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Darwinism

The Rise of a Scientific Theory

Why are things the way they are? How did they come to be this way? And what – if anything – might this tell us about the meaning of life? These questions have played a decisive role in shaping western thinking about the world. From the beginning of human civilization, people have wondered what explanation might be offered for the structures of the world – such as the haunting and solemn silence of the stars in the night sky, the beauty of a rainbow, and the mysterious behavior of living beings. Not only do these evoke a sense of awe; they call out for an explanation.

The earliest Greek philosophers – the pre-Socratics – argued endlessly about the nature of the world, and how it came to be as it is. They insisted that the universe was rationally constructed, and that it could therefore be understood through the right use of human reason and argument. Human beings had the ability to make sense of the universe. Socrates took this line of thought further, identifying a link between the way the universe was constructed and the best way for human beings to live. To reflect on the nature of the universe was to gain insights into the nature of the "good life" – the best and most authentic way of living. Reflecting on the clues provided in the structuring of the world thus led to an understanding of our identity and destiny.

For many, the answer lay in the divine origins of the world – the idea that, in some way, the world has been ordered or constructed. Many have found this idea to be spiritually attractive and intellectually satisfying. For Dawkins, however, the advent of Charles Darwin has shown this up as "cosmic sentimentality," "saccharine false purpose," which natural science has a moral mission to purge and debunk. Such naïve beliefs, he argues,

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Alister E. McGrath.

might have been understandable before Darwin came along. But not now. Darwin has changed everything. Newton would be an atheist if he had been born after Darwin. Before Darwin, atheism was just one among many religious possibilities; now, it is the only serious option for a thinking, honest, and scientifically informed person. Dawkins' robustly positive take on Darwinism and the message that it brings to the world can be seen in a short talk he gave on BBC Radio in 2003, in which he set out his personal creed:

> [We should] rejoice in the amazing privilege we enjoy. We have been born, and we are going to die. But before we die we have time to understand why we were ever born in the first place. Time to understand the universe into which we have been born. And with that understanding, we finally grow up and realise that there is no help for us outside our own efforts.[1]

Dawkins argues that Darwin marks that decisive point of transition, providing us with the only reliable explanation of our origins. Intellectual history is thus divided into two epochs – before Darwin, and after Darwin. As James Watson, the Nobel Prize winner and co-discoverer of the structure of DNA put it, "Charles Darwin will eventually be seen as a far more influential figure in the history of human thought than either Jesus Christ or Mohammed."

But why Darwin? Why not Karl Marx? Or Sigmund Freud? Each of these is regularly proposed as having brought about an intellectual earthquake, shattering prevailing assumptions and ushering in radical new ways of thinking which lead to the bifurcation of human thought. The theories of biological evolution, historical materialism, and psychoanalysis have all been proposed as defining the contours of humanity come of age. All, interestingly, have been linked with atheism, the movement that some Europeans in the eighteenth and nineteenth centuries hoped might prove to be an intellectual and political liberator. So why Darwin? To ask this question is to open up the issues which so deeply concern Dawkins, and which have such wider implications.

To appreciate the contributions of Richard Dawkins to debates about evolutionary theory and the relation of science and religion, we must first contextualize his ideas. This opening chapter is a scene-setter, providing the background against which Dawkins' ideas about the "selfish gene" and "blind watchmaker" are to be seen. Before we can make sense of Dawkins' distinctive approach, we need to set him in his proper context,

[1] Richard Dawkins, "Alternative Thought for the Day." BBC Radio 4, August 14, 2003.

and tell the story of the emergence of the form of evolutionary thought that is often referred to as "Darwinism."

Natural Selection: Charles Darwin

The publication of Charles Darwin's *Origin of Species* (1859) is rightly regarded as a landmark in nineteenth-century science. On December 27, 1831, HMS *Beagle* set out from the southern English port of Plymouth on a voyage that lasted almost five years. Its mission was to complete a survey of the southern coasts of South America, and afterward to circumnavigate the globe. The small ship's naturalist was Charles Darwin (1809–82). During the voyage, Darwin noted some aspects of the plant and animal life of South America, particularly the Galapagos Islands and Tierra del Fuego, which seemed to him to require explanation, yet which were not satisfactorily accounted for by existing theories. The opening words of the *Origin of Species* set out the riddle that he was determined to solve:

> When on board HMS *Beagle* as naturalist, I was much struck with certain facts in the distribution of the organic beings inhabiting South America, and in the geological relations of the present to the past inhabitants of that continent. These facts, as will be seen in the latter chapters of this volume, seemed to throw some light on the origin of species – that mystery of mysteries, as it has been called by one of our greatest philosophers.[2]

One popular account of the origin of species, widely supported by the religious and academic establishment of the early nineteenth century, held that God had somehow created everything more or less as we now see it. The success of the view owed much to the influence of William Paley (1743–1805), archdeacon of Carlisle, who compared God to one of the mechanical geniuses of the Industrial Revolution. God had directly created the world in all its intricacy. We shall explore the origins and influence of Paley's thinking in the fourth chapter of this work; at this stage, we need merely note that Paley was of the view that God had constructed – Paley prefers the word "contrived" – the world in its finished form, as we

[2] Charles Darwin, *On the Origin of the Species by Means of Natural Selection*. London: John Murray, 1859, 1. Note that all six editions of this work are now easily accessed online: http://darwin-online.org.uk. Accessed August 5, 2014.

now know it. The idea of any kind of development seemed impossible to him. Did a watchmaker leave his work unfinished? Certainly not![3]

Darwin knew of Paley's views, and initially found them persuasive. However, his observations on the *Beagle* raised some questions. On his return, Darwin set out to develop a more satisfying explanation of his own observations and those of others. Although Darwin appears to have hit on the basic idea of evolution through natural selection by 1842, he was not ready to publish. Such a radical theory would require massive observational evidence to be marshalled in its support.

Some earlier works advocating the evolution of species – most notably, Robert Chambers' *Vestiges of the Natural History of Creation* (1844) – were so incompetent scientifically that they threatened to discredit the ideas that they tried to advance.[4] Thomas H. Huxley, who would later champion Darwin's theory, damned the book as a "once attractive and still notorious work of fiction," and its author as one of "those who . . . indulge in science at second-hand and dispense totally with logic."[5] Chambers was a publisher, not a scientist, and was a little naïve at points; for example, in taking seriously a highly improbable report that living creatures had resulted from passing electric currents through potassium ferrocyanate solution.

As a result of Chambers' muddying of the waters, there was now no way that a radical new theory of biological origins could be launched without overwhelming documentation, guaranteed to disarm its critics through its sheer weight of observational data and close evidence-based argument. Darwin's *Origin of Species* provided such a work, offering both evidence of the phenomenon of biological evolution and an explanation of its mechanism.

Philosophers of science draw an important distinction between a "logic of discovery" and a "logic of confirmation." To simplify what is rather a complex discussion, we might suggest that a logic of discovery is about how someone arrives at a scientific hypothesis, and a logic of confirmation about how that hypothesis is shown to be reliable and realistic.[6] Sometimes hypotheses arise from a long period of reflection on observation; sometimes

[3] See further John T. Baldwin, "God and the World: William Paley's Argument from Perfection Tradition – A Continuing Influence." *Harvard Theological Review* 85 (1992): 109–20.

