



DARWIN'S DICE

The Idea of
CHANCE
in the Thought of
Charles Darwin

CURTIS JOHNSON

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Acknowledgments

THE SYSTEMATIC STUDY of chance in nature's operations has an ancient pedigree, dating back at least to the writings of Empedocles (5th c. BCE) and Aristotle (4th c. BCE). If one were permitted to acknowledge debts to the no longer living, I would begin by acknowledging them. It is not simply that they wrestled with the idea of chance in nature; they did so in just the way Darwin did. Darwin himself was not directly influenced by these authors. I doubt he ever read anything by Empedocles, and his acquaintance with Aristotle's writings came only late in his life, long after he had developed and refined his own ideas. But these two ancient thinkers put a Darwinian sort of chance into a long tradition of thought that is with us still.

Any work of this sort could not be undertaken without the insights of other scholars laboring in the same fields. It would be impossible to give an exhaustive account of what I owe to all of these men and women, but I refer the interested reader to the bibliography for a register of most of my debts to other authors. Several of these stand out for special mention: the volume of collected essays edited by Gigerenzer, G. et al., eds., 1989; a two volume work edited by [Krueger and Morgan, 1987](#); and several individual works by those whom I regard as leading authorities in the study of chance in evolutionary biology today, especially John Beatty, James Lennox, and Roberta Millstein. I have no personal acquaintance with any of these authors but my work has benefited beyond measure by the foundation laid by them.

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My greatest debts are to my wife and daughters Sophia and Alexis, and my parents for constant encouragement and support. Sophia is the artist who produced the illustrations for the chapter headings; Alexis created the graphic on p. 59. Above all, I could not have undertaken this work without the untiring support and assistance in every manner of way—too many to enumerate—of my wife Loretta.



CHARLES DARWIN'S "big idea" is generally thought to be his discovery of the mechanism of natural selection in evolution. That discovery was without question a big idea. But, as Darwin himself often confessed, natural selection cannot work without prior variations in the organisms that will be selected or not for survival. Whence the variations, or at least what did Darwin believe about this? That is the question I examine in what follows. Darwin thought "variations" are in many or most cases "just by chance." I hope to show what he meant by this expression and what he believed the implications are once one accepts it. "Chance variation" may have been an even bigger idea for Darwin than natural selection, or so I shall attempt to show.

Thus, whatever "Darwinism" is, this is not a book about Darwinism. Nor is it a book about contemporary evolutionary theory or the "new synthesis" or the "extended synthesis."¹ It is rather a book about "chance" in Darwin's writing. To that extent it must confront "Darwinism" more broadly, even in its recent and contemporary incarnations, if only to situate the problems it deals with in proper context.

But an answer to "what is Darwinism" is surprisingly elusive. Even if we grant that "Darwinism" is "whatever Darwin said it is," the problems of identifying Darwinism only begin there. Darwin's views seem to have evolved over the course of a long and prolific career as a scientist, author, and correspondent. Did he maintain a consistent position? Was "Darwinism" always the same thing for Darwin? Many scholars who have considered this question, perhaps most, have held and defended the view that his ideas did change, so that "Darwinism" as "whatever Darwin said it is" is a moving target (Lennox, 2004; Beatty, in Mueller and Pigliucci, eds., 2010; Hull, in Kohn, ed., 1985; Ospovat, 1980; Browne, 1982; Gayon, 2003).

To mention only the most notorious example, the *Origin of Species*, from its first appearance in 1859 through the last edition (sixth, 1872) underwent revisions, many of decided significance, for each new edition (cf. *Origin* 1959, *Variorum* edition, editor's introduction; and for additional discussions, Moore, 1979, 133; Vorzimmer, 1970, *passim*; Ruse, 1979, 210–11; Browne, 1995, 200–206).² But that is only the beginning of the story. From the time of his *Notebooks*, containing Darwin's earliest reflections on the origin of species question (1836–1842), through his late book on earthworms (1881) Darwin tinkered almost obsessively with the way he chose to present his theories. This fact raises the suspicion that he did in fact change his mind and that he came to mal

“adjustments” to the theory along the way.³

My view is that “Darwinism” had a single meaning to Darwin from beginning to end. Yes, changes were made in exposition, over and over again, and in one sense, as a philosophical platitude, one cannot change one’s way of saying something without changing what one says, and therefore what one is taken to mean.⁴ But another way of thinking about changes in presentation is to ask whether the author intended a change in meaning, especially as regards core beliefs and elements of a theory. In this regard, according to the well-established “principle of charity” in philosophical studies, one looks for “philosophical consistency” and decides that a significant shift in outlook has occurred only when forced to do so by irrefutable evidence.⁵

In the case of Darwin such evidence is hard to come by. Even explicit statements by Darwin such as “I probably underestimated the importance of factor ‘x’ (e.g., so-called ‘use-inheritance’) in earlier versions of my theory,” do not rise to the level of strong evidence for a shift in basic outlook, yet this is the sort of evidence upon which arguments for a shift is often based.⁶ Placed alongside a considerable body of contrary evidence, the case for an ever-changing “Darwinism” is weakened. One is not free to ignore the evidence supporting a Darwinian change. But one may overcome it if countervailing evidence is available and if a better explanation for the supporting evidence is available.

On the other hand, Darwin did change his mode of exposition, repeatedly. An examination of the Darwinian corpus shows that many of the most important changes centered on how he wished to present the role of “chance” in evolution to an ever-expanding reading public, especially after the *Origin* first appeared. But the changes started to appear much earlier, from unguarded reflections in the 1836–1839 *Notebooks* to the more publicly attuned 1842 “Sketch” and 1844 “Essay” (Kohn and Stauffer, 1982) all the way through the several editions of the *Origin* and beyond. Something deliberate is going on here, and to discover what that something is motivates the work presented here. To anticipate, I wish to make and defend the following claims:

- (1) Darwin discovered “chance” as a basic factor in evolution from an early time in his career, perhaps mid-1837.⁷
- (2) Darwin understood some important implications of this discovery from a nearly equal early period for how his views would be received, specifically: (1) that “chance” (in its primary meaning for Darwin) would be regarded as a “dangerous” idea (in this he was correct); (2) that he probably had to readjust his own religious views in light of his discovery; (3) that he could not in good conscience pretend to himself or the world that he did not really mean it; (4) that to ensure scientific acceptance of his discovery he would need to cast the role of chance in ways that, while preserving its central meaning, would either obscure its role in his theory or at least make it seem innocuous to otherwise friendly natural philosophers and scientists; and (5) that to accomplish this end he would need to rework his wording in his published writings.
- (3) Changes made by Darwin in how he chose to present “chance” in his theory may be of greater significance than any others in the Darwinian corpus. At a minimum they are extremely important in seeing how he “evolved” in mode of expression.

I understand that these are strong and for some readers controversial claims. Whether they can be supported will depend on the evidence from Darwin’s oeuvre. I present what evidence I could assemble in the following pages and must let the reader decide whether the evidence and supporting argumentation are up to the challenge.

