

**ON THE EVOLUTION OF THE SPECIES CONCEPT: DARWIN'S SPECIES REALISM**

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University of Pittsburgh, 2018

Certain conceptual issues persist stubbornly in philosophy, changing form and focus over time. Analysis of historical and philosophical development of concepts can help us to understand the contemporary conceptual issues we face. In this thesis, I examine conceptual change in the case of a historically slippery concept in the philosophy of biology – the species concept. Broadly put, a species concept answers the question, “What is it to be a species?” The work of Charles Darwin in the nineteenth century had interesting consequences for the species concept in terms of conceptual development. Here is an interesting claim: Darwin is a species realist. It is a contentious one, debated throughout the historical and philosophical literature on Darwin. I wish to raise and resolve a new concern: Darwin is a species realist, even though he denies certain properties which, on the views of his peers, *make species real*. This apparent contradiction gives rise to two questions: first, *how* can Darwin resolve this issue and be a species realist? Second, *why* is he motivated to take such a stance? Then, with answers to these two questions in mind, I ask, what is the structure of this conceptual shift? I give historically motivated answers to the first two questions, and then sketch a philosophical framework which incorporates the first two questions and answers the third.

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## **PREFACE**

In completing this undergraduate thesis, I am truly grateful for the intellectual community at the University of Pittsburgh, the University Honors College, and the Department of History & Philosophy of Science. Thank you especially to Sandy for dedicating so much of her time and attention to directing this project, John for advice and encouragement on my draftiest drafts, and of course, to Aaron: co-director, mentor, general superhuman. I am grateful also for all my other mentors in the HPS department, and to the friends, family, and members of the Philosophy of Science Club who have been subjected to this project in its various states of panic and clarity. Your nodding and furrowed brows are deeply appreciated.



## 1.0 INTRODUCTION

Certain conceptual issues persist stubbornly in philosophy, changing form and focus over time. Analysis of historical and philosophical development of concepts can help us to understand the contemporary conceptual issues we face.<sup>1</sup> In this thesis, I examine conceptual change in the case of a historically slippery concept in the philosophy of biology – the species concept. Broadly put, a species concept answers the question, “What is it to be a species?” In contemporary philosophy of biology, the issues surrounding the species concept are collectively referred to as ‘the species problem’ – some reviewers claim there are around 70 proposed species concepts (Mayden, 1997), and none is universally applicable nor unanimously satisfying.<sup>2</sup> In spite of the fact that the species concept has eluded consensus on its characterization throughout history, biologists have made a great deal of progress in the fields of evolution, genetics, and speciation – fields where one might expect a seemingly fundamental notion as that of ‘species’ to be well-understood. An analysis of the changes in the species concept over time may help to elucidate how the concept is operating in contemporary biology and philosophy, and further, *why* we continue to have a species problem.

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<sup>1</sup> See Lennox (2001).

<sup>2</sup> For some more literature on the abundance of and conflict among species concepts which initially helped to motivate this project, see Wiley and Mayden (2000), Velasco (2008), Valen (1976), Mayr (1942), and Claridge, Dawah, and Wilson (1997).

In order to better understand the development of the species concept, I will consider one of the particularly interesting issues that arises in connection with it: that of *species realism*. Here is what turns out to be a puzzling claim: Darwin was a species realist. He believed that our species designations picked out groups that are produced by nature – even if, as we will see, those groups are not distinct. The question of species realism, within the larger question of the nature of the species concept, is still somewhat controversial, though the debate now seems to lean toward a consensus on realism.<sup>3</sup> But as I will show, species realism was a complicated stance for Darwin to take.

I will raise and answer two major questions about the significant development of the species concept which came about as a result of Charles Darwin's theory of evolution by natural selection, in particular with his publication of *The Origin*. I will argue that Darwin is indeed a species realist, though his realist stance about species is puzzling for this major reason: when his contemporaries are species realists, they believe species are also immutable and categorically distinct from varieties. And when they are not species realists, they are so *because they deny the existence of those properties*. Darwin rejects the very things which his peers think make species real. I ask: how could Darwin be a species realist in the face of this apparent contradiction? And, if I can establish *how* Darwin can make his theory do this, I then ask: *why?* Why go to great and meticulous lengths to *continue being a species realist* when he might very well have chosen not to be?

In the first chapter, I consider the “how” question. How could Darwin be a species realist, when his claims about species run counter to the very properties which, on the views of his peers, *make species real*? I will show that in order to maintain what would otherwise seem to be

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<sup>3</sup> See Wiley and Lieberman (2011) for discussion on the state of species realism in contemporary biology.

an incoherent position, Darwin makes significant revisions in *what it is for a species to be real*. In the second chapter, I ask: *why* does Darwin choose to be a realist about species in nature, when he might reasonably have chosen the opposite stance? From an angle of historical analysis, I show that species realism is closely related to the particular kind of *origin account* given for species. In particular, Darwin's origin account for new species is organic evolution; he proposes that species are causal players in the production of new species. I contrast this with the origin account of special creation – which accounts not only for the production of new species, but for the origin of organic life itself. While Darwin provides an origin account for new species distinct from special creation, he finds a new motivation for realism: because species *groups* help to causally determine the course of evolution, they are not artificial groupings imposed by conventions of systematics.

In the third chapter, I develop a philosophical framework which helps to visualize and explain the changes to SPECIES and SPECIES REALISM discussed in the previous two chapters.<sup>4</sup> A crucial feature of this conceptual shift is that Darwin seeks to maintain the referent of SPECIES – he is *talking about* the same thing in nature that, say, Charles Lyell is *talking about*. But he makes significant and fundamental revisions to the content of the concept. I detail the revisions that Darwin makes in terms of reconfiguring the non-referential semantic structure of the complex concept SPECIES. I conclude by summarizing the overall conceptual shift in SPECIES and SPECIES REALISM.

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<sup>4</sup> Small caps are used to mention concepts. Single quotes will be used to mention terms.

## 2.0 HOW COULD DARWIN BE A SPECIES REALIST?

### 2.1 INTRODUCTION

Certain natural philosophers, including Carl Linnaeus, Comte de Buffon, and Charles Lyell, were instrumental in establishing the species concepts prevalent in the 18<sup>th</sup> and 19<sup>th</sup> centuries. Though their individual conceptions of species differ in several respects, each relies on an association between the commitment to species realism and the belief that species are both immutable and categorically distinct from varieties. These are claims about the properties of species (this will be important in the next chapter, where I will discuss claims about the *origin(s)* of species as opposed to properties). In addition, because they believe species are distinct and immutable, their method for testing a species – determining whether some group of organisms is or is not a species – is to form a constituent definition based on those properties.<sup>5</sup>

The three aforementioned naturalists embrace species realism, but others, in response to new evidence, instead reject the realist stance. J.B. Lamarck believes he has evidence of transformation – evidence against immutability and category distinctness – and because he agrees with Linnaeus, Buffon, and Lyell in their understanding of what it is for a species to be

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<sup>5</sup> A constituent definition for a species treats the species as a class, defined by the property or properties shared by all and only the members of the species. The role of these definitions with regards to species is further discussed in 2.2.1 in the case of Buffon's species concept.

real, he rejects species realism. For all of these natural philosophers, immutability of species and category distinctness between species and varieties are bound up with species realism.

Given this association between species realism on the one hand, and immutability and distinctness on the other, Charles Darwin appears to be doing something strange in his *Origin of Species*. He rejects immutability and category distinctness, a necessary consequence of proposing gradual evolutionary change. But unlike Lamarck, who also proposes a theory of gradual evolutionary change, Darwin remains a species realist. This would appear contradictory: Darwin's contemporaries and predecessors did not allow for holding a realist view about species without believing in immutability and category distinctness. Darwin is a species realist, but rejects those things which, on their view, make species real. How could Darwin be a species realist?

I will argue that when Darwin develops his theory of evolution by natural selection in *The Origin*, he not only makes new empirically supported claims of gradualism and evolution, but also effects a change in *what it is for species to be real*: there are really two conceptual shifts going on – in SPECIES and SPECIES REALISM. Darwin's change can be described as having two steps. In his first step, he makes his new claims about nature: he rejects the properties of immutability and distinctness and instead claims that species are mutable and evolve gradually. This is the beginning of a conceptual shift in SPECIES. And this step has consequences for a belief in species realism: those features which constitute natural boundaries *do not exist*. Therefore, his second step is to resolve this apparent contradiction by instead tying his belief in species realism to his belief in community of descent. This is the completion of the conceptual shift in SPECIES.<sup>6</sup> Consequently, instead of testing the reality of a species by looking for constituent definitions,

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<sup>6</sup> It is also the entirety of a conceptual shift in species realism – see 4.2.2.

Darwin believes we should look for characters which reveal common ancestry and conclude we have identified a real species when we have found shared characters that allow us to construct a branching pattern of descent.

I will first give a historical account of the relationships among realism, immutability, distinctness, and constituent definitions evident in the work of 18<sup>th</sup> and 19<sup>th</sup> century naturalists. I will then give an account of Darwin's view. I will specify the changes he makes in what it is to be a species and in what it is for a species to be *real*, and I will then describe the consequent change Darwin effects in how we determine if a species that we believe we have identified is indeed a real one.

Here I must make two notes about terminology. First, the meaning of 'real' is consistent among the naturalists I will discuss, including Darwin. To be real is to be a feature of nature, rather than of artifice or construction contingent upon human interest. Darwin's impact was *not* to change the ontological doctrine of realism, nor the meaning of 'real.' Rather, he changed what it is for a *species* to be real in nature.<sup>7</sup> Second, in the case of Linnaeus, the question is framed in terms of naturalness, rather than reality. Others will use explicitly ontological terms, like 'real' and 'exist.' In each case, I will show that the naturalist under consideration is referring to species realism.

