CHAPTER 3

POPULATION THINKING

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1. Population Thinking as a Metaphysical Thesis: Mayr and Sober

When speaking abstractly about Darwin's great contribution to biology, commentators of all sorts habitually sum up Darwin's innovation in one phrase, "population thinking." Ever since Ernst Mayr introduced the phrase in the middle of the twentieth century, you find population thinking attributed to Darwin in most historical treatises and evolutionary biology textbooks. Depending on the commentator, population thinking is supposed to have changed the way we think of species, extinction, diversity, and adaptation, that is, all of the main concepts associated with Darwin's theory of evolution. Boyd and Richerson go so far as to proclaim that "culture can't be understood without population thinking" (Richerson and Boyd 2005, 5). Given the fanfare, hopefully population thinking refers to a substantive theory which accurately describes Darwin's great achievement and is not just a bit of sloganeering. After all, we already have a phrase to describe Darwin's innovation, "natural selection." So, what is population thinking? What makes it so novel?

Ernst Mayr says that population thinking is a metaphysical theory that opposes the Platonic doctrine of "essentialism" or "typological thinking." Mayr writes, "[T]he ultimate conclusions of the population thinker and of the typologist are precisely the opposite. For the typologist the type (*eidos*) is real and the variation an illusion, while for the populationist, the type (average) is an abstraction and only the variation is real. No two ways of looking at nature could be more different" (Mayr 1959, 2). Mayr's essentialism, as defined in the just-quoted passage, amounts to the view that types, including conceptual categories and mathematical abstractions—e.g., triangles and averages—are "real" while individual variation is illusionary. In contrast, population thinking entails the opposite view: Types are not real in nature (do not exist), only individuals exist. Here's another passage where Mayr describes the difference:

> It was Darwin's genius to see that this uniqueness of each individual is not limited to the human species but is equally true for every sexually reproducing species of animal and plant. Indeed, the discovery of the importance of the individual became the cornerstone of Darwin's theory of natural selection. It eventually resulted in the replacement of essentialism by population thinking, which emphasized the uniqueness of the individual and the critical role of individuality in evolution. . . . And variation, which had been irrelevant and accidental for the essentialist, now became one of the crucial phenomena of living nature. (Mayr 1991, 42)

For introducing this bit of metaphysics, which emphasizes the uniqueness of individuals, to biology, Mayr calls Darwin a "genius." Yet, surely Mayr's version of the essentialistic/population thinking contrast is too simplistic to attribute to biologists who lived before and after Darwin. Before Darwin, did no one believe that individual differences exist in nature? Did essentialists like Linnaeus actually believe that individual differences are illusionary, like the shadows in Plato's cave? If so, what would he have made of the difference between poodles and Great Danes? Likewise, do modern biologists really deny the existence of averages as properties in the biological world to be discovered? No. As Sober argues, Mayr's characterizations of the central tenets of essentialism and modern population thinking are inaccurate: "no population biologist would deny that there are such things as averages. . . . The historical record shows that typologists realized that the differences between individuals *exist*" (Sober 1994, 162).

There must be more to Darwin's great insight than the rather silly metaphysics that Mayr attributes to essentialists and Darwinians. Further, it is a bad sign for an account of "Darwin's genius" when its central claim tends to be contradicted by other such accounts. For Mayr, "to see the uniqueness of each individual" is the cornerstone of Darwin's theory. In contrast, Andrew Brown (2004, 15) claims, "one of the foundations of success [for natural selection] is . . . [that] the individual simply does not exist from the point of view of natural selection." Elliott Sober too contradicts Mayr in an account of what population thinking entails: "population thinking involves ignoring individuals; it is holistic not atomistic" (Sober 1994, 176).

Sober argues that the existence of variation, as Mayr has it, is not at issue between essentialism and population thinking; both agree that variation exists. Rather, the two views represent distinct strategies for explaining variation. Sober thinks that by adopting his approach we can better understand, among other

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things, how population thinking has "transformed our conception of what is real" (1994, 162). He thinks that his proposal is an elucidation of much of what Mayr says about the differences between essentialists and Darwinian population thinkers, discounting passages like the ones cited above where Mayr's metaphysics gets sloppy.