It may fairly be asked, against whom am I making these claims? Darwin’s thoughts, as many commentators have observed, are often refracted through the lens of the reception of his views as they became more widely known by a broader reading public. For example, M. J. Hodge has suggested that

Darwin's "reception" among a large reading public was created and promoted by his son Francis, who published letters edited by Francis, as well as in Francis's own interpretive essays—the so-called Franciscan interpretation. Francis did not alter Darwin's words but he did make choices about what should be published after his father's death and what should remain private. Later commentators have offered different interpretations of what Darwinism meant to Darwin as more of Darwin's "private" writings became public. The point here is only that how a thinker is understood is often a result of much more about what others have said as it is about what the thinker wrote himself.

I have not been motivated in this work by a desire to show disagreements with previous interpretations, although, inevitably, my arguments will challenge many of them. But I got my start in Darwinian studies by examining only the words and works of Charles Darwin. I thus started out with no axes to grind. I believe this is an advantage, insofar as my readings were not at first influenced by the readings of other scholars. Naturally, over the course of years of engagement with the vast literature on Darwin and Darwinism I have come to see where my work intersects, overlaps, and disagrees with this literature. I try to give a full account of my many debts to the scholars who have been laboring in the field and to show where my arguments differ from theirs. But I try to set out and move through with a clean slate, basing my claims on Darwin's *ipsissima verba* rather than on what others have said.

DARWINISM

The Darwinian theory, usually rendered in shorthand as the theory of "descent with modification by means of natural selection," may be reduced to a syllogistic core that goes something like this:⁸

- (1) Variation. All creatures that reproduce (sexually or asexually—it doesn't matter⁹) will produce offspring that *vary* slightly from themselves. An offspring might have slightly longer legs, or a slightly shorter beak, or slightly more hair, than its parents, and so it is said to vary. It is important to say that Darwin often claimed that he did not know *how* or *why* variations occur, only that they do occur. No parents' child is identical to its parents, but how it will vary no one can predict. Darwin could often do no better than to say that any variation from parent to child is due to what we must, in our ignorance, call *chance*.
- (2) Heritability. Variations are often passed along in reproduction. Children with longer legs or more hair are likely to have children with these same traits, or even with these same traits more pronounced, and so on down the line of generation. In other words, variations often have a tendency to be *preserved*.
- (3) Competition for survival. More creatures are born in every species or group than can normally survive. They reproduce faster than the resources upon which they depend for sustenance. Therefore, some—actually many—must perish, as a regular fact of life. Only the few ever survive. This phenomenon came to be called by Darwin "survival of the fittest," an expression that was invented by Herbert Spencer and brought to Darwin's notice by the co-discoverer of the theory of natural selection, A. R. Wallace.

If these three events occur in nature—and Darwin was certain they did—then the mechanism of Natural Selection would allow evolution to happen.

- (4) Natural Selection. This principle determines who are the winners and losers in the perpetual struggle for existence. Those creatures that have varied in "favorable" directions are more likely to survive than those that have not varied, or have varied in unfavorable ways. For example, in a climate where longer hair provides a better protection against death by freezing

than shorter hair, a variant individual with longer hair will be “selected” by nature to survive ~~against its rivals who have been born with shorter hair, and this successful variant is likely to~~ pass along the winning trait to its offspring. Again, Darwin did not claim to know how or why some individuals happened to vary—happened to be born with longer hair in our example—but only that if they did vary in favorable directions, they had a better chance to be selected for survival than ones that did not vary.¹⁰

Of these four parts or ideas of the theory, this book is mainly about the first—variation—and even more narrowly, only variations that Darwin attributed to chance. The other ideas, of course, are fundamental to the theory, and no one believes that Darwin ever wavered from his belief in them, or the primacy of natural selection among other factors that play a role in evolution. What is usually the issue in arguments for a changing Darwinism, rather, is the role played by “chance” in explaining variation. This idea more than any other sets Darwin’s theory apart from all other evolutionary theories in his day, and thus is important for establishing Darwin’s theory as distinctive “Darwinian.” The idea of “chance,” and the role it plays in the modification and “transmutation” of species, remained steadfast and the same in Darwin’s thought from his first revelations in 1837–1838 about what goes on in nature to all subsequent works where he addressed the question.¹¹ It is also, as shall show, the one part of his theory that underwent the most dramatic changes in exposition.

These changes, directly and indirectly, account in turn for most of the suspicion that Darwin actually changed his mind, even though those who bring forward this argument have not been entirely clear about the importance of this shift for their own arguments. For example, one typical argument is that Darwin became more “Lamarckian” over the years.¹² This is generally taken to mean that Darwin came to strengthen a role for so-called “use-inheritance” in evolutionary change. What generally goes unnoticed in these accounts is that “use-inheritance” can only be strengthened by diminishing a role for something else, and that something else is usually “chance.” In fact the impression that Darwin strengthened “use-inheritance” is generated in part by the fact that he did (in words) reduce or even disguise the role that he had earlier assigned to chance. But if he did not really change his mind about chance, he did not really change his mind about use-inheritance.

DARWIN’S APPROPRIATION OF CHANCE

Chance as an important factor in how to understand nature was not Darwin’s unique discovery. Philosophers and naturalists had much to say about “chance,” even in quasi-evolutionary contexts long before Darwin, as is the case, for example, with the Greek philosopher Empedocles (4th c. BCE) as recorded in Aristotle’s *Physics*. Aristotle too considered what sort of role chance might be said to play in natural events.¹³ But the idea that chance might play a role in shaping the organic world, in such a way that random variations paradoxically give rise to apparent design and order, was no part of the scientific mainstream of Darwin’s day. If anything, chance was anathema to most scientists and philosophers (cf. D. Hull, 1973, 15, 55–68; Browne, 2006, 92–3). To most thinkers, chance connoted a variety of ideas that seemed contrary not only to revealed and natural religion but also to common sense. Even skeptical thinkers like David Hume, who made serious efforts to consider the possibility that chance may have some role to play in nature, came to reject it (*Dialogues Concerning Natural Religion*, 1779, Pts. II, IV, V, VII, XII; cf. D. Dennett, 1995, 28–33; Dawkins, 2006, chapter 4). Most people did not even consider the possibility. The many writers who most influenced Darwin’s thinking about nature—men like Lyell, Whewell, Herschel, and before them William Paley, with their deep admiration for nature’s orderliness and evident design—dismissed a role for chance out of hand.¹⁴

Darwin, by contrast, understood from his earliest reflections on the origin of species question

1837–1838 that he would be required by the tenets of his science to make room for a role for “chance in the evolution of new species. Our question concerns how he handled this issue. “Chance” as Darwin used it was a bogey for most of his audience, friendly and unfriendly alike. Chance, at least in one important sense, means fortuity, and most people in Darwin’s day, and even now, could not accept a world in which fortuity played a guiding role in evolution.¹⁵ Yet Darwin believed fortuity was at the very core of modifications leading to the origin of new species.¹⁶ The implications of any such view were significant. The earth, its geological features, and its organic inhabitants are here only through lucky accidents? For many people that was a hard pill to swallow. Darwin did accept it, but also knew he would have to get his audience to accept it too if he were to succeed in establishing his theory as the correct account of the origin of species.

