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ARTICLE

Theory Choice as Niche Construction: The Feedback Loop between Scientific Theories and Epistemic Values

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Abstract

We focus on a neglected aspect of scientific theory choice: how the selection of theories affects epistemic values. Building on Kuhn, we provide a general characterization of the feedback-loop dynamic between theories and values in theory choice as analogous to the relationship between organisms and the environment in niche construction. We argue that understanding theory choice as niche construction can explain how certain values acquire more weight and a specific application over time, and how resistance to scientific change can, therefore, arise. We illustrate our picture by looking at the Mendelian–biometrician controversy.

1. Introduction

Past choices have consequences. From retirement plans to hangovers, many experiences in our lives are determined by the history of our choices. Abstract entities have a history of choices, too. Countries, institutions, ideas, all have a historical dimension, since what they are at a given moment is shaped by what they were in the past. Even in science, philosophers have long recognized that scientific theories are indeed historical entities, partly shaped by the values of the scientific communities that developed them (e.g., Kuhn 1962; Hull 1988; Longino 1990). However, less attention has been devoted to characterizing the historical dimension of these values.[1] Yet, since these values play a central role in shaping scientific theories, we must consider their historical development to better understand how they interact with theories.

In this paper, we focus on the historical dimension of epistemic values by analyzing how these values are themselves affected by the process of scientific theory choice.

[1] That said, see Chang (2012) and Shan (2020) for two recent examples of works that address this issue.

Despite the fact that the role of values in theory choice has been widely debated in philosophy of science, this dimension of the relationship between values and theories has not received much attention. Philosophers have, in fact, generally focused on how values influence the selection of scientific theories and not, as we do in this paper, on how theories influence values. Starting from Kuhn's (1977, 335-6) seminal remarks on the feedback-loop dynamic between values and theories in theory choice, we characterize this kind of mutual influence between scientific theories and epistemic values as structurally analogous to the one between organisms and environment in niche construction. That is, epistemic values directly select scientific theories, the selection of which, in turn, indirectly affects the weight and the application of the values that selected them in the first place. By clarifying this neglected feedback-loop dynamic, we offer a novel perspective on theory choice that can explain how certain values acquire more weight and a specific application over time and how resistance to scientific change can arise. We illustrate our novel picture of theory choice by virtue of a case study: the controversy between the continuous and the discontinuous views of variation and evolution at the turn of the twentieth century. More precisely, we identify the emergence of an epistemic niche between the continuous theory of evolution and the values of generality and scope that had a pivotal effect in delaying the acceptance of Mendelism.

In section 2 we introduce the philosophical background of our discussion by looking at how values are traditionally conceptualized in debates on theory choice, that is, as mere selective factors. We then highlight how Kuhn's seminal paper on theory choice sketches a different picture, whereby theories and values are in a relationship of mutual influence, understood in terms of a feedback-loop dynamic. In section 3, we present our novel picture of theory choice that builds on Kuhn's remarks to characterize the relationship between scientific theories and epistemic values as a feedback-loop dynamic structurally analogous to the one between organisms and the environment in niche construction. In section 4, we analyze a case study containing a clear example of such a niche-construction process: the disagreement involving continuous and discontinuous theories of variation and evolution at the turn of the twentieth century. Section 5 concludes.

2. Theories and values in theory choice

Traditional discussions of scientific theory choice conceptualize the way in which scientists choose theories as a one-way process. In this process, scientists (or the infamous scientific community) actively choose scientific theories or alternative units of theory choice, which are the passive element of this process. This choice is usually assumed to rely on certain values that the chosen theory allegedly maximizes, at least relative to its rivals. Thus, the relationship between epistemic values and scientific theories is traditionally conceived as unidirectional, in the sense that the direction of selection is always from values to theories.

Kuhn's (1977) seminal discussion of epistemic values and theory choice is usually considered a paradigmatic example of the standard picture of theory choice we just described. The original aim of Kuhn's paper was to answer the many critiques of irrationality that were raised against his characterization of scientific theory choice as depicted in *The Structure of Scientific Revolutions* (Kuhn 1962). To further explain his

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views on scientific rationality, Kuhn stressed that the ineliminability of values in scientific theory choice is compatible with a pragmatic kind of scientific rationality. According to Kuhn, the choices of a scientific theory are always dependent on certain epistemic values (like simplicity, accuracy, empirical adequacy, and the like). This is because, even if scientists could agree on which values to consider, the weighting and the application of each value fundamentally involve a subjective element that cannot be eliminated, thus precluding the possibility of a universal algorithm for theory choice. Discussions of values are thus always present in episodes of scientific theory choice, and these entities crucially guide how a new paradigm is adopted by a scientific community.

Philosophical discussions of scientific theory choice following on from Kuhn upheld the ineliminability of values when scientists choose theories. Several philosophers analyzed in detail the nature and the extent of the influence that values exert on the choice of a theory (e.g., Laudan 1984; McMullin 1983; Earman 1993; Sankey 1995; Okasha 2011; Morreau 2013; Bradley 2017). A further matter of philosophical discussion concerned whether the ineliminable role of values in science is restricted only to epistemic values. Several authors (e.g., Longino 1990, 1996; Lacey 1999; Laudan 2004; Douglas 2013) argued, in fact, that non-epistemic values, such as social, cognitive, and pragmatic values, also crucially influenced many episodes of scientific theory choice in the history of science. Related discussions concerned which notion of scientific rationality (Longino 1990; Douglas 2009), progress (Laudan 1978; Shan 2020), and objectivity (Daston and Galison 2007) fits with such a value-laden picture of scientific theory choice.