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<sup>7</sup> Again – see 4.2.2

## 2.2 REALISM, IMMUTABILITY, AND CATEGORY DISTINCTNESS

Several historical examples of prominent naturalists show that the belief in species realism was often concurrent with commitments both to a categorical distinction between the species group and the varieties within a species, and to immutability. A commitment to a categorical difference between species and varieties is a commitment to the belief that, for example, the differences that mark different *breeds* of dogs are categorically distinct from the differences which distinguish dog from wolf. Those latter two commitments can be distinguished but are themselves necessarily tied together for species. Categorical distinctness means that species have natural boundaries, and immutability implies the maintenance of these boundaries over time.<sup>8</sup>

### 2.2.1 Buffon Becomes a Species Realist When Definitions Become Possible

The first case, that of Buffon, illustrates an explicit conversion to species realism when evidence shows constituent definitions to be achievable. Buffon revises his species concept, maintaining the relationship between beliefs in natural boundaries for species and species realism. In his 1749 *Histoire Naturelle*, he claims that species are artificial, because when studying organisms in finer and finer detail, a systematist eventually arrives at the consideration of individuals – Buffon

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<sup>8</sup> The historical examples are not given chronologically; rather, they are organized to best show the common association of beliefs among the naturalists discussed. The first three examples show a commitment to realism and both immutability and category distinctness, and the last shows the simultaneous rejection of all of these commitments.

thinks that individual organisms alone “exist in nature” (Buffon, 1749). Because identifying species supposedly picks out natural *groups* based on differences, but important differences can be found down to the level of the *individual*, the search for constituent definitions of species is a flawed enterprise. Buffon writes,

[Thus] nature, proceeding by unknown gradations, cannot wholly lend herself to these divisions [into genera and species]... There will be found a great number of intermediate species, and of objects belonging half in one class and half in another” (Buffon, 1749).

In other words, looking for discrete classes of organisms to call species is misguided, as the boundaries for classes do not exist. Consequently, species are not real. However, Lovejoy points out that Buffon reversed his position when presented with evidence of hybrid infertility. The evidence for reproductive boundaries prompted Buffon to commit to a category for species distinct from the small gradations between varieties, and also from species anti-realism to species realism: in Lovejoy’s terms, reproductive boundaries proved to Buffon that species were “objective and fundamental realities” (Lovejoy, 1936, p. 230). The boundaries provide discrete classes and thus the grounds on which to constitutively define species. Buffon is only a species realist when he is convinced that the criteria of immutability and category distinctness can be met.<sup>9</sup>

### **2.2.2 Linnaean Classification and Naturalness**

Carl Linnaeus, in his botanical writings in the 18<sup>th</sup> century, is committed to species and genera being natural groups (here, ‘natural’ has the same sense as Buffon’s ‘real’) and also to ‘species’

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<sup>9</sup> For discussion of constituent definitions for species, I have benefitted from Sober (1980), though here I make only the claim that naturalists sought constituent definitions, and remain neutral about the larger claim Sober presents about a narrative of *essentialism* for species.



as a different kind of designation than ‘variety.’ His views on mutability and the existence of hybrid species change throughout his life, but the idea of mutability remains bound up with the commitment to naturalness even as he questions, and later accepts, that hybrid species exist. In his early writings, he is less concerned about articulating what a species *is* and more concerned with discovering natural species. He believes we approach the ideal of a natural system of classification when we study organisms carefully enough. His species concept is therefore somewhat implicit, and he does not make claims about realism *per se*. His assertions of the *naturalness* of species and genera as groups, and not of varieties in the same sense, however, are evidence for his commitment to species realism. He holds the ideal of a natural system – though he understands his own system to be artificial, he takes this artificiality to be the shortcoming of our limited knowledge, not a consequence of an unstructured natural world:

And it is not possible to hope that our age will be able to see any natural system, nor perhaps will posterity. Nevertheless, **we are striving to know the plants; so meanwhile artificial and substitute classes have to be assumed** (Linnaeus’s *Genera plantarum*, 1737, translated by Müller-Wille and Reeds (2007, p. 567), emphasis mine.)

A Linnaean natural system should arrange as best it can what nature shows to us:

All that truly can be known by us depends on a clear method by which we distinguish the similar from the dissimilar. The more natural the distinctions this method comprises, the more clearly the idea of things emerges to us. The more objects our understanding engages with, the more difficult it becomes to work out a method – and the more necessary. Nowhere has the Great Creator placed so many objects before the human senses as in the vegetable kingdom, which covers the whole globe that we inhabit (Linnaeus’s *Genera plantarum*, 1737, translated by Müller-Wille and Reeds (2007, p. 564)).

Linnaeus, as a botanist, is focused on classifying plants. But this passage demonstrates that his project is one of *discovery* of the existing, created groups. The distinctions between groups are *there* by virtue of God’s will, and the more closely we approach an account of those distinctions, the more natural our system is.

Having established that Linnaeus held a commitment to species realism (though given in terms of naturalness), I will now show that he also believed that species and varieties were categorically distinct. Linnaeus writes in *Philosophia Botanica* that “We reckon the number of species as the number of different forms that were created in the beginning” while “The number of varieties is the number of differing plants that are produced from the seed of the same species” (Linnaeus, 1751, pp. 113-114). Expounding on the idea of a variety, he writes,

A variety is a plant that is changed by an accidental cause: *climate, soil, heat, winds, etc.*, and likewise it is restored by a change of soil. Kinds of varieties are *size, fullness, curling, colour, savour, and smell*. Varieties could be excluded from botany, but *Housekeepers* value large and curly ones. *Gardeners* value full and coloured ones. *Physicians* value savoury and smelly ones (Linnaeus, 1751, p. 114).

Thus, he shows that varieties are not the true groupings given to us by nature, rather they are differences within the species group. Additionally, he claims that varieties could be excluded from botany if not for interest from parties outside the field (Linnaeus, 1751, p. 114) – they are not important to classification in the fundamental way that species are.

The distinction is made clearer by his discussion of the different kinds of arrangements of organisms (specifically, plants) that can be formed. Arrangement of organisms is “the divisions and connections of the vegetables” and constitutes “the foundation of nomenclature,” and it can be *practical*, establishing species and varieties, or *theoretical*, establishing higher taxa. Additionally, “practical arrangement can be managed by one who has no understanding of system” (Linnaeus, 1751, p. 111). While genera are also natural, they require some systematic methodology to establish. Thus, even between species and genera, which are both “made in the first place such as it is,” there is something more foundational or obvious about species (Linnaeus, 1751, p. 111).

What about his views on immutability? Linnaeus’ transition from complete denial of

hybrid species (as quoted above) to acceptance of several new hybrid species of plant is relatively well-known. However, it poses a challenge for his ideal of naturalness. Even as he begins to acknowledge the existence of hybrid species in his later writings, he is hesitant to say whether or not these hybrid species were intended at the beginning by a creator (Ramsbottom, 1938). For Linnaeus, the grounding for the reality or naturalness of species is creation and admitting to the existence of hybrid species threatens that reality. His hesitance to say that the hybrid species were not intended reflects the association between realism and natural boundaries – and the concession that the creator may have intended these species is a way to preserve their reality by the same standards he had previously used. Linnaeus thus operates under the association between realism and natural boundaries, and the evidence for naturalness is our discovery of the boundaries between species.

### **2.2.3 Lyell’s Empirically Discoverable Species Definitions**

Charles Lyell, principally responding to J.B. Lamarck’s theory of transformation,<sup>10</sup> criticizes the idea that species could transform into other species over time. His critique illustrates the connection between realism and natural boundaries for species – Lyell maintains his commitment to realism *because of* his commitments to immutability and category distinctness, which he believes are evidenced by our ability to empirically discover the limits of variation. He argues for species as real groups with discoverable natural limits. In his *Principles of Geology*, Lyell responds to Lamarck directly, arguing that Lamarck does not have sufficient evidence to support his theory of transformation. In particular, Lamarck lacks evidence for the formation of

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<sup>10</sup> Lamarck’s theory is discussed in the next section, because his adherence to the same association of beliefs as these other naturalists makes clear the tension that will arise when Darwin’s theory comes into play.

new organs. Lyell gives an empirical explanation for the apparent gradation between species by appealing to domestication, which essentially tests the limits of variation within a species. He claims that the capacity for domestication already exists inherent to the species, and this is why some animals are fit for domestication and some are not (Lyell, 1832, p. 47). Additionally, to refute Lamarck's mechanism of evolutionary change, Lyell cites that in many cases, learned faculties (for example, a pig trained for hunting) are not passed on to offspring (Lyell, 1832, p. 42). From domestication and observation in nature, Lyell infers that:

[T]he entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no further deviation can be obtained by continuing to alter the circumstances, though ever so gradually, indefinite divergence, either in the way of improvement or deterioration, being prevented, and the least possible excess beyond the defined limits being fatal to the existence of the individual (Lyell, 1832, p. 65).

This constitutes an empirical objection to mutability. His explanation also includes an element of reproductive isolation, which enforces immutability. He writes that, “[t]he intermixture of distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring,” and he ultimately concludes that “[f]rom the above considerations, it appears that species have a real existence in nature, and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished” (Lyell, 1832, p. 65). Lyell's commitment to fixed ranges of variation explains differences observed among organisms without appealing to mutability, and this defense also reinforces the distinction between a species and a variety. Reproductive boundaries and observable limits to domestication show that species have naturally existing boundaries between them, while ‘varieties’ only describes the differences observed within the fixed boundary of the species. We can, then, define species constitutively, because each of them will possess a defining feature about which the individuals vary. He is responding to Lamarck, who, as we will see in

the next section, denied the reality of species *because* he rejected the basis for such definitions as Lyell describes.

