Introduction

Charles Darwin's *Origin of Species* (1859) argues for two big ideas, both expressed metaphorically: the 'tree of life' and 'natural selection'. New species of animals and plants have descended from earlier ancestral species; and these lines of descent with divergent modifications have branched and re-branched, like the branches on a tree. If all these lines trace to one first, common ancestral species, then all life forms one tree. Natural selection has been the main cause of these divergent modifications. By selective breeding, humans make, in a domesticated species, varieties fitted for different ends: strong, heavy horses for ploughing, and light, fast ones for racing. In the wild, over eons, natural selective breeding, due to the struggle to survive and reproduce ('the struggle for existence'), works unlimited changes in branching lines of adaptive descents, from fish ancestors fitted for swimming to bird descendants fitted for flying and mammals for running.

Our book is about Darwin's idea of natural selection. He called it that to mark the relation between selection in the wild and selection on the farm, or 'artificial selection'. Understanding this big Darwinian idea requires understanding his thinking about the relation between artificial and natural selection. Traditionally one considers, as Darwin did, how natural selection could be *analogous* to artificial selection, and how his argument from selection on the farm to selection in the wild could be an *argument by analogy*. But there are two difficulties. First, there is no consensus about what is meant by saying that two things are 'analogous', with specialists writing on Darwin no more in agreement than other writers on arguments by analogy. Second, several recent commentators have taken the radical revisionist line that, for Darwin, the relation between artificial and natural selection has been misidentified as one of analogy. But, once again, there is no consensus among these revisionists as to what the relation is.

We hold that Darwin was indeed arguing by analogy on behalf of natural selection, and that his analogical argument conformed to the oldest, ancient Greek view of analogy: the view taken by Eudoxus and, following him, by Aristotle, who construed analogy as proportion, as repeated ratio, as relational comparison. What is new in this book is the first sustained interpretation of Darwin's selection analogy as belonging in this distinctive tradition in the structural and functional understanding of analogy. We conclude that, in arguing from artificial to natural selection, Darwin was doing analogy, and doing it Aristotle style; that this was a good thing for him to be doing; and that he did it very well.

By way of a brief introduction to analogy as proportion, consider three examples, moving rapidly from the mathematical to the causal, and from the unremarkable to the remarkable:

- 1 is to 2 as 5 is to *x*.
- Socks are related to feet as gloves are related to hands. Since socks warm feet, gloves, which cover hands as closely as socks cover feet, are correctly inferred to warm hands.
- Stockbreeders are causally related to their livestock as the struggle for existence is causally related to wild organisms. The causal relationships are, in other words, the same in kind. But since the stockbreeders' selective breeding (artificial selection) is much less discriminating, comprehensive and prolonged – and so less powerful – than selective breeding by the struggle for existence (natural selection), the causal relationships differ in degree. Where artificial selection, the weaker cause, can produce only new varieties within extant species, natural selection, the stronger cause, can be inferred to produce comparably greater effects: not merely new varieties but new species.

Familiarly enough, '1 is to 2 as 5 is to *x*' specifies a mathematical proportionality. If, as here, three of the four terms are given, then – shifting from analogy to argument by analogy – the fourth can be calculated from them. Not so, of course, with the gloves analogy, or with the struggle-for-existence analogy. In these examples, given any three terms, empirical inquiry is required to establish the fourth. Furthermore, the relations in these examples are not mathematical but causal relations. Concentrating on what concerns us here, artificial selection mediates between its causes – the stockbreeders' actions – and its effects, the changes wrought in domestic animals; while natural selection mediates between its very different causes – the struggles for existence – and its very similar effects, the changes wrought in wild animals. The four related terms are

not quantities, but the analogy is four-term proportional; and so an argument from this causal analogy is an argument from proportionality such as Aristotle was the first to analyse and validate.