[4] For further details, see James A. Secord, *Victorian Sensation: The Extraordinary Publication, Reception, and Secret Authorship of Vestiges of the Natural History of Creation*. Chicago: University of Chicago Press, 2000.

[5] T. H. Huxley, review of "The Vestiges of Creation." *The British and Foreign Medico-Chirurgical Review* 26 (1854): 425–39.

[6] For a good account, see Christiane Chauviré, "Peirce, Popper, Abduction, and the Idea of Logic of Discovery." *Semiotica* 153 (2005): 209–21.

they come about in a flash of inspiration. Yet if the logic of discovery can often be more inspirational than rational, the same is clearly not true of the logic of justification. Here, any hypothesis – however it is derived – is rigorously and thoroughly checked against what may be observed, to determine the degree of empirical fit between theory and observation. There is no reason to suggest that Darwin's notion of natural selection came about in a moment of inspiration, on the Galapagos or anywhere else. His theory began taking shape in 1837 and 1838. In Darwin's case, the logics of discovery and justification both seem to have been based primarily on extensive reflection on often puzzling observations.[7]

Darwin's own account of how he developed his theory of natural selection makes it clear that it was later reflection on observations that brought about his insight. When he boarded the *Beagle* in 1831, he tells us, he was inclined to the view that the flora and fauna of a given region would be determined by their physical environment. His observations caused him to question this belief, and to search for alternative explanations – one of which gradually came to dominate his thinking. Let us listen to Darwin's own account of things:

> During the voyage of the *Beagle* I had been deeply impressed by discovering in the Pampean formation great fossil animals covered with armor like that on the existing Armadillos; secondly, by the manner in which closely allied animals replace one another in proceeding southwards over the Continent; and thirdly, by the South American character of most of the productions of the Galápagos archipelago, and more especially by the manner in which they differ slightly on each island of the group; none of these islands appearing to be very ancient in the geological sense. It was evident that facts such as these, as well as many others, could be explained on the supposition that species gradually become modified; and the subject haunted me.[8]

On his return to England, Darwin set about building up his repository of evidence for evolution. As Darwin reflected on his own observations, and supplemented them with those of others, a number of points emerged as being of particular significance. For Darwin, four features of the natural world in particular seemed to require particularly close attention, in the light of problems and shortcomings with existing explanations, especially the idea of "special creation" offered by religious apologists such as

[7] See the reflections of Scott A. Kleiner, "The Logic of Discovery and Darwin's Pre-Malthusian Researches." *Biology and Philosophy* 3 (1988): 293–315.

[8] Charles Darwin and Nora Barlow, *The Autobiography of Charles Darwin, 1809–1882: With Original Omissions Restored*. New York: Norton, 1993, 118.

William Paley:[9] rudimentary organs, extinction, geographical biodiversity, and adaptation. While Paley's theory – which we shall consider in more detail in Chapter 4 – offered explanations of these observations, they seemed increasingly cumbersome and forced. A better explanation, Darwin believed, had to lie to hand. None of these could be regarded as "proofs" of natural selection; nevertheless, they possessed a cumulative force in suggesting it was the best explanation of what was actually observed.

The point here is that a number of explanations could be offered for what was observed in nature. The debate concerned which of these explanations was the best. Now, the word "best" is difficult to define. Do we mean the simplest theory? The most elegant? The most natural? The great English natural philosopher William Whewell (1794–1866) – much admired by Darwin – used a rich visual image to communicate the capacity of a good theory to make sense of, and weave together, observations. "The facts are known but they are insulated and unconnected ... The pearls are there but they will not hang together until some one provides the string."[10] The "pearls" are the observations and the "string" is a grand vision of reality, a worldview, that *connects* and *unifies* the data. A grand theory, Whewell asserted, allows the "colligation of facts," establishing a new system of relations with each other, unifying what might have otherwise been considered to be disconnected and isolated observations. The "pearls" were the observations that Darwin had accumulated; but what was the best string on which to thread them?

The pearls – to continue with this visual analogy – include four categories of observations which clearly require to be strung together.

1 Many creatures possess "rudimentary structures," which have no apparent or predictable function – such as the nipples of male mammals, the rudiments of a pelvis and hind limbs in snakes, and wings on many flightless birds. How might these be explained on the basis of

[9] Scott A. Kleiner, "Problem Solving and Discovery in the Growth of Darwin's Theories of Evolution." *Synthese* 62 (1981): 119–62, especially 127–9. Note that substantially the same issues can be discerned in Johann Kepler's explanation of the solar system: Scott A. Kleiner, "A New Look at Kepler and Abductive Argument." *Studies in History and Philosophy of Science* 14 (1983): 279–313.

[10] William Whewell, *Philosophy of the Inductive Sciences.* 2 vols. London: John W. Parker, 1847, vol. 2, 36. As has often been pointed out, Whewell's theory of induction is open to criticism: see, for example, Laura J. Snyder, "The Mill–Whewell Debate: Much Ado about Induction." *Perspectives on Science* 5 (1997): 159–98.

Paley's theory, which stressed the importance of the individual design of species? Why should God design redundancies? Darwin's theory accounted for these with ease and elegance.

2 Some species were known to have died out altogether. The phenomenon of extinction had been recognized before Darwin, and was often explained on the basis of catastrophe theories, such as a universal flood, as suggested by the biblical account of Noah. Darwin's theory offered a neater account of the phenomenon.
3 Darwin's research voyage on the *Beagle* had persuaded him of the uneven geographical distribution of life forms throughout the world. In particular, Darwin was impressed by the peculiarities of island populations, such as the finches of the Galapagos Islands. Once more, the doctrine of special creation could account for this, yet in a manner that seemed forced and unpersuasive. Darwin's theory offered a much more plausible account of the emergence of these specific populations.
4 Various forms of certain living creatures seemed to be adapted to their specific needs. Darwin held that these could best be explained by their emergence and selection in response to evolutionary pressures. Paley's theory of special creation proposed that these creatures were individually designed by God with those specific needs in mind.

So what could be inferred from these? What was the best explanation of these observations? The best string to connect them? The challenge facing Darwin was to find a theoretical framework which could accommodate these observations as simply, elegantly, and persuasively as possible. Darwin's method is a textbook case of the method of "inference to the best explanation" which is now widely regarded as lying at the core of the scientific method.[11] Darwin was quite clear that his theory of natural selection was not the only explanation of the biological data which could be adduced. He did, however, believe that it possessed greater explanatory power than its rivals, such as the doctrine of independent acts of special creation, as set out in the writings of William Paley: "Light has been shown on several facts, which on the belief of independent acts of creation are utterly obscure."[12]

Many popular accounts of the scientific method emphasize the importance of prediction. If a theory does not predict, it is not scientific. Darwin

[11] For the best general statement of this method, see Peter Lipton, *Inference to the Best Explanation*. 2nd edn. London: Routledge, 2004.