#### **2.2.4 J.B. Lamarck, Species Anti-Realist**

J.B. Lamarck is perhaps the most interesting case of the tie between species realism and natural boundaries, because he maintains the connection between realism and natural boundaries and throws the two commitments out together. Lamarck published his *Zoological Philosophy* in 1809, in which he proposes a theory of transformation and denies the reality of species. He rejects species realism because he believes he has evidence challenging the distinction between species and varieties, and because his theory contradicts immutability. Lamarck understands the definition of species as follows: “Any collection of like individuals which were produced by others similar to themselves is called a species.” However, he notes that this definition usually implies an understanding of constancy when he writes, “to this definition is added the allegation that the individuals composing a species never vary in their specific characters, and consequently that species have an absolute constancy in nature” (Lamarck, 1809, p. 35). He challenges the contemporary view on species through these three questions:

- (1) Are species of “absolute constancy”?
- (2) Are species “as old as nature”?
- (3) Have species “all existed from the beginning just as we see them to-day”? (Lamarck, 1809)

‘Constancy’ here includes both immutability and the distinction between species and varieties groups. The groups exist with boundaries, and do not change appreciably over time. Lamarck answers these questions negatively – the basis for his doubt is that as we progress in studying natural history, we are faced with increasing difficulty of determining what is a species

(Lamarck, 1809, p. 40). This suggests to Lamarck that rather than hard distinctions between species, a gradation exists:

The species of these genera, arranged in series according to their natural affinities, exhibit such slight differences from those next to them as to coalesce with them. These species merge more or less into one another, so that there is no means of stating the small differences that distinguish them (Lamarck, 1809, p. 37).

His proposition of gradualism is incompatible with the idea of constancy that he outlines in his definition of species and his questions (1)-(3). How can species have existed for all time as the apparent groups that we see today, if we find it increasingly evident that those delineations are not truly there? His doubt is furthered by his acceptance of the existence of hybrid plants (Lamarck, 1809, p. 39). His commitment to *gradualism* affects his commitment to *constancy* because it challenges the idea of a strict distinction between species and varieties designation. Indeed, Lamarck thinks the difference between the two categories is arbitrary:

Hence, naturalists come to arbitrary decisions about individuals observed in various countries and diverse conditions, sometimes calling them varieties and sometimes species. The work connected with the determination of species therefore becomes daily more defective, that is to say, more complicated and confused (Lamarck, 1809, pp. 35-36).

This breakdown of the difference in designation contributes to his rejection of species realism – arbitrary distinctions do not pick out real things in nature. Based on these considerations, Lamarck questions “whether the idea of species has any real foundation” (Lamarck, 1809, p. 40).

As he develops his theory of transformation, he takes a stance necessarily opposed to immutability. His response to the species realism question is to deny that species are real groups in nature; rather, they are apparent groups which endure only insofar as their environment remains constant. Importantly, he rejects species realism *because* he believes he has evidence for mutability and *because* he believes that that which we call species are really no different from varieties. Like Linnaeus, Lamarck thinks that mutability threatens the reality of species. Unlike

Linnaeus, however, he does not hesitate to accept this consequence of hybridization and concedes that species are not real groups in nature. Sterility between very different organisms is really only evidence for gradualism:

It is true that often nothing results from these strange copulations, especially when the animals are very disparate; and when anything does happen the resulting individuals are usually infertile; but we also know that when there is less disparity these defects do not occur. Now this cause is by itself sufficient gradually to create varieties, which then become races, and in the course of time constitute what we call species (Lamarck, 1809, p. 39).

Here, it is important that Lamarck writes “what we call species,” rather than simply “species.” He implies that what species appear to be is actually illusory – they are snapshots in overall gradualistic change.

Lamarck’s rejection of species realism as a consequence of the association between beliefs in realism and natural boundaries is even more evident when we consider his views prior to 1800 – before he was a transformationist, he was committed to the constancy of species in nature. He reflects that he “thought for a long time that there were constant species in nature” in his 1802 *Recherches sur l’organisation des corps vivants*. Richard Burkhardt remarks in his book *The Spirit of System: Lamarck and Evolutionary Biology* that throughout his writings prior to 1800, Lamarck never challenges the immutability of species, actually insisting upon their reality in nature (Burkhardt, 1977, pp. 87-88). When Lamarck becomes convinced of mutability and the gradation between all living things, he transitions from insisting upon the reality of species to questioning whether the idea of species has “any real foundation” at all. Discarding species realism in response to this theory change is evidence of the strong association among the three ideas.

## 2.3 DARWIN'S SPECIES REALISM

In this section, I characterize Darwin's view. I will show that Darwin rejects immutability and distinctness between species and varieties, but that in spite of this, remains a species realist. This observation – that he makes claims of gradualism and evolutionary change like Lamarck does, but is not led to the same conclusion about the reality of species – is the key indicator that some deeper revision of what it is for a species to be real is going on.

### 2.3.1 Darwin is a Species Realist

In *The Origin*, Darwin writes that the term 'species' is "one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other, and that it does not essentially differ from the term variety, which is given to less distinct and more fluctuating forms" (Darwin, 1859, p. 52). The difference between a species and variety is then a matter of degree, or amount of difference, rather than a categorical difference in each kind of designation. Darwin makes this claim when he writes, "Undoubtedly there is one most important point of difference between varieties and species; namely, that the amount of difference between varieties, when compared with each other or with their parent-species, is much less than that between the species of the same genus" (Darwin, 1859, p. 57). Here, we can see Darwin dispense with the commitments to the existence of boundaries between species and to a separate category called 'variety.' Practically, we can decide on which term to apply by examining the degree of difference among organisms, and in particular the degree of constancy (as opposed to variability) of shared traits (Darwin, 1859, p. 423). This is the first step of the Darwinian shift in what it is for a species to be real. Rather than naturally delineated groups within which some variations occur, Darwinian



species are groups recognizable by relative similarity within themselves and degree of difference from other groups.

However, in contrast to Lamarck, and though he also uses the term ‘arbitrary’ with regards to distinguishing species from varieties, Darwin is not led to anti-realism about species. Evidence for Darwin’s species realism suggests he does not mean ‘arbitrary’ in the same sense as Lamarck – I will argue that Darwin is not suggesting that there is *nothing to* species groups, as Lamarck was.

To demonstrate that Darwin does remain committed to species realism despite rejecting those features of nature and despite acknowledgment that species names are not firmly attached to a strictly defined group, I will briefly draw on Beatty (1985) and Ghiselin (1969). Beatty shows that Darwin rejects the *species definition* of his fellow naturalists because their definition included immutability; instead, Darwin forms his species concept based on the properties of the *referent* of the definition espoused by the others – the things in nature that appear to be grouped into species. This poses a problem for species realism. Beatty notes that Darwin often seems to deny the reality of species when he makes claims like those quoted from *The Origin* above.<sup>11</sup> Beatty and Ghiselin respond to this problem by pointing out that Darwin affirms the reality of the species *taxon*, rather than the species *category*:

There is no statement in the entirety of Darwin’s published writings, which, properly interpreted, asserts that there is nothing more than a name between the individuals of a species. For, in technical terms, Darwin was denying the reality, not of taxa, but of categories (Ghiselin, 1969, p. 93).

Ghiselin is claiming that Darwin did not deny that taxa are formed based on something real, but that species themselves do not form categories, and that the species category is not some

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<sup>11</sup> Though I argue for Darwin’s species realism using evidence from *The Origin*, Beatty draws more from his longer text *Natural Selection*, an examination of which (the Stauffer (1975) edition) proves convincing of Darwin’s realist stance.

grouping determined in some fundamentally different way than other groupings of organisms (i.e., not *categorically* distinct from, say, varieties). Darwin believes there are real collections of organisms, which are the things that taxonomists call ‘species,’ but the boundaries of those taxonomic groups do not exist in nature – so the species category cannot be real as defined in the sense understood by his fellow naturalists. Thus, Darwin affirms the reality of the apparent groups in nature, rather than those delineated by the species definitions of his contemporaries, while Lamarck, for example, denies that the properties of organisms naturally group them at all. The fact that Darwin does not “assert that there is nothing more than a name between the individuals of a species” (Ghiselin, 1969, p. 93) suggests that Darwin *did* conceive of species realism as having the same definition as his fellow naturalists, that is, that species designations pick out something real in nature.<sup>12</sup>

### 2.3.2 The Apparent Contradiction

However, even if we note that Darwin modifies what it is to be a species and accept Beatty and Ghiselin’s explanation that Darwin affirms the reality of the species taxon and not the species category, we are still left with a question about realism. They showed that Darwin does think species satisfy the requirements for something to be *real*, i.e., Darwin *is* a species realist, in some sense. But this raises a problem. Darwin appears to be both (a) claiming that species are real, and (b) denying that species are immutable and categorically distinct from varieties. As we have just seen, however, immutability was *part of what it meant for species to be real at this time*. There are therefore two possibilities: either Darwin’s position is incoherent, or Darwin changes the

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<sup>12</sup> David N. Stamos (2007) also asserts that Darwin is a species realist, but via a different argument. A close comparison of my argument with Stamos’ would be illuminating, though I cannot do it here.

requirements for species realism. If the referents of the term ‘species’ are indeed real groups, but they are not the naturally-bounded groups defended by Darwin’s contemporaries, they must be real in a different sense. What is it, then, on Darwin’s view, for a species to be real? I.e., what *is required of a species* for us to consider it real?

### **2.3.3 The Solution: Darwin Revises the Requirements for Species Realism**

Darwin’s new requirement for species to be real is that they are produced by the historical process of descent – he ties his commitment to realism to the theory of community of descent. Evidence for this (and further evidence that Darwin was indeed a species realist) is found in Darwin’s discussion on classification in *The Origin*, where he lays out his theory’s implications for taxonomy. He claims that an accurate classification *has an underlying basis in nature* – classification is “evidently not arbitrary like the grouping of stars in constellations” (Darwin, 1859, p. 411). Nor is a true classification a revelation of the order of creation – Darwin says that knowing an order of creation would give us no additional information about nature (Darwin, 1859, p. 413). However, Darwin does favor the idea that classification should reflect a “something more” about nature:

But many naturalists think that something more is meant by the Natural System; they believe that it reveals the plan of the Creator; but unless it be specified whether order in time or space, or what else is meant by the plan of the Creator, it seems to me that nothing is thus added to our knowledge. Such expressions as that famous one of Linnaeus, and which we often meet with in a more or less concealed form, that the characters do not make the genus, but that the genus gives the characters, seem to imply that something more is included in our classification, than mere resemblance (Darwin, 1859, p. 413).

