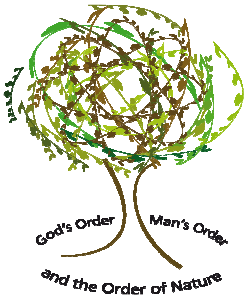
ISSN 2045-5577



ORDER: GOD'S, MAN'S AND NATURE'S

DARWIN'S LAWS

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The Governance of Nature – October 2010

Abstract: There is widespread agreement among contemporary philosophers of biology and philosophically-minded biologists that Darwin's insights about the intrusion of chance processes into biological regularities undermines the possibility of there being biological laws. Darwin made references to "designed laws." He also freely described some laws as having exceptions. This paper provides a philosophical analysis of the notion of scientific laws that was dominant in Darwin's time, and in all probability the one which he inherited. The analysis of laws is then used to show how it could have been natural for Darwin to believe in designed laws that had exceptions, and to highlight the continuity between the metaphysics of pre-Darwinian, Darwinian, and contemporary biological science. One important result is the removal of one motivation for the anti-laws sentiment in philosophy and biology.

> "By nature, I mean the laws ordained by God to govern the Universe"
>
> Charles Darwin, *Natural Selection* (1856-1858: 224)

> "It has been said that I speak of natural selection as an active power or Deity; but who objects to an author speaking of the attraction of gravity as ruling the movements of the planets? Every one knows what is meant and is implied by such metaphorical expressions; and they are almost necessary for brevity. So again it is difficult to avoid personifying the word Nature; but I mean by Nature, only the aggregate action and product of many natural laws, and by laws the sequence of events as ascertained by us."
>
> Charles Darwin, *On the Origin of Species* [3rd ed] (1861: 85)

I. THE IMPORTANCE OF DARWIN'S CONCEPT OF NATURAL LAW

The view that there are no laws in biology is widespread among biologists and philosophers. The thesis is motivated by two distinct but related ideas, articulated most eloquently by John Beatty (1995). The first idea is that there are no exceptionless regularities of a "distinctively biological" variety (*ibid*: 47). The second idea is that, even if there were distinctively biological exceptionless regularities, it would not matter, because any such regularity is susceptible to subversion by the "rule-breaking capabilities of the agents of evolutionary change," notably chance variation and natural selection (*ibid*: 51). The significance for both of these observations for the thesis derives from their relation to the concept of *necessity* – typically treated as the *sine quo non* for lawhood. The thought is that if something is *necessary*, then it (in *some* sense) *has* to be the case (Fine 2002). Both the lack and potential fragility of exceptionless regularities shows that, apparently, nothing of a distinctively biological sort *has* to be the case.

Charles Darwin comes into the picture in three important ways: (1) as the first person to focus on and demonstrate the centrality of chance events (inherited variations being the primary one) in producing new species and varieties; (2) as the person who discovered natural selection; and (3) as someone whose stated mission was to discover the "laws of life,"[i] and who, in discovering natural selection, thought he *had* discovered a – perhaps *the* – crucial principle governing biological phenomena. Given that the case against the possibility of distinctively biological laws rests primarily on the roles of chance and natural selection as biological lawbreakers, it would seem that Darwin's interest in laws presents us with a triad which, if not inconsistent, certainly contains some uncomfortable tension:

(a) Darwin thought there were distinctively biological laws

(b) Darwin understood the biological roles of chance variation and natural selection

(c) The biological roles of chance variation and natural selection undermine the possibility of distinctively biological laws

There are several ways in which we might attempt to ease the tension. For someone who wishes to maintain (c), the most promising path would be to argue that, although Darwin used the term "law" on many occasions (even referring to natural selection as a law [Darwin 1871: 136]), what he meant by "law" was something different – perhaps something weaker – than the conception of natural law that dominates contemporary science and philosophy. I will argue that the apparent promise of this resolution is illusory, and that there is sufficient evidence that Darwin's notion of *law* is ours as well. The upshot of this argument, of course, is that the tension contained in (a) – (c) is preserved. My recommendation for easing the tension will be to give up

(c), for which I will argue in due course. Giving up (c) generates its own set of problems, since it will require some positive account of how biological laws and chancey biological events can come to a truce. I propose a strategy for drafting such a truce in the conclusion.

My argument will proceed as follows. I first show that laws play the same role in Darwin's science as they do in ours. I then present a case against (c) by examining Darwin's concept(s) of *chance* and the function(s) of chance in Darwin's theory of natural selection. The role of chance in Darwin's theory turns out to have significant implications of the metaphysics of law, both in terms of how we understand natural necessity as well as the importance of exceptionlessness.

I. BACKGROUND: THE DIVINE NOMOCRACY

Countless contemporary philosophers have argued that the importance of laws for science lies in their ability to *explain* their instances, ground *inductions*, and "support" counterfactual or otherwise subjunctive conditionals.[ii] For many of these philosophers, it is the view that science consists primarily in these activities that makes the discovery of laws of nature the ultimate goal of scientific investigation. Although this may sound like a familiar characterization of the nature of science, with respect to *biological* investigation it is a relatively recent phenomena, one which was just gaining a foothold around the time of Darwin's birth.

The champions of this new conception of biological science were known as the *philosophical naturalists*.[iii] Despite some divergent metaphysical predispositions, what united the philosophical naturalists was their agreement that (1) the central scientific task of the natural historian had shifted from that of *discovery and classification* of different types of life to *explanation* of their form and distribution, and that (2) the discovery of the *laws* of biological form and distribution was an essential element of their explanation, and, therefore, constitutive of the science of the living world. This quote from the idealist anatomist Robert Knox is typical of the movement:

> the mere observance of a fact is of no value whatever, unless that fact be placed in its relations with all others.[iv]

What good, urges Knox, is an inventory of what exists without an understanding of how things hang together? Nearly one hundred years prior to Knox's exhortation, Buffon would express the same dissatisfaction with the "mere observance of a fact," and set out to uncover a way by which we might endeavor to *understand* natural history instead of just documenting it (Wohl 1960: 187).

But what allows us to place a fact "in its relations with all others"? Knox and Buffon would, in their respective eras, again converge on how we illuminate the biological world: we under-

stand nature's facts by discovering nature's *laws*, a "duty," in Knox's words, which naturalists assume upon observation of nature. Alexander von Humboldt (1822), whose *Personal Narrative* Darwin held in the highest esteem, echoes in between Knox and Buffon the centrality of laws to an adequate understanding of biogeographic distribution, as would fellow traveler De Candolle, who saw the science of historical biogeography is *nothing other than* discovering the laws of geographic distribution of species (Nelson 1978: 281).[v]

As Dov Ospovat (1981) illustrated, this sort of science resonated with the young Darwin, and would continue to influence his approach to nature throughout most of his career. All the way through the publication of the *Origin*, what we find is a Darwin who puts laws at the center of his theorizing, what Hodge (1983) refers to as his "zoonomical explanatory program." Laws often appear in Darwin as rules laid down by the Creator which the phenomena obey, evidenced by such famous remarks as that the "Creator creates by . . . laws,"[vi] that Darwin is inclined to see everything as the "result of designed laws,"[vii] that there are "laws impressed on matter by the Creator,"[viii] and so on (see also Richards 1997).[ix] Here, I would argue, we see Darwin responding to two conceptually distinct but intersecting lines of influence that were prominent at the time. One is, of course, Natural Theology. But it is a specific type of Natural Theology, one which stresses the role of God as *lawgiver*, rather than, say, *watchmaker*. Part of the reason for the emphasis on God as a lawgiver was, or at least was claimed to be, theological: it is more befitting of a Supreme Being that He should govern phenomena by designing a grand coordinated system, rather than by coming down from On High to manage the world's quotidian goings-on. Several authors have remarked on the growing sentiment during the early 19th century that to attribute every pedestrian detail to a Divine Craftsman would portray God as suffering "the imperfections of human legislation" (Herschel 1831: 37; see also Ospovat 1981 [esp. Chapter 1]; Brooke 1979, 1992, 2009; Manier 1978: 48-49). By integrating "contingencies" into a grand system, laws were seen as a way of preserving God's influence over the course of events, without having to conceive of each micro-state of affairs as the direct instantiation of an explicit Divine decree. Ospovat (1981: 20), describing Louis Agassiz's position during the 1830s, nicely sums up the state of play:

> Biologists contribute most effectively to natural theology not by discovering more examples of the adaptation of structure to function and organism to environment, but rather by discovering the laws that constitute the creator's plan.