Darwin realized he would need to tread carefully. His early public presentations of the theory, especially in the *Origin* itself, were not careful enough. Under the onslaught of criticism that the *Origin* received after its first appearance in 1859, Darwin decided that he needed to downplay, or perhaps better disguise the role of, chance if his theory were to be generally accepted.¹⁷ In light of this recognition he adopted a variety of rhetorical strategies that added up to a deliberate campaign to retain chance as a central element while making it appear to most readers that he did not; or, as with the “stone-house” metaphor (discussed in [chapter 7](#) of the present work), making it appear less “dangerous” an idea than many supposed.

DARWIN’S RELIGIOUS VIEWS

Darwin’s early recognition of chance in causing variation also has implications for how we understand the evolution of his religious beliefs. The customary view, based mainly on his *Autobiography* and the small selection of letters that was available to a large audience previous to the mammoth “Correspondence Project” (1985 to present), is that he gradually shifted from “early orthodoxy” to a “liberal form of theism,” and then in later years “into an agnosticism tending at times toward atheism” ([Herbert, 1974](#), 232; [Moore, 1979](#), 314–15; [Ruse, 1979](#), 180–4; [Ruse, 2010](#), 1–8; [Lennox, 2004](#); [R. Richards, 1989](#), 77–7; [N. Gillespie, 1979](#), ch. 8; [Beatty, 2006](#)).¹⁸

It seems probable that his departure from Christian faith was earlier, more abrupt, and more complete than this view indicates. The reason for thinking so stems from the same source that many of Darwin’s contemporaries rejected a role for chance in nature’s workings: a chance-governed world seems tantamount to a godless world. Einstein made this very connection himself 75 years later when he famously said, “God does not play dice with the universe.”¹⁹ Darwin undoubtedly understood this implication of his theory, but rather than conclude that chance plays no role in nature he appeared to have concluded instead that God does not have much to do with nature at all.²⁰

How new this idea was in Darwin’s day is suggested by a quote from one who could not accept it: Charles Kingsley (a distinguished professor of History at Cambridge University and correspondent with Darwin), no doubt reflecting a common view, observed in 1871, “God is great, or else there is no God at all” (in [Moore, 1979](#), 339; for Moore’s analysis of Darwin’s religious views in the *Notebook*, 319–25 and nn. 56–87). The 1871 comment of St. G. Mivart’s (a younger aspiring biologist and devoted Catholic) was more pointed: “Unhappily the acceptance of your views means with many the abandonment of the belief in God and the immortality of the soul” (*CCD*, vol. 19, 36). Unlike Mivart and Kingsley, and many others, Darwin appears to have adopted the second half of the disjunct: not that “God is great,” but rather “there is no God at all.”²¹

Some students of Darwin’s thought will wish to make an objection to this claim. But let us look at Darwin’s words. In May 1860, only a few months after the *Origin* first appeared, Darwin had this

say to his early American supporter, the Harvard botanist Asa Gray:

With respect to the theological view of the question; this is always painful to me.—I am bewildered.—I had no intention to write atheistically. But I own that I cannot see, as plainly as others do, & as I shd. wish to do, evidence of design and beneficence on all sides of us. There seems to me too much misery in the world. I cannot persuade myself that a beneficent & omnipotent God would have designedly created the *Ichneumonidae* with the express intention of their feeding within the living bodies of caterpillars, or that a cat should play with mice. Not believing this, I see no necessity in the belief that the eye was expressly designed. On the other hand, I cannot be contented to view this wonderful universe, and especially the nature of man, & to conclude that everything is the result of brute force. I am inclined to look at everything as resulting from designed laws, with the details, whether good or bad, left to the working out of what we may call chance. Not that this notion at all satisfies me. I feel most deeply that the whole subject is too profound for the human intellect. A dog might as well speculate on the mind of Newton.—Let each man hope and believe what he can.

Darwin continues in the same letter:

Certainly I agree with you that my views are not at all necessarily atheistical. The lightning kills a man, whether a good one or a bad one, owing to the excessively complex action of natural laws.—A child (who may turn out an idiot) is born by action of even more complex laws,—and I can see no reason, why a man, or other animal, may not have been aboriginally produced by other laws; & that all these laws may have been expressly designed by an omniscient Creator, who foresaw every future event & consequence. But the more I think the more bewildered I become; as indeed I have probably shown by this letter (*CCD* 8, 223 [May 22, 1860]).

The question for Darwin came down to whether the notion of an “undesigned nature” made any sense. Two months later, after continuing to ponder, Darwin wrote again to Gray, and again showed that he was still in a quandary:

One more word on “designed laws” & “undesigned results.” I see a bird which I want for food, take my gun and kill it, I do this *designedly*.—An innocent & good man stands under a tree and is killed by a flash of lightning. Do you believe (& I really shd. like to hear) that God *designedly* killed this man? Many or most persons do believe this; I can’t and don’t.—If you believe so, do you believe that when a swallow snaps up a gnat that God designed that that particular sparrow shd. snap up that particular gnat at that particular instant? I believe that the man and the gnat are in the same predicament.—If the death of neither man nor gnat are [*sic*] designed, I see no reason to believe that their *first* birth or production shd. be necessarily designed. Yet, as I said before, I cannot persuade myself that electricity acts, that the tree grows, that man aspires to the loftiest conceptions all from blind, brute force (*CCD* vol. 8, 275 [July 3, 1860]).

Well, which is it, designed laws, or “blind, brute force,” with no foresight or intention by any designer about what laws should be created or how they would operate? For anyone who wonders what Darwin really believed, the passages just quoted give no clear answer. “Brute force,” which Darwin could not fully accept as an explanation for life’s diversity, apparently refers to the means by which variations arise, and may equally well be rendered by the word “chance.” He had no doubt that once variations did arise they would be pruned and preserved by non-intelligent processes. But how did they arise in the first place?

Darwin continued to express his doubts and uncertainties to other correspondents in the months after the *Origin* first appeared. For example, to Charles Lyell in August 1861 Darwin responded with skepticism to Gray’s argument that the course of streams are “designed” by an intelligent maker:

I doubt whether I have made what I think clear; but certainly A. Gray’s notion of the course of variation having been led, like a stream of water by Gravity, seems to me to smash the whole affair. It reminds me of a Spaniard whom I told I was trying to make out how the Cordillera were formed; & he answered me that it was useless for “God made them.”...I must think that such views of Asa Gray & Herschel merely show that the subject in their minds is in Comte’s theological stage of science²² (*CCD* vol. 9 [August 1, 1861]).