This phrase appears in Linnaeus’ *Philosophia Botanica*, in which he says that “A character does not exist to form a genus, but to make it known” (Linnaeus, 1751, p. 132). Darwin takes

Linnaeus' statement as one of species realism – that classification is not of artifice but captures some real properties of nature. Linnaeus' "something more," however, does refer to the order of creation – characters make known the true structure of nature as created by a god. Darwin seeks to retain the realism implied by Linnaeus' statement, but to replace the "something more" to which Linnaeus refers – for Darwin, the reality of species will not be grounded in creation. Darwin's "something more" is genealogical history – the branching structure produced by descent from a common ancestor. The pattern that we observe as a result of common descent – "groups within groups," as Darwin calls it, can be traced by observation and empirical methods, producing an accurate classification. For species to be real, in the Darwinian sense, is for them to be products of a historical process of genealogical descent. Rather than constructing definitions which make finite boundaries between species, we can treat species as vaguely-bounded groups that over time arrange in a branching structure.

### **2.3.4 How Do We Identify a Real Species?**

If what makes species real is the process of community of descent, we must be able to determine that a group has, in fact, been produced by descent. Darwin criticizes the classificatory practices of his peers, whom he says focus too much on physiologically important characters, a method which leads to conflict and inaccurate classification. Instead, he recasts Linnaeus' ideal of a natural system in an evolutionary context:

All the forgoing rules and aids and difficulties in classification are explained, if I do not greatly deceive myself, on the view that the natural system is founded on descent with modification... I believe that the *arrangement* of the groups within each class, in due subordination and relation to the other groups, must be strictly genealogical in order to be natural; but that the *amount* of difference in the several branches or groups, though allied in the same degree in blood to their common progenitor, may differ greatly, being due to the different degrees of modification which they have undergone; and this is expressed by

the forms being ranked under different genera, families, sections, or orders (Darwin, 1859, p. 420).

In Darwin's proposal that a classification based in descent would give us the natural organization of nature, we can find his test for the reality of a species. It is no longer the formulation of a definition based on detecting the natural delineations of species. Rather, Darwin's test is the identification of features which reveal the structure of descent – characters which show us ancestry. This makes Darwin's procedure for identifying species diagnostic rather than definitional – we can reasonably determine when a true species has been identified, though we cannot definitively locate a clear boundary.<sup>13</sup> These features are most relevant for classification regardless of their other functions, a belief Darwin expresses when he writes, “Again, no one will say that rudimentary or atrophied organs are of high physiological or vital importance; yet, undoubtedly, organs in this condition are often of high value in classification” (Darwin, 1859, p. 416). Linnaeus' proposition that the genus gives the character is thus reinterpreted by Darwin: the genus (and other higher groupings, depending on degree of difference) is defined by shared characteristics inherited from a common ancestor. Based on the theory of common descent, if we can pick out the groups that are arranged in its requisite branching structure, we are justified in believing these are real species groups, not of artifice but of nature.

## 2.4 CONCLUSIONS

Darwin does modify the species concept – he claims that those things which we call ‘species’ are not, in fact, immutable and distinct from something else that we call a ‘variety’. He also

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<sup>13</sup> The distinction between diagnostic and definitional species concepts is defended in Ghiselin (1984), and I thank John Beatty for helpful discussion on differently functioning species concepts.

maintains that species are some kind of real group laid out by nature in a way that scientists can empirically discover. But in order to so change the species concept while also maintaining species realism, he must make a further modification – a second conceptual shift, this time to the concept of species realism. On Darwin's view, what it is for a species to be *real* is no longer for it to be *naturally bounded*. Rather, species are real in virtue of the fact that they are produced by a real process of descent, which creates the branching natural structure of organisms in groups within groups. Without redefining the notion of 'real,' Darwin modifies what it means for a *species* to be real by tying realism to his new theory of branching descent.

He then must revise the test for species realism – the proper method to determine the relationships among organisms is to study shared characters which reveal ancestry. This modification allows Darwin to understand species in a way that relates species to the real, natural processes which caused them to come into being as we observe them. It makes species realism entirely compatible with evolutionary change, while in prior theories of evolution, it seemed that the belief in species realism must be discarded – on the Darwinian view, scientists can conceive of species as vaguely-bounded groups which are the product of important natural processes and have explanatory power in understanding other natural processes.

### 3.0 WHY IS DARWIN A SPECIES REALIST?

#### 3.1 INTRODUCTION

In the previous chapter, I showed that Darwin modifies the concept of species realism such that he can claim that *if* species are to be real groups, those groups *need not be* immutable and categorically distinct. I contrasted Darwin's theory with Lamarck's on this point: Lamarck is comfortable proposing a theory of evolutionary change without claiming that there are real groups in nature which we call 'species.' Acceptance of gradualism and mutability alone, then, is not enough to drive a change in what it is for species to be real. In the last chapter I asked *how* Darwin could be a species realist; here I ask *why* he is. Why does Darwin not choose the Lamarckian, anti-realist route? Here, I explore some of Darwin's motivation to be a species realist, when he might reasonably have chosen not to be.

I noted earlier that for Carl Linnaeus, the distinctions among species, and between species and varieties, are present due to the will of God. Generally, this is true for each naturalist who believes in a form of special creation (though the details of individual beliefs about creation differ among them). This observation – that there is a role for a creator in understanding species – raises an important question which I have not yet addressed. I have shown that several influential predecessors and contemporaries of Darwin took immutability and category

distinctness as “part of what it means for a species to be real.” But this notion needs further explanation. Which “part”? Why are these properties associated with species realism?

I will answer this question by exploring the role of *origin accounts* in the species realism. My investigation into the role of origin account in species realism will further illuminate the association between immutability and category distinctness with species realism: as I will show, these properties are associated with species realism when that realism is dependent upon an origin account for species in a particular way. Specifically, I will argue that this is true in the case of Charles Lyell, for whom species realism is dependent upon his belief in special creation.<sup>14</sup>

The difference between Lyell’s and Darwin’s origin account that has consequences for species realism is in the character of the cause described: Lyell’s origin account (i.e., his assignment of causal responsibility for the appearance of new species) is an instantaneous cause which happens throughout the course of nature. As I will show, Darwin’s species realism is *also* dependent upon his origin account, but differently. His origin account *will* be a process of change: I argue that while Darwin and his species realist contemporaries *both* hold a realist stance which relies on their proposed origin accounts, Darwin’s realism has a new motivation: in his theory, *species themselves* are causally involved in the origin account for new species. Thus, although Darwin rejects the origin account upon which Lyell’s realism is dependent, his own theory provides *a different reason* that realism depends on origin account. And this different causal role for his origin account illuminates a distinction between the origin of new species and the primary origin of organic life.

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<sup>14</sup> There are numerous possible interpretations of special creation held by different naturalists at the time. I have chosen to contrast Darwin and Lyell because of Lyell’s influence on Darwin and because of his arguments which seek explanations by secondary causes and thus give a rather complex role to an Author of Nature.



The chapter is structured as follows: I first show that Lyell's species realism is dependent upon his origin account and detail the way in which it is dependent. I then show that Darwin's species realism is similarly dependent upon his origin account, but that in his case the dependence is related to the causal power of species within Darwin's theory. I conclude by showing that this difference helps to explain why Darwin is motivated to maintain species realism despite rejecting that which the realism of his peers depends upon.

### **3.2 PROPERTIES, ORIGINS, & ORIGIN ACCOUNTS: LYELL'S SPECIES REALISM**

In this section I detail particular kind of dependence that exists between Charles Lyell's species realist stance and his belief in special creation as an origin account. His case is interesting for two reasons: first, his work, especially his *Principles of Geology* (PG) had a major impact on Darwin as he formulated his theory. Second, Lyell makes wholly empirical arguments when he makes scientific claims about species and species realism, but afterwards invokes special creation as an origin for new species. Lyell, though primarily committed to discovering secondary laws set by an Author of Nature, did reserve a role for a creator in his theory, and this creator was ultimately responsible for species and their properties (including their natural boundaries, their limits to variation).

### 3.2.1 Realism Dependent Upon Origin Account

In Lyell's case, the properties of species which are associated with his species realism (immutability and category distinctness) are dependent upon his origin account. In order to show a dependence of *properties* upon *origins*, I must make clear the distinction between the two. The discussion in the previous chapter was almost exclusively concerned with properties. Immutability and category distinctness are, for Darwin's peers, properties of real species. Their origin, by contrast, is the *source* of their reality. For example, in this case the origin of species is creation by God, and, *because they were so created*, they have certain properties, namely, they are immutable and distinct from varieties.

We can say, then, that Lyell's species realism is *dependent* upon his origin account – the source of their reality is the circumstances of their creation. Lyell's *species realism* is dependent upon his origin account, and the *properties* of immutability and category distinctness are also dependent upon the origin account. Their *origin* is the source of their *reality* and also their *properties*, and therefore, those are the properties of real species, which we detect empirically. Contrast this with realism dependent instead upon properties – for example, one could be a realist about the chemical substance of water regardless of its particular synthesis pathway.<sup>15</sup>

The example of water is illustrative, but a properties-dependent realism about species is possible as well, though we see it much later in the history of the species concept: Consider the Biological Species Concept, in which the reality of species is dependent upon their reproductive potential. Their reproductive potential might be dependent on their genealogical history (and thus, origin), but their reality is directly dependent on the property of reproductive potential.

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<sup>15</sup> I owe this example to discussion with Aaron Novick and Sandra Mitchell, which was motivated by Chang (2012).

Modern conceptions of species realism dependent on origins might include an understanding of species as spatiotemporally extended individuals, like those of Ghiselin (1974) and Hull (1976). This discussion of upon what our species realism depends, then, might be of relevance to the modern species problem.

### 3.2.2 The Role of Origin Account for Lyell's Realism

I've claimed that Lyell's species realism is dependent upon his origin account, and I've shown how this might reasonably be the case. I now support that claim and complete the connection between Lyell's realism and his origin account. What is the historical case for the dependence of Lyell's species realism upon his origin account of special creation?