The other reason for Darwin's attraction to structuring biological debates around God's nomocracy was, I would suggest, that it had come to be seen as befitting of *science itself* that the

investigator should endeavor to discover laws. The shift towards a law-centered science of living things marks what historian of science Philip Rehbock aptly dubs the end of the divide between natural history and natural philosophy (Rehbock 1983: 7). What had once been the domain of the philosophers had become that of those interested in solving what they saw as full-blooded *scientific* problems. We often think of the term “natural philosophy” as the word for science of a bygone era. It seems an adequate characterization for some sciences, but the "science" of the living world prior to the philosophical naturalist movement was very much unlike the sort of thing in which natural philosophers tended to be interested. The following quote from 19th century naturalist James Grierson, which appears in Rehbock’s monograph, is interesting in terms of what it tells us about the prevailing conception of relevant scientific problems for biologists in the early 19th century as well as the way in which it illustrates the significance of the development of *philosophical* naturalism:

> It is sufficient for [the botanist or zoologist] to know what place in this system the plant or the animal is to be referred to, what are its distinguishing properties, what are its uses, economical, medical, or ornamental.[x]

In contrast, while the philosophical naturalists readily acknowledged the importance of these problems to science, the solutions to those problems were in many ways a means to the ultimate goal of the science of living things – the discovery of laws.

II. THE SCIENTIFIC ROLE OF DARWIN'S LAWS

That Darwin saw laws as important to science in general, and to his particular scientific interests, is therefore, I think, fairly clear. As described above, there are multiple reasons why this would have been so, and multiple lines of evidence – direct (as in Darwin's own words) and indirect (Darwin's particular scientific context) – pointing in this direction. I'd like now to look at the sort of scientific *work* Darwin's "laws" were supposed to do, such that they would have made a law-centered science attractive to Darwin. Here I focus on the role of Darwin's "laws" in explanation, induction, and counterfactual reasoning, arguing that they function in Darwin's scientific practice in ways which are relevantly similar to how laws are thought to function in contemporary science. For each task, I first present evidence of a general perception within 19th century science that laws can and do perform it, drawing on the work of the period's master narrators, John Herschel and William Whewell. Some authors (notably Michael Ruse [1975] and David Hull [1975, 1983, 2003]) have argued for a direct causal relationship between the picture of science as encapsulated in Herschel's *Preliminary Discourse on Natural Philosophy* and in Whe-

well's *Philosophy of the Inductive Sciences*, on the one hand, and the formulation and structure of Darwin's theory, on the other. I am persuaded by these arguments, but I do not make as strong a claim as this in what follows. It suffices for the purposes of my own argument to show that there is an important similarity between Darwin's "laws" and theirs. The second tier of evidence comes in the form of similar comments made by naturalists working on the sorts problems which Darwin himself took up. By showing that the role of laws in Darwin's scientific context is isomorphic to ours, I hope to add credibility to the claim that Darwin shares our conception of natural law. Finally, I present evidence from Darwin's own pen which further supports this claim.

1. Explanation

1.1. Darwin's Context

Robert Butts, in his study of the central components of Whewell's philosophy of science (Whewell and Butts 1989), suggested that Whewell was in fact an early proponent of something like the deductive-nomological model of scientific explanation (*ibid*: 17). This is certainly the impression I get from reading Whewell, particularly with regards to the passages upon which I draw below. However, an interpretive difficulty lies in the fact that both Whewell and Herschel are typically inclined to speak of *explanations* in ways that do not make explicit use of the term "law." Instead we normally see explanations described as coming in the form of "theories," "principles," and "causes," the latter of which are distinguished from laws by both authors in various places.[xi] To complicate matters, both authors are inclined to speak of *laws* in ways that do not make explicit use of the term "explain" or its derivatives. What we typically see instead is laws described as being *extended*, *applied*, and other notions with a similarly explanatory tone. I defer to Butts in inferring that, at least in Whewell's case, the reason that laws are often found in association with activities that look and sound a lot like explanation is because Whewell held that laws can explain things. These difficulties aside, neither Whewell nor Herschel is reluctant to describe this or that law as explaining certain facts. Below I present what I take to be uncontroversial examples of their faith in the laws' explanatory power.

Herschel, for instance, refers to Thomas Young's work on *destructive interference* – the dimming effect produced by out-of-phase waves of the same wavelength and frequency – as "a principle in optics, which, regarded as a physical law, has hardly its equal for beauty, simplicity, and extent of application…" (Herschel 1831). He continues:

> The experimental means by which Dr. Young confirmed this … were as simple and satisfactory as the principle itself is beautiful;

> but the verifications of it, drawn from the *explanation it affords* of phenomena apparently the most remote, are still more so. Newton's colours of thin films were the first phenomena to which its author applied it with full success. Its next remarkable application was to those of diffraction, of which, in the hands of M. Fresnel … *it also furnished a complete explanation* … (260 - 261; my emphasis).

Whewell also explicitly describes laws as endowed with the power to explain. Early in the *Novum Organon Renovatum* he describes the "Attraction of Gravitation" as a "general law" which

> might have been successfully applied to the explanation of facts, if Newton had throughout treated Attraction as the result of an *Ether* diffused through space; a supposition which he has noticed as a possibility (76).

Laws are cast in a similar role later on, when Whewell is describing the deductive extension of empirical theories:

> In the other sciences also [i.e., besides astronomy] which have been framed by a study of natural phenomena, we may find examples of the explanation of new phenomena by applying the principles of the science when once established. Thus, when the laws of the reflection and refraction of light had been established, a new and poignant exemplification of them was found in the explanation of the Rainbow by the reflection and refraction of light in the spherical drops of a shower … (237).

Incidentally, he also mentions in this discussion the same explanatory powers which Herschel attributed to the "physical law" of interference (which Whewell refers to as a "doctrine"[xii]). Again, however, as in Herschel, this in not the primary guise in which the term "law" appears.

Turning to matters more directly biological, Alfred Russell Wallace was among those investigators, mentioned above, who were interested in discovering the laws of the living realm. In his important essay on what was known as "the succession of types" – the tendency of a region's extant taxa to resemble its fossil taxa – Wallace uses a handful of biogeographical facts to deduce

> the following law:–*Every species has come into existence coincident both in space and time with a pre-existing closely allied species…*

which he refers to in the essay's title as "the law which has regulated the introduction of new species" (note the governing connotation). He goes on to assert that

> *This law agrees with, explains and illustrates* all the facts connected with the following branches of the subject:–1st. The system of natural affinities. 2nd. The distribution of animals and plants in space. 3rd. The same in time, including all the phænomena of representative groups, and those which Professor Forbes supposed to manifest polarity. 4th. The phænomena of rudimentary organs (Wallace 1855: 186; my emphasis).

1.2. Darwin's Pen

Earlier I mentioned that Darwin preferred a natural theology where God is cast as *lawgiver* rather than watchmaker, and that he and others often gestured partly towards theological motivations for this position. But there were also strong *scientific* reasons for the focus on laws. It is Darwin the *scientist* who dismisses Whewell's biological explanations in terms of "the will of the deity" as antithetical to the scientific goals of explanation and prediction.[xiii] Here, criticizing special creationism in his notes on John Macculoch's (1837) *Proofs and Illustrations of the Attributes of God*, he could not be clearer on the role of laws in science:

> The explanation of types of structure in classes—as resulting from the will of the deity, to create animals on certain plans,— is no explanation—*it has not the character of a physical law* /& is therefore utterly useless (Darwin 1838b, quoted in Manier 1978: 42; Darwin's emphasis).

I think the most natural reading of this passage commits Darwin to the view that scientific explanation requires reference to a physical law, that laws are the only things that can explain. This reading is corroborated by the fact that the same sentiment had initially inspired the philosophical naturalist movement of which Darwin considered himself a part (Sloan 2003) – *real* science seeks explanations, and only laws can provide them.[xiv] The centrality of laws to *science*, rather than to God's grandeur, is what takes precedent here.

