if all art should be complex, the choice is clear. I reject both of these monistic norms; I am a pluralist about artistic simplicity and complexity because I see value in both. True, there may be extremes that are beyond the pale. We are alienated by art that is far too complex and bored by art that is far too simple, but between those two extremes there is a vast space of possibilities.[2] Different artists at different times and places have had different goals. Artists are not in the business of trying to discover the uniquely correct degree of complexity that all artworks should have. There is no such timeless ideal.

Science is different, at least according to many scientists. Einstein (1933) spoke for many when he said that "it can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation

[1] Robert Browning uses "less is more" in his 1855 poem "Andrea del Sarto, called 'The Faultless Painter'."

[2] Here it is useful to contrast Arnheim's (1954) idea that good art creates order with Peckham's (1967) thesis that art is valuable because of the disorder it induces.

of a single datum of experience." This influential point of view holds that the search for simple theories is not optional; rather, it is a requirement of the scientific enterprise. When theories get too complex, scientists reach for Ockham's razor, the principle of parsimony, to do the trimming. This principle says that a theory that postulates fewer entities, processes, or causes is better than a theory that postulates more, so long as the simpler theory is compatible with what we observe. This formulation of the principle is preliminary; it will be fine-tuned in what follows. For example, what does "better" mean?

The long history of the principle of parsimony reveals that there were several such principles in play, not just one. That's why the title of this book is in the plural; the subject at hand is Ockham's *razors.* Different thinkers have meant different things by parsimony and different justifications for principles of parsimony have been constructed. My goal in this book is to describe this diversity and to determine when parsimony is relevant and when it is not. It is obvious that simple theories may be beautiful and easy to remember and understand. The hard problem is to explain why the fact that one theory is simpler than another tells you anything about the way the world is.

Ockham's razor was prominent in the history of science, but it remains important in contemporary science as well. It was used to defend Copernican astronomy, but it now plays a role in evolutionary biology and in cognitive psychology. Scientists, philosophers, and statisticians have had their separate insights into Ockham's razor, so this book will touch a number of bases. Aristotle will be shoulder to shoulder with Akaike, and Newton and Darwin will each have their say. However, there is more to Ockham's razor than the use that is made of it in science. The principle of parsimony is deployed when non-scientists reason about non-scientific questions. This is no surprise, if scientific modes of reasoning are continuous with forms of reasoning that are used in everyday life. Another non-scientific use of parsimony is more puzzling. Philosophers sometimes appeal to Ockham's razor when they evaluate philosophical theories. If the arts and the sciences diverge in the status they accord to simplicity, where does philosophy belong? Is philosophy more like the arts or more like the sciences in terms of the value it should assign to parsimony?

This book is not simple, but the sequencing of chapters is. Chapter 1 provides a brief history of the divergent ideas that were developed before 1900 concerning why the principle of parsimony makes sense. Chapter 2 introduces the ABCs of probability theory and puts them to work; after describing some

failed attempts in the twentieth century to use probability to elucidate and justify Ockham's razor, I describe two "parsimony paradigms" that allow justifications of the principle of parsimony to be made clear. Chapter 3 is about phylogenetic inference in biology and Chapter 4 is about chimpanzee mind-reading in psychology. In both instances, scientists have invoked principles of parsimony and there has been scientific controversy about parsimony's relevance. In Chapter 5, I examine the use of Ockham's razor in philosophy.

Parsimony arguments that draw conclusions about the way the world is from the fact that one theory is more parsimonious than another differ from each other at two levels. First, some of them succeed while others fail. Second, the successful arguments succeed for different reasons, and the unsuccessful arguments go wrong in different ways. Fortunately, this second sort of heterogeneity is not endless; there are recurrent patterns that bring order to the diversity found among the successes and to the diversity found among the failures. I have tried to find a simple philosophical framework for understanding parsimony, but I have been guided by the idea that the framework should not be too simple; it must be complex enough to capture the phenomena. As a philosopher, I am on the side of Mies and Einstein.

1 A history of parsimony in thin slices (from Aristotle to Morgan)

In this chapter I discuss some interesting historical cases in which Ockham's razor has been put to use, but the main focus is on the history of attempts to justify the principle of parsimony. Why buy the idea that simpler theories are better than theories that are more complex? A variety of answers to this question have been offered. Some think that the principle of parsimony is justified by what we have learned from observing nature. Others think that the razor has a theological justification. Still others think that valuing parsimonious theories is part of what it means to be rational. And yet another faction regards the principle as rock bottom – they think the principle is correct but that it can't be justified at all.