I have shown that the hallmark of Lyell's species realism is that we can empirically discover the limits to variation – by experiments in breeding and observations of hybrid infertility, we have evidence that there are natural boundaries beyond which organisms cannot vary while remaining viable. Recall that Lyell's argument for the reality of species at the beginning of Volume II of PG is a targeted refutation of Lamarck's theory of transformation. It is important to note that origin account – special creation – is not a part of this argument against Lamarck. It is, however, part of the *conclusion* of the argument. Consider this list (paraphrased) in which Lyell summarizes the support for his main claim that Lamarck's theory is unsubstantiated by evidence, and we need not conclude that species are real in nature:

1. Organisms of the same species do vary; the degree to which they vary is dependent upon the particular species. Thus, some species vary greatly while others vary less. This occurs in response to external circumstances.
2. This degree of allowed variation is part of the specific character.
3. Acquired traits, instincts, or abilities are only heritable when they are closely related to the behaviors and habits of the organism in its natural state; unusual or uncharacteristic behaviors are not heritable.

4. The extent of variation can be observed in a relatively short period of time, and beyond these limitations, organisms cannot survive. This is demonstrated empirically by domestic breeding.
5. Organisms are averse to interspecific breeding, which maintains the natural boundaries between one species and another. Hybrids are only perpetuated by breeding with “pure species,” and are thus not independently sustainable.
6. “From the above considerations, it appears that species have a real existence in nature, and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished” (Lyell (1832, pp. 64-65)).

It is clear from Lyell’s sixth point that, minimally, origin account has *something* to do with species realism – once we have found natural limits to variation and concluded that therefore species are real, we can immediately also conclude that each was created with its present properties. But this is also puzzling – why does Lyell add this claim to his conclusions, when special creation did not enter into his argument at any point prior? It is curious that Lyell should make a wholly empirical argument against Lamarck and then make an unexpected conclusion about special creation. His conclusion is that his refutation to Lamarck is sufficient to say that we need not reject the idea that God created specific forms – he does not (and need not) here argue *for* special creation, he believes but does not seek to *prove* that special creation is ultimately responsible for each property of species.

Is there a stronger claim to be made here? I propose that Lyell’s species realism is dependent upon special creation in this particular sense: special creation is the source of reality for species and the source of all their properties, but it does little further work in explaining the appearance of new species. While a creator is ultimately responsible for every property of species, this is all we can learn from focusing on the creation, and the rest of our scientific inquiry belongs in uncovering the laws and properties produced by that creator.

Because the argument in PG Chapter IV cited above is not concerned with the details of Lyell’s belief in special creation, I turn instead to the first journal in *Sir Charles Lyell’s Scientific*

*Journals on the Species Question* (Lyell, 1855-1856) for evidence. Two entries will be of interest here – the first is from 1855, and the second from a year later, in 1856. The significance of the first entry is to summarize quite nicely Lyell’s view on the role of the creator in the behavior and property of species, which is consistent with his argument for their reality in PG. The significance of the second is to show Lyell questioning his prior views – Lyell begins to reconsider those things which he once said were the marks of real species and considers what it might look like to explain the appearance of new species. This will show Lyell’s concern about just the thing that I’ve claimed his origin story does not do.

In the first entry, Lyell lays out some general principles of an Author of Nature who acts according to detectable and predictable regularities. He claims that:

Assuming therefore certain laws similar to those which require gills in a fish & lungs in a bird & certain constitution to endure great cold & to enable a species to fight its way & stand its ground against others, **a new species cannot at any given period be created arbitrarily. Assuming that Omnipotence rules by self-imposed laws, by which alone Man can comprehend the Universe** (Lyell, 1855-1856, p. 4), emphasis mine.

Prior to this, Lyell has already established that extinction must occur and “new ones must come in or the Earth would be depopulated” (Lyell, 1855-1856, p. 4). This means that new species must be created in such a way that they fit well in their environments, consistent with the fit we observe in already existing species. This principle may lead to the creation of similar species – for example, species within the same genus – if their conditions for existence are similar (Lyell, 1855-1856, p. 6).

But here is the interesting case, where the role of the creator is made clear: Lyell makes an argument in which he shows that two very similar species on two islands, distinct for a long time but close enough for migration, are more likely to have been created once and one migrated than for two independent creations to have occurred. It is within this argument that he clearly

shows that the role of the creator is to place each new species with its long-term fate determined:

The starting of each species from one point seems consistent with the simplicity of Nature... **If I place a species each on two or more islands of a group at first, or a species capable of spreading in time to the same islands, the same forethought is required in an omniscient being, or one capable of grappling with so profound a problem.** The idea of providing for the continuance of the species by a precaution, such as placing it simultaneously at first in a multitude of spots so that some one of these may succeed, is obviously to assimilate the creative power to a being of limited prescience. It may be the occasion of spreading to another island of the group may not be destined to occur for a myriad of centuries & in this time the island will be submerged; if so, the species will not be placed there but in some other island, if a myriad be too short a period. **The creation therefore of species from single original stocks may imply a higher foreknowledge of future events** (Lyell, 1855-1856, p. 7) emphasis mine.

To summarize Lyell's general principle: extinction occurs, so we must allow some mechanism of species introduction, for which the Author of Nature is responsible in some regular and detectable way. Often it is introduction of varieties by migration, but it can be newly created species – we can see this when Lyell discusses the “forethought” required in creating species that are intended to persist for determinate amounts of time. This is the crucial role of a creator in the fate of species – the Author of Nature, at the time of creation (whichever time that may be) has in mind, so to speak, all the properties and the fate of the species. And these creations happen in a regular way, according to the self-imposed laws of the creator.

On April 29, 1856, Lyell writes an entry titled “Origin & Reality of Species.” He begins:

After conversation with Mill, Huxley, Hooker, Carpenter & Busk at Philos. Club, conclude that the belief in species as permanent, fixed & invariable, & as comprehending individuals descending from a single pairs or protoplasts is growing fainter – no very clear creed to substitute. Indefinite time & change may, according to Lamarckian views, work such alterations as will end in races, which are as fixed [as] the negro for example & unalterable for the period of human observation, as are any known species such as the Ibis cited by Cuvier...**The successive creation of species is a perpetual series of miraculous interferences instead of the government of the organic creation by general laws.** Huxley shows that types intermediate between Mammalia & Birds & other great divisions are not met with in Geology as they would be if there was a continual development from one original type. Were there many first germs? (Lyell, 1855-1856, p. 57), emphasis mine.

While Lyell certainly does not discard his previous views about a creator operating under self-imposed laws, he seems to be reconsidering whether it is consistent with the idea of self-imposed natural laws to repeatedly interfere with the creation of new species. Lyell's reconsideration is consistent with my claim that his initial views on successive species creation identify only an instantaneous, intervening cause, which does not account for a process of species production, though it seems this is what Lyell wants.

At the end of this entry, Lyell concludes with a speculative statement about what it might look like to have a natural origin account for species that does factor directly into their reality:

The dignity of Geology would no doubt gain could we once conclude with any feeling of certainty, that the progressive development theory, the origination of species from modifications resulting from geological changes & a tendency to improvement, accompanying those modifications, were true – for then geology, ethnology and history would blend into one & the books of God's works would unfold to us by degrees the physical history of our species as well as of the beings which are now our contemporaries. But at present the mystery involving the subject does not appear to diminish. Our time of observation and of comparison of living & extinct nature is too short (Lyell, 1855-1856, p. 60).

I conclude, then, that the creator has this role in Lyell's species realism: The Author of Nature is responsible for every species and every aspect of each species. And those properties which allow us to discover the limits of variation show us that the putative species is indeed one of the Author's works. But, this is the extent of the causal responsibility of the Author of Nature – Lyell's special creation does not provide a clear explanation for the appearance of new species, as their introduction seems to be a process while his mechanism of their introduction seems to be instantaneous.

### 3.3 DARWIN'S NEW ORIGIN ACCOUNT AND MOTIVATION TO BE A SPECIES REALIST

#### 3.3.1 Realism Dependent Upon Origin Account, Again

Given that Darwin rejects the origin account which is the source of reality for contemporary species realists, we might expect that Darwin should be more motivated to say that species are *not* real. Again, it often seems like this is the case. Why not throw out species realism with special creation, as Lamarck did?<sup>16</sup> Indeed, why be a realist about *groups* at all? The entities in Darwin's theory might be lines of descent, or only the individual organisms. Yet he believes that groups (and species) are real in nature. That Darwin's species realism is *dependent upon his origin account* is a consequence of the argument I made in the first chapter. Darwin's origin account of new species is descent from a common ancestor: a new species is produced as ancestral species diverge over many generations. If it is community of descent, rather than immutability and distinctness which marks a true species, then Darwin's species realism is rooted in this community of descent.

But so far, I have only shown a parallel with Lyell: both naturalists' species realist stance is rooted in their respective origin accounts. What is different about the dependence in Darwin's case? Answering this question should illustrate a reason for Darwin to be a realist about species-as-groups without holding the belief that motivates Lyell's. I argue that the answer is this: In Darwin's theory, species, and importantly, *species as groups of organisms* are causally fundamental. Darwin is working with a standard of identifying natural causes espoused by John

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<sup>16</sup> Note that Lamarck did believe in an Author of Nature, and thus did not reject *creation*, but being a species anti-realist, rejected *special* creation.



Herschel. Darwin's commitment to Herschel's standard, and his claim that species-as-groups are acting causally in natural selection will lead him to species realism.

### 3.3.2 Darwin and the *Vera Causa* Principle

Of what is Darwin seeking a cause, and what sort of cause is he seeking? Ultimately, Darwin's goal is to explain observations about the geographic distribution and strong correlation of traits between organisms and other organisms and their environment (and the explanation is evolution by natural selection). He wants to explain the apparent structure in nature, including the way that organisms seem to be well-suited to their environment and well-coordinated with other species. Darwin intends to explain these observations about nature by identifying a *vera causa*, as articulated by John Herschel. He subscribes to what M.J.S. Hodge calls the *vera causa* principle (VCP) (Hodge, 1977, p. 238).