A common feature of extant discussions of values in theory choice is their exclusive focus on how values influence the selection of scientific theories. Few discussions take into consideration, instead, the other direction of this relationship, namely, whether and how theories affect values. This is surprising, given that influential authors like Kuhn (1962, 1977) and Laudan (1984) emphasized how the epistemic values that guide a given scientist's practice are often affected by the paradigm or research tradition within which she is working. Indeed, Kuhn (1977) explicitly stated that the relationship between values and theories is one of mutual influence. In the last part of his paper, in fact, Kuhn stressed that one fundamental caveat of his picture of scientific theory choice is that epistemic values should be considered, to a certain extent, as historically changing entities. This is because "both the application of these values and, more obviously, the relative weights attached to them have varied markedly with time and also with the field of application" (Kuhn 1977, 335). In addition, Kuhn suggests that a specific pattern of covariance between theories and values can be observed, whereby changes in the role or weight of values often follow changes in scientific theories:

> Many of these variations in value have been associated with particular changes in scientific theory. Though the experience of scientists provides no philosophical justification for the values they deploy … those values are in part learned from that experience, and they evolve with it…. What may seem particularly troublesome about changes like these is, of course, that they ordinarily occur in the aftermath of a theory change. (Kuhn 1977, 335).

Kuhn goes one step further and characterizes this covariance in terms of a "feedback loop through which theory change affects the values which led to that change" (Kuhn 1977, 336).[2] Kuhn's model for the covariance between values and theories is then the notion of a feedback loop, i.e., the dynamic by virtue of which the outcome of a certain system or process becomes the input for the same system or process at a later stage. We take Kuhn's feedback-loop model of scientific theory choice to be the following: first, epistemic values operate a direct selection among theories within a scientific domain; then, the outcome of this selection feeds back into the values, by producing modifications on either their application or their weight.

By virtue of this feedback-loop characterization, Kuhn stresses that the relationship between scientific theories and epistemic values is one of mutual influence. Yet, as we saw, the influence that values exert on theories has been extensively discussed in philosophy of science, whereas the reverse influence, that theories exert on values, has not received much attention. In the remainder of this paper we focus on such hitherto under-discussed influence, and we analyze its role for our overarching perspective on scientific theory choice.

3. Theory choice as niche construction

In this section we further characterize the feedback-loop dynamic between values and theories envisaged by Kuhn. We conceptualize this dynamic as structurally analogous to the one between organisms and the environment described by niche-construction theorists. By virtue of this analogy, we offer a better-rounded picture of scientific theory choice, which characterizes the relationship between values and theories as one of mutual influence.

Before introducing our analogy, one terminological specification is in order. For the purposes of our analysis, we consider scientific theories to be certain sets of theoretical assumptions central to the practice of a given scientific community. Theories, understood in this way, are different from disciplinary/methodological frameworks, which comprise a much broader and more diverse assemblage of commitments related to the epistemic activities, goals, and values of a scientific community.[3]

Our picture of theory choice is centered around a structural analogy involving the relationship between values and theories in theory choice and the relationship between organisms and the environment in niche construction.[4] Both relationships are relationships of mutual influence structured around a feedback-loop dynamic, where a first, major selective influence (of values on theories in theory choice and of the environment on organisms in niche construction) is followed by a minor, reverse

[2] For a thoroughgoing analysis of the feedback-loop idea in Kuhn's philosophy, see De Benedetto and Luchetti (forthcoming).

[3] This distinction between theories and methodological frameworks, as well as the specific understanding of scientific theories upon which it is based, is, of course, in practice, often a matter of degree and context and by no means should be considered absolute in character.

[4] Our structural analogy between niche-construction processes in biology and scientific theory dovetails with, but does not necessarily imply, recent accounts of epistemic and cognitive niche-construction processes (cf. Griffiths and Stotz 2000; Stotz 2010; MacLeod and Nersessian 2013; Rouse 2016).

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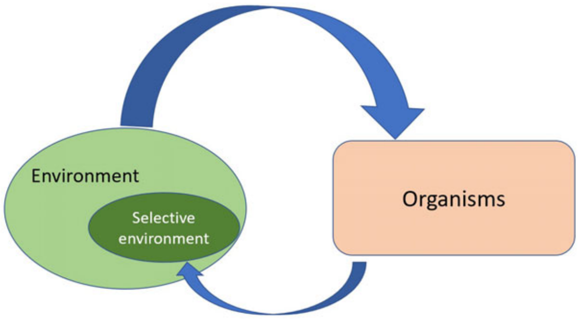

Figure 1. The feedback-loop dynamics between organisms and environment in niche construction. Arrows indicate the directions of the selective influences, while their size represents the strength of the selective force involved.

influence (of theories on values in theory choice and of organisms on the environment in niche construction).