According to Sober, the explanatory goal for essentialists is to find an underlying order that unites and underlies the variation one sees in nature. The essentialist's strategy is to adopt Aristotle's natural-state model, which distinguishes between, on the one hand, the natural state for a kind of object and, on the other, the forces that interfere with an object's exhibiting its natural state. Newton provides a good illustration of the difference. Newton's first law of motion states that the natural state of a body in motion is to remain in motion; the natural state of a body at rest is to remain at rest. The forces external to the body that cause it to deviate from its natural state are the interfering forces. The first law incorporates both concepts: If a body is not acted upon by an external force (the interfering force), then it will remain at rest or in uniform motion (either of its natural states depending on initial condition).

In biology, the distinction between natural states and interfering forces is best illustrated in Aristotle's theory of heredity. For Aristotle, reproduction that is free from interference produces offspring that exactly resemble their father. Differences between offspring and their father are explained by interfering forces. If the interfering forces are strong enough, "monsters" form. Monsters are deviations from natural patterns of reproduction. Here, Sober connects with Mayr's conception of typology—natural laws in reproduction lead to the production of natural types, and deviations from a type are caused by interfering forces. Sober attempts to apply Aristotle's natural-state model to biological theories up to Darwin's day, including preformationism, epigeneticism, explanations of polydactyly, and the account of the great chain of being.

So, for Sober, the rise of population thinking is a rejection, not just of typological thinking, but more fundamentally, of the natural-state model of explaining variation. Population thinkers are, according to Sober, "statistical thinkers." Statisticians apply probability theory not to find an underlying order that explains away or "sees through" individual differences but, particularly in the case of inheritance, to account for variation at one generation as a consequence of variation at a previous generation. "Both typologists and population thinkers seek to transcend the blooming, buzzing confusion of individual variation," writes Sober (1994, 176). Both do this by identifying properties which remain constant throughout a system's transformation. The difference is this: The typologist seeks invariances in the natural tendency by each individual organism. The invariant properties for populationists, like Francis Galton, Darwin's cousin and Victorian polymath), are found in the population variances sustained across generations.

Earlier, I mentioned that Sober and Brown contradict Mayr's account of the fundamental differences between the typologist and the population thinker. Now we can see what's behind the contradiction. For Mayr, the typologist considers population properties to be "real" and individual differences "illusionary." For Sober, the main difference concerns the level of organization where invariances are found. Hence, Sober's view contradicts Mayr's: The typologist emphasizes the natural tendencies of individuals while the populationist emphasizes population properties. Yet, Sober argues that there is a sense in which Mayr is right that the population thinker emphasizes individual organisms: "In models of natural selection in which organisms enjoy different rates of reproductive success because of differences in fitness, natural selection is a force that acts on individual (organismic) differences" (1994, 176).[1] Sober concludes, "Putting my point and Mayr's point, thus interpreted, together, we might say that population thinking endows individual organisms with more reality *and* with less reality than typological thinking attributes to them." Later, I will offer an alternative account of what constitutes Darwinian population thinking without requiring a commitment about the forces of selection and without commitment to the sense in which individuals or populations are real.

Earlier, I said that, for Sober, population thinking is statistical thinking. What makes statisticians like Galton population thinkers is that they treat variability as obeying their own laws rather than instances of deviation from a type's natural state. Compare Galton's theory of inheritance from that of Aristotle. Recall that, for Aristotle, the natural state of inheritance is exemplified in the case where offspring exactly resemble their father. The ubiquitous variation we see in nature is due to forces that interfere with the natural state of parent-to-offspring inheritance. Galton viewed the variation in inheritance patterns as due to variation from the previous generation. According to Sober and to Hacking (1975, 1983), Galton's shift in thinking amounts to elevating statistical laws to the realm of reality. What makes the laws of variation "real" is that the variation to which they refer are law-like and causally efficacious. The statistics that Galton applies to explaining inheritance patterns sufficiently explain inheritance without the need to reduce the statistics to some lower-level substratum, like an individual's natural tendency. In a phrase, Galton's variation begets variation (see Hacking 1990 for details).