When Hodge discusses the VCP, he is drawing from Herschel's philosophy of science as published in in *A Preliminary Discourse on the Study of Natural Philosophy*. Herschel characterizes the study of the natural world as a search for causes:

Again, when he contemplates still more attentively the thoughts, act, and passions of this is sentient intelligent self, he finds... above all, that **he is irresistibly impelled, from the perception of any phenomenon without or within him, to infer the existence of something prior which stands to in the relation of a cause, without which it would not be...** He finds, too, that it is in his power to acquire more or less knowledge of causes and effects according to the degree of attention he bestows upon them, which attention is again in great measure a voluntary act; and often when his choice has been decided on imperfect knowledge or insufficient attention, he finds reason to correct his judgement, though perhaps too late to influence his decision by after consideration. A world within him is thus opened to his intellectual view, abounding with phenomena and relations, and of the highest immediate interest (Herschel, 1851, pp. 5-6) emphasis mine.

Hodge, analyzing Herschel and the VCP, describes these standards for identifying causes in nature:

As a rough approximation, then, we may take the whole rule or principle to specify the following: in explaining any phenomenon, one should invoke only causes whose existence and competence to produce such an effect can be known independently of their putative responsibility for that phenomenon (Hodge, 1977, p. 239).

Additionally, some further information about *vera causae* from Herschel will be important here – first about real causes, and second about analogies. Herschel makes this explicit point about *non-artificial* causes:

Experience having shown us the manner in which one phenomenon depends on another in a great variety of cases, we find ourselves provided, as science extends, with a continually increasing stock of such antecedent phenomena, or causes (meaning at present merely proximate causes), competent, under different modifications, to the production of a great multitude of effects, besides those which originally led to a knowledge of them. **To such causes Newton has applied the term *vera causae*; that is, causes recognized as having a real existence in nature, and not being mere hypotheses or figments of the mind** (Herschel, 1851, p. 144) emphasis mine.

I will return to the emphasized portion of this quotation later to further discuss the relationship between realism and causality for Darwin. But Herschel also claims that identifying analogous causes is a strong way to identify true causes. He writes, “If the analogy of two phenomena be very close and striking, while, at the same time, the cause of one is very obvious, it becomes scarcely possible to refuse to admit the action of an analogous cause in the other, though not so obvious in itself” (Herschel, 1851, p. 149).

I accept Hodge’s argument as good evidence that Darwin does indeed subscribe to the VCP as a standard for identifying causes in scientific study.<sup>17</sup> His argument for Darwin’s adherence to the VCP is summarized as follows:

...in conforming his argumentation to that ideal, Darwin knowingly constructed three distinct, evidential cases, three component arguments, on behalf of natural selection: first, a case for its existence as a causal process going on in the world; second, a case for its adequacy, its competence to produce, adapt and diversify species; and, third, a case for its responsibility, for, that is, its having produced the species now living and the extinct species found as fossils. So, in sum, natural selection exists, it can have that sort and size

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<sup>17</sup> But see Lennox (2005) for further discussion on Darwin’s methodological influences in this regard.

of effect, and it has indeed formed the species that have originated so far (Hodge, 1992, p. 462).

Another line of evidence for Darwin's commitment to the VCP is his strategy of argument by analogy. The cause of changes in domestic animal species is selection by man – Darwin argues that an analogous but more powerful cause acts in nature to produce the organisms with the properties that we observe. From these considerations, we can conclude that Darwin did seek to align his theory with the VCP. But this tells us about the structure of Darwin's argument for *natural selection*, not species realism. When Darwin replaces the origin account of special creation with the *vera causa* natural selection, what consequences will this philosophical commitment have on his views about species groups as natural entities?

### **3.3.3 A Causal Role for Species Leads to Species Realism**

How does understanding Darwin's standards for causes connect origin account with species realism – i.e., how do these beliefs about causality help to motivate Darwin's species realism? I argue that the answer is that species – the actual *group-ness* of species – has a causal role in Darwin's theory. And, as Herschel claims, true causes must not be artificial. I extend this to claim that since Darwin's species groups are causal, they must not be artificial. I do not mean to say that Darwin wishes to call *species* a perfect example of a *vera causa*, and accordingly I do not seek a complete proof of species as existing, competent, and responsible for some phenomenon. Natural selection is overall what Darwin is trying to prove as an existing, competent, responsible cause for the production of new species (and this is what Hodge (1977) demonstrates). But, as another consequence, the VCP connects realism with causality for Darwin.

First, recall from the Herschel passage above that true causes must be “causes recognized as having a real existence in nature, and not being mere hypotheses or figments of the mind” (Herschel, 1851, p. 144). I will establish that are species-as-groups causal for Darwin, and then that this commitment to their causal power motivates his commitment to their reality in nature.

Species, importantly *species-as-groups* (as opposed to individuals or lineages) are required to produce the branching pattern that Darwin proposes:

The several subordinate groups in any class cannot be ranked in a single file, but seem rather to be clustered round points, and these round other points, and so on in almost endless cycles. On the view that each species has been independently created, I can see no explanation of this great fact in the classification of all organic beings; but, to the best of my judgement, it is explained through inheritance and the complex action of natural selection, entailing extinction and divergence of character, as we have seen illustrated in the diagram (Darwin, 1859, pp. 128-129).

As we saw in Darwin’s discussion on classification, Darwin thought that seeing the tree structure of nature connected the apparent groups which are used for classification with their natural properties, thereby acknowledging causal power of the groups to contribute to the divergence of new groups.

In what way are species causal in the production of new species? And how does this contrast with the way that an Author of Nature is causal in the production of new species for Lyell? Darwin’s species are both produced by ancestral species, and the producers of descendent ones. Evolution occurs when natural selection acts on an ancestral species. Darwin’s principle of natural selection is based on the struggle for existence: selection allows only those organisms best suited to their environment to survive to reproduce. It thus relies on relative degree of adaptation – selected individuals are so selected because they are *better suited* than their conspecifics; in modern terms, this is relative fitness. *Relative* fitness only exists within a group,

giving the species group a causal role in Darwin's theory. Species groups are produced by a process which requires groups.

If the groups which we call species were to be artificial, we would not find evidence suggesting a causal role for their being groups, nor for the things on the basis of which we group them. That is, if Darwin believes he has evidence that species act causally in the production of new species, he has evidence that these groups are not artificial. His origin account for new species is a process which requires ancestral species. This can be contrasted with the origin of new species by creation, which in Lyell's case motivates realism by stipulating natural boundaries. Therefore, community of descent, which I have argued is tied to species realism, provides the basis for Darwin to believe that species are causal in the production of new species. His species realism is thus motivated.

### **3.4 CONCLUSIONS**

I've shown that species-as-groups are causally participating in a process of change – species participate by producing new species. And this causal participation motivates Darwin to believe that species are real in nature, not artificial. Contrast this with Lyell's belief that an Author of Nature repeatedly though predictably creates a species with its fate and all its properties determined. In Darwin's case, species realism is dependent upon an origin story which forms a causal process, while in Lyell's, species realism is dependent upon an instantaneous determinant cause. From this comparison we can see that while Darwin rejects special creation as an origin account, he is confronted with a new motivation to be a species realist, and thus holds a different realist stance that is nonetheless dependent upon his origin account.

I have shown that the relationship between origin account and species realism for Darwin is similar to that of Lyell in one sense – realism is sourced from an origin account – but different in another important one: Darwin’s origin account connects to his realism because he views species as active parts of a causal process. It seems that Darwin is attempting to do something like what Lyell speculates about in his journal entry (which makes sense, as Lyell there articulates a general scientific goal of his time). He is proposing a natural origin account for species that does not require the repeated intervention of a creator to produce new species. In making this proposal of origin account, Darwin is attributing causal power to species themselves. This, given his commitment to VCP standards of causation, motivates his position as a species realist.

## 4.0 CONCEPTUAL STRUCTURE REVISION

### 4.1 INTRODUCTION

The previous two chapters showed first how Darwin could be a species realist (by making certain modifications to the concepts SPECIES and SPECIES REALISM), and second gave one account of Darwin's motivation to be a species realist (as a consequence of his particular change in origin account). In this chapter, I address together the questions of how and why Darwin is a species realist, though from a different angle. I shift my discussion from properties to concepts. The properties of species groups that I discussed in the first chapter are, as I will show, component concepts of the complex concept SPECIES. I will illustrate the modifications that Darwin effects in the concepts SPECIES and SPECIES REALISM in terms of conceptual structure. Specifically, I will show how the concept SPECIES REALISM is part of the structure of the concept SPECIES, and then explain how Darwin modifies both concepts simultaneously by means of piecemeal revision to this structure.

The concept SPECIES, as I will show, incorporates the concept SPECIES REALISM in its structure, along with other component concepts. I will show that Darwin's modifications are these: (1) a modification to the concept SPECIES by revising the content of the concept (*which* component concepts it contains) and (2) a modification to the *relationships* among component concepts, including a modification to SPECIES REALISM where he revises its relationships within

the structure of SPECIES. In establishing this structural framework picture of the conceptual shifts that Darwin initiates in these two concepts, I will make an argument for how Darwin can make fundamental revisions to the concept SPECIES while maintaining the reference of the term ‘species.’ I argue that the conceptual change occurring in this case amounts to a modification to the non-referential semantic structure of SPECIES, and that this characterization captures Darwin’s ability to make fundamental revisions to the content of SPECIES without altering its reference.

I am making a claim about scientific change: Darwin’s work on the species question shows a particular kind of complex revision of a theory and its component concepts. This can be contrasted with theory change which prompts scientists to wholly reject some of the concepts in the “old” theories. I will first characterize the structure of the content of the concept SPECIES – I will draw briefly on some theory of concepts in cognitive science and justify this approach to understanding conceptual change in SPECIES. I then address the role of SPECIES REALISM as a component concept in the structure of SPECIES. I then discuss Darwin’s maintenance of the reference of the concept SPECIES, a topic briefly mentioned in the first paper, before defending my central claim about conceptual structure revision. I show why this particular kind of revision allows Darwin to make significant changes to the concept SPECIES without losing its reference.

## **4.2 CONCEPTUAL STRUCTURE**

### **4.2.1 The Concept SPECIES**

In this section I give a philosophical framework for understanding the species concept – or rather, as we will see, species *concepts* (plural). I claim that the content of the species concept is



best represented in terms of its conceptual structure beyond that of definition. Accordingly, I address what I mean by ‘conceptual structure,’ and then justify this approach to studying the concept ‘species’ and its development in scientific theories. I then sketch a general way that the naturalists I have studied build up conceptual structure for their individual species concepts. This last point is intentionally broad; I will give a more detailed picture of their species concept structures in the section describing the revisions that Darwin makes.