In what follows we hope to persuade readers that placing Darwin's analogical argument from artificial selection to natural selection in the context of this Aristotelian tradition illuminates not only Darwin's argument but a range of topics extending well beyond it. We must emphasise, however, that it is no part of our brief to suggest that Darwin structured his argument as he did because he read Aristotle, or any later writer on analogy as proportion. As far as possible, we trace how the young theorist came to construct his causal theorising in that way; but we have found no reason to think that he was following what was said by any logical or rhetorical authorities on Aristotelian analogy. We shall say more on this topic in our concluding chapter, but for now, a parallel may clarify this issue. Like many scientific theorists, Darwin often constructed arguments conforming to the logical form modus tollens, or denying the consequent: the form of argument where the falsity of a statement is inferred from the falsity of another consequent statement that it entails. But bringing what logicians have said about modus tollens over the millennia to the examination of a Victorian scientific thinker's argument does not require believing that they learned from a logic book about this way of arguing. And so likewise, in our view, for Darwin's constructing his excellent examples of Aristotelian analogies.

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Although this book is meant to be read straight through, an initial, high-altitude pass over its contents most usefully begins in the middle, with a trio of chapters (4–6) on the *Origin of Species*. Darwin called the *Origin* 'one long argument', and these chapters clarify how the whole argument is conducted, how Darwin's analogical reasonings about natural and artificial selection support his argument, and how his various metaphors are grounded in those analogical reasonings. Chapter 4 aims to show that Darwin structured the *Origin* as he did, and placed his selection analogising as he did within that structure, in conformity with a now unfamiliar ideal for the conduct of a scientific argument: the vera causa, or 'true cause', ideal. On Darwin's understanding of this ideal, it demanded, first, that the cause of interest be shown to exist, on the basis of evidence which is independent of what one is trying to explain; second, that, again on independent evidence, this cause is powerful enough to produce the effects

to be explained, so that they *could have been* effects of this cause; and third, that this cause has *actually* been responsible for bringing about those effects. For Darwin, the argument by analogy from artificial selection to natural selection served to meet the second and third demands, by providing grounds for believing that, whereas selection on the farm could produce only new varieties within existing species, selection in the wild could go far further and produce new species.

Chapter 5 narrows the focus, from the overall structure and strategy of the *Origin* to this argument for the greater causal efficacy of natural selection compared with artificial selection. To secure this conclusion Darwin has to put in a lot of not-easy-to-follow work which, we suggest, is most easily grasped by seeing the argument as proceeding in two stages. In the first stage Darwin gives reasons for thinking that the same relation which holds between the stockbreeder and new varieties on the farm also holds between the struggle for existence and new varieties in the wild. In the second stage he gives reasons for thinking that, although the effects of the struggle will be the same in kind as the effects of the stockbreeder, the former effects can nevertheless be different in degree, accumulating to the point where not merely new varieties but new species are formed.[1]

[1] For readers eager for a more rigorous version: It is important to distinguish between Darwin's analogy and his argument based on that analogy. In its simplest form, Darwin's analogy has this structure:

The struggle for existence (B) is causally related to organisms in the wild (D) as the stockbreeder (A) is to organisms on the farm (C).

This is a statement of the analogy and not an argument to or for the analogy, nor an argument by or from it. Here, B and A may be called 'analogous' because, for some C and D, B is to D as A is to C. The two causal relations – natural and artificial selection – are analogous because their respective causes are.

Turning now to Darwin's argument, let us first consider the general structure of the simplest form of an argument from or by such an analogy:

A is F.
B is analogous to A.
Being F is invariant under this analogy.
Therefore B is F.

This is a valid argument form, so the strength of any argument with this structure depends on how well-justified the premises are.

Assimilating Darwin's initial argument by analogy to this structure gives us the following:

A stockbreeder (A) selectively breeds his or her animals and plants so that new domestic varieties are produced (is F).

The struggle for existence (B) is related causally to wild animals and plants (D) as the stockbreeder (A) is to his or her animals on the farm (C).

The same selective causal relation produces the same effect (being F is invariant).

Therefore, the struggle for existence selects in ways resulting in the production of new wild varieties.