This was a bold claim for Darwin to make to his mentor and friend Lyell, whose own religious convictions that God made the laws governing geological nature were often affirmed in his great work *Principles of Geology* (1830–1833). Darwin must have known that he was challenging Lyell’s deepest

theological convictions. Perhaps to soften the blow, Darwin added the following:

The view that each variation has been providentially arranged seems to me to make natural selection entirely superfluous, & indeed takes the whole case of appearance of new species out of the range of science.—It seems to me that variations in the wild and domestic conditions are due to unknown causes & are without purpose & insofar accidental; & that they become purposeful only when they are selected by man for his pleasure, or by what we call natural selection in the struggle for life under changing conditions. I do not wish to say that God did not foresee everything which would ensue; but here comes very nearly the same sort of wretched embroglio as between free-will & preordained necessity (CCD vol. 9 [August 1, 1861]).

These letters to his close associates must be taken to disclose some of Darwin's deepest thoughts 1860–1861 on the subject of divine intelligence in the creation of species. What do the passages tell us? Strictly speaking they tell us three things that are not mutually consistent: (1) that Darwin had never *intended* to write “atheistically” (by itself, of course, that does not mean he had no atheistic leanings); (2) that he can see no evidence of “design” (or, therefore, an omniscient God) in natural productions; and (3) the whole subject of design and God is too profound for him to know what to believe. Perhaps God created natural laws at the beginning and then left the world alone so as to allow His laws to play out according to an invisible divine plan. But it is not clear that Darwin really believed that. His ultimate refuge in all the passages reproduced above (and many more) was that the whole question was too profound for him to take it on (see [chapter 3](#) below for a further development of this subject).

MEANINGS OF CHANCE

“Chance” in evolutionary biology is not just one among a wide range of concepts that require systematic attention. It is, in one of its several meanings, an entire way of thinking about nature, one that in this case separates Darwin from most other systematic biologists of his own time and most of those prior to him. It also separated him from a number of naturalists who came after him and were especially offended or disturbed by his views about the place of chance in his theory.

The role of chance in the biological sciences was not Darwin's original brainchild; it had been studied in biological contexts since Greek antiquity. But Darwin, more than anyone else, brought it into nineteenth-century biological theory, and it remains a subject of interest and importance in evolutionary theory today (see [chapter 1](#)). Understanding Darwin's evolving views and expressions about chance helps illuminate some modern controversies. It also shows how one person—Darwin—confronting the dilemmas posed by his discovery of chance, negotiated the difficulties, and emerged at the end of his career with formulations that were strikingly different from those with which he began. Eventually, by the time of the publication of his *Descent of Man* (1871) and *Expression of Emotions* (1872), he simply stopped talking about chance altogether. The word and the idea, no matter how expressed, had evidently become a quagmire he could do without.

TWO MEANINGS OF CHANCE IN DARWIN'S THOUGHT

Chance is a complex concept that has various applications in human thought and speech.²³ It can mean anything from “coincidences” to “probabilities” to “propensities” to “degrees of rational belief,” and more.²⁴ In Darwin's writing it tends overwhelmingly to mean one of two things: the *likelihood* or *probability* that some organisms will survive in the struggle for existence (this is related to the *adaptedness* to existing conditions); and the *fortuity* that new variations will be well adapted to the conditions, or better adapted than their rivals (Hodge, in [Krueger, 1987](#), vol. 2, [chapter 10](#); [Lennox, 2004](#)). The former idea may be rendered in statistical terms, or, if one prefers, as a percentage. For example, an evolutionary biologist might cast the likelihood of a well-adapted variant to be 90

greater to survive and reproduce than a poorly adapted one (e.g., [Brandon, 1990](#), 11; [Lennox, 2004](#)). Empirical confirmation is available, at least in principle, even if the matter is complicated. The latter idea is better characterized as a stochastic concept: what variations occur in nature just happen, with no probabilities being assigned either for their appearance or non-appearance. The former statistical idea is subject to precise measurement (again, in principle, as a probability), the latter not.²⁵ Darwin himself did not employ rigorous statistical analyses of his “chances of survival” idea, although he was on the track of doing so when, for example, he sent questionnaires to field biologists asking about their observations of natural processes. But he did not even begin to apply probability theory to the causes of variations. He made guesses about what these causes are but he unfailingly admitted that an understanding of such causes could often be no more than guesses.

“Probability of survival” and “fortuity of variation” are connected concepts (because both refer to and depend upon the idea of adaptation), but they are fundamentally different. I explore the distinction more fully in [chapter 1](#). But as a preliminary, I draw attention to the following concerns. First, much of the recent scholarship on “chance” as a concept in scientific studies centers on statistics and probability theory ([Gigerenzer et al., 1989](#), *passim*; [Krueger et al., eds., volume 2, 1987](#), chapters 10–13; [Millstein, 2011](#), 425 ff.; [Lennox, 2004](#)). Darwin grasped that some organisms, because of their structures and habits, have a greater probability of surviving than others. This is an important claim, no doubt. But Darwin did not employ a statistical analysis of this phenomenon, or even pretend to. It seems that he was not well acquainted with probability theory or statistics, and it is evident that he did not pretend to study his claim with scientific rigor. He simply ventured the opinion that some organisms have a better chance of survival than others because it was a necessary deduction from other aspects of his theory. If variations occur, if a struggle for survival is a part of natural history, if the more fit tend to survive against the less fit, then it must follow as a matter of logic (even without empirical confirmation) that the “chances” for survival will favor the more fit. Darwin’s claim has stood up to empirical scrutiny over the 150 years since he wrote by botanists, zoologists, and other natural scientists, but Darwin himself did not do the mathematical and statistical analyses that would be required today for empirical verification.

A second concern is whether “cause unknown” (for any variation that appears) can really be called “chance” or can be a source of concern to Darwin’s intended audience. The issue may be divided into two parts. The first is whether “cause unknown” really means, or to Darwin did mean, “chance cause.” The other is whether the idea of an “unknown cause” was as innocuous an idea as it might first seem to be.

As to the first, some people might dispute that “cause unknown” is the same as “chance” because the former refers only to a lack of knowledge on the part of observers studying the phenomenon, whereas the latter seems to suggest “no cause.” Darwin sometimes suggested that he meant nothing more than “our ignorance” when he said variations come about “by chance” (*Variorum*, V. 4–5). I do not wish to argue that Darwin was being dishonest or disingenuous in this suggestion. He was committed to the idea that all natural events (including variations) have “causes,” and thus are fortuitous only from the standpoint of human understanding. No alarm here, even for a theologically disposed audience.

But “chance as unknown cause” is not everything or even mainly what Darwin believed. The expression “unknown cause” suggests a cause that *can* be known, even if at present the cause is not known. If the cause *were* known, and it was a theologically acceptable cause, for example a directing agency such as God, Darwin’s sympathetic readers would have had nothing to fear about the theory. But Darwin’s thought was more radical. By “unknown cause” he implied in his more private and less guarded moments that the cause of at least some variations is *unknowable*, even in principle ([Beatty, 2006](#), develops the distinction). And the reason for the unknowability of such causes is not lack of

human understanding but rather a lack of a directing rational agency. When Darwin looked at nature's productions, especially the appearance of new variations, he could not fathom any conceivable reason in many cases for why those that occurred did occur or why some that might have been expected to occur, on any customary notion of cause, did not occur. Variations were often, as far as Darwin could tell, simply random with respect to survival needs: some would survive, some would perish, but variations could not be "designed" or be considered "rational" with either of these outcomes in view (cf. *CCD* vol. 9 [August 1, 1861], 225, letter to Lyell).