In order to see this structural analogy better, let us briefly introduce the main tenets of niche-construction theory (NCT). In the classic neo-Darwinian framework, the environment is considered as the external factor that exerts selective pressures on organisms which, in response to these pressures, evolve adaptations via natural selection to "fit" the environment. However, organisms can also fit the environment by enacting behaviors that transform the environment. These niche-constructing activities emerge as responses to environmental selective pressures but, by transforming the environment, they contribute to changing those selective pressures. Therefore, while the environment exerts a direct selective pressure on organisms, organisms are responsible for an indirect selective pressure that happens through the medium of the selective environment, i.e., all those environmental factors on which organisms themselves exert their causal influence (Fig. 1). This, in turn, prompts further adaptive responses from the organisms that affect their fitness, thus generating looping effects that are at the basis of the co-creation of the selective environment of certain species, that is, of their environmental niches (cf. Odling-Smee, Laland, and Feldman 2003). Generally, the direct pressure from the environment to organisms is considered to have a major selective role compared to the minor influence exerted by organisms via the medium of the selective environment. However, as a result of this process, members of many species inherit the cumulative environmental changes induced by previous generations, which can echo in macro-evolutionary patterns (e.g., Danchin et al. 2011; Erwin 2008).

Our analogy between theory choice and niche construction can then be further specified as follows.[5] The mutual influence between scientific theories and epistemic values can be viewed as analogous to the relationship between organisms and the environment as conceptualized by niche-construction theory. Just like the external environment exerts selective pressures on competing organisms in the domain of life, each choice among scientific theories is the result of a selection process that is

[5] It should be noted that Kuhn (1990) himself draws an analogy between scientific development and niche-construction processes in biology. Yet, Kuhn's analogy involves the worlds inhabited by scientific communities, rather than their choices of theories and values. As such, we do not discuss Kuhn's analogy here, since it is completely independent from our own. For a discussion of Kuhn's analogy and a proposal on how to extend it, see De Benedetto and Luchetti (2023).

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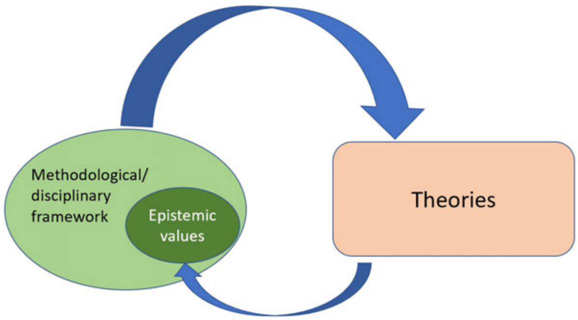

Figure 2. The feedback-loop dynamics between epistemic values and scientific theories.

influenced by methodological and disciplinary commitments that crucially include epistemic values. However, as we have seen, according to NCT, organisms themselves can have an impact on certain parts of the environment, modifying it through their niche-constructing activities. More precisely, even though niche-constructing activities emerge as responses to environmental selective pressures, by transforming the environment they contribute to changing those selective pressures. In this way, we can see how certain "niche-constructing activities" of theories, that is, some of their traits that have emerged in response to selective pressures, can, in turn, modify part of the environment, that is, the epistemic values. Analogously to what occurs between organisms and the environment, in the case of theory choice the methodological or disciplinary framework also exerts a direct selective influence on the theories held by individuals embracing that framework. However, theories can have an indirect effect on those selective pressures by having an impact on certain components of the framework, more specifically, its epistemic values (Fig. 2).

More specifically, we maintain that the weight and the application of epistemic values in the selection process, i.e., in the choice among theories, is partly determined by the niche-constructing activities of previous generations, viz., by the outcome of previous choices among theories. In a nutshell, the result of previous choices, i.e., a certain theory "winning" or "losing" a certain step of the selection process, influences the selective pressures exerted by a certain epistemic value during a later choice. Obviously, not all previous choices are relevant to determining the selective pressures of a current choice, as this will be the case only at a local level, depending on the history of the epistemic interactions within and among certain fields and disciplines. In this sense, each theory choice context "inherits" the cumulative effect of previous relevant choices that determines the selective environment within which that choice has to be made. Therefore, even though the direct influence of the disciplinary/methodological framework on theories at a specific time is generally more sizable than the influence of theories on the epistemic values belonging to the framework, in the long run the indirect selective pressure of theories can produce substantial effects, leading to the emergence of a niche of theories and values. This feedback-loop dynamic between scientific theories and epistemic values shows the significance of the diachronic dimension of scientific theory choice. Later choices among theories can be influenced by the outcome of earlier relevant choices, in that the weight and the application of the epistemic values contributing to later stages of selection can be affected by those theories having "won" or "lost" previous stages of selection.

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This effect can lead to the building of a niche co-constructed by a certain theory together with one or more epistemic values.