When Darwin dwells upon the contrast between the weaker causal power of the stockbreeder and the much stronger causal power of the struggle for existence, he occasionally helps himself to metaphorical language – 'Man can act only on external and visible characters: nature cares nothing for appearances, except in so far as they may be useful to any being', and so on. Chapter 6 provides an analysis of these and other metaphors in the first four chapters of the *Origin* with a view to exploring their argumentational functions. Attention to these metaphors, in tandem with the analogies which they express, can help deepen an appreciation both of the potentialities of the argument-as-proportion tradition and of Darwin's skill in exploiting those potentialities. As we will stress throughout, when it is *relations* that are being analogised, the pairs of items bearing those relations can be strikingly different from each other. Moreover, once an initial analogy is in place, it can suggest extensions, which in turn can suggest further extensions. Shakespeare was a virtuoso of metaphors underpinned by imaginatively extended relational analogies. But Shakespeare wrote plays and poems, not scientific arguments. What makes Darwin's metaphors remarkable – and even more virtuosic than Shakespeare's – is their disciplined fealty to the analogies that carry parts of Darwin's argument.

By way of preparation for these *Origin*-centred chapters, our opening chapters (1–3) set out long-run, medium-run and short-run background stories. The long-run story, in Chapter 1, starts with Pythagorean mathematics, and with work, ascribed to Eudoxus, on proportion. It then moves to Aristotle, who showed how analogy as proportion could be deployed in a wide variety of empirical contexts, and who completed the Greek founding of the tradition of analogical reasoning most pertinent to Darwin's argument practices. When Aristotle affirms, for example, that scales relate functionally to fish as feathers do to birds, modelling of similar triangles is still a pertinent precedent. But the mathematical limitations are transcended for all posterity. Moreover, Aristotle emphasises that analogies can support insightful, suggestive metaphors such as one from later classical times: if fins are to fish as wings to birds, and fins are to water as wings to air, then we may say metaphorically that fish fly in water and birds swim through air.

The medium-run story, in Chapter 2, concerns the century and a half before Darwin wrote the *Origin*. On the one hand, this Greek tradition was alive and well in Darwin's day. On the other hand, this tradition no longer had a monopoly on even elite understanding of analogical arguments, with consequences that have sown confusion ever since, down to

our own day. In particular, it was in the later eighteenth century that the Scottish philosopher Thomas Reid introduced an account of such arguments based not on proportion but on similitude. Reidian analogy is similitude between known and inferred properties, whether relational or not. Saturn, Mars and other planets are known to resemble the Earth in orbiting and being lit by the Sun, in having their own moons and so on. Inferably, then, they probably resemble the Earth in being inhabited. According to Reidian analogy, if two or more objects are all known to have certain properties, they probably also share other properties that some of those objects are not known but may be inferred to have. The shadow of doubt that now falls over whether analogical arguments, Darwin's included, can ever be really strong arguments is largely of Reid's making.

These two initial chapters cover millennia, centuries and decades. With Chapter 3 the pace slows to years, months and days. Here we unfold the short-run background story to the analogical argument of the *Origin*, covering the quarter century from Darwin's earliest causal–analogical conjectures about species extinctions, in 1835, through his pre-1859 theorising about species origins. By mid-1838 Darwin, in his private notebooks, had been for months comparing and contrasting species being naturally formed in the wild with variety formation under domestication. In doing so he distinguished between natural domestic varieties formed in regional isolation as adaptations to natural local influences such as soil, climate and vegetation, and artificial domestic varieties that are often monstrous and made by such unnatural arts as selective breeding. Naturally enough, he compared species being naturally formed in the wild with natural variety formation in domestic species, and insisted that nothing like artificial selective breeding was going on in the wild and influencing natural species formation. His arriving at his selection analogy, near the end of 1838, entailed a direct reversal of this comparison and this contrast. So Darwin in no sense discovered species-making natural selection via analogical reasoning from variety-making artificial selection. The point bears emphasis, because so many popular and even scholarly histories do not appreciate it.

After Chapters 4–6 come two final chapters which put our analysis of Darwin's analogical argument and its prehistory to work in various ways. Chapter 7 tests our reconstruction against the views of four revisionist commentators on the argument. We conclude, unsurprisingly, that none of the revisionists' principal proposals are reconcilable with our own or preferable to them. But in showing why, in the light of Darwin's texts and contexts, these proposals are unacceptable, we take full advantage of the

opportunities offered to explore a diverse set of subsidiary topics, from his use of imaginative conjectures in the *Origin* to the possibility that his distinction between artificial and natural selection encodes a distinctly Victorian vision of social hierarchy. Throughout we try to underscore the value of an awareness of the analogy-as-proportion tradition in interpreting Darwin's analogising, in the *Origin* and beyond.