[12] Charles Darwin, *On the Origin of the Species by Means of Natural Selection*. 6th edn. London: John Murray, 1872, 164.

was quite clear that his theory did not predict, and could not predict. That was just the nature of things.[13] The nature of the scientific phenomena was such that prediction was not possible for Darwin. This point unhappily led some philosophers of science, most notably Karl Popper, to suggest that Darwinism was not really scientific.[14]

This point is no longer taken seriously. More recent studies, especially in the philosophy of biology, have raised interesting questions about whether prediction really is essential to the scientific method. This issue emerged as important in the nineteenth-century debate between William Whewell and John Stuart Mill over the role of induction as a scientific method.[15] Whewell emphasized the importance of predictive novelty as a core element of the scientific method; Mill argued that the difference between prediction of novel observations and theoretical accommodation of existing observations was purely psychological, and had no ultimate epistemological significance. The debate, of course, continues. In a recent discussion of the issue, leading philosophers of biology Christopher Hitchcock and Elliott Sober argue that while prediction can occasionally be superior to accommodation, this is not always the case.[16] Situations can easily be envisaged where accommodation is superior to prediction. Prediction is neither intrinsically nor invariably to be preferred to accommodation. The relevance of this point to the scientific character of Darwin's approach will be obvious.

The *Origin of Species* sets out with great care why the idea of natural selection is the best mechanism to explain how the evolution of species took place, and how it is to be understood. Darwin proposed that a process of "natural selection" had to be proposed as nature's analogue to the process of "artificial selection" in stockbreeding. Darwin was familiar with

[13] See especially the detailed study of Elisabeth Anne Lloyd, "The Nature of Darwin's Support for the Theory of Natural Selection." In *Science, Politics, and Evolution*. Cambridge: Cambridge University Press, 2008, 1–19.

[14] Karl R. Popper, "Natural Selection and the Emergence of Mind." *Dialectica* 32 (1978): 339–55.

[15] Snyder, "The Mill–Whewell Debate." Snyder elsewhere argues that Whewell's views on induction have been misunderstood, and merit closer attention as a distinctive approach: Laura J. Snyder, "Discoverers' Induction." *Philosophy of Science* 64 (1997): 580–604.

[16] Christopher Hitchcock and Elliott Sober, "Prediction vs. Accommodation and the Risk of Overfitting." *British Journal for Philosophy of Science* 55 (2004): 1–34. The "weak predictivism" defended by Hitchcock and Sober has parallels elsewhere: see, for example, the careful assessment of approaches in Marc Lange, "The Apparent Superiority of Prediction to Accommodation as a Side Effect." *British Journal for Philosophy of Science* 52 (2001): 575–88; David Harker, "Accommodation and Prediction: The Case of the Persistent Head." *British Journal for Philosophy of Science* 57 (2006): 309–21.

these issues, especially as they related to the breeding of pigeons.[17] The first chapter of the *Origin of Species* therefore considers "variation under domestication" – that is, the way in which domestic plants and animals are bred by agriculturists. Darwin notes how selective breeding allows farmers to create animals or plants with particularly desirable traits. Variations develop in successive generations through this process of breeding, and these can be exploited to bring about inherited characteristics which are regarded as being of particular value by the breeder. In the second chapter, Darwin introduces the key notions of the "struggle for survival" and "natural selection" to account for what may be observed in both the fossil records and the present natural world.

Darwin argues that this process of "domestic selection" or "artificial selection" offers a model for a mechanism for what happens in nature. "Variation under domestication" is presented as an analogue of "variation under nature." A process of "natural selection" is argued to occur within the natural order which is analogous to a well-known process, familiar to English stockbreeders and horticulturalists: "As man can produce and certainly has produced a great result by his methodical and unconscious means of selection, what may not nature effect?"[18]

Darwin's theory had considerable explanatory force – a point recognized by many at the time, even those who were anxious about the implications of his ideas for the place of humanity within nature. Yet there was a serious problem with the theory. How did nature "remember" and "transmit" these new developments? How could a rising generation "inherit" the traits of its predecessor? What mechanism could be proposed by which these new developments could be passed on to future generations? Darwin's contemporaries generally believed that characteristics of the parents were "blended" when they were passed to the offspring. But if this was the case, how could a single mutation be spread throughout a species? It would be diluted to the point of insignificance, like a drop of ink in a bucket of water. It seemed that Darwin's evolutionary hypothesis was in genetic difficulties. Variation would simply become diluted. A new trait would be like a teaspoon of white paint falling into a vat of black treacle: it would vanish from sight.

Darwin's *Origin of Species* went through six editions, and Darwin worked constantly to improve his text, adding new material, amending existing material, and, above all, responding to criticisms in what can only

[17] On which see James A. Secord, "Nature's Fancy: Charles Darwin and the Breeding of Pigeons." *Isis* 72 (1981): 163–86.
[18] Darwin, *Origin of the Species.* 1st edn. 1859, 83.

be described as a remarkably open manner. Of the 4,000 sentences in the first edition, Darwin had rewritten three in four by the time of the final sixth edition of 1872. Interestingly, some 60% of these modifications took place in the last two editions, which introduced some "improvements" that now seem unwise – for example, his incorporation of Herbert Spencer's potentially misleading phrase "the survival of the fittest."[19]

The contents of these successive editions of the *Origin of Species* make it clear that Darwin's new theory faced considerable opposition on many fronts. Some traditional Christian thinkers saw it as a threat to the way in which they had interpreted their faith; others saw Darwin's theory as offering new ways of understanding and exploring traditional Christian ideas.

Yet Darwin's theory also provoked controversy within the scientific community, with many scientists of his day raising concerns about the scientific foundations of natural selection. If the successive editions of *Origin* are anything to go by, Darwin's theory was criticized by many scientists of the day on evidentiary grounds. Yet this is the norm, not the exception, in scientific advance. Criticism of a theory is the means by which – to use a Darwinian way of speaking – we discover whether it has survival potential. The reception of a scientific theory is a communal affair, in which a "tipping point" is gradually reached through a process of debate and reflection, often linked with additional research programs. Darwin's theory appears to have met more sustained opposition from the scientific community than from its religious counterpart, especially on account of its failure to offer a convincing account of how innovations were transmitted to future generations.

A good example of such scientific criticism can be seen in Henry Charles Fleeming Jenkin's concerns about "blending inheritance."[20] Jenkin (1833–85) was a Scottish engineer, heavily involved in the business of developing underwater telephone cables, who identified what Darwin clearly believed to be a potentially fatal enquiry flaw in his theory. Jenkin pointed out that, on the basis of existing understandings of hereditary transmission, any novelties would be diluted in subsequent generations. Yet Darwin's theory depended on the transmission, not dilution, of such characteristics. In other words, Darwin's theory lacked a viable understanding of genetics. Darwin responded to Jenkin in the fifth edition of

[19] Spencer (1820–1903) used the phrase in his *Principles of Biology* (1864); Darwin incorporated it into the fifth edition of the *Origin*: "This preservation of favourable variations, and the destruction of injurious variations, I call Natural Selection, or the Survival of the Fittest"; Charles Darwin, *Origin of Species.* 5th edn. London: John Murray, 1869, 91–2.