A less trenchant but no less relevant passage occurs in the third edition of the *Origin*, where Darwin is arguing for the explanatory power of the idea of species' singular geographic origin:

> If the existence of the same species at distant and isolated points of the earth's surface, can in many instances be explained on the view of each species having migrated from a single birthplace; then, considering our ignorance with respect to former climatal [*sic*] and geographical changes and various occasional means of transport, the belief that this has been the universal law, seems to me incomparably the safest (Darwin 1861: 384).

The "view of each species having migrated from a single birthplace" can be construed as a "universal law" and can explain "many instances" in which there exists "the same species at distant

and isolated points of the earth's surface." In support of this, Darwin cites Lyell's own arguments in vol II of *Principles of Geology* (about which I will have more to say below).

In this section I have only given attention to instances where the terms "law" and "explanation" are explicitly used in direct association with each other. The result is, I think, a strong *prima facie* case for the claim that Darwin conceived of laws as having explanatory power. Had I broadened the scope of textual evidence to include terms like "principle," "theory," and "cause," all of which have a certain nomic ring to them and which are frequently used interchangeably and in association with nomic terms, there would have been no end of examples upon which to draw. Similar remarks apply to terms and reasoning patterns that function the way "explanation" and its derivatives function. To do so would have been imminently reasonable, and I see Butts as having employed this strategy when attributing to Whewell a deductive-nomological theory of explanation. However that would potentially leave a lot of room to argue over the niceties of terms other than "law" and "explanation." Rather than introduce those complications, I have taken a more conservative approach.

2. Induction

2.1. Darwin's Context

As good Victorians, Herschel and Whewell are in the main more concerned with the frontiers to which a scientific law might be pushed than with deepening our understanding of what is already familiar. Discussions of induction feature the laws in three distinct capacities:

(1) what we aim to formulate when we venture beyond a collection of facts; (this corresponds to what we might call [and what Whewell *did* call (Whewell 1858: 163)] an *inductive "leap"*)

(2) instruments which allow us to foretell events (this corresponds to what we might call *projection).*

(3) beneficiaries of *successful* extension beyond the data upon which the law is based (this corresponds to what we might call *inductive confirmation*).

Philosophers interested in induction and the role of laws therein tend to be concerned with laws *qua* (2) and (3), and so my remaining comments in this section will aim in this direction. And while I too see (2) and (3) as rich sources of philosophical problems, the significance of (1) should not be underestimated. I take it as expert testimony which corroborates the claim that

Darwin was part of a scientific community in which there was general agreement that the point of science was to discover laws.

Both Whewell and Herschel were struck by the laws' ability to foretell events. In Herschel, laws allow "us before trial to say what will take place in cases analogous to those originally contemplated," which, in turn, will allow "us to extend our views beyond the circle of instances from which it was obtained" (Herschel 1830: 167). For example, Snell's Law, when applied to a stick in water, allows us to "describe beforehand what will happen" to the extent that it

> enables any one to say exactly *how much* the stick will be bent, and *how far*, and in what *direction*, the apparent situation of an object seen through the glass will deviate from the real one (*ibid*: 29-30).

More fundamentally,

> Of several questions relating to the connection between the motion of material bodies and its cause, such as *What will happen* when a moving body is surrounded on all sides by others not in motion? *What will happen* when a body not in motion is advanced upon by a moving one? It is evident that the answers to such questions as these can be no other than *laws of motion* in the sense we have above attributed to laws of nature, viz. a statement in words of what will happen in such and such proposed general contingencies (*ibid*: 89-90).

One obvious reason why the laws' ability to ground predictions was important concerned science's *usefulness*, a connection familiar since Bacon (Whewell 1858: 240ff; Herschel 1831: Part I, Chapter 3). The real marvel of laws, though, lay in their ability to be *confirmed* by their successful predictions. It is this property of laws to which both authors devote the bulk of their nomic remarks. To wit:

> It is in the precise proportion that a law once obtained endures this extreme severity of trial, that its value and importance are to be estimated; and our next step in the verification of an induction must therefore consist in extending its application to cases not originally contemplated; in studiously varying the circumstances under which our causes act, with a view to ascertain whether their effect is general; and in pushing the application of our laws to extreme cases (Herschel 1831: 167).

And in Whewell:

> Men cannot help believing that the laws laid down by discoverers must be in a great measure identical with the real laws of nature, when the discoverers thus determine effects beforehand in the

> same manner in which nature herself determines them when the occasion occurs … Such a coincidence of untried facts with speculate assertions cannot be the work of chance, but implies some large portion of truth in the principles on which the reasoning is founded. To trace order and law in that which has been observed, may be considered as interpreting what nature has written down for us, and will commonly prove that we understand her alphabet. But to predict what has not been observed, is to attempt ourselves to use the legislative phrases of nature; and when she responds plainly and precisely to that which we thus utter, we cannot but suppose that we have in a great measure made ourselves masters of the meaning and structure of her language. The prediction of results, even of the same kinds as those which have been observed, in new cases, is a proof of real success in our inductive processes (Whewell 1858: 87)

As an early pioneer of biogeography and of a nomocentric science of living things, Buffon encapsulates the laws' projective powers when he likens the laws to a "compass that can guide us in our investigations" (Buffon 1797: 118). Buffon's nomic pretensions are well known , having famously endeavored to found a new science of living things based on the structure of Newtonian mechanics (Grene and Depew 2004: 64-91; see also Wohl 1960). His eponymous Law, which today might better be called *allopatry*, is a close ancestor of what Wallace refers to above as "the law which has regulated the introduction of new species."[xv] Wallace, too, expresses his confidence in the ability of laws to ground predictions when he deduces from the "law" that "[e]very species has come into existence coincident both in space and time with a pre-existing closely allied species" the conclusion that

> In all those cases in which an island has been separated from a continent, or raised by volcanic or coralline action from the sea, or in which a mountain-chain has been elevated, in a recent geological epoch, the phænomena of peculiar groups or even of single representative species *will not exist* (*ibid*: 189, my emphasis).

In other words, there will never be a species or group on a newly formed bit of land that fails to closely resemble the extinct and contemporaneous species and groups nearby.

2.2. Darwin's Pen

The entirety of the passage quoted at the beginning of §1.2 reads as follows:

> The explanation of types of structure in classes—as resulting from the will of the deity, to create animals on certain plans,— is no explanation—*it has not the character of a physical law* /& is therefore

> utterly useless.—it foretells nothing / because we know nothing of the will of the Deity, how it acts & whether constant or inconstant like that of man.—the cause given we know not the effect.

The connection between prediction and laws was, for Darwin, part of a larger view about the nature of science, one which put laws front and center in a dramatic way. The following note-book entry, made in the same year as the one above, is illustrative:

> Now in different species of genus Sus, see Cuvier Ossemens fossiles, do vertebrae *vary*? Although no new fact be elicited by these speculations even if partly true *they are of the greatest service towards the end of science, namely prediction, till facts are grouped & called there can be no prediction. — The only advantage of discovering laws is to foretell what will happen & to see bearing of scattered facts* (Darwin 1838a: 67, second emphasis mine)

Here prediction is the goal of science, and without laws there can be no prediction (recall from above that law formation *is* the process by which "facts are grouped & called").

With respect to the ability of laws to be confirmed by their instances, Darwin unambiguously expresses a conception of natural law which includes this feature when discussing the bearing of some fossils he had discovered during the *Beagle* voyage upon the law of succession of types (fossils which, incidentally would play an important role in his conversion from special creationist to species transmutationist)[xvi]:

> they formed part of an animal allied to the guanaco or llama, but fully as large as the true camel. As all the existing members of the family of Camelidæ are inhabitants of the most sterile countries, so may we suppose was this extinct kind … *The most important result of this discovery, is the confirmation of the law that existing animals have a close relation in form with extinct species*. As the guanaco is the characteristic quadruped of Patagonia, and the vicuna of the snow-clad summits of the Cordillera, so in bygone days, this gigantic species of the same family must have been conspicuous on the southern plains (Darwin 1839: 208-209).

The idea that Darwin and/or his contemporaries had a relevantly different conception of *law* than our own continues to lose credibility.