Finally, in Chapter 8, we consider the bearing of our analysis on wider disagreements about and within Darwinian science. Once again we return to Aristotle, to emphasise that the Aristotelian character of Darwin's analogical argument in no way implies that Darwin's science was Aristotelian, and also because Aristotle provides a useful point of entry into complex questions about the relationship between 'art' and 'nature' in Western thought. Whether we consider the Aristotelian tradition on that topic, or the tradition associated with the Aristotelianism-rejecting Robert Boyle, or the Boyle-rejecting tradition begun by the Romantics, Darwin's analogical argument appears on inspection to be a poor fit for all of them. Taking seriously Darwin's taking seriously the breeders' art helps too, we suggest, when we ask about the relationship between his science and the capitalism of his time and place, which was far more agrarian than tends to be remembered. Turning from pre-Darwinian to post-Darwinian contexts, we look, later in the chapter, at how the analogy remained instructive for three major theorists in the Darwinian tradition: Francis Galton, Alfred Russel Wallace, and Sewall Wright.

It is no purpose of ours to insist that Darwin's analogical argument must remain scientifically important for all time. If we enable readers to understand more fully how Darwin understood the argument, and to appreciate how considerable was Darwin's skill in putting the argument as he did, that will be achievement enough. Nevertheless, so long as Wright's side of his famous debate with Ronald Fisher on natural selection attracts proponents, so long, we suggest, will Darwin's argument live.

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In our experience as readers, a book like ours benefits from an introduction which supplies not only a high-altitude overview but a fairly detailed inventory of the chapter contents, the better to help readers see the wood for the trees (to invoke another venerable analogy). We close this Introduction accordingly.

Chapter 1: Analogy in Classical Greece

Analogy as proportion first played a decisive role in science in solving the problem presented to early Greek mathematics by incommensurable magnitudes. Pythagorean mathematics taught that the relative magnitude of any two lengths, A and B, could be commensurably specified by two whole numbers, *m* and *n*, such that, if A is extended to *m* times its length and B to *n* times its length, then the two extended lines will be equal. But pairs of lines were later found not meeting this specification; and Pythagoras's own triangle theorem – equating the square of the hypotenuse to the sum of the squares of the other two sides of a right-angled triangle – proved this possibility. The Pythagorean account of relative magnitude was duly replaced by an account, almost certainly due to Eudoxus, that covered both incommensurable and commensurable magnitudes. It did so by specifying when four magnitudes, A, B, C, D, are such that A divided by B equals C divided by D (A/B = C/D); and so, proportionally, when A is to B as C is to D (A:B::C:D).

Here A and B must be quantities of the same kind, distances travelled, say; but C and D could be of another kind, times taken perhaps. A four-term relation allowed comparison of quantities of different kinds; and Greek mathematics took the word ἀναλογία as the name for such a four-term relation. In the theory of similar triangles this form of reasoning provided a valid proof by analogy for the further properties two such triangles must share, by treating each as a model for the other. This Euclidean and Eudoxian geometry included an initial examination of analogical relations and modellings pertinent to all our chapters here.

Analogy as proportion, as, more literally, repeated ratio, was soon moved by Aristotle beyond its mathematical confinements to diverse unmathematical, empirical reasonings. While remaining committed to proportionality itself as essential to analogy, he freed it from the limitation that when A is to B as C is to D, A and B must be items of the same kind, and likewise for C and D even if A and C are unalike. With this limitation removed Aristotle can argue to and from fins being to fish as wings are to birds. He can formulate analogies where the two objects being compared are, as he says, remote. For objects close in character, direct comparisons will be appropriate, especially comparisons identifying shared properties; but for objects remote in character indirect relational comparisons will be more apt: scales being to fish as feathers are to birds, or fins being to water as wings are to air. Remote objects can be compared by identifying their relations to other remote objects, in later lingo to other 'relata'. There was

a price, readily incurred, for this new Aristotelian freedom. With a four-term relation among quantities, knowing the values of any three allows, by what became called the rule of three, calculation of the fourth; but, if it is not known what is to fish as wings are to birds, these three known terms do not determine what this unknown fourth must be. Only empirical inquiry into fish structures and their functions can do so.