The snapshots I present in this chapter are varied, but there is agreement on something important – that parsimony is not an optional, aesthetic frill. Was this historical consensus on the right track? In this chapter, I use this history to begin assembling epistemological tools for assessing the status of parsimony considerations; the search for tools will continue in subsequent chapters.

The naming ceremony

It may seem that the inevitable start of our story is William of Ockham (*c.* 1285–1348), since it is he for whom the principle was named. The naming ceremony apparently occurred long after Ockham. In his 1649 book *On Christian Philosophy of the Soul*, Libert Froidmont (1587–1653) claims to coin the phrase. He speaks of a "*novacula occami*" (a novacula is a small knife or razor) in describing one of Ockham's critics, Gregory of Rimini (d. 1358), who

> excellently drew Ockham's razor . . . [against] its author, since Ockham multiplied entities without necessity . . . However, I call this axiom

> Ockham's and the nominalists' razor because they used that [axiom] to trim and shave off all distinct entities, leaving a plurality only of names. Hence they are designated by the name "nominalists." (Hübener 1983, pp. 84–85)[1]

It is pleasing that this name for the principle comes to us from someone whose name means *cold mountain*. Quine (1953a, p. 4) says that the principle of parsimony expresses a "taste for desert landscapes," but he could just as easily have said that the principle evokes the austere beauty of a frozen summit.

The much-cited slogan "entities should not be multiplied beyond necessity" does not appear in Ockham's writings, but he does say that "it is futile to do with more what can be done with fewer"[2] and that "plurality should not be posited without necessity."[3] Ockham was not the first person to have endorsed these maxims (Thorburn 1918); similar formulations are to be found in the writings of Thomas Aquinas (1224–1274) and in those of Ockham's teacher Duns Scotus (1266–1308).[4] "Ockham's razor" is an example from philosophy of Stigler's (1980) Law of Eponymy, that no scientific idea is named after its original discoverer. Stigler named the law after himself, even though he says that it was the sociologist Robert Merton who discovered it. With tongue in cheek, Stigler chose the law's name so that it would be an instance of itself.

Unfortunately, Ockham didn't say much about why the principle of parsimony ought to be followed (Adams 1987, p. 158). He relied on the fact that he and other philosophers found it sensible; the maxim was common ground, so Ockham felt he could use it as an undefended premise in his arguments.

[1] I am grateful to Rega Wood for this translation from the Latin and for calling my attention to Hübener's essay, which corrects Thorburn's (1918, p. 349) claim that the *novaculum nominalium* metaphor was unknown in the seventeenth century and was invented in the eighteenth by Condillac in his 1746 *Origine des Connaissances Humaines*. Thorburn (pp. 349–350) also says that the English variant, "Occam's razor," first appeared in William Hamilton's (1852, p. 590) *Discussions*.

[2] Ockham, 1986b, Tractatus de Corpore Christi, cap. 28, pp. 157–158.

[3] Ockham, 1986a, Ordinatio I, d.27, q.2, p. 202.

[4] Here are two relevant passages: (1) "If a thing can be done adequately by means of one, it is superfluous to do it by means of several; for we observe that nature does not employ two instruments where one suffices" (Aquinas 1945, p. 129); (2) "we should always posit fewer things when the appearances can be saved thereby . . . therefore in positing more things we should always indicate the manifest necessity on account of which so many things are posited" (Duns Scotus 1998, p. 349).

Ockham did not claim that pluralities never exist nor that complex theories are never true. For example, he says that the road to salvation that God created is *un*parsimonious and notes that this does not mean that the arrangement is flawed or unfitting (Adams 1987, p. 159). At first glance, his maxim seems to say nothing about the way the world actually is; it tells you when you should decline to postulate the existence of something, not whether that something exists. In contrast, there are other versions of the principle of parsimony that unmistakably make claims about the world. Ockham was well aware of a version of this type. For Ockham and other medievals, Aristotle was a starting point for philosophical reflection. Aristotle, not Ockham, provides a better beginning for our story, the seventeenth-century naming ceremony notwithstanding. We'll return to Ockham in due course.

Aristotle's principle that nature does nothing in vain

In his book *Movement of Animals*, Aristotle (384–322 BCE) says that "nature does nothing in vain, but always does what is best, from among the possibilities, for the substantial being of each kind of animal" (2, 704b11–17).[5] Aristotle invokes this principle in many passages. For example, in *The Generation of Animals* (II 5), he asks why males exist. Aristotle raises the question because he thinks that uniparental reproduction is a real possibility. Citing his principle, he concludes that males must play *some* functional role in reproduction. This led him to ask what biparental reproduction contributes that uniparental reproduction cannot. Although this application of Aristotle's principle may seem sensible, it must sound naïve and overstated to the modern ear that is schooled in the lessons of avoiding uncritical adaptationism (Gould and Lewontin 1979). "Nature does nothing in vain" sounds wrong when you think about ear lobes, eye colors, philtrums (the grooves under our noses), and male nipples. Aristotle's maxim seems to conflict with Charles Darwin's (1807–1882) comment in *The Origin of Species* that nature is peppered with structures that "bear the plain stamp of inutility" (Darwin 1859, p. 480).