3. Counterfactuals

3.1. Darwin's Context

The late Marjorie Grene and David Depew (2004: 169) observed that Herschel's description of laws as "provision[s] for cases that may occur," allowing for the "contemplation of possible

occurrences" (Herschel 1831: 36) was an early expression of the sentiment that laws support counterfactuals.[xvii] In addition, Michael Ruse refers to Herschel's insight that "laws … allow for counterfactuals" as one reason why "[t]he 1830s conception of 'law' was, in certain respects, surprisingly modern" (Ruse 1975: 509). For Whewell's part, the laws' ability to support counterfactuals was of fundamental importance:

> *Force is any cause which has motion, or change of motion, for its effect*; and thus, all the exchange of velocity of a body which can be referred to extraneous bodies,—as the air which surrounds it, or the support on which it rests,—is considered as the effect of forces; and this consideration is looked upon as explaining the difference between the motion which really takes place in the experiment, and that motion which, as the law asserts, would take place if the body were not acted on by any forces (Whewell 1847: 217, Whewell's emphasis; quoted in Ducheyne and Weber 2007: 278)

But the supremely significant feature of Darwin's scientific context in this regard is Charles Lyell, who routinely uses laws to show what sorts of states of affairs could or would follow from certain hypothetical antecedent conditions. Lyell employs laws in this way both in arguing against Lamarck's account of species transmutation, and in arguing *for* the "singular geographic origin" of species (Hodge 1983b: 28; Manier 1978: 34). His strategy in both cases is to "assume that" certain "laws prevail in the economy of the animate creation" (Lyell 1990: 23) and then determine whether the operation of those laws is consistent with the available evidence:

> . . . let us suppose every living thing to be destroyed in the western hemisphere, both on the land and in the ocean, and permission to be given to man to people this great desert, by transporting into it animals and plants from the eastern hemisphere, a strict prohibition being enforced against introducing two original stocks of the same species.
>
> Now the result we conceive of such a mode of colonizing would correspond exactly, so far as regards the grouping of animals and plants, with that now observed throughout the globe (*ibid*: 124-125).

In arguing against transmutation, Lyell attempts to account for the known tendency of species to contain varieties which "differ in some cases, more decidedly than species" by once again assuming "for the present, these rules hypothetically," (chief among them being that "the organization of individuals is capable of being modified to a limited extent" but that "there are fixed limits beyond which the descendants from common parents can never deviate from a certain type") and then bidding the reader to "see what consequences may naturally be expected to

result" (*ibid*: 23). Since (surprise!) Lyell concludes that the hypothesized law that descendants never deviate fundamentally from their type is consistent with the known variation within species and the denial of species transmutation, we have "no ground for questioning the instability of species" (*ibid*: 35).

Each of these instances shows Lyell displaying the laws ability to "support" counterfactuals (in a sense I'll leave unspecified for the purposes of this paper; see Lange 2009 for a detailed account). For species transmutation, we're asked to ponder on what would (and wouldn't) follow, were there a law of nature which prevented species from transmutation – would species be able to vary to the degree that they do? In the case of species' singular geographic origin, we're asked to consider what would we should expect to observe, were there a law, a "strict prohibition being enforced," which prevented the introduction of different stocks of the same species at different geographic loci – would a world in which that law operated look like our world in the relevant respects?

Of course, what we find is that the observed phenomena are indeed consequences of the antecedent conditions along with hypothesized laws. Lyell's application of the concept of *law* in this way comports with Herschel's description of laws as "provision[s] for cases that may occur," allowing for the "contemplation of possible occurrences" (Herschel 1831: 36). By showing that the *actual* phenomena were *possible* on the presumption of certain laws, Lyell was able to establish a theory's explanatory adequacy.

3.2. Darwin's Pen

The laws' power to portray the possible did not escape Darwin's attention. One of Darwin's chief strategies in the *Origin* is to "contemplate possible occurrences" under the operation of natural selection as a way of resisting objections to his theory, what James Lennox calls a "Darwinian thought experiment" (Lennox 1991, 2005). Lennox argues that, in addition to protecting the theory from objections, Darwinian thought experiments were used to display natural selection's ability to promote population differentiation (Lennox 2005: 90). While I think this is correct, another way to think about Darwinian thought experimentation is to view both of its functions as effects of a common cause – the laws' "providing for cases that may occur" and thus underwriting the "contemplation of possible outcomes." Each fact that is not axiomatic to a theory is, in a sense, a potential source of difficulty. This applies even to the deductive consequences of a theory's axioms, as Darwin himself suggests when he reflects on "the difficulty of multiplying effects & to <produce> conceive the result with that clearness of conviction" (Darwin 1838-1839: 5e; quoted in Lennox 2005: 96). In this regard, the fact that there are species and

varieties is of a piece with, for example, the fact that there is are biological sexes, something which Darwin referred to as a "very great difficulty" for his theory (Darwin 1838b: 159e; quoted in Lennox 2005: 95): they are both facts which the theory of natural selection can possibly explain. By showing that the occurrent phenomena (especially the "difficulties" for his theory) are at least possible in a world governed by natural selection, Darwin exploits the laws' capacity to support subjunctive conditionals – to tell us what could or would have been the case if such-and-such (in this case, the lawfulness of natural selection) were true.

III. Flaws of Nature?

I have argued for the view that Darwin's notion of *law* is the same as ours. My evidence has been that laws figure into explanation, induction, and subjunctive inference in Darwin and in his scientific community in ways that we find familiar and appropriate for laws. In structuring my argument this way, I have left untouched questions which relate directly to the *metaphysics* of Darwin's "laws." One potential problem generated by this strategy, it might be said, is that Darwin's metaphysics of law may differ radically from ours, a difference which would go undetected by focusing solely on the laws' role in scientific practice. Thus I have not shown that Darwin's laws *are* ours, only that they *work* the way ours do. Despite its skeptical tone, I think there is actually a *prima facie* basis for this objection, and thus for balking at the inference I've recommended.

David Lewis once observed that "[f]ew would deny that laws of nature, whatever else they may be, are at least exceptionless regularities" (Lewis 1986b: xi), and indeed the chief philosophical arguments against the existence of biological laws focus on problems for exceptionless regularities in the biological world. Now, while I think Lewis is right about many contemporary philosophers, it is less clear that his remarks would have resonated with Darwin and the scientific community of which he considered himself a part. There is one feature of laws of nature we find mentioned in the 19th century which, from a contemporary perspective, is metaphysically curious: their ability to tolerate *exceptions*. Thus there is perhaps some substance to the worry that Darwin's "laws" could not be ours, despite their apparently similar behaviors. Below I will offer an interpretation of Darwin's metaphysics of law that explains the ability of laws to tolerate exceptions while preserving what I take to be the crucial metaphysical ingredient in the laws' recipe (and also the one most in conflict with the notion of *exceptions*) – viz., *necessity*.

As our first example, consider the following remark penned by Darwin early into his *Beagle* voyage:

> The law of the succession of types, although subject to some remarkable exceptions, must possess the highest interest to every *philosophical* naturalist" (Darwin 1839: 210)

The "law of the succession of types," the fact that a region's extant types closely resemble its extinct types, was *indeed* of the highest interest to every philosophical naturalist, being as it was a central problem in the burgeoning discipline of biogeography (Sloan 2003). Notice, however, that the succession of types' lawhood and its exceptions are uttered in the very same breath.

To show that this is not an isolated incident, observe that we can find references to exception-tolerating laws as far back as Buffon, in 1761:

> We do not presume to affirm categorically that, of all the animals that live in warm climates in one or the other continent, there is none that lives in both... *If some exceptions are discovered (which is difficult for me to imagine), they could involve only a few cases, and would not destroy the general law that I have just established*… (Buffon 1761: 118, my emphasis; quoted in Nelson 1978: 275)

Buffon's remarks add an important new dimension to the relationship between laws and exceptions. Here he suggests that whether or not some proposition has exceptions is, up to a point, just plain *irrelevant* to questions of lawhood. This is particularly significant in light of Buffon's professed Newtonianism, since it suggests that Buffon saw exception-toleration as consistent with Newton's conception of *law*, which is normally held up as the gold standard for laws of nature.