There is certainly a way of characterizing SPECIES in the classical sense of a concept: we can think of ‘species’ as a term with a definition, and that the concept is individuated by those definitional criteria (Margolis & Laurence, 1999). Conceptual structure, broadly, describes the component concepts of some lexical concept like SPECIES (Margolis & Laurence, 1999). It seems, then, that a definition of ‘species’ would be a minimal account of the concept’s structure: a list of necessary and sufficient conditions to be met in order for some group of organisms to be a species. It is precisely this kind of concept structure that has so eluded scientists and philosophers. There is, however, a more inclusive and appropriate alternative. Margolis and Laurence, in their survey of types of concept structure, give several (competing) alternatives to the structure afforded by the classical notion of concepts. The classical notion falls into a category they call “compositional reference-determining structure.” They give another category, termed “non-referential semantic structure,” which includes structure that does not determine reference of a concept, but contributes to the content of the concept:

The suggestion is that a concept can have structure that is partially constitutive of its content even if the structure isn’t implicated in an account of the concept’s reference. The thing we want to emphasize is that this is a different position than the Fregean view that there is more to the meaning of a concept than its reference. After all, it was part of the Fregean program that sense determines reference. In contrast, the present suggestion is

that in addition to a reference, concepts have another aspect to their content, but one that doesn't determine their reference (Margolis & Laurence, 1999, p. 73).<sup>18</sup>

From my study of the history of the species concept, I am led to adopt this sort of understanding of its structure.<sup>19</sup> Importantly, it allows for fundamental changes in the content of the species concept without affecting basic claims about reference, which seems to be what Darwin has done.

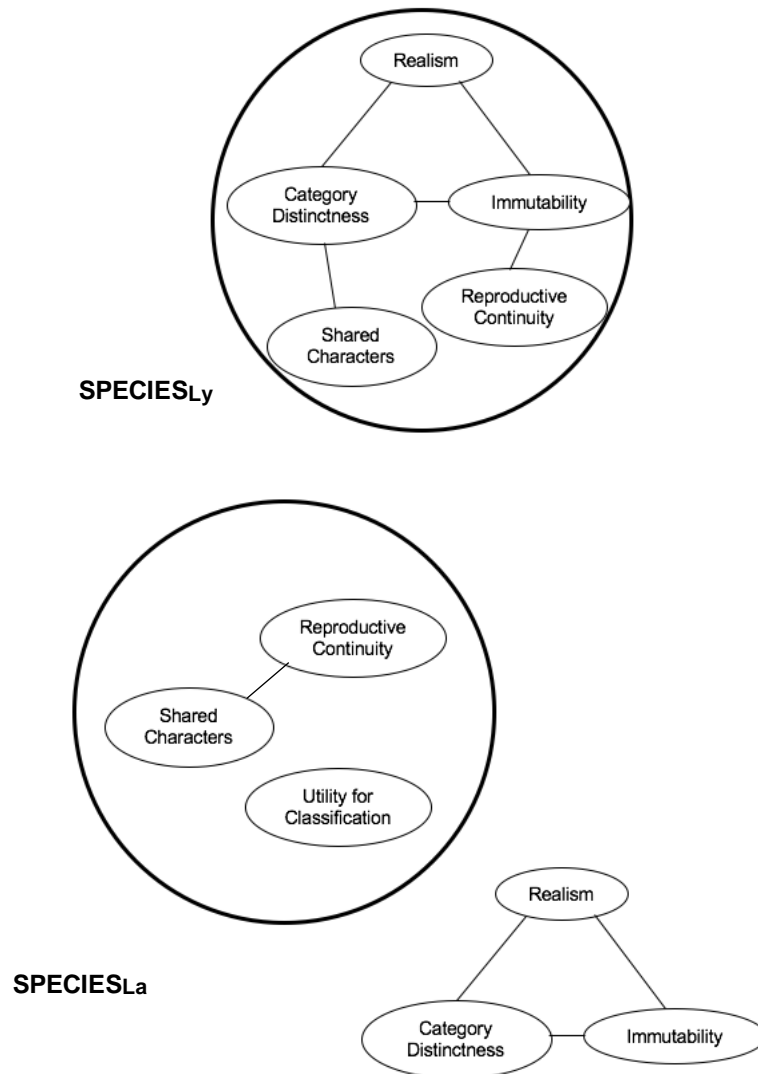
Including component concepts other than definitional criteria in giving an account of some naturalist's species concept is justified because it allows recognition of the importance of the *relationships* among component concepts. To think of SPECIES only in the classical, definitional sense would be limited in that it would lack an account of these relationships. The species concept seems in a sense *bigger* than a term with a definition – it seems to incorporate commitments to other concepts, and different species concepts seem to incorporate different commitments, all while being used to *talk about* the same thing. The *relationships among the component concepts* are crucial to the representing and understanding some particular naturalist's species concept. Therefore, it is more appropriate to adopt a broader structural understanding of the species concept. This characterization acknowledges SPECIES as a complex concept, rather than a simple term with a definition. The structures of the species concepts of those naturalists which I have studied are composed of some collection and the relationships among such basic concepts as these: species realism, immutability, categorical distinctness, definition, etc. By “relationships among” the concepts I capture what I described in my first

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<sup>18</sup> It should be noted that Margolis and Laurence are giving a survey of theories about concepts in the context of cognitive science. “Non-referential semantic structure” describes a *category* of concept theories, rather than one particular theory. They note that “some two-factor conceptual role theories may fall in this category.” In this paper I intend not to give a detailed argument for this type of theory as a best among types of concept theories, but I adopt it as at the least a useful and appropriate way of characterizing the concept ‘species’ in a way that is charitable to the concept's role in scientific theories.

<sup>19</sup> Background literature on psychological concepts, including Weiskopf (2009), and conceptual & theory change, including Kitcher (1978) and Stanford and Kitcher (2000) were helpful in forming this framework.

chapter: that certain commitments about the nature of species seem to be tied together in that a naturalist cannot accept one without the other.



**Figure 1. Species Concept Structures**

Lyell's species concept (SPECIES<sub>Ly</sub>) contains CATEGORY DISTINCTNESS and IMMUTABILITY bound up with REALISM. Lamarck's species concept (SPECIES<sub>La</sub>) rejects all three associated component concepts.

This kind of broad inclusive understanding of species concept structure is important as it allows Darwin a smooth concept revision while *maintaining reference*, a concern for other writers on this topic. I further discuss this maintenance of reference as a crucial aspect of Darwin's revisions in 4.3, which spells out in detail the structural revisions Darwin makes.

#### 4.2.2 The Concept SPECIES REALISM

In this section I explore the structure of the concept SPECIES REALISM. As I noted in the previous section, SPECIES REALISM is a component concept within the structure of the concept SPECIES. How is SPECIES REALISM different from SPECIES? SPECIES REALISM is a component of the structure SPECIES in the sense that should a naturalist be identified as a species realist, the claim that species are produced by some natural process or properties will be *included* in a complete account of that naturalist's species concept. Consider Figure 1. Species Concept Structures – note that SPECIES<sub>Ly</sub> includes REALISM, but SPECIES<sub>La</sub> does not. Additionally, the concept does not seem to have the same extensive structural network.<sup>20</sup> SPECIES REALISM will either be excluded or included in the structure of some naturalist's species concept.

But – I am talking about species realism as a *concept* (SPECIES REALISM) as opposed to species realism as merely a question about the *reference* of another concept (namely, the concept SPECIES). The objection is this: is SPECIES REALISM really its own concept, and a component concept of SPECIES? Or is a species realist simply someone who claims that the term 'species' does, in fact, refer? Thinking of SPECIES REALISM as a concept rather than a question about whether or not 'species' refers is correct because it captures a distinction that I made in the first chapter: the relevant question here is whether or not species are *real in nature*. The distinction is between real and *artificial*, not between referring and non-referring. Darwin makes this distinction himself in *The Origin*. He writes, "From the first dawn of life, all organic beings are found to resemble each other in descending degrees, so that they can be classed in groups under

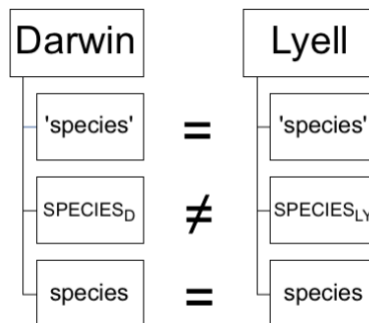
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<sup>20</sup> I might even say they are different kinds of concepts: 'species realism' refers to a stance that apparent groups of organisms are so apparent due to natural grouping processes. The structure of 'species realism' then will not *contain* other concepts in the same way that 'species' does.

groups. This classification is evidently not arbitrary like the grouping of the stars in constellations” (Darwin, 1859, p. 411). In this quote, Darwin draws a distinction between referring vs. non-referring on one hand, and realist vs. nominalist on the other. This allows an explanation of the case of Lamarck, for example: he is a species anti-realist, and yet he continues using the term ‘species’ in explaining his own theory. For a species anti-realist, the term refers minimally to the apparent groups that other naturalists pick out as species. But Lamarck need not remain committed to the idea that nature, by some process, formed those groups.

### 4.3 STRUCTURAL REVISIONS IN SPECIES REALISM AND SPECIES

In this section, I argue for my central claim that a detailed account of piecemeal framework revision describes *how* Darwin can make conceptual structure revisions which fundamentally alter the content of his species concept but do not affect its reference. What is the concern here? Darwin and his contemporaries (for example again, Charles Lyell) use the same term to refer to the same thing, *and yet they have significantly different species concepts* (see Figure 2. Comparing Term, Concept, and Referent).



**Figure 2. Comparing Term, Concept, and Referent**  
 Darwin and Lyell (for example) use the same term to name the same referent but hold concepts with different content and structure.