Aristotle has a reply. When he refers to *nature* in his principle, he doesn't mean what we mean by "nature" – the totality of everything that happens in space and time. Rather, he has in mind the individual *natures* that different organisms possess. It is because of the tiger's nature that tigers have

[5] I am grateful to Paula Gottlieb for helpful discussion on Aristotle.

sharp teeth. Aristotle's natures give rise to the natural tendencies that lead organisms to develop various traits. These natural tendencies are subject to interference; tigers born without sharp teeth are still tigers. This is Aristotle's *natural state model* (Sober 1980). We can combine the modern concept of *nature* with Aristotle's concept of *natures* to formulate an Aristotelian point: not everything that happens *in nature* happens *because of the natures* of individual organisms. Aristotle says that his principle applies only to traits that are universal within a kind (*Generation of Animals*, V.1). Ear lobes and eye colors vary; Aristotle has no problem with the idea that they lack functions (Lennox 2001). Aristotle also allows that some traits may be byproducts; in *On the Soul* (III.12.434a31–2) he says that " . . . everything in nature exists for the sake of something or will be an accident of those things which are for the sake of something." Male nipples are not a counterexample to "nature does nothing in vain."

Aristotle's principle is *teleological*; it says that the nature of a thing drives it to achieve a goal. Although Aristotle didn't think that everything has a *telos*, he did think that teleology (the idea of "final causes") should not be restricted to biology. For example, in *On the Heavens* (ii, clr, 296b, 310b, 2–5), he says that it is in the nature of heavy objects in the sublunar sphere to fall towards the center of the Earth in a straight line, though, of course, objects often fail to do this. Rocks are goal-directed, just as tigers are.

The maxim that often comes to mind when people now think of Ockham's razor is negative, but it is usually understood to have a positive complement. There is "do not accept a postulate if it is *not* needed to explain anything," but there is also "accept a postulate if it *is* needed to explain something." Aristotle's principle is not a restatement of either. It isn't purely negative, and its positive message is teleological. Even so, Aristotle's *nature does nothing in vain* is an important part of the history of Ockham's razor, as I'll explain.

What justification does Aristotle provide for his maxim? In *Physics* (II.8) and in *Parts of Animals* (I.1), he defends the need for teleology by considering the alternative, which he calls "chance." This is the view that Aristotle attributes to Empedocles, who held that the order we see in the universe is due to objects moving randomly in the void. Some objects stick together. Stable combinations persist while unstable ones fall apart.[6] Aristotle claims that chance leaves various facts unexplained, pre-eminently the regular

[6] Empedocles's idea resembles Darwin's idea of natural selection.

development of the organisms in a species as they move from embryo to juvenile to adult. He also thinks that statements about chance presuppose the truth of other statements that are teleological. For example, if two people meet on the street "by chance," this is because the two had goals that did not include their meeting. This is Aristotle's "philosophical justification" for *nature does nothing in vain* (Lennox 2001, p. 214).

This justification is full of holes. First, the claim that teleological concepts are needed to explain *some* facts about nature is not enough to show that nature does *nothing* in vain. Second, Aristotle is wrong in his claim that Empedocles can't explain the highly regular ontogenies of organisms. Even if chance explains the origination of various features of organisms way back when, that does not mean that the descendants of those ancient ancestors must obtain those features by the same chancy process; they can obtain them by inheritance from their parents. Third, many chance statements are true without any implication of teleology. The example of two people meeting "by chance" is atypical; as we will see in the next chapter, statements about probability can be true without there being a goal or a plan. Finally, statements about function and purpose can be true without Aristotle's natural state model being right. One alternative is to use Darwin's theory of natural selection. According to this approach, the reason hearts have the function of pumping blood, not of making noise, is that hearts evolved because they pump blood, not because they make noise (Wright 1976).[7]

There is another passage in which Aristotle suggests a different justification for his principle. In *Generation of Animals* (V.8.788b21), he says that "... we assume, basing our assumptions on what we see, that nature does nothing in vain in so far as is possible in each case." The verb "to see" (from *ορά ω*) is not metaphorical, and so the question arises of how our visual observations tell us that nature does nothing in vain. Perhaps Aristotle's idea is that we observe that the principle *works*; it is supported by its many successful applications. The principle tells you to seek out the function that a biological structure has. When you discover the function, the principle scores a success. Understood in this way, the principle isn't prior to what we discover when we investigate nature, but is a useful after-the-fact summary of what those investigations have yielded (Gottlieb and Sober forthcoming). This defense of

[7] Another alternative to Aristotle is the account of function-claims developed by Cummins (1975). There are others.

nature does nothing in vain appeals to observations. Aristotle does not think that his principle is *a priori*.