Darwin's understanding of chance in this latter sense (random with respect to future adaptive needs) did much to separate Darwin's thought from the tradition of natural philosophy he had learned from his mentors. Causes "make sense" from the standpoint of what can be expected in nature and of their ability, therefore, to make accurate predictions. No doubt Darwin believed the natural order "made sense," insofar as it "holds together." But it did not make sense in terms of how it held together from "causes" as normally understood. If variations are just thrown up at random, like the way dice fall in a given toss or cards turn up in a blind draw, nature's order becomes a major puzzle.²⁶ Random variations would seem to lead to the idea of an unordered or even chaotic world. Darwin did not believe the world was chaotic. Indeed, he always admired the order he found in it. But he could not believe the world was governed by a presiding rational intelligence that ensured its order. He was thus forced to confront one of the major dilemmas of his life: how can one get order out of random processes? His solution was, of course, the idea of natural selection. But the solution would only be a solution if the prior step in transmutation, variation, was itself random. Natural selection is a breakthrough idea only against the background of "chance variations." One may abbreviate by saying Darwin's theory gets its critical bite and novelty by its ability to explain how order comes out of fortuity without invoking "higher powers."

Darwin, however, never did abandon the idea that variations are "caused." He was simply at a loss about how to give a comprehensive account of those causes. He did try to say what they are, and offered valuable suggestions (the subject of [chapter 3](#) in the present work). But often he was reduced to puzzlement. Understanding has naturally progressed since Darwin wrote. The rediscovery of Mendel's writing in the early part of the twentieth century, and the many advances in mathematical, cellular, molecular, and genetic biology since then, have improved biologists' understanding of what kind of question Darwin was up against in his search for causes and where to look for them. But even today it is impossible to get away from the language of "chance" in variation. The *mechanisms* of variation are better understood than ever, but the ability to predict what variations will occur and what will not is not much better off than when Darwin wrote. So we still encounter in the leading works of evolutionary biology today the ideas of "random drift," "sampling error," "fortuitous recombination," "point mutations," and the like. Many scholars continue to insist that biological evolution—what species will someday appear and what ones will not—is mostly guesswork. One finds few biologists today attributing variations to a directing intelligence. They still prefer to say "chance."

If Darwin's ideas of "chance" caused worry and alarm in his reading public, it would have been chance only in the sense described here—"randomness with respect to future adaptive needs." Unlike "unknown causes" that might nevertheless be known someday, Darwin's chance seemed to his reading audience to rule out "knowability," and this in turn ruled out intelligence and design. That idea did frighten many people, as I show below. Darwin could not duck the controversy by either denying chance or allowing intelligent design. He was stuck with "chance as randomness" whether he was happy with it or not. The present work focuses on chance in this restricted sense. This is the point of controversy and the element of his theory that must be credited with making his idea a "dangerous" one to many of his readers.

Why was Darwin's theory of "evolution through natural selection" successful as the correct account of how biological diversity arose? After all, Darwin was by no means the first evolutionary thinker. Even "natural selection" was not altogether new with him, as he candidly acknowledged (a bit after the fact) in his "Historical Sketch," appended to the first American and third English edition of the *Origin* (both in 1861), retained and enlarged in subsequent editions (Johnson, 2007). What truly was novel about Darwin's approach was making room for "chance" in the modification of species and the transmutation into new species. The three most well-known evolutionists prior to Darwin—his grandfather Erasmus, the French zoologist J. B. Lamarck, and the anonymous author of the sensation novel *Vestiges of the Natural History of Creation* (Robert Chambers)—all produced accounts of evolution that not only did not require chance but in fact ruled out a role for it. Evolution of new species, they believed, was guided and directed, either by a superior intelligence or by innate faculties and potencies within living organisms that enabled them to adapt to changing conditions.²⁷

If anything distinguishes Darwin's theory from these earlier versions, it was his focus on variation.²⁸ What Darwin discovered is that variations appear to occur "in all directions," not just favorable, let alone progressive ones (e.g., *CCD* vol. 8, 340 [September 1, 1860], to Lyell; *ibid.*, 341 [September 2, 1860] to Hooker; *ibid.*, 355 [September 12, 1860] to Lyell). From this perspective, when variations occur is "just a matter of luck," good, bad, or indifferent. Above all, it is impossible to predict what variations will happen to come along, and the ability to make predictions, Darwin knew, is a hallmark of a good science (Darwin, 1958, 109; and Hull, 1973, 32–3).

But, even granting that variations are "caused," to say that they are "by chance," as Darwin often did, caused alarm.²⁹ Even before the *Origin* first appeared or before anyone had any idea about Darwin's theory, philosophers, scientists, and theologians were worried about any possible role for chance in the organic or inorganic world (Ruse, 1979, 71–4; also Moore, 1979, 106–10—citing Lyell's "disquiet and alarm," and similar concerns voiced by Romanes, Butler, and James, going back to 1855, cited in J. Moore, 1979; Gigerenzer et al., 1989, surveys the "empire of chance" from the seventeenth to the twentieth centuries in a variety of scientific disciplines). What was the worry about? If it needs to be spelled out, the worry was the implications of this view for a designed world and by extension, for an omniscient deity who presided over the design.

Several strands of pre-Darwinian thought, whatever the provenance, converged to make the concept of an undesigned universe a centerpiece of criticisms of chance. Whether species had evolved or not—and differences of opinion on this point were rife even before, not to mention after the *Origin*—almost no one could accept chance as a factor in the process.

The worries about chance, however, grew decidedly more pronounced after the appearance of the *Origin*, thanks in large part, no doubt, to Darwin's employment of the word to describe how variations at least sometimes come about.³⁰ The first edition of the *Origin*, for example, invokes "chance" as "cause" of variation at least a dozen times—even though usually Darwin took pains to qualify the notion so as to make it mean, in effect, "cause unknown," and simultaneously to make clear his opinion that "unknown cause" does not mean "no cause."³¹ But concerns persisted. This point was forcefully brought home to Darwin in 1871, in a letter from the cleric and botanist George Henslow (son of Darwin's friend John Stevens Henslow). Henslow implored Darwin to condemn in writing the "wild and false assertion" made by many of his clerical brethren and other evolutionists that Darwin was "an *Atheist* and all the rest of it!" (*CCD* vol. 19, 713, original emphasis).

I should very much like to hear from you [Henslow continued] if the following impression which I have is correct: viz., that when you speak of *Chance* in connection with Nat. Selection you leave it to be understood that *higher natural laws* (but undiscoverable at present) cause the issue of specific forms out of those "chance" variations (*ibid.*, original emphasis).