An additional aspect of the analogy is worth spelling out.[6] In NCT, organisms are considered as agents, in that they actively contribute to the process of natural selection, because their activities produce environmental modifications that alter the relevant selective pressures. While, of course, it would be quite odd to claim that theories are agents in the same way, since the locus of agency is in an individual scientist or a scientific community, the analogy holds if we consider that theories have an active role in that they provide elements of the worldview within which scientists work. It is in this sense, by producing modifications to the scientists' worldview which, in turn, provides fundamental commitments of their disciplinary/methodological framework, such as the weight and application of epistemic values, that theories can be considered as active. However, it should be remembered that our analogy is just an analogy and, as such, it leaves room for aspects of disanalogy between biological niches and epistemic niches.[7]

The idea of a feedback loop between scientific theories and epistemic values defies standard approaches to theory choice, which usually treat this process as a static, unidirectional phenomenon. As we stressed in the last section, in fact, the relationship between scientific theories and epistemic values is traditionally modeled as involving only a direct selective influence of values on theories. Our contention is, instead, that the process of theory choice often also involves an indirect, although weaker, selective influence resulting from the impact of theories on values. Such an indirect selection should not be expected to have significant effects in every case of scientific theory choice, since it is far weaker than the traditionally highlighted selective influence of values on theories. Just like in the biological realm, where not every case of natural selection involves niche-constructing activities, not every episode of scientific theory choice involves the construction of an epistemic niche between theories and values. Nevertheless, as we see in the case study in the next section, this hitherto under-appreciated reverse influence of theories on values arguably plays a crucial role in explaining why in certain cases of scientific theory choice certain (applications of) epistemic values seem more important than others, and why resistance to scientific and methodological change might arise.

4. Case study: The disagreement over the nature of biological variation and evolution (1895–1904)

In this section we describe an example of the niche-construction process between scientific theories and epistemic values by relying on a case study from the history of biology. We focus on the disagreement involving continuous and discontinuous views of variation and evolution by natural selection at the turn of the twentieth century. More specifically, we examine three key episodes related to this disagreement: the 1895 report of the Royal Society Committee, the homotyposis controversy, and the

[6] We thank an anonymous reviewer for suggesting we reflect more on this aspect of the analogy.

[7] For instance, two disanalogies between the biological domain and the domain of theory choice could concern the possibility of a normative stance with respect to niches (arguably more evident for the scientific domain) and the scope of the selective environment included in the niche (arguably larger in the biological case).

resolution of the controversy over Mendelian inheritance. We show not only that certain epistemic values were relevant to determining which theoretical view would prevail as an outcome of each of these episodes, but also that the outcome of these episodes influenced the values which had motivated the prevalence of a certain theoretical view at an earlier stage.[8]

The core of the theoretical disagreement under our scrutiny concerned whether natural selection operates in a continuous or discontinuous way. That is, whether the natural selection of small phenotypic variations among individuals of the same species is sufficient for evolution to take place or if, on the contrary, "big jumps," i.e., unusual or novel traits that sometimes appear in certain individuals of a species, are required. The controversy over the continuous or discontinuous nature of variation and evolution started right after the publication of *The Origin of Species* in 1859, with Darwin himself holding a continuist position. This disagreement was highly entangled with another scientific controversy over the nature of the inheritance mechanism, whose resolution led to the emergence of classical and population genetics in the 1910s. A central part of the debate over the nature of inheritance has been referred to by several historians and philosophers of science as the "controversy between biometricians and Mendelians" (e.g., Frogatt and Nevin 1971; Mayr 1973; Olby 1989a; Provine 1971). Our historical reconstruction deals with the period in which supporters of biometrical methods, particularly Karl Pearson and W. R. Weldon, were engaged in sharp disputes with proponents of Mendelism, most notably William Bateson. Although these scientists were deeply involved in the inheritance controversy, we mostly consider their theoretical views concerning the continuous or discontinuous nature of variation and evolution and how these views interacted with the epistemic values belonging to their broader methodological commitments.

Since the nature of the opposition between biometricians and Mendelians has been extensively debated (Kim 1994; Mackenzie 1981; Roll-Hansen 1980), and the adequacy of this dichotomy as a historical framework has recently been questioned (e.g., Ankeny 2000; Vicedo 1995; Pence 2011; Stoltzfus and Cable 2014; Shan 2021), a few clarifications on our analytic perspective are in order. First, we follow Morrison (2002) in her characterization of the main divergences between the biometrical and the Mendelian approaches as being methodological in character. Their contrast was, in fact, essentially rooted in the belief that the study of inheritance should be based, respectively, only (Pearson) or primarily (Weldon) on statistical analysis, or on experimental methods (Bateson). Second, it must be pointed out that multiple lines of inquiry were pursued and several competing theories of inheritance coexisted at the turn of the twentieth century, thus presenting us with a theoretical heterogeneity that is hardly reducible to the biometricians–Mendelians dichotomy (e.g., Müller-Wille and Rheinberger 2012; Shan 2020). In fact, the diversity of theoretical and methodological commitments held by the scientists involved in these controversies prevents the identification of a consensus converging into two Kuhn-like competing paradigms, a biometrical and a Mendelian, understood as disciplinary matrices (Müller-Wille 2021). Therefore, the historical stretch that we consider is best characterized in terms of a pre-paradigmatic period of genetics, rather than an

[8] Note that throughout this paper we consider "theoretical view" and "scientific theory" as synonymous.