Aristotle endorses a second principle when he discusses his idea of the *unmoved mover*. Unlike *nature does nothing in vain*, this second principle has nothing to do with goals. Aristotle thinks that each thing that moves is caused to move by something outside itself. He also holds that there are no actual infinities. Aristotle thinks that when we trace a present motion back to an earlier motion, and that earlier motion back to one that is still earlier, the chain must reach its first member, an unmoved mover, after finitely many steps. This conclusion leaves open how many unmoved movers there are. In *Physics* (8.6.259a), Aristotle fills in this blank: "We ought . . . to suppose that there is one rather than many . . . Here it is sufficient to assume only one mover, the first of unmoved things, which being eternal will be the principle of motion to everything else." Aristotle's example concerns the specifics of motion, but the principle he invokes is more general. The point of relevance is that Aristotle is using a minimum principle to justify a conclusion about the way the world is, and his principle expresses no commitment to teleology.[8] There is one unmoved mover rather than several because postulating just one suffices to explain the motions we observe. As we will see, subsequent thinkers use Aristotle's phrase *nature does nothing in vain* but give it a meaning that approximates his minimum principle. They thereby leave Aristotle's teleology behind.

How Ockham wields his razor

Ockham was a nominalist – he denied the existence of "universals." What are they? Let us begin with what they are not. Universals contrast with particulars. Particulars are the individual things that populate the universe – you, the hive of bees in the park, the Eiffel Tower, Planet Earth. Universals are supposed to be the properties that multiple individual things have in common. For example, Socrates and Plato are particulars, and both philosophize. Does that

[8] This isn't what is going on in another passage in which Aristotle appeals to the idea that less is more. In the *Posterior Analytics* (1.25.2), he says "we may assume the superiority *ceteris paribus* of the demonstration which derives from fewer postulates or hypotheses – in short, from fewer premises; for given that all these are equally well known, where they are fewer knowledge will be more speedily acquired, and that is a desideratum." Here the advantage attributed to minimality has nothing to do with determining what is true.

mean that the statement "Socrates and Plato both philosophize" describes three things – the two men plus the universal to which the two individuals belong? Ockham's answer is *no*. According to Ockham, the two individuals exist and there is Socrates's philosophizing and Plato's as well. Each of these properties is unique to the individual who has it. There is no universal here – there exists no property of philosophizing that is shared among particulars. It is the human mind's invention of concepts (in this instance, the concept of philosophizing) that fosters the illusion the universals exist.

Was Ockham's nominalism motivated by his passion for parsimony? Did he deny the existence of universals because he thought they aren't needed to explain anything? This is what Froidmont says in the passage from him that I quoted, but the claim is not borne out by Ockham's writings. Ockham rejects universals because he thinks that the idea of a universal is *contradictory*. He didn't think that universals *might* exist though considerations of parsimony should lead us to deny that they do. His denial cuts deeper; he thought that universals *cannot* exist. They are like round squares and married bachelors. The universal of being human is supposed to be a single thing, and it's also supposed to be found in each individual human being. So the universal is both one and many, which is impossible. Ockham didn't need Ockham's razor to be a nominalist (Spade and Panaccio 2011).[9]

So where in his theorizing does Ockham actually use his razor? One place is in his discussion of what it takes for something to change. Medieval philosophers, inspired by Aristotle, wanted to have a theory that characterizes what happens when a particular changes. For example, when Socrates changes from healthy to sick, what's going on? Many philosophers held that all change, including this one, must involve the production or destruction of a thing. Since Socrates exists before and after he changes from healthy to sick, there must be some additional thing that is involved, or so they thought. The "things" these philosophers were thinking about are not physical objects – for example, disease-causing micro-organisms. Rather, they were thinking about "qualities." There is a thing called "Socrates's health"; it was annihilated and replaced by a thing called "Socrates's sickness."

[9] Ockham's criticism of universals may remind you of another puzzle – the puzzle of the trinity. How can God be three persons and one person at the same time? Ockham thought that this idea is illogical. However, he did not reject the trinity; rather, he rested his religious conviction on faith, not reason (Kaye 2007).