Darwin politely declined to assuage Henslow's concerns, and instead referred Henslow to his earlier public statements on the matter (*ibid.*, 714 and n. 2). Those earlier published statements, as we shall see, neither affirm nor deny the charge of atheism. Rather they say simply that Darwin finds the question too profound for his limited intellect to answer (e.g., *Variation* vol. 2, 431–2).

Henslow's worries were just those of other scientists friendly to Darwin, such as Charles Lyell and Asa Gray, who accepted a Darwinian account of evolution by means of natural selection. It was not evolution to which they objected, nor even the mechanism of natural selection, but the prior step—“chance” variations ([Gigerenzer et al., 1989](#), 132–6). This idea would not do. The variations, they believed, must be “guided” or designed. The stumbling block was unguided variations. If that idea could be replaced with variations directed to be what they are by a higher power, the rest of the theory would get a clean pass (cf. [Lyell, 1863](#), 506). Darwin decided to ride out the storm of criticism rather than capitulate.

1. For readers interested in current developments in evolutionary theory, a good place to begin is M. Pigliucci and Gerd Muellr eds., *The Extended Synthesis*, MIT Press, 2010.

2. All references to Darwin's *Origin of Species* are to the *Variorum* edition published in 1959 under the editorship of Mor Peckham. The references are to the *Variorum* page number, followed by the chapter number in Darwin's text (given in roman numerals), followed by the line number of the passage as given in Peckham. Small italicized letters *a*, *b*, *c*, *d*, *e*, and *f* at the end of Peckham's line numbers refer to the number of the edition of the *Origin*: *a* as the first edition is not used; *thereafter*, *b* = second, *c* = third; and so forth.

3. Herbert (1974, 226); Moore (1979, 127, 145, 176); Vorzimmer (1972); E. Mayr (1982, 690–3); E. Mayr (1963, xxiv–xxvii); Bowler (1983, 67); M. Ruse (1979, 211); P. Bowler (1993, 49); J. Browne (2003, 208, 283–4, 315, 354, 369, 407); *Correspondence of Charles Darwin* (hereafter *CCD*), vol. 11 (1999, 137 n. 6); J. Costa (2009, 494–5); Beatty (2010, 22). H. E. Gruber (in Kohn, ed. 1985, 17) refers to “the ambiguities in Darwin's position [about the species question] at every point in his development.”

4. Darwin of course did modify his theory as he went along. It did not sprout full-grown from his mind overnight. The “complete theory,” whatever that might mean, was years in development. This aspect of Darwin's thought has received a great deal of scholarly attention, especially in the last 25 years as more of his private notes and correspondence has been made available to a broad reading public (e.g., several essays in Kohn, ed., 1985, including especially chapters 1–9 and chapter 26, and detailed references within those chapters; cf. also Kohn, 1980; Kohn, Smith, and Stauffer, 1982; F. Sullo way (1982); S. Herbert, 1974, 1977, and references; Sloan 1986). My assertion pertains to the “syllogistic outline” of the theory, and more particularly to Darwin's views on the role of chance in variation.

5. I shall not debate in this work the question of whether it is possible to assign “authorial intention” from an examination of an author's oeuvre. I shall accept as a premise that it is possible to make plausible inferences about what Darwin intended, granting that the premise is sometimes contested. For a defense of the premise, cf. M. J. S. Hodge and D. Kohn (1985), in D. Kohn, ed. (1985, 205).

6. The standard example of Darwin's “shift” in assigning “explanatory weight” for various factors in his theory comes in *Descent of Man* (1871, 152–3): “In the earlier editions of the “Origin of Species” I probably attributed too much to the action of natural selection or the survival of the fittest [as compared with] inherited effects of habit [and] direct action of surrounding conditions.” This statement (and similar ones, as, for example, in letters Darwin sent to St. G. J. Mivart in early 1871 [*CCD* 19, 30–9]) seems gratuitous. In larger context Darwin did not alter the priority of importance of explanatory factors: natural selection first, “chance variations second, and inherited habit and “direct action” third. R. J. Richards (1989, 193–5 and n. 29) for discussion. David Hull (chapter 26 in D. Kohn, ed., 1985) provides a useful analysis of “Darwinism” as an ever-shifting historical construct that lacks “essence” that many scholars have attempted to find, although even Hull appears to find two “essences” in Darwin's thinking about what “Darwinism” is: pluralism (i.e., the acknowledgment of multiple causes of variation) and Lyellian gradualism (800–9). No doubt many of the modern controversies about what “Darwinism” means center on these two factors. But Darwin also always insisted on the primacy of the mechanism of natural selection in evolutionary change and, as I argue here, on “chance” (properly understood) as the most important cause of variation. Recent defenders of the idea of a “Darwinian essence” include Gould (2002, Chapter 2); and Lennox, 2004.

7. R. J. Richards (1989), 90–1 cites F. Cuvier (1827) as a plausible initial source for Darwin's idea of “chance variation.” But even if Darwin first discovered “chance variation” in Cuvier's “fortuitous modification, fugitive want, accidental habit” we must recall that Darwin would have to take these ideas further than Cuvier did (Cuvier was anti-transmutation) in order to get to his own theory of “indefinite modification” and “species change.”

8. This is Darwin's core and would not necessarily be accepted by all “Darwinians,” in his own day or, much less, in ours. But few self-described Darwinians of any age or stripe would likely find fault with this account of what Darwin himself believed to be the crux of his theory of evolution. A similar, if somewhat expanded reproduction of the core is Lennox (2004).

9. Some scholars find a decisive shift in Darwin's views about sexual v. asexual reproduction from his earliest musings about the species question, in which sexual reproduction was at first the basis of all variation, to a somewhat later view that asexual reproducing organisms could also yield variations. Discussions include Hodge and Kohn in Kohn, ed., (1985); and, in Krueger et al. eds. (1987, vol. 2, chapter 10).

10. As early as 1838 (before he read Malthus) Darwin tried to set out the core of his theory in abbreviated form. It remained remarkably fixed and unvarying to this day. Darwin's first summary was in *Notebook E-58* as follows: “Three principles will account for all: (1) Grandchildren like grandfathers [i.e., heredity]; (2) Tendency to small change <<especially with physical change>> [i.e., variation]; (3) Great fertility in proportion to support of parents [i.e., superfecundity].” Natural Selection is not mentioned. Darwin continued to attempt to capture the core both in the “Sketch of 1842” (*EBNS* 57), and the “Essay of 1844” (*ibid.* 133–4); and again four times in *Origin* (once at the end of Chapter IV on “Natural Selection,” (*Origin* 270: IV. 384); once at the end of Chapter VII on “Instinct” (*Origin* 423: VII. 288); and twice in the final chapter called “Recapitulation and Conclusion,” (*Origin* 719: XIV. 8; 758–XIV. 268–70). Darwin appears to have seen Natural Selection as an additional premise to the other three, from which he wished to derive another conclusion entirely—viz., the formation of new species through time (see Lennox, 2004). Perhaps Darwin's stylistically most brilliant exposition is the tidy summary at the end of Chapter VII of the *Origin*: “To my imagination [the beautiful changes and adaptations in nature] are all small consequences of one general law, leading to the advancement of all organic beings—namely multiply, vary, let the strongest live and the weakest die” (*Origin* 423: VII. 288). Here again the formation of new species is the consequent of the premises. Cf. S. J. Gould (2002); A.G.N. Flew (1956); Kohn (1980); R. Lewontin (1978); and R.J. Richards

note on Lewontin, 1989, 100 n. 97); and David Hull, (2001), 54–5 for other formulations of the “syllogistic core,” all only variations on Darwin’s formulations. [Beatty \(1984\)](#) provides an efficient summary of Darwin’s idea of natural selection in the context of “chance variation.”