Yet another, indeed clearer, discussion of the relation between laws and exceptions occurs in the work of Danish physicist and philosopher Hans Christian Ørsted during his criticism of another Danish philosopher, Henrik Steffens. Ørsted accuses Steffens of deviating from a "clear view of experimental science" when he (Steffens)

> offers as an argument against the law that *heat expands all bodies*, that there are real exceptions. Granted that there are exceptions to this, for which we could not account, shall such a universal comprehensive law, which is exhibited in such a countless number of natural events, no longer remain a law? In that case, the law discovered by Newton on the motions of the moon would be no law, so long as the grounds were not found for the many small deviations which were not discovered for a century afterwards (Ørsted *et al.* 1852: 287)

The question Ørsted poses is, in what way do genuine exceptions bare on the nomic status of some putative law? His answer seems to be that, even in the case where there are "exceptions

… for which we could not account," a well confirmed law should and (in the important case of Newton's laws) *does* remain well confirmed. Furthermore, the idea that this was the prevailing sentiment would, I think, explain Darwin's and Buffon's willingness to retain their respective laws of interest despite the existence or even *prospect* of genuine exceptions. These laws are extraordinarily well confirmed. What matters is whether they help us solve lots of scientific problems, not whether they are exceptionless.

Lewis (Lewis 1986a: 122) credits John Stuart Mill's *System of Logic* with an early version of the analysis of natural law with which Lewis himself is usually associated.[xviii] Mill's analysis here does sound very much like Lewis's:

> the question, What are the laws of nature? may be stated thus:– What are the fewest and simplest assumptions, which being granted, the whole existing order of nature would result? (Mill 1859: 190)

Now, Mill takes no explicit stance in this section on the relevance of exceptions to the nomic status of a putative law. He does later on, however, when lamenting "the popular prejudice that all general truths have exceptions":

> The rough generalizations suggested by common observation usually have exceptions; but the principles of science, or in other words, the laws of causation, have not. "What is thought to be an exception to a principle," (to quote words used on a different occasion,) "is always some other and distinct principle cutting into the former; some other force which impinges against the first force, and deflects it from its direction. *There are not a law and an exception to that law, the law acting in ninety-nine cases and the exception in one. There are two laws*, each possibly acting in the whole hundred cases, and bringing about a common effect by their conjunct operation (*ibid*: 258-259, my emphasis).

The implication is fairly clear: there's no such thing as a law and an exception to that law; there are just laws, which are exceptionless. Herschel (1830: 100) signals his agreement when he writes that "[w]e may therefore regard a law of nature … as a proposition announcing that a whole class of individuals agreeing in one character agree also in another"; or, in the case of the resolution to "observed deviations" to the law of gravitation, that

> there are neither exceptions nor residual facts, but fulfillments [*sic*] of general rules, and essential features in the statement of the case, *without* which our induction would be invalid, and the law of gravitation positively untrue (*ibid*: 202, Herschel's emphasis).[xix]

Mill goes on to argue that the cause of "the popular prejudice that all general truths have exceptions" is a "habit of neglecting" a particular "necessary element in the precise expression of the laws of nature" (Mill 1859: 258) – namely, that a law must be expressed in the form of *tendency*. When we fail to express the law as a *tendency* in nature, framing it instead as a general description of the occurrent phenomena, most laws appear to have exceptions. For example,

> if it were stated to be a law of nature that all heavy bodies fall to the ground, it would probably be said that the resistance of the atmosphere, which prevents a balloon from falling, constitutes the balloon an exception to that pretended law of nature.

"But," he continues,

> *the real law is, that all heavy bodies* tend *to fall*; and to this there is no exception, not even the sun and moon … The rule, and the so-called exception, do not divide the cases between them; each of them is a comprehensive rule extending to all cases. To call one of these concurrent principles an exception to the other, is superficial, and contrary to the correct principles of nomenclature and arrangement. (*ibid*: 259, my emphasis).

For Mill, then, "real laws" are exceptionless with respect to *tendencies*, rather than with respect to occurrent facts. We must frame the law in terms of a tendency in order "to accommodate the expression of the law to the real phenomena" (*ibid*: 258).[xx]

Where does this leave us with respect to Darwin's "laws"? The way I see it, we have three options:

(i) Dismiss as a slip of the pen Darwin's assertion that some genuine law has exceptions; Darwin's "laws" remain ours.

(ii) Reject the claim that Darwin's "laws" are ours since Darwin's "laws" can tolerate exceptions and ours can't

(iii) Provide some way of understanding Darwin's notion of "exceptions" that makes his metaphysics of laws acceptable by our lights.

Since I already believe that Darwin's "laws" are ours, I am tempted to pick option (i). But those less sympathetic will not be so easily seduced. Plus, there are independent reasons to think that Darwin's reference to exceptions was not just carelessness on his part. For one, we've seen remarks from leading scientist-philosophers which corroborate the legitimacy of Darwin's usage. Second, there is, I think, a strong tradition in the history of science of just *not caring* whether there are "stubborn anomalies" – exceptions that simply will not go away – so long as a law is sufficiently well confirmed and continues to perform its scientific duties (Laudan 1977). Of

course, that tradition does not *have to* imply something about our concept of natural law, but it certainly is suggestive. So the reference to exceptions should be treated as genuine, and the problem of exceptions remains.

But the case for (ii) seems equally weak. First, *prima facie*, the argument from scientific practice for the similarity between Darwin's "laws" and ours is too strong to reject it on the basis that, despite this, Darwin might have thought that laws could tolerate genuine exceptions. The compossibility of exceptions and successful discharge of scientific duties might just as easily be used as evidence that the emphasis on exceptionlessness is a red herring: apparently exception-tolerating laws can perform the same tasks as exceptionless laws. *Ergo*, perhaps we were wrong in insisting on exceptionlessness as an important part of lawhood, and Darwin's "laws" are ours after all. If all that exceptionlessness had going for it was the assumption that it is required for the laws to do their scientific work, then it appears exceptionlessness doesn't have much going for it. I don't expect this line of reasoning to be decisive against (ii); at the very least, though, it shows that the "exceptionlessness" criterion needs to be motivated independently and for reasons other than that it allows the laws to function as they do in scientific practice.[xxi] So while (ii) does not obviously fail, it does seem to have far less going for it then the positive claim for which I've been arguing.

That leaves (iii). For my purposes, pursuing (iii) makes good sense, since it strengthens the case for equivalence between Darwin's "laws" by arguing directly for similar metaphysics of law, rather than indirectly via the argument from scientific practice presented in §II. Thankfully, Mill's comments suggest a strategy for pursuing (iii): First, show that Darwin's reference to "exceptions" is best interpreted as a reference to an independent line of causality, a "comprehensive rule extending to all cases;" and second, find evidence that Darwin thought of laws in terms of *exceptionless tendencies*.

IV. The Details Left to Chance

In a famous 1860 letter to Asa Gray, Darwin proclaimed that he was "inclined to look at everything as resulting from designed laws, with the details . . . left to the working out of what we may call chance." Among the "designed laws" numbered natural selection, and among the "details" numbered the occurrent biological facts such as organismal form and distribution. For Darwin, "chance" enters the picture in two prominent ways: (1) as the agent responsible for the menu of materials from which nature can select (this is the sense employed in his correspondence with Gray, brought out vividly in his "architect" analogy at the end of *Variations*) – call this

chance$_1$; and (2) as the explanation for why some individuals leave more descendants than others – call this *chance*$_2$. What I want to do in the remainder of this paper is show how each of these two senses of "chance" functions in Darwin, how they are related, and how, on this understanding, exceptions to biological regularities don't pose a problem for biological laws.

1. Chance$_1$*: The "Chance" of "Exceptions"*

The Darwin aboard the *Beagle* knew, as did other naturalists, that a region's extant forms sometimes fail to resemble its extinct forms – cases of what were in his words "exceptions" to the law of succession of types. These "exceptions" were thought to be the product of the sort of "chance" events in which Darwin took particular rhetorical delight, such as when the occasional bird's nest sits upon a detached bit of iceberg, destined for shores unknown, or when the occasional land-bird is blown clear "across the whole Atlantic Ocean, from North America to Ireland or England;" where

> seeds could be transported by these wanderers only by one means, namely, in dirt sticking to their feet, which is in itself a rare accident. Even in this case, how small would the chance be of a seed falling on favourable soil, and coming to maturity! But it would be a great error to argue that because a well-stocked island, like Great Britain, has not, as far as is known (and it would be very difficult to prove this), received within the last few centuries, through occasional means of transport, immigrants from Europe or any other continent, that a poorly-stocked island, though standing more remote from the mainland, would not receive colonists by similar means (*Origin* I: 364-365).