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episode building up to a scientific revolution (Shan 2021). For these reasons, we limit our focus to the specific disagreement between continuous and discontinuous evolution (and not to the whole biometrician–Mendelian controversy). This, was, in fact, a relatively well-defined theoretical disagreement,[9] which pre-dated the peak of the dispute between biometricians and Mendelians and yet was strongly influenced by the methodological stances held by the scientists involved.[10] Most importantly, the epistemic values attached to these methodological stances are also clearly identifiable, despite the methodological heterogeneity characterizing the controversy over inheritance.

For the purposes of our reconstruction, we consider only Pearson and Weldon as representatives of the biometric methodological standpoint and supporters of the continuity view, and Bateson as a representative of Mendelism and supporter of the discontinuity view.[11] Eventually, the apparent contrasts between biometrical methods and Mendelism were solved by the synthetic paradigms of classical and population genetics, while the theoretical controversy between continuous and discontinuous views of variation and evolution was found to be a spurious one. Yet, we show that a pivotal element that fueled this specific theoretical disagreement is the feedback-loop dynamic between the continuous view of variation and evolution held by Pearson and Weldon and the values of mathematical generality and breadth of scope central to the biometrical methodology.

Finally, we want to emphasize a further reason for our choice of this case study: as we mentioned above, the controversy between continuous and discontinuous views on evolution belongs to a pre-paradigmatic stage of genetics. This makes it an excellent candidate for our study of the feedback-loop dynamics between values and theories because, as Kuhn (1977, 331) stressed, it is exactly at these stages that values have most impact on theory choice and, therefore, the effects of the feedback-loop dynamic between theoretical views and epistemic values are more prominent.

4.1. From the origin of the disagreement to the 1895 report of the Royal Society Committee

As we previously mentioned, the disagreement over the continuous or discontinuous nature of variation and evolution started right after the publication of Darwin's *The Origin of Species*. A leading figure during the early stages of this disagreement was Francis Galton, who embraced the view that natural selection acts primarily upon sports, that is, in a discontinuous fashion. Galton thought that this view best supported his law of regression, a mathematical correlation expressing the relative contribution of each ancestor to the phenotypic traits of the offspring. The disagreement between supporters of continuous evolution, including Darwin himself,

[9] This is not to say that this disagreement implied a dichotomy between two opposite stances, since it came with several in-between positions, whereby small individual differences were thought to be more relevant to the workings of natural selection than big leaps, or vice versa. For details, see Provine (1971).

[10] This disagreement has also been discussed as the "biometry vs. mutationism" controversy, given the relevance of de Vries' (1901) mutation theory in providing an argument for discontinuous variation and evolution.

[11] Note, however, that, according to Shan (2020), Weldon showed a greater methodological openness during the later stages of his life and work.

and defenders of discontinuous evolution further consolidated during the 1880s and into the early 1890s. Galton was influential both for the biometricians who adopted his statistical methods for the analysis of variation, and for those who later embraced Mendelism and supported his view of evolution by discontinuous leaps.

After discovering Galton's work, Weldon, a morphologist and embryologist, decided to apply his quantitative method to study variation and organic correlation. Weldon soon realized that he had to use statistical studies of populations to demonstrate evolutionary relationships, so he asked the mathematician Karl Pearson to collaborate. Weldon and Pearson became the founders of the biometrical school. They were convinced that statistical analysis was best suited to study continuous variation and, thus, rejected Galton's own concern that the force of regression would block the effect of selection on small individual variations.

In 1886, William Bateson, a friend and former fellow student of Weldon, went to Russia to conduct experiments that would test correlations between phenotypic variation and environmental differences. In contrast with Darwin's (Darwin 1859) own conclusions in *Origin* (cf. his famous argument discussing finches in the Galapagos Islands that evolved different beaks to adapt to different environments), Bateson believed he had found no general correlation between phenotypic traits and environment, leading him to think that small individual variations had little role in natural selection. More generally, Bateson was astonished by the lack of empirical data concerning the variation of plants and animals, and he progressively distanced himself from Weldon's position on continuous evolution. In 1894, he published *Materials for the Study of Variation*, a report including 886 cases of discontinuous variation that supported the view of discontinuous evolution.

In 1895 the Committee for Conducting Statistical Inquiries into the Measurable Characteristics of Plants and Animals, instituted by the Royal Society in 1893, produced its first report concerning the disagreement between continuous and discontinuous views of variation and evolution. The Committee reported that the natural selection of small individual variations is sufficient to explain the direction and rate of evolution, and affirmed that the statistical method is the only viable way to experimentally test the Darwinian hypothesis. However, limited empirical evidence was provided, and Bateson, himself highly unsympathetic to the statistical treatment of variation, criticized the measurement accuracy of their few data. He wrote to Galton, chairman of the Committee, to explain his criticisms. Despite their opposite views on statistics, they had similar inclinations on discontinuous evolution, and Galton eventually had him and other sceptics of the biometrical approach included in the Committee in 1897 to rebalance the composition of members.

The 1895 report of the Royal Society Committee can be taken as a first moment of collective evaluation of the disagreement over the continuous or discontinuous nature of variation and evolution. We can see how the outcome of the report was influenced by the fact that several members of the Committee endorsed the use of biometrical methods introduced by Galton and developed by Pearson as the most important tool to analyze phenotypic variation distributions. The great appeal of the statistical analysis central to the biometrical methods lay also in its promises of providing a general mathematical framework for the study of biological variation and inheritance. As we previously mentioned, the mathematical features of these tools seemed to the biometricians better adapted to the study of continuous variations.