11. [Hodge and Kohn, in Kohn, ed., \(1985, 185–205\)](#), argue that “chance variation” did not make an appearance in the *Notebooks* until the relatively late *Notebook N* (1839). They connect its discovery by Darwin to Darwin’s realization that selection under domestication, wherein chance variation provides the raw materials for the breeder’s craft, must have an analogue in nature. I accept the latter part of this argument, but I find evidence in the *Notebooks* that Darwin contemplated the possibility of chance variation much earlier, as early as 1837. I also demur from their contention that Darwin did not have “his own theory” until 1839. His discovery of chance in 1837 or earlier was plausibly his basis for thinking he had a theory of his own prior to the encounter in late 1838 with Malthus. Cf. also [Kohn, 1980](#); and n. 19 below. R. J. [Richards \(1989\)](#), 90–9 offers useful suggestions about “chance” in the development of Darwin’s thinking, taking the question back to his encounter with F. Cuvier’s 1828 “Essay on the Domestication of Mammiferous Animals,” first cited by Darwin in the *B Notebook* (1836), but the focus here is on “changed environments” that come about “by chance” rather than changes in organic structures that are purely “by chance.”

12. I examine the question in depth in [chapter 8](#), “Darwin’s Giraffes.” Note 2 of that chapter documents recent authorities who have argued for a Darwinian shift to Lamarckism; note 6 gives a partial bibliography of recent studies of Lamarck in the context of Darwinian evolutionary theory.

13. So did F. [Cuvier \(1827\)](#), cited in R.J. [Richards, \(1989, 90–1\)](#). More on Darwin’s possible sources in [chapter 6](#) of the present work.

14. Whewell, in fact, despite his commitment to induction in science, could never give up a role for miracles in organic adaptations. Even natural laws could not do all the work necessary to explain organic adaptations: “Nothing has been pointed out in the existing order of things which has any analogy or resemblance, of any valid kind, to that creative energy which must be exerted in the creation of new species” (1840, 2: 133–4). About chance Whewell had this to say: “The assumption of a Final Cause [i.e., designed purpose] in the structure of each part of animals and plants is as inevitable as the assumption of an Efficient Cause for every event. The maxim that in organized bodies nothing is *in vain*, is as necessarily true as the maxim that nothing happens *by chance*” (1840, vol. 1, Aphorism CV, xxxv, original emphasis). Herschel too needed “design,” not chance. Darwin, as much as he may have followed Herschel and Whewell in other ways, could not go along with them here. Cf. M. [Ruse \(1975, 1978\)](#); [Thagard \(1978\)](#); [Gildenhuys \(2004\)](#); and [chapter 3](#) of the present work for an examination of Darwin’s debt to the philosophical ideas of John F. Herschel and William Whewell. Cf. also Hull (in [Kohn, ed., 1985](#), Chapter 26); Schweber (in [Kohn, ed., 1985](#), 47–9).

15. Creationists and intelligent designers are not often found defending natural selection as a mechanism for preserving and destroying whole lines of life, for the reason that, by definition, if the Creator (or Intelligence) designs it, it is perfect, just as the Creator intended. As regards *species*, this is no doubt their position. But at the same time Creationists and intelligent designers—least some of them—do acknowledge *variation* among individuals in a species, and also acknowledge that unfavorable variations hurt survival prospects of some individuals in nature and that some favorable variations help to enhance survival prospects of individuals who have them (a review of some of the recent literature can be found in Freeman Dyson, *New York Review of Books*, October 4, 2001, 24–7; and R. [Dawkins, 2006](#), 113–4). Darwin was well aware of this (cf. *CCD* vol. 6, 371 [April 12, 1857] in a letter to Hooker: “The most firm stickers for independent [i.e., intelligent] creation admit [variation]”). Thus, Creationists and intelligent designers *might* be willing to embrace natural selection as the mechanism of sortition for preserving and destroying individual variant types. This implies or entails no embrace of evolution of *species* in biological history.

16. Whatever Darwin may have believed in private or said in public, the “revolution” he wrought is generally believed to have removed “conscious or purposeful design” from natural processes. Alexander [Rosenberg \(1985, 246\)](#) sums up this way: “One of the most salient features of Darwin’s revolution is that it ended forever the biological appeal of the argument from design, which founded the teleology of nature on the desires, intentions, and conscious designs of God.” “Chance” in Darwin’s thought (as “chance variation”) has received scholarly attention in recent years, notably by [Beatty \(2006\)](#), who discusses chance in Darwin’s study of orchid varieties; [Lennox \(2004\)](#), who associates “chance” with Darwin’s attack on “special creationism”; and [Millstein, 2000, 2001](#), who discusses “chance” in contemporary evolutionary theory more generally. Other references to this literature are given below.

17. As will be discussed later, most of the early scholarly reviews of Darwin’s *Origin*, those appearing in 1860–1861, did not even notice the role of “chance” in the theory. I can find only one review in that first wave of critical commentary, that of F. W. Hutton, that notices the important role for “chance” (*The Geologist* 1860, 3: 464–72; reprinted in D. L. Hull 1973, 293–30; cf. Hull “Comments,” 300–1). Darwin’s concern about the damage being done to the reception of his theory may have been prompted in part by this review, but more likely by letters he received from correspondents in the same period, especially those from Asa Gray and Charles Lyell.

18. Ruse, a proponent of the view that Darwin’s religious views changed over the years in an “agnostic” direction, has strengthened his stance in more recent work, in his chapter to the co-edited volume *The Cambridge Companion to the “Origin of Species”* (Ruse and Richards, 2009, 2): “In religion, [Darwin’s trip in Wales with Adam Sedgwick in 1831] was important because Darwin’s rather literalistic Christianity started to fade and he became something of a deist, believing in God as unmoved mover and that the greatest signs of His powers are the workings of unbroken law rather than signs of miraculous intervention.” See also [ibid.](#), for evidence that suggests Ruse believes Darwin remained a deist from then on.

19. [Dawkins, 2006, Chapter 1](#), makes a good case that this often-quoted statement (and others by Einstein) does not show that Einstein was a “believer” in a Christian God, as much as many believe it does.

20. The “God” in question here is the nineteenth-century God of Victorian England—an omniscient, omnipotent, omnipresent

deity who was widely believed to play a determining role in life's complexities, whether immediately or remotely. God was generally considered to be "good," again in a mid-nineteenth century British sense. Darwin generally refrained from going in details about what the word "God" meant to him (he often confessed that he was simply "in a muddle" about so profound an issue) and to fill in all the details from historical context would take us too far afield. But cf. Ruse (various dates) and Dawkins (2006, Chapter 2) for ample discussions.