[20] On which see Michael G. Bulmer, "Did Jenkin's Swamping Argument Invalidate Darwin's Theory of Natural Selection?" *British Journal for the History of Science* 37 (2004): 281–97.

the *Origin*. The reply is generally thought to be very weak and unsatisfactory. But how could it be otherwise?

The answer, of course, lay in the writings of the Austrian monk Gregor Mendel (1822–84), which we shall consider in the next section. While the confluence of Mendel's theory of genetics and Darwin's theory of natural selection still lay some years in the future, it can be said that perhaps the greatest of Darwin's difficulties would not remain problematic for much longer.

Darwin himself was fully aware of the need for a comprehensive account of the mechanics of inheritance. The theory he developed (known as "pangenesis") was based on hypothetical "gemmules" – minute particles which somehow determine all characteristics of the organism.[21] These "gemmules" had never been observed; nevertheless, Darwin argued that it was necessary to propose their existence to make sense of the observational data at his disposal. Each and every cell of an organism, and even parts of cells, was understood to produce gemmules of a specific type corresponding to the cell or cell part. These are able to circulate throughout the body and enter the reproductive system. Every sperm and egg contains these hypothetical gemmules, and are thus transmitted to the next generation. It was an ingenious solution; yet it was not right.[22] Darwin's theory of pangenesis actually only involved partial blending, "since the patent elements fuse but the latent elements do not."[23] Darwin's theory faltered, lacking a plausible theory of genetics.

Yet even though Darwin did not believe that he had adequately dealt with all the problems which required resolution – most notably, the question of the transmission of genetic information – he was still confident that his explanation was the best available. A comment added to the sixth edition of the *Origin of Species* makes this point clear.[24]

> It can hardly be supposed that a false theory would explain, in so satisfactory a manner as does the theory of natural selection, the several large classes of facts above specified. It has recently been objected that this is an unsafe method of arguing; but it is a method used in judging the common events of life, and has often been used by the greatest natural philosophers.

[21] The theory is set out in his *The Variation of Animals and Plants under Domestication*. 2 vols. London: John Murray, 1868.

[22] Conway Zirkle, *The Early History of the Idea of the Inheritance of Acquired Characters and of Pangenesis*. Philadelphia, PA: American Philosophical Society, 1946.

[23] A point stressed by Michael G. Bulmer, *Francis Galton: Pioneer of Heredity and Biometry*. Baltimore, MD: Johns Hopkins University Press, 2003.

[24] Darwin, *Origin of Species*. 6th edn. London: John Murray, 1872, 444. This comment is not present in earlier editions of the work.

While recognizing that it lacked rigorous proof, Darwin clearly believed that his theory could be defended on the basis of criteria of acceptance and justification that were already widely used in the natural sciences, and that its explanatory capacity was itself a reliable guide to its truth.

The Mechanics of Inheritance: Gregor Mendel

Unknown to Darwin, the issues that he was finding so troublesome were being investigated at that time in a quiet monastery garden in central Europe. Gregor Mendel was a monk who entered the Augustinian monastery of St. Thomas in the Austrian town of Brünn (now the Czech town of Brno) during his twenties. His monastic superiors were impressed with his enthusiasm but not his existing levels of education. They sent him to the University of Vienna for further study (1851–3), during which time he specialized in physics, chemistry, zoology, and botany. After returning to the monastery, he taught in a local school, and conducted some experiments in the monastery garden. He had been encouraged by both his teachers at the University of Vienna and the abbot of his monastery to explore his interest in hybridization in plant populations. In effect, Mendel studied the heredity of specific characteristics as they were passed on from parent plants to their offspring. These experiments came to an end when he was elected abbot of the monastery in 1868, and faced new administrative responsibilities.

Mendel's experiments involving growing something like 28,000 pea plants over the period 1856–63 and observing how characteristics were transmitted from one generation to the next. He chose to focus on seven easily determined characteristics of his peas. Two of the best known of these are the color of their flowers (purple or white?) and the color of their seeds (yellow or green?). As he observed the patterns of inheritance of these characteristics, Mendel noticed some significant recurring features. Because he used so many plants and recorded his findings so meticulously, his results could be subjected to detailed statistical analysis which disclosed certain regular, recurring mathematical patterns of immense importance. In cross-pollinating plants that either produce yellow or green peas exclusively, Mendel found that the first offspring generation always has yellow peas. However, the following generation consistently has a 3:1 ratio of yellow to green. Certain characteristics, such as yellow seeds, were found to be "dominant" over other "recessive" characteristics, such as green seeds.

From his research, Mendel was able to formulate three fundamental principles which seemed to govern inheritance:

1 That the inheritance of each trait – such as the color of the flower or seed – seems to be determined by certain units or factors that are passed on to descendants.
2 That an individual plant inherits one such unit from each parent for each of these traits.
3 That traits which do not show up in an individual may nevertheless be passed on to a later generation.

Mendel thus proposed a theory of "particulate inheritance," in which characteristics were determined by discrete units of inheritance that were passed intact from one generation to the next. Adaptive mutations could spread slowly through a species and never be "blended out," as some contemporary theories of genetics held. The evolutionary implications of this were considerable. Darwin's theory of natural selection, building on small mutations over long periods of time, suddenly became much more plausible.

Mendel set out his ideas at the Natural History Society of Brno early in 1865. They were received politely, but not enthusiastically, and were published the following year.[25] It seems that hardly anyone read the *Verhandlungen des naturforschenden Vereins in Brünn*, and the article languished unnoticed, despite having been sent to the libraries of some 120 institutions including the Royal Society and the Linnean Society in London. In 1868, Mendel was elected abbot of his monastery, and found himself overwhelmed with administrative responsibilities. He was unable to undertake further research, or advance his ideas more widely. It was only in 1900 that the significance of Mendel's Laws were fully appreciated, following their "rediscovery" by Carl Correns in Germany (1864–1933), Hugo de Vries in the Netherlands (1848–1935), and Erich von Tschermak-Seysenegg in Austria (1871–1962), and their importance more fully realized.[26]

Questions have been raised about the integrity of Mendel's work. In 1930, the British mathematical biologist Ronald A. Fisher (1890–1962) published a landmark work in Darwinian theory, which argued that Mendel's empirical results could have been predicted by an armchair scientist, armed only with "a few very simple assumptions," concerning

[25] Gregor Johann Mendel, "Versuche über Pflanzen-Hybriden." *Verhandlungen des naturforschenden Vereins in Brünn* 4 (1866): 3–47.