Such empirical relational comparisons play major roles in the comparative teleological anatomy of Aristotle's biological works. In these indirect comparisons, two animals as unalike as a bird and a fish can be models of each other.

Aristotle's biology was not called 'biology' and was not biology as Darwin's generation would know it. Aristotle's cosmology and his metaphysics, the foundations for his science of life, were no longer foundational for natural history and comparative anatomy more than two millennia on. But the legacy of his theory and practices of analogical comparisons endured. Darwin had to hand on HMS *Beagle* a brand-new little book – by the Oxonian John Duncan on *Analogies of Organised Beings* – a book acknowledging Edward Copleston and his former tutee Richard Whately as mentors who had enlightened the author about analogy, as proportional, relational likening, as taught by their own mentor Aristotle. Darwin's copy has no annotations so he is unlikely to have read it carefully and profitably.

Chapter 2: Analogy in the Background to the *Origin*

Mediaeval philosophers of all three leading Abrahamic faiths deployed Aristotle's teachings in their novel analogical comparisons of talk about God and about his creatures. The scholastic authors of the high middle ages, in their precision and sophistication, emulated their master, and in doing so gave 'analogy' new uses and meanings. Aristotle in presenting his account of analogy had talked of words 'being said in many ways', as in saying 'A is F' and 'B is F' when A and B have no common intrinsic property. Such cases include not only proportional analogies, but also cases where, for example, some diet for cows is said to be 'healthy', because it causes cows to be 'healthy' in what is today often called the 'focal meaning' of this word. Perhaps because they misread Aristotle, the school men called all these cases instances of 'analogy', while retaining the contrast between analogy and simple similitude. With their preoccupation with analogy's implications for such ontological and linguistic questions, they had little interest in argument by analogy. So, in preparing historiographically for

our chapters on Darwin's *Origin,* we write only very briefly about what Aristotle's mediaeval followers did with his legacy as analyst of analogy.

The precision and sophistication of the scholastics was not emulated by Renaissance and Enlightenment authors in the sixteenth and seventeenth centuries, in their revivals of Epicurean, Stoic and Platonic alternatives to Aristotle's legacies for philosophy and for the sciences. Today's historical dictionaries for vernacular European languages, like the encyclopaedias from those centuries, confirm that 'analogy' and its cognates became used in diverse and casual ways, acquiring many uncoordinated meanings with little in common except some association with 'similarity'. These undisciplined discursive habits extended into the early eighteenth-century decades, when the battle between the ancients and the moderns turned in favour of authors declining deference to Greek and Roman antiquity. Within the norms of his time, Joseph Butler countered deism, in his 1736 book on the *Analogy of Religion, Natural and Revealed, to the Constitution and Course of Nature,* with no explication for the leading term in his title.

As we have already noted, an enduring alternative to the Aristotelian view of analogy as relational comparison traces to Thomas Reid, over two decades before Darwin's birth, and is still prominent today. And by the beginning of Darwin's century, there were three influential clarifications of analogical reasoning. Kant in Germany and Copleston in England independently returned to Aristotelian analogy as proportion, making no concession to the Scotsman Reid's recent version of analogy as similitude. Kant drew mainly on Aristotle himself. With his concern to demarcate cognitive roles for reason and experience, Kant emphasised the differences between analogies constituting a priori mathematical knowledge, and those contributing to empirical knowledge a posteriori; and so he dwelled especially on analogies, prominent in the natural sciences, asserting sameness of causal relations and supporting inferences from the known to the unknown consequences of those causal relations.

In England, at Oxford, Copleston saw himself as in descent from William King, an Irish Anglican bishop who, along with Peter Browne and the more famous George Berkeley, had discussed, early in the eighteenth century, the implications of analogy as proportionality for venerable questions concerning human knowledge of God. In the late 1820s, Whately, another Oxonian affirming his debts to King and soon to be an Anglican Archbishop in Ireland, gave analogy as proportion a place in both his logic and his rhetoric texts, just as Aristotle had. Well into Darwin's adult life, Whately stayed resolutely committed to the Aristotelian understanding of analogy; while John Stuart Mill carefully