This combines my *how* and *why* questions: Darwin has (probably) many reasons for maintaining the reference of the term ‘species,’ and the way in which he revises the concept should be centered around maintaining that reference.<sup>21</sup>

#### 4.3.1 Determining Reference for SPECIES

When Beatty (1985) makes the claim about Darwin’s communication strategy in *The Origin*, he first explains that Darwin is in fact a species realist, despite some suspiciously anti-realist comments in *The Origin*. Importantly, he makes the claim that Darwin thought his fellow naturalists were pointing at the things in nature which are rightly called species – i.e., SPECIES, for Darwin and his contemporaries, named the same referent, though their respective claims about species properties differed. This tells us *that* Darwin was a species realist, and Beatty in the rest of his paper gives one reason why – that Darwin’s goals were primarily to do with communicating his theory to other naturalists (Beatty, 1985, p. 228).

What contributes to the reference determination of SPECIES? What I called a “test” for real species in the first chapter is related to a method for determining the reference for the concept SPECIES. In the sense that I described, the two tests are different: in one case naturalists look for constituent definitions, and in the other case (Darwin’s), we should look for characters which reveal ancestry. However, there is a similarity between these “tests” in a broad, practical sense: in both cases, scientists should look for *shared characters*.<sup>22</sup> And there is another test –

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<sup>21</sup> I direct the reader again to Stamos (2007). Stamos argues that the conceptual revision Darwin makes to the concept SPECIES is primarily to its extension; I do not respond to Stamos here, though this would be an immediate future direction for this argument.

<sup>22</sup> Though the details of *which* shared characters are to be counted is often quite contentious.

reproductive continuity.<sup>23</sup> Recall that Linnaeus partially determined the boundaries of varieties within species by assessing reproductive continuity – he wrote that “[t]he number of varieties is the number of differing plants that are **produced from the seed of the same species**” (Linnaeus, 1751, pp. 113-114) emphasis mine. And in Lyell’s argument against Lamarck, reproductive continuity helps to determine species because different species are averse to hybridization (Lyell, 1832, p. 49). These concepts – SHARED CHARACTERS and REPRODUCTIVE CONTINUITY are component concepts of SPECIES for Darwin and his peers, and these *do* contribute to reference (though neither is sufficient in all cases). The others mentioned, though clearly crucial to the concept’s content, do not contribute to reference.

#### 4.3.2 Revising the Structure of SPECIES

Major theory changes sometimes bring with them radical conceptual change, especially with regards to existential commitments. The concept ‘phlogiston’ was famously rejected as non-referential in response to changing theories about combustion. We might reasonably be on the lookout for this type of shift in Darwin – after all, the theory of natural selection requires species to do things that many others deemed theoretically and empirically impossible (namely, changed somehow in order to produce new species).

But Kitcher (1978) suggests the referential story is somewhat more complicated, and both Stanford and Kitcher (2000) and Stanford (2015) are unsatisfied with idea that these kinds of changes as the most significant mode of conceptual change in science.<sup>24</sup> And it does not seem

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<sup>23</sup> Reproductive continuity is *very* important to the history of the species concept, and there is a detailed analysis to be done about it, though unfortunately I cannot do it here.

<sup>24</sup> Though in a slightly different context – they are primarily engaged in debates about scientific realism as a whole, which, though not irrelevant to my discussion here, is not quite what I am arguing about.

to be the mode of change for SPECIES. Lamarck did not abandon the *use* of the concept SPECIES, even though he was a species anti-realist. And even when Darwin made fundamental revisions to the content of SPECIES, he retained its reference. Maybe we should not be surprised – a concept so old and variable as SPECIES should be expected to change in complex ways throughout time.

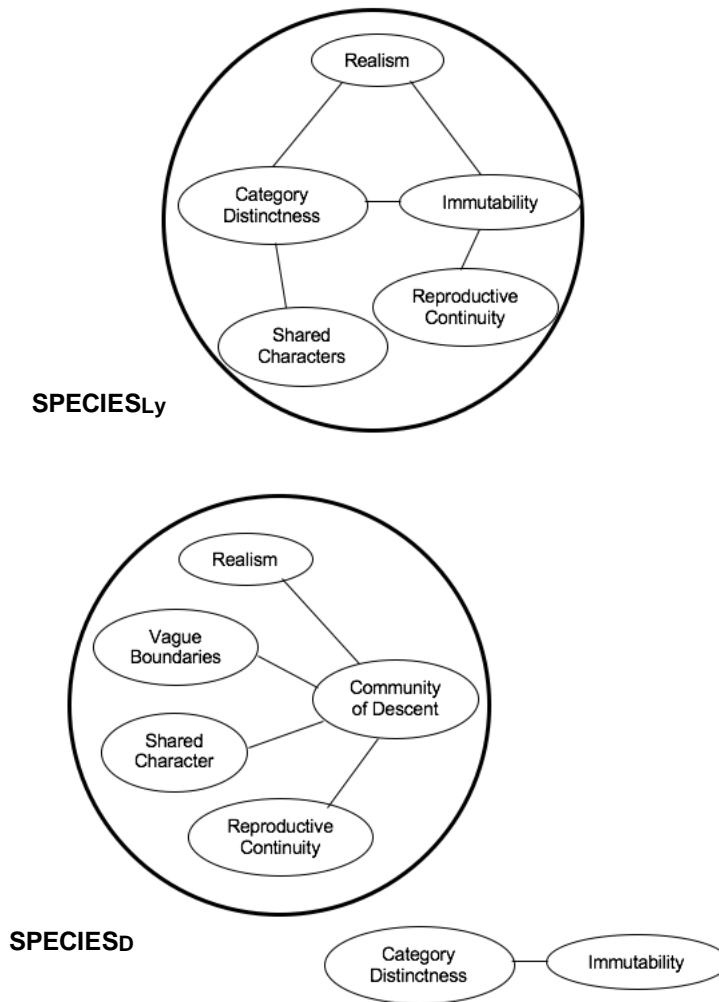
I give a way of looking at concept change in SPECIES in the face of significant theory change about organisms and evolution (namely, the proposition of evolution by natural selection) which describes complex revision and explains, at least in part, the persistence of certain terms and referents. This is a descriptive account of this particular shift in the concept SPECIES. Depiction of conceptual structure in a framework is not unpopular – a comment by Carl Hempel in his *Philosophy of Natural Science* is similar to what I am describing:

Scientific systemization requires the establishment of diverse connections, by laws or theoretical principles, between different aspects of the empirical world, which are characterized by scientific concepts. Thus, the concepts of science are the knots in a network of systematic interrelationships in which laws and theoretical principles form the threads. The more threads converge upon, or issue from, a conceptual knot, the stronger will be its systematizing role, or its systematic import (Hempel, 1966, p. 94).

I wish to use something like this model to describe the internal structure of concepts, and also to make it dynamic – to use it to account for conceptual change. In this case, I want to use it to construct frameworks for SPECIES that incorporate and allow for change in non-referential semantic structure. To reiterate what I argued in the first chapter: Darwin undoes an association between immutability and category distinctness on one hand and species realism on the other. I argue here that this is a revision in the structure of the concept SPECIES, namely, the component concept SPECIES REALISM is tied with IMMUTABILITY and CATEGORY DISTINCTNESS such that other naturalists include or exclude them *together* in the conceptual structure. The idea that *what makes species real* is their strict natural boundaries is a theoretical principle which binds the two



concepts. Darwin’s revision is to untie those – deny that principle – and reconfigure the structure of SPECIES.



**Figure 3. Darwin's Conceptual Structure Revision**

Overall, the conceptual structure for Darwin’s species concept (SPECIES<sub>D</sub>) is formed by deletion of two components (CATEGORY DISTINCTNESS and IMMUTABILITY) and introduction of another (COMMUNITY OF DESCENT). And the relationships between SPECIES REALISM and the rest of the network have also been altered – REALISM is now tied to COMMUNITY OF DESCENT. CATEGORY DISTINCTNESS and IMMUTABILITY have been excluded together.

As I argued in 4.3.2, the component concepts critically involved in determining reference are SHARED CHARACTERS and REPRODUCTIVE CONTINUITY, but *not* IMMUTABILITY, CATEGORY DISTINCTNESS, or COMMUNITY OF DESCENT. And this makes sense, because those things were often difficult for this era’s non-evolutionists to find and determine exactly. But things like

shared characters and reproductive continuity were practically involved in species determination all the time – witness Lyell’s examples of hybrid sterility and limits to domestication.

#### **4.4 CONCLUSIONS**

I showed that the species concepts of various naturalists can be quite different in content while sharing a term and a referent. The observation of these fundamentally different concepts while maintaining consistent use of a term and consistent reference to the same groups in nature leads to a representation of conceptual structure which allows for changes that do not alter reference. The structures I have proposed for these influential naturalists’ species concepts include non-referential semantic structure – component concepts which do not contribute to the reference of SPECIES. The advantage of describing concepts in this way allows detailed analysis of the change in such concepts over time – the addition and removal of component concepts, and the revision of the principles that form the relationships between them.

## 5.0 CONCLUSION

I have first raised the question of how Darwin could be a species realist, when he rejects the properties which, to his peers, mark a real species in nature. I showed that he can hold this position by substantially revising what it means for a species to be real. I then asked why Darwin might be motivated to hold such a stance, when it was possible for him to instead take an anti-realist stance about species. I offered one motivation – while Darwin’s origin account for species is different than those of his contemporaries, namely Charles Lyell, species realism is nevertheless dependent upon the origin account, though the dependence is importantly different. Lastly, I took a broader perspective on the species concept and detailed the mechanism of conceptual change occurring at Darwin’s publication of *The Origin*. I showed that naturalists at this time held different species concepts – that is, their species concepts differed in content and structure – though they used the same term to name the same referent. I claimed that Darwin could make such significant changes to the content of SPECIES without altering its structure because the changes were made to component concepts which did not originally contribute to the determination of SPECIES reference. Overall, I have given an analysis of the instance, motivation, and structure of conceptual change in SPECIES and SPECIES REALISM that Darwin initiates when he proposes his theory of evolution by natural selection and provided a philosophical framework for this particular conceptual shift that may be useful in other cases, including analysis of the contemporary species debate.

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