[26] See for example Carl Correns, "G. Mendels Regel über das Verhalten der Nachkommenschaft der Rassenbastarde." *Berichte der deutschen botanischen Gesellschaft* 18 (1900): 158–68.

the Mendelian notion of "factorial inheritance."[27] Fisher also suggested, on mathematical grounds, that Mendel's reported observations were just too good to be true. Mendel's segregation ratios were far higher than the principles of variation statistics would permit. Since such segregation ratios could occur only very seldom, the integrity of Mendel's ideas would have to be reconsidered. This view is still encountered. As recently as 1991, it was argued that Mendel's "account of his experiments is neither truthful nor scientifically likely," and that "most of the experiments described in *Versuche* are to be considered fictitious."[28] However, the basis of such criticisms is now generally regarded as discredited, and there seems to be no real case to answer.[29] Mendel kept detailed notebooks of his observations, and recorded everything – even when the results did not fit neatly with his emerging theories.[30]

Mendel possessed a copy of Darwin's *Origin of Species*, and clearly realized that his own research explained one of the major difficulties facing Darwin's theory.[31] He marked the following passage with double lines in the margin. In Darwin's original English, this reads:[32] "The slight degree of variability in hybrids from the first cross or in the first generation, in contrast with their extreme variability in the succeeding generations, is a curious fact and deserves attention." As Mendel's most distinguished biographer pointed out, this curiosity would not remain mysterious for much longer: "Mendel must have felt some gratification in the thought that his theory was soon to explain this curious fact."[33] Mendel seems to have appreciated the importance of his own ideas to Darwin. Yet Darwin, as far as can be seen, never knew of Mendel's ideas, nor their far-reaching implications for his own theory.

[27] Ronald A. Fisher, *The Genetical Theory of Natural Selection*. Oxford: Clarendon Press, 1930.

[28] Frederico di Trocchio, "Mendel's Experiments: A Reinterpretation." *Journal of the History of Biology* 24 (1991): 485–519. For a response see Franz Weiling, "J. G. Mendel hat in der Darstellung seiner Erbsenversuche nicht gelogen." *Biologie in unserer Zeit* 4 (1995): 49–53.

[29] The best review in English is Daniel J. Fairbanks and Bryce Rytting. "Mendelian Controversies: A Botanical and Historical Review." *American Journal of Botany* 88 (2001): 737–52.

[30] Allan Franklin, *Ending the Mendel–Fisher Controversy*. Pittsburgh, PA: University of Pittsburgh Press, 2008, 6–7.

[31] More specifically, a copy of the second German edition of 1863, based on the third English edition of 1861. Only two passages are double-marked in this way.

[32] Charles Darwin, *On the Origin of Species by Natural Selection*. 3rd edn. London: John Murray, 1861, 296.

[33] Vítezslav Orel, *Gregor Mendel: The First Geneticist*. Oxford: Oxford University Press, 1996, 193.

Dawkins himself points out that things would have been very different if Darwin had had access to these results.[34] He suggests that "Mendel perhaps did not realize the significance of his findings, otherwise he might have written to Darwin."[35] I am inclined to suspect that he did realize the significance of his findings, as the unusually heavy marking of that passage from the *Origin of Species* indicates. Perhaps he felt that he had already done enough to publicize his results. After all, he was a monk, and hence perhaps disinclined to any further self-advertisement. In any case, his treatise was listed in several major British English-language sources by 1881.

Mendel had shown that inheritance seemed to be determined by certain "units" or "factors." But what where these units? This brings us to the discovery of the gene, an important event in its own right, and of fundamental importance to Dawkins' exposition of a Darwinian worldview.

The Discovery of the Gene: Thomas Hunt Morgan

The significance of Mendel's ideas had been appreciated in the English-speaking world by the Cambridge geneticist William Bateson (1861–1926), who expended considerable effort in attempting to clarify the principles governing inherited characteristics or traits, including inventing the term "genetics" to designate the field of studies. Yet Bateson was strongly opposed to the suggestion that evolution could proceed by the accumulation of the small changes that Mendel's theory seemed to offer, and Darwin's theory seemed to require. Indeed, it is possible to argue that Bateson and his followers significantly impeded the synthesis of Darwinian evolution by natural selection and Mendelian genetics on account of their misgivings concerning its explanatory potency.[36]

By 1905, Bateson had established that certain traits were linked in some manner, although the pattern of coupling (later to be interpreted as "complete" and "incomplete" coupling) was far from clear. Bateson used a series of vague physical analogies – such as "coupling" and "repulsion" – in an ultimately unsuccessful attempt to explain his puzzling observations.[37]

[34] *A Devil's Chaplain*, 67–9.

[35] *The Selfish Gene*, 34.

[36] See the detailed analysis in Peter J. Bowler, *The Eclipse of Darwinism: Anti-Darwinian Evolution Theories in the Decades around 1900*. Baltimore, MD: Johns Hopkins University Press, 1983; Jean Gayon, *Darwinism's Struggle for Survival: Heredity and the Hypothesis of Natural Selection*. Cambridge: Cambridge University Press, 1998.

[37] Recent scholarship has suggested Bateson's ideas were more plausible than realized at the time: see Patrick Bateson, "William Bateson: A Biologist ahead of His Time." *Journal of Genetics* 81, no. 2 (2002): 49–58.

Bateson's writings suggest that he thought in terms of certain forces (analogous to magnetic or electrical forces) which were capable of attracting or repelling factors of genetic significance. In the end, the solution was set out in a seminal paper published by the American geneticist Thomas Hunt Morgan (1866–1945) in 1926.[38] The solution? The gene.

Excited by Mendel's ideas, Morgan had exploited the short reproductive cycle of the fruit fly *Drosophila melanogaster* to explore the transmission of heritable characteristics. Like Mendel, he chose to focus on some well-defined characteristic traits that occurred in pairs. The most famous of these was the color of the eyes. Noting the patterns of distribution of red and white eyes, Morgan modified Mendel's theory in an important respect: he argued that not all genetic traits are passed on independently, as Mendel had supposed. Instead, some genetic traits seemed to be linked, and are thus inherited together, rather than individually.

Morgan's most important conclusion concerned the "units" or "factors" which transmitted these traits, now known as "genes." It had been known for some time that the division of cells was accompanied by the appearance of tiny rod-shaped, threadlike structures, known as "chromosomes." Some had speculated that these chromosomes might be responsible for transmitting hereditary information. Morgan was able to provide overwhelming evidence that this was indeed the case. The "genes" responsible for transmitting this information were physically located on the chromosomes. As microscopes with increasing resolution were developed, it eventually became possible to confirm this visually.

Morgan's fruit flies had four unusually large chromosomes, which made them particularly easy to study microscopically. He discovered that there were four distinct groups of traits that appeared to be inherited together, corresponding exactly with the number of pairs of chromosomes observed in *Drosophila*. He also found that one of the four linkage groups had fewer characteristics than the other three. This seemed to tie in with the fact that one of the *Drosophila* chromosomes was smaller than the other three. While further work on the role in hereditary transmission of the chromosomes in the cell nucleus was still needed, a coherent picture was now beginning to emerge.