In addition, considerations of scope were important for the Committee's evaluation, since embracing the continuity view accounted for the existence of small individual differences that were left unexplained by the discontinuity view. On the other hand, Bateson criticized the outcome of the report, lamenting the lack in measurement accuracy of the data provided and, more generally, the scarcity of empirical data. In sum, the values of mathematical *generality* and breadth of *scope* were central for the biometrically oriented Committee to prefer the continuity view at this stage, despite the fact that the scarce evidence available was not pointing in any specific direction so as to give any conclusive advantage to either of the two views. In a nutshell, we can say that, in this first moment of collective evaluation, the values of mathematical generality and breadth of scope had a decisive selective influence on the continuity view.

4.2. From the 1895 report of the Royal Society Committee to the homotyposis controversy (1900–1901)

In 1896 Pearson joined the Committee, soon followed, as we have seen, by Bateson and some of his supporters. In the following years, tension started to increase between Bateson, on the one hand, and Pearson and Weldon on the other. As early as in 1897, Bateson had started breeding experiments and, in 1899, he proposed hybridization experiments that resembled those described by Mendel in his work, the significance of which had not yet been appreciated for the study of heredity (Olby 1985; Shan 2020). By Bateson's own admission, the results of his experiments would have required to be analyzed statistically. In 1900, Hugo de Vries, Carl Correns, and Erich von Tschermak brought Mendel's work to the attention of the international scientific community (Olby 1989b; Rheinberger 1995; Shan 2020). Bateson immediately incorporated Mendel's laws as a perfect complement to the theory of discontinuous evolution, as he thought that Mendelian heredity could only act on discontinuous variations.[12] Yet, Bateson's incorporation of Mendel's contribution as the obvious complement to discontinuous evolution led the most influential biometricians to reject it straight away. In the light of these events, several new controversies fueled the disagreement between supporters of continuous evolution and advocates of discontinuous evolution, who had found in Mendel's work a novel, albeit wrongly appropriated, ally. For the purposes of this section, we focus only on one of these controversies, viz., the homotyposis controversy, as it shows the emergence of the feedback-loop dynamic between the view of continuous evolution and the values of mathematical generality and breadth of scope. The conclusion of this controversy provides a second moment of collective evaluation.

Pearson started working on his theory of homotyposis in 1899, before Mendel's work was rediscovered. This theory was an attempt to explain offspring variability by understanding heredity as an instance of a more general relation, i.e., homotyposis. According to Pearson, this general relation denoted correlations of phenotypic resemblance in siblings, as well as those relative to undifferentiated-like organs (Pearson 1901). Based on sixty pages of statistical correlations of data from the

[12] Although Mendel had used only discontinuous characters in his experiments on peas, he had himself indicated that his laws could account even for continuous variation.

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vegetable kingdom, Pearson argued that homotypic correlation and fraternal correlation were equal, as they had very similar mean values. In other words, he concluded that the variation of undifferentiated-like organs in an individual was the same phenomenon as variation between brothers. Therefore, heredity was nothing but a special case of homotyposis.

This conclusion was at odds with Mendel's theory of heredity, which Bateson had known for several months when Pearson presented his work on homotyposis at the meeting of the Royal Society in November 1900. Pearson had assumed that sperm cells and ova were undifferentiated-like organs, and this was crucial to his argument that homotypic correlation and fraternal correlation were equal. However, Mendel believed that his experiments showed conclusively that the germ cells must be differentiated, as each of them had a different combination of differentiating elements, which showed in the hybrid results of the cross-fertilization experiments. Bateson did not rebut Pearson's theory on these grounds, as he did not believe that Mendel's differentiating elements were material bodies, nor did he disagree with Pearson's assumption that the variation of undifferentiated-like organs in an individual was the same phenomenon as variation between brothers. Yet, he did not believe that there was any theoretical distinction between differentiation and variation in a single individual or population, as assumed by Pearson, who, according to Bateson, was once again ignoring the importance of discontinuous variation for evolution (Bateson 1901). After this exchange, Pearson and Weldon decided to found their own journal, *Biometrika*, as they grew increasingly dissatisfied with the publishing provided by the Royal Society. Bateson tried to win Pearson to the cause of Mendelism, but received heated responses from both Weldon, who criticized Mendelian inheritance in 1902, and Pearson himself, who replied to Bateson's criticism of homotyposis by attacking Bateson's loose definitions and his lack of mathematical understanding.