"Chance" events like these were tremendously important for Darwin's later theorizing, and for his argument in the *Origin*. For it is "chance" events that produce the variations from which nature selects.[xxii] Now, the variation in this passage is generated by a particular type of "chance" event – *viz*., "chance" migration. But it fits into a much more general and deeply sophisticated conception of the respect in which variations are "accidental" or the product of "chance."

To get a better handle on Darwin's understanding of *chance*$_1$, let us first turn to the *Origin*, for it is here that we find the beginning of what would become a decade-long effort to explicate the precise sense in which variation is the result of "chance." The first line of Chapter 5 – "The Laws of Variation" – begins with this:

> I HAVE hitherto sometimes spoken as if the variations—so common and multiform in organic beings under domestication, and in

> a lesser degree in those in a state of nature—had been due to chance. *This, of course, is a wholly incorrect expression*, but it serves to acknowledge plainly our ignorance of the cause of each particular variation (Darwin 1859: 131, my emphasis).

Later, in volume II of *The Variations of Animals and Plants Under Domestication*, Darwin would provide a vivid explanation of why his use of the word "chance," while "wholly incorrect," was more than apt:

> Let an architect be compelled to build an edifice with uncut stones, fallen from a precipice. The shape of each fragment may be called accidental; yet the shape of each has been determined by the force of gravity, the nature of the rock, and the slope of the precipice,—events and circumstances, all of which depend on natural laws; but there is no relation between these laws and the purpose for which each fragment is used by the builder. In the same manner the variations of each creature are determined by fixed and immutable laws; but these bear no relation to the living structure which is slowly built up through the power of selection, whether this be natural or artificial selection.

The analogy reappears in the last couple of pages of *Variations* (vol II), where Darwin further clarifies the notion of *chance*$_1$ and its relation to natural law:

> Now, the fragments of stone, though indispensable to the architect, bear to the edifice built by him the same relation which the fluctuating variations of each organic being bear to the varied and admirable structures ultimately acquired by its modified descendants … The shape of the fragments of stone at the base of our precipice may be called accidental, but this is not strictly correct; for the shape of each depends on a long sequence of events, all obeying natural laws; on the nature of the rock, on the lines of deposition or cleavage, on the form of the mountain which depends on its upheaval and subsequent denudation, and lastly on the storm or earthquake which threw down the fragments. But in regard to the use to which the fragments may be put, their shape may be strictly said to be accidental (Darwin 1868: 430-431).[xxiii]

The "chance" or "accidental" nature of variation is not *brute* chance, much less a genuine "accident of nature." Rather, variation is accidental *with respect to* the uses to which it is put by natural selection. It is unquestionably law-governed, but the laws of nature that produce variation operate independently of the law which governs the fate of different organismal forms.

As Mill had insisted, for Darwin "there are not a law and an exception to that law, the law acting in ninety-nine cases and the exception in one. There are two laws … each of them is a

comprehensive rule extending to all cases." Darwin's reference to "exceptions," then, is best understood as a reference to *chance*$_1$ events, events that *are law-governed* but *accidental with respect to* the law of succession of types. The "common effect" of the "conjunct operation" of these laws is "the real phenomena" – i.e., a spectacularly consistent but occasionally imperfect succession of types.

2. Chance$_2$: "Better Chances"

We've discharged the first demand from Mill: show how to interpret "exceptions" in terms of laws of nature. On to the second: find evidence of an exceptionless tendency associated with Darwin's nomic claims.

We can distinguish *chance*$_1$ from another important sense of "chance" found throughout Darwin's work, one to which he appeals when he refers to organisms in certain situations having a "better chance" than others of surviving and reproducing, such as when he suggests that "the extreme varieties and extreme species will have a better chance of surviving or escaping extinction" (Darwin and Stauffer 1975: 238), or that

> forms existing in larger numbers will always have a better chance, within any given period, of presenting further favourable variations for natural selection to seize on, than will the rarer forms which exist in lesser numbers (Darwin 1859: 177).

It is "better chances" that translate into a *tendency* for such-and-such to happen, as reflected in the conclusion which follows the preceding quote: "Hence, the more common forms, in the race for life, will *tend* to beat and supplant the less common forms, for these will be more slowly modified and improved" (*ibid*: 177, my emphasis).

Here, then, is clear evidence that Darwin thought of natural selection as a causing a *tendency* in nature – a tendency for forms with better *chances* of survival and reproduction to *actually* outreproduce other forms. We can amplify this point by appreciating the relationship between *chance*$_1$ ("chance events") and *chance*$_2$ ("better chances" of survival and reproduction). Jonathan Hodge has phrased the relation this way:

> (i) it is 'a matter of chance' as to what what variations are generated in any environmental conditions; but (ii) it is not a 'matter of chance' as to which are more or less successful, in those conditions, in contributing offspring to subsequent generations (Hodge 1983b: 287).

In other words, variation is accidental (with respect to environmental conditions). But the relationship between "better chances" of survival and reproduction and a *tendency* "to beat and supplant" other forms of life is, for Darwin, no accident. In contrast to the "accidental" connection between variations and the environmental conditions in which they arise, what connects "better chances" with "tendencies to beat and supplant" other forms of life is "not a 'matter of chance" – the connection is a *necessary* one.

The reason the existence of a *law* of natural selection is important here is because we can imagine a world where some individuals, due to their better adaptedness, have a better chance of surviving and reproducing but in which those individuals quickly die or fail to leave relatively many descendants (in the same way we can imagine a world where an individual buys almost all the lottery tickets and still loses, or in which all sodium-19 atoms last beyond their half-life of 40 nanoseconds). The law of natural selection governs what happens as a result of having "better chances" of survival and reproduction: under the influence of natural selection, "better chances" of survival and reproduction result in certain forms "tending to beat and supplant" others. Had natural selection not been included in the grand system of natural laws, better chances of survival and reproduction would not have resulted a *tendency* for certain forms to beat and supplant others. Those forms with better chances would have done no better than chance (Consider: in the case where offspring do not resemble parents, better chances of surviving and reproducing *might not have resulted in* the tendency of some forms to beat and supplant others).[xxiv]

Understood in this way, there may be "exceptions" to better adapted forms *actually* outreproducing those poorly adapted; such things can happen by chance$_1$. For Mill, this is just a consequence of the general fact that

> [a]ll laws of causation are liable to be … counteracted, and seemingly frustrated, by coming into conflict with other laws, the separate result of which is opposite to theirs, or more or less inconsistent with it. And hence, with almost every law, many instances in which it really is entirely fulfilled, do not, at first sight, appear to be cases of its operation at all (Mill 1859: 257)

By contrast, there will never be an exception to forms with better chances of reproductive success *tending* to outreproduce those with worse chances of reproductive success. Is this the sort of tendency that Mill would have recognized as nomic? He certainly seems to have suggested as much when he wrote, "What [Darwin] terms 'natural selection' is not only a *vera causa*, but one proved to be capable of producing effects of the same kind with those which the hypothesis ascribes to it" (Mill 1874: 382; quoted in Hull 1973: 27).

I have been arguing that Darwin understood natural selection to be a law which governs the relationship between $chances_2$ and tendencies.[xxv] I think this is precisely the way in which the principle of natural selection is treated in contemporary biological science. Take the relationship between selection and drift as one classic example. Fitness values furnish us with expectations for a population's composition in future generations. When the population is very small and the actual composition of future generations deviates from those expectations, we don't mark it down as yet another exception to Darwin's principle of natural selection. Why? Because it does not impugn the lawful relationship between having a better chance of reproductive success, on the one hand, and tending to beat and supplant other forms of life, on the other. The nomic status of natural selection can tolerate the failure of better adapted types to become widespread in the population. What it cannot tolerate is that such failure be *systematic* – i.e., that better adapted types *tend not* to become widespread in the population.