Morgan outlined his findings and assessed their significance in two papers published in the journal *Science* in 1910 and 1911. Morgan's chromosomal theory of heredity assumed that each chromosome contains a collection of small units called genes (a term he borrowed from the Danish

[38] The best study is still Garland E. Allen, *Thomas Hunt Morgan: The Man and His Science*. Princeton, NJ: Princeton University Press, 1978.

physiologist Wilhelm Johannsen who had been a colleague at Columbia University in 1909), with different genes having specific locations along specific chromosomes. The Mendelian notion of discrete hereditary factors could now be stated in terms of "genes." What has come to be known as the "neo-Darwinist" synthesis was now possible – Mendelian genetics as the basic explanation of evolutionary change, linked with the process of Darwinian natural selection as determining its outcome.[39]

One of the greatest achievements of the early scientific revolution of the seventeenth century was the "mathematization of nature." The growing realization that the deeper structures of nature could be represented mathematically was both a stimulus to scientific reflection,[40] and the cause of deeper reflection on why mathematics was so "unreasonably effective" in representing reality.[41] Unsurprisingly, many began to wonder if Darwin's basic ideas were capable of expressing mathematically. If Darwin was indeed the "Newton of the grassblade,"[42] might not mathematics prove as effective at uncovering the law governing the biological world as effectively as Newton had uncovered the laws of motion?

The first significant attempts to develop a mathematical theory of natural selection took place in the 1920s, predominantly through the formulation of theoretical population genetics by Ronald A. Fisher – whose criticisms of Mendel we noted earlier – although with important contributions from J. B. S. Haldane (1892–1964) and Sewall Wright (1889–1988).[43] It is possible to see Fisher's landmark work *Genetical Theory of Natural Selection* as "a kind of mathematical–Mendelian appendix to *The Origin of Species.*"[44] Fisher, Haldane, and Wright developed sophisticated mathematical models of evolution which accounted for the manner in which mutations arise and spread through a population through natural selection. By about 1932, the first phase of the "evolutionary synthesis" was complete; the second phase was catalyzed by Theodosius Dobzhansky

39 For Morgan's mature statement of this theory, see Thomas H. Morgan, *The Theory of the Gene*. New Haven, CT: Yale University Press, 1938.

40 Joella G. Yoder, *Unrolling Time: Christiaan Huygens and the Mathematization of Nature*. Cambridge: Cambridge University Press, 1988.

41 See the classic study of Eugene Wigner, "The Unreasonable Effectiveness of Mathematics." *Communications on Pure and Applied Mathematics* 13 (1960): 1–14.

42 John F. Cornell, "Newton of the Grassblade? Darwin and the Problem of Organic Teleology." *Isis* 77 (1986): 405–21.

43 The best studies are Alan Grafen, "Fisher the Evolutionary Biologist." *The Statistician* 52 (2003): 319–29; A. W. F. Edwards, "Mathematizing Darwin." *Behavioral Ecology and Sociobiology* 65, no. 3 (2011): 421–30. Grafen refers to Fisher as "Darwin's mathematician."

44 A. W. F. Edwards, "The Genetical Theory of Natural Selection." *Genetics* 154 (2000): 1419–26.

(1900–75) on the publication in 1937 of his landmark book, *Genetics and the Origin of Species*, which offered an explanation of how species came into existence.

Yet further clarification was needed concerning the molecular basis of genetics. A decisive step forward was made in the United States during the Second World War – to which we now turn.

The Role of DNA in Genetics

Morgan's discovery of the critical role of the chromosomes in genetics sparked new interest in their chemical composition. What were these threadlike fibers actually made of? The Swiss biochemist Friedrich Miescher (1844–95) established the chemical composition of cell nuclei in 1868. He determined that they contained two basic components – a nucleic acid (now known as deoxyribose nucleic acid, and universally known by its acronym DNA), and a class of proteins (now known as histones).[45] These nucleic acids were not regarded as particularly important biologically. Chemical studies suggested they were not very diverse and they had only a small number of components.

In 1938, the American biochemist Phoebus Levene (1869–1940), then working at the Rockefeller Institute in New York, discovered that DNA was basically a remarkably long polymer.[46] However, he took the view that this long polymer simply consisted of repeated units of four basic nucleotides: adenine (A), guanine (G), thymine (T), and cytosine (C). For this reason, many (including Levene himself) regarded DNA as highly unlikely to have any major role in the transmission of inherited characteristics. It was too simple chemically to encode genetic information. Many believed that the ultimate key to the molecular basis of genetics would lie in proteins found within the chromosomes.

As is so often the case, the key to solving this riddle came from an unexpected source. In 1928, the English bacteriologist Fred Griffith (1879–1941) was involved in investigating a pneumonia epidemic in London. While investigating the *pneumococcus* responsible for this outbreak, Griffith made the surprising discovery that live *pneumococci* could acquire genetic traits from other, dead *pneumococci* in a process he termed

[45] See Ralf Dahm, "Friedrich Miescher and the Discovery of DNA." *Developmental Biology* 278, no. 2 (2005): 274–88.

[46] For a brief assessment of Levene's significance, see Robert D. Simoni, Robert L. Hill, and Martha Vaughan, "The Structure of Nucleic Acids and Many Other Natural Products: Phoebus Aaron Levene." *Journal of Biological Chemistry* 277, no. 22 (2002): 23–4.

"transformation." But how could this be? All that the dead *pneumococci* could transmit were chemicals: specifically, two types of nucleic acid – ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) – and protein. How could these bring about genetic change in living cells?

The importance of Griffith's work was not appreciated until a research team headed up by Oswald Avery (1877–1955) replicated his findings at the Rockefeller Institute in New York. Avery and his team began detailed studies of how genetic information was transmitted to living *pneumococci*. They conducted a series of experiments which demonstrated that genetic information was not mediated by proteins, or by RNA, but specifically by DNA.[47] This was a momentous discovery, even if it would be some time before its full implications were appreciated. If DNA – and no other substance – was the carrier of hereditary information, it must have a much more complex structure than had previously been appreciated. Yet nobody knew what this structure was, nor how DNA was able to play such a critical genetic role.

This gave new impetus to a remarkable series of studies. Rosalind Franklin (1920–58) undertook pioneering X-ray crystallography work on DNA, which did much to facilitate the ground-breaking work of the English physicist Francis Crick (1916–2004) and the American geneticist James Watson (b. 1928) demonstrating a double-helix structure for DNA.[48] This achievement was a remarkable physical discovery in itself. Yet it also opened the way to understanding how DNA could pass on genetic information. Watson and Crick immediately realized that the pairing of the bases in this double-stranded DNA had to be the key to its function as a replicator and as the transmitter of genetic information. They wrote: "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."[49] In other words, a knowledge of the physical structure DNA suggested a mechanism by which it could replicate itself.[50]

On the basis of this research, Crick proposed what he called the "Central Dogma" – namely, that DNA replicates, acting as a template for RNA, which in turn acts as a template for proteins. The long and complex DNA molecule

47 Oswald Avery, Colin MacLeod, and Maclyn McCarty, "Studies on the Chemical Nature of the Substance Inducing Transformation of Pneumococcal Types: Induction of Transformation by a Desoxyribonucleic Acid Fraction Isolated from Pneumococcus Type III." *Journal of Experimental Medicine* 79 (1944): 137–58.

48 Francis H. C. Crick and James D. Watson, "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid." *Nature* 171 (1953): 737–8.