21. How should one interpret Darwin's unwillingness to state publicly what his views about "God" were? Even Emma, his wife, could not be sure where he stood on this key question (CCD 19, [1871] 106). One can only guess. One guess is that he had become an atheist from early on (1837?) and wished to hide this opinion from even his closest intimates. Another guess, perhaps more plausible, is that, after having given the question a great deal of thought, he decided any answer either way would be "unphilosophical," and so just set the question aside as insolvable (for example, CCD vol. 19, 551 in a letter to F. E. Abbott). I will address the question more fully in subsequent chapters.

22. Auguste Comte viewed the development of knowledge as having progressed through three stages: theological, metaphysical, and positive. Darwin had read an extensive review of the first two volumes of Comte's *Cours de philosophie positive* (Comte, 1830-1842) in 1838 (see CCD vol. 2, letter to Charles Lyell, September 14, 1838; and vol. 9, August 1, 1861, n. 12).

23. At a recent conference on Darwin (San Diego, 2011), when I mentioned to the philosopher David Depew that I was working on "chance in Darwin's thought," he said "a complex topic. No, a very complex topic." I believed it then, and believe it even more so now.

24. An excellent review of the various meanings of chance in contemporary evolutionary theory is Millstein (2011, 425 ff). She identifies seven distinct meanings, all of which she attempts to subsume under what she calls a "unified chance concept." Three of these she traces back to Darwin himself, and of these three I shall be concerned mainly with her "sixth" meaning: evolutionary chance (variations leading to species changes that come about with no necessary connection to future adaptive needs).

25. Beatty (1984, 204-5) draws a contrast between "stochastic" (or random) and "deterministic" processes in evolution (see also Richardson, 2006; Millstein, 2000, 2011; Eble, 2006; Grantham, 1999). His argument is that evolution is *always* a "stochastic" process (i.e., always involves randomness) because: (1) contrary to Hardy-Weinberg, populations in nature are never of an infinite size (in which case random shifts in gene-frequencies over time would "balance out" to no net changes); and (2) because "random drift" is always or nearly always *one* factor in the distribution of gene-frequencies in natural populations. He does not claim that "natural selection" by itself (i.e., without any role for random drift) would be a "deterministic" process; he does not consider the case (but Richardson, 2006, 646, building on Beatty's work, makes the claim that it would be). But neither did Darwin. Beatty (and many others) is "Darwinian" in recognizing stochasticity in evolution. He departs from (or improves upon) Darwin's theory by: (1) attributing chance variations to "random drift" in gene-frequencies (Darwin was innocent of any knowledge of genes or "sampling errors" and so simply said "chance"); and (2) in arguing that "drift" and "selection" can and do act "concurrently" rather than "consecutively" in evolution. A more recent formulation is Beatty, in Krueger (1987, vol. 2, chapter 11); cf. also Lennox (2004).

26. A nice example from Darwin's day comes from William Thompson in his presidential address to the British Association for the Advancement of Science in 1871, in which he referred to Jonathan Swift's "absurd machines...that write books by random rearranging words" (quoted in CCD vol. 19, 526 n. 7).

27. James Lennox (2004) argues that Darwin's discussion of variation in his theory (in the sense of "random") was a response to two sets of criticism: those who wanted to see "design" in evolution, and those who followed Lamarck in seeing no room for chance in transmutation. "Apart from those urging Darwin to give up chance in favor of design, he had pressure to abandon chance from another direction, the evolutionary philosophy of Jean-Baptiste Lamarck. Lamarck's is another, materialistic argument against the variation in nature being a matter of chance. It is true that Darwin's theory could dispense with Lamarckian "adaptation of living beings to their changing environments" and also his "progressivism." But I do not find any "pressure" on Darwin from this quarter. The group he was most concerned with was the former—colleagues and friends (many of them) who wanted design. As to Lamarck, Darwin early on simply dismissed him and turned his back on his views, as most of the people he cared about the most had also done (see chapter 8 of the present work).

28. CCD vol. 13, 390 (supplement), [February 7, 1857] to B. P. Brent, where Darwin refers to his forthcoming species work as "my book on variation," underscoring the importance of this theme for his overall project. The editors of CCD (*ibid.*, n. 8) claim that Darwin "sometimes" used the same expression in referring to this work (without citing where in the correspondence this could be found).

29. That chance might be thought to be the source of variation was a common worry in the 1860s and 70s: "To gaze on such a universe [as ours], to feel our hearts exult within us the fullness of existence, and to offer in explanation of such beneficent provision no other word but *Chance*, seems as unthankful and iniquitous as it seems absurd....The hypothesis of Chance is inadmissible" (from *Contemporary Review* of September 1875, submitted by "P. C. W" and quoted in Asa Gray *Darwiniana*, 297-8; cf. John Beatty, 2006, 1-14 who analyzes the role of "chance" in Darwin's *Orchids*). For typical statements at the time about "chance" as the only alternative to design, cf. Paley's *Natural Theology*, 40-1, 281-7; Asa Gray's *Darwiniana*, 117, 125-26, 298 (Gray represents his own views and those of many other natural philosophers); CCD, vol. 8, 496 (from Darwin to A. Gray [November 1860]), vol. 10, 428 (from Gray to Darwin [August 1862]); vol. 11, 525 (from Gray to Darwin [July 1863]).

30. James Lennox (2004) makes the claim that Darwin *never* referred to variations as caused "by chance" in the *Origin*. Yet at the same time he allows that Darwin sometimes said selection operates on variations that "happen to occur [in nature]." I do not see the distinction, unless the only thing Lennox means is that Darwin did not use the *exact words* "variations occur by chance." Certain variations that just "happen to arise" must be considered "chance variations" in Darwin's meaning.

31. Darwin sensed that some confusion as between “laws” and “chance” would result from his views when they were made public as he confessed to his friend Hooker in 1856: “(No doubt the variability is governed by laws, some of which I am endeavouring very obscurely to trace).—The formation of a strong variety or species, I look at as almost wholly due to the selection of what may be incorrectly called *chance* variations or variability” (*CCD* vol. 5, 282 [23 November 1856], to Hooker, Darwin’s emphasis). Sometimes Darwin used the word “accident” rather than “chance”: “Hence, we may conclude that under domestication instincts have been acquired, and natural instincts have been lost, partly by habit, and partly by man selecting and accumulating, during successive generations, peculiar mental habits and actions, which at first appeared from what we must in our ignorance call an accident” (*Orig* 389: VII. 80). The idea is like that expressed at the beginning of [chapter 5](#) of the present work: variations occur, by what process we know not, and so attribute them to “our ignorance.” But this again refers to the *how* of variation, not the *what*, as I describe below. The only thing we can know, by observation, is whether the novelty is well adapted or not. If it is, it survives; if it is not, and the struggle with competitors is fierce (as it almost always is), it will perish.

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