Let us return finally to the law of succession of types. We saw how $chance_1$ allowed us to make sense of Darwin's conjoining a law and exceptions to that law, but that at most shows that, *if* the "law" of succession of types were *truly* a law, it would not be threatened by the sorts of things Darwin had in mind when he referred to "notable exceptions" to it. In order to understand how the "law" of succession of types could be a law of nature, we need to say something about what the law could possibly *necessitate*, given that it clearly does not necessitate a perfectly uniform, exceptionless chain of resemblance between a region's extant types and its extinct types. In other words, what *must* be the case if the "law" of succession of types is a law of nature? Drawing upon our discussion of the nomic structure of natural selection, what we can say is that the law of succession of types necessitates a *tendency* for extant types to resemble extinct types. If the "law" of succession of types is truly a law, then a region's extant types must *tend to* resemble extinct types. Now of course, there is a fair amount of vagueness associated with the question of whether a region's extant types *tends* to resemble its extinct types. But that is as it should be, if scientific practice is any indication. For any putative law, the boundary between its being *necessary* and its *not* being necessary will be fuzzy; it evidently does *not* depend simply on whether or not there is or will be exceptionlessness at the level of the phenomena (as opposed to *patterns* or *tendencies* in the data). It will depend in large part – perhaps entirely – on what sorts of scientific tasks we are able to accomplish with use of the law.

V. CONCLUSION

We began this discussion with an uncomfortable set of propositions:

(a) Darwin thought there were distinctively biological laws

(b) Darwin understood the biological roles of chance variation and natural selection

(c) The biological roles of chance variation and natural selection undermine the possibility of distinctively biological laws

Most of the arguments in this paper have been in support of (a). And while it is well known (most of all to Darwin) that Darwin had no understanding of the precise mechanisms of variation, he understood as well as anyone what the *fact* of chance$_1$ variation meant, for biological evolution and beyond.[xxvi] Thus (b) must be retained as well. The focus of §IV has been the weakness of (c). I have provided a positive argument for the lawhood of natural selection based on historical evidence (Darwin's understanding of natural selection and Mill's conception of natural law), philosophical analysis of what natural selection renders necessary, and evidence from contemporary biological practice. Thus natural selection is no enemy to biological laws; quite the reverse.

What about chance variation? I presented two arguments which showed how a couple of specific laws, natural selection and the law of succession of types, were not threatened by chance variation. But is there some general way of protecting the notion of biological lawhood from the intrusion of chance? While a detailed treatment of this question lies beyond the scope of this paper, we can say something brief but important by taking a cue from the way in which the two specific laws were able to absorb chance disruptions of empirical regularities: stop looking for exceptionlessness at the level of the occurrent phenomena. Paleontologists appreciated this point a long time ago. Faced with a comparatively small and irremediably patchy data set, the strategy has always been to look for general *trends* which suggest the influence of some law or other. The possibility of undiscovered species which violate the trend, while real, is generally not seen as a worry for the nomic status of some putative law. What matters is whether things *tend* to happen in a particular way, not whether they do so invariably. A necessary tendency is, after all, *still* a necessity. The specter of biological variation, even in all its chanciness, cannot by itself undermine the possibility of necessary tendencies. To quote Darwin (sort of), there is grandeur in this view of law.

REFERENCES

Beatty, J. (1995). "The Evolutionary Contingency Thesis" in Wolters and Lennox (ed.) (1995)**:** 45-81.

— (2006) "Chance Variation: Darwin on Orchids." *Philosophy of Science* **73**(5): 629-641.

— (2008). "Chance Variation and Evolutionary Contingency: Darwin, Simpson, *The Simpsons*, and Gould" in Ruse (ed.) (2008)**:** 189-210.

Beebee, H. (2000) "The Non-Governing Conception of Laws of Nature." *Philosophy and Phenomenological Research* **61**(3): 571-594.

Bendall, D.S. and Darwin College. (1983). *Evolution from Molecules to Men*. New York: Cambridge University Press.

Brandon, R. (2006) "The Principle of Drift: Biology's First Law." *Journal of Philosophy* **103**: 319-336.

Brandon and Rosenberg (2003). "Philosophy of Biology" in Clark and Hawley (ed.) (2003)**:** 147-180.

Brooke, J.H. (1979). "The Natural Theology of the Geologists: Some Theological Strata" in Jordanova and Porter (ed.) (1979).

— (1992) "Natural Law in the Natural Sciences." *Science and Christian Belief* **4**(2): 83-103.

— (2009). "'Laws Impressed on Matter by the Creator'? The *Origin* and the Quesiton of Religion" in Ruse and Richards (ed.) (2009)**:** 256-274.

Buffon (1797 [1761]). *Buffon's Natural History: Containing a Theory of the Earth, a General History of Man, of the Brute Creation, and of Vegetables, Minerals, &C. &C.*

Cartwright, N. (1999). *The Dappled World: A Study of the Boundaries of Science*. New York: Cambridge University Press.

Clark, P. and Hawley, K. (eds.) (2003) *Philosophy of Science Today* New York: Oxford University Press.

Darwin, C. (1837-1838). *B Notebook.*

— (1838a) "Darwin's Abstract of John Macculoch 1837 "Proofs and Illustrations of the Attributes of God"." *DAR 71: 55-05*.

— (1838b). *D Notebook*.

— (1838-1839). *E Notebook*.

— (1839). *Journal of Researches into the Geology and Natural History of the Various Countries Visited by H.M.S. Beagle Etc*. London: Henry Colburn.

— (1859). *On the Origin of Species by Means of Natural Selection*. London: J. Murray. [1st ed.]

— (1860). Letter to Asa Gray (May 22nd).

— (1866). *On the Origin of Species by Means of Natural Selection*. London: J. Murray. [4th ed.]

— (1868). *The Variation of Animals and Plants under Domestication* (vol II). London: John Murray.

— (1871). *The Descent of Man, and Selection in Relation to Sex*. London: John Murray.

Darwin, C. and Stauffer, R.C. (1975). *Charles Darwin's Natural Selection: Being the Second Part of His Big Species Book Written from 1856 to 1858*. London ; New York: Cambridge University Press.

Debus, A.G., Theerman, P.H. and Parshall, K.H. (eds.) (1997) *Experiencing Nature: Proceedings of a Conference in Honor of Allen G. Debus* Boston: Kluwer Academic Publishers.

Ducheyne, S. and Weber, E. (2007) "The Concept of Causation in Newton's Mechanical and Optical Work." *Logic and Logical Philosophy* **16**(265-288).

Fine (2002). "The Varities of Necessity" in Gendler and Hawthorne (ed.) (2002)**:** 253-282.

Giere, R.N., Westfall, R.S. and Indiana. University. Dept. of History and Philosophy of Science. (1973). *Foundations of Scientific Method: The Nineteenth Century*. Bloomington, IN: Indiana University Press.

Godfrey-Smith, P. (2009). *Darwinian Populations and Natural Selection*. New York: Oxford University Press.

Grene, M. and Depew, D.J. (2004). *The Philosophy of Biology: An Episodic History*. New York: Cambridge University Press.

Heidelberg, L. and Rheinwald, R. (eds.) (1983) *Probability since 1800: Interdisciplinary Studies of Scientific Development* Bielefeld: Universität Bielefeld.

Herschel, J.F.W.b. (1830). *A Preliminary Discourse on the Study of Natural Philosophy*: Longman Rees Orme Brown and Green.

Hodge, M. (1983a). "Law, Cause, Chance, Adaptation and Species in Darwinian Theory in the 1830s, with a Postscript on the 1930s" in Heidelberg and Rheinwald (ed.) (1983a)**:** 287-330.

— (1983b) "Drawin and the Laws of the Animate Part of the Terrestrial System (1835-1837): On the Lyellian Origins of His Zoonomical Explanatory Program." *Studies in history of biology*: 1-106.

Hodge, M.J.S. and Radick, G. (eds.) (2003) *The Cambridge Companion to Darwin* New York: Cambridge University Press.

Hull, D.L. (1973). *Darwin and His Critics : The Reception of Darwin's Theory of Evolution by the Scientific Community*. Cambridge, Mass.: Harvard University Press.

— (1983). "Darwin on the Nature of Science" in Bendall (ed.) (1983)**:** 63-80.

— (2003). "Darwin's Science and Victorian Philosophy of Science" in Hodge and Radick (ed.) (2003)**:** 168-191.

Jordanova, L.J., Porter, R. and Science., B.S.f.t.H.o. (eds.) (1979) *Images of the Earth: Essays in the History of the Environmental Sciences.* Chalfont St. Giles: British Society for the History of Science.