49 Crick and Watson, "Molecular Structure of Nucleic Acids," 738.

50 For a good introduction, see C. R. Calladine, *Understanding DNA the Molecule and How It Works*. 3rd edn. San Diego, CA: Elsevier Academic, 2004.

contains the genetic information necessary for transmission "encoded" using the four basic nucleotides: adenine (A), guanine (G), thymine (T), and cytosine (C) arranged in sequences of "base pairs" (in that adenine is always linked to thymine, and guanine to cystosine in the double-helix structure of DNA), attached to a sugar and phosphate spine. It is the sequence of these base pairs which determines the genetic information transmitted.[51]

So why is this so important for an understanding of evolutionary biology? The most important point to emphasize is that Darwin's theory of natural selection required variation to take place *and* to be transmitted, rather than diluted, to following generations. Natural selection would then take place, determining whether or not the genetic code for this variation would survive. The neo-Darwinian synthesis is grounded in the assumption that small random genetic changes (mutations) over long periods of time occasionally have positive survival value. Organisms possessing these favorable mutations should have relative advantage in survival and reproduction, and they will tend to pass their characteristics on to their descendants. Assuming that there are differential rates of survival, it is not difficult to see how a favorable characteristic can become established and transmitted.

The key point is that genetic variation takes place in nature, that the process of natural selection determines whether this variation survives, and that the process of genetic replication ensures that this variation is transmitted. Evolution thus proceeds by fixation of these rare beneficial variations, and the elimination of maladapted variations through the process of natural selection. This, however, still leaves open many of the problems of evolutionary biology. To give an example: at what level does natural selection take place? Is it at the level of genes themselves? Or of individual organisms which contain those genes? Or at the level of kin (closely related individuals) or groups? We shall consider these issues later in this work, as we engage with Dawkins' views on these themes.

What's in a Name? "Darwinism" or "Evolutionary Theory"?

Many scientific theories are initially known by the names of their originators or chief advocates. A good example is "Copernicanism," a term that is used in a specifically *historical* sense to refer to the way of

[51] For further details see such works as Anthony J. F. Griffiths, *An Introduction to Genetic Analysis*. 7th edn. New York: Freeman, 2000; idem, *Modern Genetic Analysis: Integrating Genes and Genomes*. 2nd edn. New York: Freeman, 2002.

thinking about the solar system developed in the sixteenth century by Nicolaus Copernicus (1473–1543) and his immediate followers.[52] Yet the term "Copernicanism" refers to a theory which incorporates both the *correct* central heliocentric assumption, and the *incorrect* subsidiary assumption that all the planets orbit the sun in perfect circles at constant speeds.[53] The former assumption was subsequently affirmed, just as the second was corrected, by Johannes Kepler (1571–1630).[54] The term "Copernicanism" thus designates a particular model of the solar system, which includes some elements now considered to be correct, and others which are recognized as being wrong. Nobody uses the term "Copernicanism" any more to refer to the solar system. The debate has moved on.

So is the same also true of "Darwinism"? Nobody would deny the historical importance of Charles Darwin, whose works set out the theory of descent with modification through natural selection.[55] But should we continue to use the term "Darwinism" to refer to contemporary theories of biological evolution, when they have moved on so much?

Some writers would defend the continued use of the term in this sense. Jean Gayon argues that the term "Darwinism" acknowledges the manner in which Darwin has "constrained the conceptual and empirical development of evolutionary biology ever after."[56] Others, however, find the use of the term "Darwinism" deeply problematic.[57] Why should contemporary thinking about evolution be described in this manner? Evolutionary thought has moved on since Darwin. Surely "Darwinism" should be used in an essentially historical sense, to refer to the ideas that Darwin himself developed. As is well known, modern evolutionary biology has developed a range of ideas which are decidedly non-Darwinian – that is to say, ideas of which Darwin knew nothing. To speak of Darwinism is thus "grossly misleading," suggesting that Darwin was "the beginning

[52] See Liba Taub, *Ptolemy's Universe: The Natural Philosophical and Ethical Foundations of Ptolemy's Astronomy*. Chicago: University of Chicago Press, 1993.

[53] See Karoly Simonyi, *A Cultural History of Physics*. London: Peters, 181–5.

[54] See Carl D. Murray and Stanley F. Dermott, *Solar System Dynamics*. Cambridge: Cambridge University Press, 2001, 3–4. See further Bruce Stephenson, *The Music of the Heavens: Kepler's Harmonic Astronomy*. Princeton, NJ: Princeton University Press, 1994.

[55] See Peter J. Bowler, *Evolution: The History of an Idea*. 3rd edn. Berkeley, CA: University of California Press, 2003.

[56] Jean Gayon, "From Darwin to Today in Evolutionary Biology." In *The Cambridge Companion to Darwin*, edited by Jonathan Hodge and Gregory Radick, 240–64. Cambridge: Cambridge University Press, 2003, 241.

[57] Note the important concerns expressed in Eugenie Scott and Glenn Branch, "Don't Call It Darwinism." *Evolution: Education and Outreach* 2 (2009): 90–4.

and the end, the alpha and omega, of evolutionary biology," and that the subject changed little since the publication of the *Origin of Species*.[58] Evolutionary thought has moved far beyond the intellectual landscape originally envisaged by Darwin,[59] as a series of non-Darwinian processes – such as autopoiesis, self-organization, epigenetic mechanisms, and symbiosis – are now realized to play a significant role in the evolutionary process, considered as a whole.[60]

The modern approach to evolutionary theory, though grounded in Darwin's theory of natural selection, was initially supplemented with Mendelian genetics in the 1930s and 1940s, and subsequently by the development of mathematical systems allowing the modeling of evolution in populations in the 1940s and 1950s, and the emergence of an understanding of the molecular basis of evolution through the structures and function of RNA and DNA.[61] Continuing to talk about "Darwinism" merely fosters the inaccurate and unfortunate perception that the field stagnated for 150 years after Darwin's own day.

Historians have also raised concerns about the use of the term "Darwinism." For a start, historical research has made it clear that evolutionary thought had developed well before Darwin's time, with other writers having made signal contributions to the science. Using the term "Darwinism" perpetuates the historical myth of Darwin as a solitary genius, and fails to do justice to his intellectual context and dependencies. Without in any way denying Darwin's genius, it is essential to contextualize

[58] Olivia Judson, "Let's Get Rid of Darwinism." *New York Times*, July 15, 2008.

[59] For the continuous evolution of Darwinism, see David Depew and Bruce Weber, *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection*. Cambridge, MA: MIT Press, 1995; Evelyn Fox Keller, *Making Sense of Life: Explaining Biological Development with Models, Metaphors, and Machines*. Cambridge, MA: Harvard University Press, 2002; Timothy Shanahan, *The Evolution of Darwinism: Selection, Adaptation, and Progress in Evolutionary Biology*. Cambridge: Cambridge University Press, 2004, 11–36.

[60] Note the points made in Gregory L. Challis and David A. Hopwood, "Synergy and Contingency as Driving Forces for the Evolution of Multiple Secondary Metabolite Production by Streptomyces Species." *Proceedings of the National Academy of Sciences* 100 (2003): 14555–61.