In the aftermath of the homotyposis controversy, both the continuous and the discontinuous view appeared to be equally legitimate alternatives concerning the nature of variation and evolution. This was the case even if the introduction of Mendel's contributions to the debate on the nature of inheritance had brought about new considerations that were almost unanimously thought to weigh in favor of discontinuous evolution. This view was, in fact, thought to be more consistent with Mendelian inheritance by both Bateson, who endorsed it, and by Pearson and Weldon, who, for this reason, rejected it. In addition, Mendel's experiments directly contradicted Pearson's homotyposis—although this went unnoticed by Bateson, due to his anti-materialist inclinations—thus directly undermining a major theoretical argument in favor of the continuity view. On what grounds could Pearson and Weldon disregard this evidence? What was the source of justification for the continuity view to still be considered an equally viable option? While answers to these questions can be provided at several levels of explanation, our aim is to focus on values and their relationship with scientific theories within the process of theory choice. This relationship will prove to crucially involve a feedback-loop dynamic that, in the period between the 1895 report of the Royal Society Committee and the end of the homotyposis controversy, occurred between the continuity view and the values of generality and scope.

As we discussed in the previous subsection, the outcome of our first moment of collective evaluation, the 1895 report, resulted in the prevalence of the continuity

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view, crucially selected by the values of mathematical generality and breadth of scope. In the following years, this outcome fostered the relevance of biometrical methods, i.e., the use of statistical analysis, for the whole debate. Among biometricians, biometrical methods became further entangled with their theoretical standpoint. This can be seen as explaining, for instance, Pearson's and Weldon's rejection of Mendelian methodology based on the supposed incompatibility with their views and methods. Furthermore, biometrical methods also become more relevant for the opponents of biometricians. We saw, in fact, that Bateson became, to some extent, open to statistical analysis being helpful to his experimental methods. The increased prominence of biometrical methods resulting from the prevalence of the continuity view also increased the weight of the epistemic values that first supported the continuity view (and, thus, indirectly the biometrical methods), namely, generality and scope. Moreover, it crystallized the relevant application of these values for the dispute into the specific applications that favored the continuity view's early success, i.e., mathematical generality and breadth of scope. The centrality of generality and scope considerations can be seen, for instance, in the impermeability of Pearson and Weldon to criticisms based on empirical adequacy, which they rebutted with considerations of mathematical generality and scope. In addition, these two values shaped Pearson's development of the theory of homotyposis, which, according to Bateson, disregarded discontinuous variation on pure mathematical and statistical grounds. Even Bateson acknowledged the importance of generality and scope considerations for theories of heredity. This can be seen, for instance, in Bateson's search for greater generality and scope in the Mendelian framework, and in Bateson's lack of critiques of the unwarranted scope of Pearson's theory of homotyposis (e.g., based on the assumption that the variation between undifferentiated organs in an individual is the same phenomenon as variation between brothers). The increased weight of the values of generality and scope is what explains the fact that, after the second moment of evaluation, both the continuous and the discontinuous theory were seen as equally legitimate alternatives. This equal legitimacy of the two theories occurred despite, as we have seen, the empirical evidence already being in favor of Mendelism, which was still exclusively associated with the discontinuous theory of evolution.

In the light of this reconstruction, we can see the impact of a feedback-loop dynamic between scientific theories and epistemic values in this episode of theory choice. Specifically, it is a feedback-loop dynamic that generated a niche between the continuous view and the values of generality and scope. This feedback-loop dynamic can be schematically presented as follows. First, we saw, in the previous subsection, how the values of generality and scope determined the prevalence of the continuous view of variation and evolution, as the outcome of the first moment of collective evaluation. Such a selective influence of values on theories is the first component of our feedback-loop dynamic. Then, we saw how the prevalence of the continuity view influenced, with time, the weight and application of the two values that selected them, i.e., generality and scope, raising their prominence in the debate and crystallizing a specific way of applying them (i.e., generality qua mathematical generality and scope qua breadth of scope). Such an influence resulted in delaying the prevalence of the discontinuous view, leading the scientific community to over-emphasize the importance of these values supporting the continuous view, and to

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under-appreciate the empirical evidence in support of Mendelism (at this time associated with the discontinuous view). This second, weaker selective influence, resulting from the impact of theories on values, is the second component of our feedback-loop dynamic. We contend that this second component, which explains why (applications of) values tangled up with the continuity view had a dominant role in the dispute, is a pivotal element in understanding why the discontinuity view did not already prevail after the homotyposis controversy.

4.3. From the homotyposis controversy to the 1904 meeting of the British Association

In 1900, Hugo de Vries put forward his theory of evolution by mutation, based on a great deal of empirical observation. His theory supported the discontinuous view of variation and evolution, and it became rapidly widespread, corroborating the unfounded association of Mendelism and discontinuous evolution. Weldon was reluctant to accept the evidence of mutations as provided by de Vries and warmly endorsed by Bateson. Therefore, in 1902 Weldon started an attack against Mendel's laws of inheritance and his neglect of ancestry. Initially, he criticized the limited scope of Mendel's laws (Weldon 1902a), while a few months later he criticized the empirical adequacy of Mendel's classification of characters. He provided examples, some drawn from Bateson, showing that the Mendelian categories were inaccurate, and from that he concluded that the law of ancestral heredity was, in fact, working (Weldon 1902b). This criticism delayed the analysis of continuously varying characters in Mendelian terms, as it led experimenters to search only clear-cut characters.