Knox, R. (1855) "Contributions to the Philosophy of Zoology." *Zoologist: A Monthly Journal of Natural History* **13**: 4837-4842.

Kohn (1980) "Theories to Work By: Rejected Theories, Reproduction, and Darwin's Path to Natural Selection." *Studies in history of biology* 4: 67-70.

Lange, M. (2009). *Laws and Lawmakers : Science, Metaphysics, and the Laws of Nature*. Oxford ; New York: Oxford University Press.

Laudan, L. (1977). *Progress and Its Problems: Toward a Theory of Scientific Growth*. Berkeley: University of California Press.

— (1981). *Science and Hypothesis: Historical Essays on Scientific Methodology*. Boston: D. Reidel.

Lennox, J.G. (1991). "Darwinian Thought Experiments" in Horowitz and Massey (ed.) (1991)**:** 223-246.

— (2005) "Darwin's Methodological Evolution." *Journal of the History of Biology* **38**(1): 85-99.

Lewis, D.K. (1986a). "Postscript to 'a Subjectivist's Guide to Objective Chance'" in (1986a)**:** 114-132.

— (1986b). *Philosophical Papers*. New York: Oxford University Press.

Mill, J.S. (1859). *A System of Logic, Ratiocinative and Inductive; Being a Connected View of the Principles of Evidence, and the Methods of Scientific Investigation*. New York: Harper & Brothers.

— (1874). *A System of Logic, Ratiocinative and Inductive: Being a Connected View of the Principles of Evidence and the Methods of Scientific Investigation*. New York,: Harper & brothers.

Nelson, G. (1978) "From Candolle to Croizat: Comments on the History of Biogeography." *Journal of the History of Biology* **11**(2): 269-305.

Ørsted, H.C., Horner, L. and Horner, J.B. (1852). *The Soul in Nature: With Supplementary Contributions*. London: H. G. Bohn.

Rehbock, P.F. (1983). *The Philosophical Naturalists: Themes in Early Nineteenth-Century British*. Madison, WI: University of Wisconsin Press.

Richards, R. (1997) "The Theological Foundations of Darwin's Theory of Evolution." *Debus, A, Theerman, P and Parshall K (eds) Experiencing Nature: Essays in Honor of Allen Debus*: 61-79.

Ruse, M. (1975a) "Darwin's Debt to Philosophy: An Examination of the Influence of the Philosophical Ideas of John Fw Herschel and William Whewell on the Development of Charles Darwin's Theory of Evolution." *Studies in History and Philosophy of Science* **6**(2): 159-181.

— (1975b) "The Relationship between Science and Religion in Britain, 1830-1870." *Church History* **44**(4): 505-522.

— (ed.) (2008) *The Oxford Handbook of Philosophy of Biology* New York: Oxford University Press.

Ruse, M. and Richards, R.J. (2009). *The Cambridge Companion to The "Origin of Species"*. New York: Cambridge University Press.

Schiller (1973) "The Genesis and Structure of Claude Bernard's Experimental Method." Giere, R.N. and Westfall, R.S. (eds.): 133-160.

Sloan, P. (2003). "The Making of a Philosophical Naturalist" in Hodge and Radick (ed.) (2003)**:** 17-39.

Wallace, A.R. (1855) "On the Law Which Has Regulated the Introduction of New Species." *Annals and Magazine of Natural History, including Zoology, Botany, and Geology* **16**(September): 184-196.

Whewell, W. (1847). *The Philosophy of the Inductive Sciences, Founded Upon Their History*. London,: J. W. Parker (3rd edition).

— (1858). *Novum Organon Renovatum*. London: John W. Parker and Son, West Strand (3rd ed).

— (1862). *Astronomy and General Physics, Considered with Reference to Natural Theology*. London: H.G. Bohn (8th edition).

Whewell, W. and Butts, R.E. (1989). *Theory of Scientific Method*. Indianapolis: Hackett Pub. Co.

Wohl (1960) "Buffon and His Project for a New Science." *Isis* **51**(2): 186-199.

Wolters, G., Lennox, J.G. and McLaughlin, P. (1995). *Concepts, Theories, and Rationality in the Biological Sciences: The Second Pittsburgh-Konstanz Colloquium in the Philosophy of Science*. Pittsburgh: University of Pittsburgh Press.

NOTES

[i] Darwin, Transmutation Notebook B: 227-228, quoted in Manier (1978: 116). Hodge (1983a: §10) discusses Darwin's preoccupation with this phrase.

[ii] I leave unspecified the sense in which laws "support" counterfactuals; see Lange 2009 for a detailed account.

[iii] See Rehbock (1983) for a detailed study of the science and metaphysics of the philosophical naturalists.
[iv] Knox 1855a: 4837; quoted in Rehbock 1983
[v] cf Whewell (1833: 3) "…nature, so far as it is an object of scientific research, is a collection of facts governed by laws: our knowledge of nature is our knowledge of laws."
[vi] Darwin (1837-1838: 98)
[vii] Darwin (1860)
[viii] Darwin (1859: 488)
[ix] One notable exception is his explicit definition of laws in the 4th edition of the Origin as "the sequence of events as ascertained by us." This is a vastly deflated notion of law compared to that found in the notebooks and in previous editions of the Origin. It is also a vastly deflated notion of law compared to that found in The Variations of Animals and Plants Under Domestication (vol II), published in the same year as the Origin's 4th edition (1868). Here we find Darwin referring to objects "obeying natural laws" and being the "result" of "general laws" (p430-432). Indeed, as late as the 6th edition of the Origin Darwin states that a particular "law governs the construction of the mouths and limbs of crustaceans" (p411). For those who would attribute to Darwin a metaphysically limp, Humean conception of law, it is in Darwin, but rarely. This is the only instance I've been able to find, and I find his commitment to it here to be amusingly half-hearted, which his contemporaneous and later work also suggests.
[x] Grierson (1823), quoted in Rehbock (1983): 8.
[xi] See Herschel (1830), Chapter 6; Whewell (1858), Chapter 7 (titled, "On Laws of Phenomena and of Causes").
[xii] On my reading, a doctrine for Whewell is a law of nature that is so well confirmed that it has become part of the theoretical bedrock (see, for example, Whewell 1858, p234).
[xiii] On Darwin's views of Whewell, see Manier (1978), esp. pp51-55.
[xiv] There is a fairly direct sense in which this view diverges from contemporary philosophy of science, since most philosophers do not think that laws are required for explanations, although they may suffice in some (or even many or most) cases. That disagreement, however, is over the nature of explanation, not laws.
[xv] In Gareth Nelson's words, "[t]he history of biogeography … is the history of Buffon's Law" (Nelson 1978: 285).
[xvi] See Kohn (1980: 68ff).
[xvii] Michael Ruse refers to Herschel's insight that "laws … allow for counterfactuals" as one reason why "[t]he 1830s conception of 'law' was, in certain respects, surprisingly modern" (Ruse 1975: 509).
[xviii] See Mill (1859) Book III, Chapter IV, §1.
[xix] In addition, both Mill and Herschel devote serious and sustained attention to methodological precepts for resolving a law's apparent exceptions. See, for example, Mill (1859), Book III, Chapter 10; Herschel (1830), Part II, Chapter 6.
[xx] cf Cartwright (1999: 28-29). Thanks to Marc Lange for the pointer.
[xxi] Since it seems weird to me to think that there could be something necessary to lawhood that makes no difference in scientific practice, I think the prospects for an independently motivated exceptionlessness are dim. One suggestive line of argument begins with the observation that there is a strong tradition of attempting to resolve exceptions that is every bit as strong as the tradition of not caring about exceptions. Why attempt to resolve exceptions if they do not matter to lawhood? This is an important question to which I do not pretend to have an answer. But to treat this issue with the detail it deserves lies beyond the scope of this paper.
[xxii] It is important here to recall that the "rule-breaking" capabilities of "chance" events are the basis upon which the argument against biological laws rests.
[xxiii] Beatty (2008) provides an interesting discussion of the broader upshots of this and related remarks by Darwin.
[xxiv] See, for example, Godfrey-Smith (2009), §3.2.
[xxv] Put another way, natural selection is a law which relates probabilities and frequencies. This understanding of natural selection is similar to one arrived at independently by Brandon (2006) and Brandon and Rosenberg (2000). 147-181
[xxvi] See Beatty (2006; 2008).