[61] For an introduction to the core developments see Ted Everson, *The Gene: A Historical Perspective*. Westport, CT: Greenwood, 2007. See further Steven A. Frank, "The Price Equation, Fisher's Fundamental Theorem, Kin Selection, and Causal Analysis." *Evolution* 51 (1997): 1712–29. The importance of information theory should also be noted: Jeffrey S. Wicken, *Evolution, Thermodynamics, and Information: Extending the Darwinian Paradigm*. Oxford: Oxford University Press, 1987; Hubert P. Yockey, *Information Theory, Evolution, and the Origin of Life*. Cambridge: Cambridge University Press, 2005; Steven A. Frank, "Natural Selection Maximizes Fisher Information." *Journal of Evolutionary Biology* 22 (2009): 231–44.

Darwin against the backdrop of evolutionary thought at the time.[62] Critics point out that the predominance and narrow focus of English-language scholarship has led to Darwin being given a position of privilege which marginalizes, often to the point of ignoring, the significant pre-Darwinian discussions in France, Germany, and Italy which helped bring about the revolutionary change in thinking from a static understanding of biological organisms to the dynamic, evolutionary viewpoint that is now taken for granted.[63] Darwin was unquestionably a major influence in bringing about this revolution; he cannot, however, be seen as its sole originator.

And what about Mendel? As we have seen, the work of Fisher and others demonstrated the critical importance of Mendel's ideas as an integral part of evolutionary thought. To use the exclusivist term "Darwinism" is to deny Mendel his fundamental place in the development of the science of evolution.

One possible solution to the dilemma is to use the label "neo-Darwinism," thus indicating both the origins of some core themes of modern evolutionary biology, while at the same time acknowledging their significant modification and amplification through subsequent research. Yet this is only one such way of designating this modification of Darwin's ideas; others which have achieved wider currency – such as the "evolutionary synthesis," "modern synthesis," the "modern evolutionary synthesis," or the "new synthesis" – avoid mentioning Darwin by name.[64] As pressure grows for modification of at least some of the elements of this evolutionary synthesis,[65] the value of the term "neo-Darwinism" seems increasingly fragile.

Modern evolutionary biologists now tend to use the term "Darwinism" rarely, except in a historical sense to designate Darwin's formative ideas.[66] The term "Darwinian" is now often used to refer to the historically

[62] See for example Pietro Corsi, *Evolution before Darwin*. Oxford: Oxford University Press, 2010.

[63] See the important discussion in Pietro Corsi, "Before Darwin: Transformist Concepts in European Natural History." *Journal of the History of Biology* 38 (2005): 67–83.

[64] A work which had an important influence on shaping the vocabulary of the field was Julian S. Huxley, *Evolution: The Modern Synthesis*. London: Allen and Unwin, 1942.

[65] See for example Ulrich Kutschera and Karl J. Niklas, "The Modern Theory of Biological Evolution: An Expanded Synthesis." *Naturwissenschaften* 91 (2004): 255–76; Massimo Pigliucci, "Do We Need an Extended Evolutionary Synthesis?" *Evolution* 61 (2007): 2743–9; Sean B. Carroll, "EvoDevo and an Expanding Evolutionary Synthesis: A Genetic Theory of Morphological Evolution." *Cell* 134 (2008): 25–36.

[66] For comment see David L. Hull, "Darwinism as a Historical Entity: A Historiographic Proposal." In *The Darwinian Heritage*, edited by David Kohn, 773–812. Princeton, NJ: Princeton University Press, 1985.

significant issue of Darwin's personal views, irrespective of the subsequent direction of the discussion about evolution.[67] A survey of the literature suggests that most modern biologists, when speaking about present-day understanding of evolutionary biology, tend to speak about "the theory of evolution" or "evolutionary biology," rather than "Darwinism." It is certainly true that Darwin's three core principles of variation, inheritance, and selection remain significant to modern evolutionary theories; nevertheless, these are now supplemented with additional notions.[68]

Some have therefore drawn the conclusion that the continuing use of the term "Darwinism" to epitomize modern evolutionary biology is as anachronistic as using "Copernicanism" to designate contemporary cosmology. The terms designate important turning points in the history of the disciplines, in the course of which at least some elements of today's thinking were developed. These have, of course, been supplemented (and modified) by many others since then. So why not abandon it, in favor of one of the many superior alternatives? There seems no obvious scientific reason for retaining it. As times passes, it is inevitable that increasing historical distance from Darwin will weaken the links between his specific formulation of the evolutionary process, and contemporary understandings of the field.[69] The use of "Darwinism" to refer to evolutionary biology as this is presently understood would seem at least unnecessary, and probably unwise.

So why retain the use of the term in this book? In part, the answer lies in Dawkins' development of the idea of "Universal Darwinism." One of Dawkins' more important contributions to the public discussion of the significance of evolutionary thought is his argument that what he terms "Universal Darwinism" represents a justified extension of Darwin's approach from the biological to the cultural domain. In developing Darwin in this way, Dawkins and others have initiated an important cultural and historical debate over the cultural authority and character of Darwinism.[70] Is Darwinism to be seen as a provisional scientific theory,

[67] Momme von Sydow, *From Darwinian Metaphysics towards Understanding the Evolution of Evolutionary Mechanisms*. Göttingen: Universitätsverlag Göttingen, 2012, 102–3.

[68] For the question of the whether a unifying narrative may be offered of the development of evolutionary theories, see Vassiliki B. Smocovitis, *Unifying Biology: The Evolutionary Synthesis and Evolutionary Biology*. Princeton, NJ: Princeton University Press, 1996, 97–188.

[69] See for example Jerry A. Fodor and Massimo Piattelli-Palmarini, *What Darwin Got Wrong*. New York: Farrar, Straus and Giroux, 2010, 95–137.

[70] There are important anticipations of this development in the writings of John Dewey: see for example John Dewey, *The Influence of Darwin on Philosophy and Other Essays*. New York: Holt, 1910, 1–26.

which has limited relevance to a broader cultural agenda? Or is it to be seen as a worldview, like Marxism, which, if correct, has major implications for a much broader cultural and social agenda?[71] Is it, as Dawkins asserts, a "universal truth?" Although this debate can be tracked back to the publication of Darwin's *Origin of Species* itself,[72] it remains important today. For some, including Dawkins, the term "Darwinism" designates a worldview, a metanarrative. For this reason, we shall continue to use the term "Darwinism" in this work, despite the concerns noted in this section.

At this point, we have laid the groundwork for a proper engagement with Richard Dawkins' important contributions to evolutionary thought, and the relation of science and faith. In the next chapter, we shall explore the significance of Dawkins' landmark work *The Selfish Gene*.

[71] This has been a major theme in the writings of John C. Greene: see especially his *Darwin and the Modern World View*. Baton Rouge, LA: Louisiana State University Press, 1961.
[72] See for example Ernst Cassirer, "Darwinism as a Dogma and as a Principle of Knowledge." In *The Problem of Knowledge: Philosophy, Science, and History since Hegel*, 160–75. New Haven, CT: Yale University Press, 1950.