As early as 1902, the mathematician G. Udny Yule had debunked this presumed incompatibility, and showed that Mendelism could account for continuous variation and was compatible with biometry and continuous evolution. However, his synthetic approach went largely unnoticed until 1918, by which time the unified framework of population genetics had emerged. In fact, in 1904, Pearson, when investigating the mathematical consequences of pure gamete theory, that is, that characters are inherited intact, still concluded that the pure gamete theory was "not elastic enough to account for the numerical values of the constants of heredity hitherto observed" (Pearson 1904). Therefore, he rejected Mendelian inheritance and suggested that the Mendelians should develop more general principles to start a new mathematical investigation. However, at the 1904 meeting of the zoology section of the British Association, Weldon and Pearson were not able to convincingly counteract the overwhelming evidence in favor of Mendelian inheritance.

In this third moment of collective evaluation, we can see how the impact of the empirical evidence in favor of Mendelian inheritance trumped any value-driven effect on the choice between continuous and discontinuous views. As such, this evidence dispelled the effect of the feedback-loop dynamic, and the related construction of the epistemic niche, between the continuous view of variation and evolution and the values of generality and scope. Despite the fact that generality still remained firmly a central defining value of biometrical methodology, considerations of scope and generality are pushed aside by the overwhelming empirical evidence in favor of Mendelism, still associated with the discontinuous view. By 1906, when Weldon died,

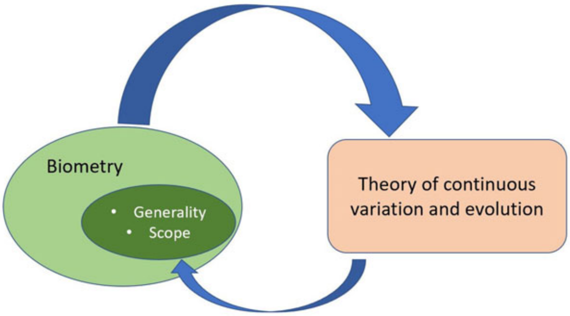

Figure 3. The feedback-loop dynamics between the continuous theory of evolution and the values of mathematical generality and breadth of scope.

the balance was clearly in favor of Mendelism, and Mendelian inheritance was still mistakenly associated with discontinuous evolution which, until the disagreement was found to be spurious a few years later, became dominant.

Our reconstruction of the controversy between continuous and discontinuous views of evolution has shown the significance of the mutual influence between scientific theories and epistemic values for understanding this historical episode. Specifically, we identified a feedback-loop dynamic between the continuous theory of evolution and the values of generality and scope that significantly affected the outcome of the second moment of collective evaluation (i.e., the homotyposis controversy) of our case study (Fig. 3). More specifically, we saw how this feedback-loop dynamic increased the weight and crystallized the specific application of the values supporting the continuous theory and, therefore, significantly contributed to delaying the acceptance of the Mendelian approach to the study of inheritance.

Historically speaking, this reconstruction of the feedback-loop dynamic between the continuous theory of evolution and the values of generality and scope dovetails with Shan's suggestion that "the Mendelian–Biometrician controversy can be viewed as a case of the resistance to the emergence of the Mendelian approach" (Shan 2021, 161). This historical case of scientific disagreement shows the advantages of our picture of theory choice as niche construction. Thanks to our modeling of the relationship between epistemic values and scientific theories as one of mutual influence, we could explain why in this controversy the values of generality and scope had such a major impact on the decision of the community and why, in turn, this led to resistance to scientific change.

5. Conclusion

Let us recap the main steps of the present work. We started by focusing on a hitherto under-discussed aspect of scientific theory choice, namely, the influence that the outcome of theory choice exerts on the epistemic values which motivated that choice in the first place. Building upon Kuhn's seminal remarks on the feedback-loop dynamic between values and theories in theory choice, we provided a general characterization of this feedback-loop dynamic between scientific theories and epistemic values by virtue of an analogy with the process of biological niche construction. More specifically, we argued that, just like a biological niche is co-constructed via the mutual influence of organisms and the environment, the

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outcomes of scientific theory choice are often the result of the mutual influence between scientific theories and epistemic values. We then illustrated our picture of theory choice as niche construction by looking at a concrete historical episode of theory choice: the controversy between continuous and discontinuous views of variation and evolution at the turn of the twentieth century. In our historical reconstruction, we saw how a particular feedback-loop dynamic significantly affected the choices of the scientific community. Specifically, we identified the emergence of an epistemic niche between the continuous theory of evolution and the values of generality and scope, a process that also provides an internalist explanation of the resistance to Mendelism.

Our picture of theory choice as niche construction highlights the historical dimension of theory choice and the diachronic character of this process. Moreover, it stresses that, just like scientific theories, epistemic values are also historical entities, the weight and application of which are partly determined by earlier related choices of the scientific community. Understanding theory choice as niche construction provides us with a mechanism by virtue of which certain values acquire more weight and a specific application over time, a mechanism that can explain the uneven weight of epistemic values in certain contexts of theory choice and cases of resistance to scientific change. Furthermore, such a picture of theory choice challenges existing accounts of scientific progress, rationality, and objectivity in that it highlights that the relationship between values and theories is not unidirectional, but is instead one of mutual influence. The extent and the scope of this mutual influence between values and theories must be contextually studied by looking at other episodes of theory choice in the history of science. These projects, as well as the goal of understanding the exact implications of this mutual influence for our general picture of scientific theory choice, constitute promising grounds for future work.

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