But, not all statistical thinkers embrace population thinking according to Sober. Adolphe Quetelet was a pioneering statistician of the early to mid-nineteenth century. His work on the application of probability theory, especially the application of the law of errors to social phenomena, was an influence for Galton's work. Yet, Sober calls Quetelet's work an instance of natural-state theorizing. Quetelet's technique involved measuring characteristics of a population, as wide-ranging as the waist size of Scottish soldiers, birth age of fathers, and various attitudes among criminals. The appearance of a Gaussian or bell-shaped distribution curve in the data indicated to Quetelet the existence of constant causes—represented by the height of the curve or the mean—perturbed by accidental causes, represented by the curve's tail ends. Quetelet coined the term *l'homme moyen* or "average man" to represent the culmination of these bell-shaped curves that defined a human population. Quetelet compared the value of the average man to social science with the value of the center of gravity to physics: Both allow us to identify the central facts for the discipline by abstracting away from the vagaries of individual differences (Sober 1994, 173).

Both Quetelet and Galton employed statistical measures to render bell-shaped curves out of the data they accumulated. But Quetelet, unlike Galton, viewed variability as something to see through to find the natural state of a population. For Galton, the variability itself is real; variability itself is lawful and causally efficacious (Sober 1994, 175). Indicative of this difference in view, Quetelet referred to the bell-shaped curves as the result of the law of errors; Galton rejected the notion that the tail ends of the curves represent "errors." Instead, he coined the term "normal law."

To sum up, for Sober, population thinking involves statistical thinking, but not all statistical thinking is population thinking. Only when statisticians treat variation as "autonomous" or real (law-like and causally efficacious) are they population thinkers.

The problem with Sober's account of population thinking is that it excludes Darwin. If population thinking amounts to, as Sober would have it, thinking about variation as irreducible statistical features of a population that are both law-abiding and causally efficacious, then Darwin is no population thinker.

Frank and Leonard Darwin, when asked whether their father was aware that the theory of natural selection is applicable to statistical analysis, responded that their father had a "non-statistical" mind (Porter 1986, 135). Perhaps this is a bit of an exaggeration given the evidence—cited by Janet Browne (1980)—that Darwin employed "biometrical arithmetic" to study variation among plants. But, there is little evidence of statistical application outside of Darwin's notebooks. Darwin's theory of natural selection, unlike its modern, post-Mendelian, synthesized version created in the early twentieth century, employs no statistical terms. While it is true that Darwin uses the term "chance" when describing natural selection ("the swiftest and slimmest wolves have the best chance of surviving, and so be preserved or selected" (1859, 90), it is pretty clear that Darwin had not much more in mind by the concept of chance than just the commonsense view that, *ceteris paribus*, not all advantageous individuals will in fact survive. Hodge (1983) disagrees with the "commonsense" interpretation and argues that Darwin understands the notion of chance in the context of the law of large numbers. Yet, even if Hodge is correct, invoking the law of large numbers when talking about the fate of a swift and slim wolf in a Malthusian struggle for survival does not make Darwin a statistical thinker, let alone one who invokes irreducible statistical laws of variation. Gigerenzer et al. put the point well:

> Darwin treated the process of natural selection as practically analogous to artificial selection, where the best individuals are always chosen—except that it is yet more subtle and refined. Darwin could hardly have been unaware that extraneous circumstances will sometimes lead to the death of an ostensibly fit individual, but there is nothing about this in the *Origin*. A statistical thinker might have said that these peculiarities will average out over a large population, or in

> the long run, but the only effect of large numbers in Darwin's theory is to increase the rate of production of favorable (as well as unfavorable) variations. Both the general theory of evolution by natural selection and the hypothesis of Pangenesis provided excellent frameworks for statistical investigation, but Darwin himself made use of statistical thought only occasionally. He never took advantage of the statisticians' view that what appears as chance in the individual can be dissolved into the large regularities governing the collective. (Gigerenzer et al. 1989, 66)

While Sober's account of population thinking provides significant insights into the role of Galton in pioneering a shift in thinking about variation, Sober loses sight of the original motivation for Mayr's argument that Darwin's great innovation is introducing population thinking to biology. Or, perhaps, Sober thinks it is more important to discuss the insight afforded by the modern statistical versions of Darwin's theory. It is difficult to tell from Sober's presentation since at the point at which statistical thinking is introduced, Darwin is just about completely dropped from the discussion. And, that is why his is not a suitable account of Darwin's population thinking. While Sober's essay suffers from a change of subject, Mayr's presentation of Darwin's "population thinking" suffers from an equivocation between Darwin's nonstatistical theory of natural selection and the modern statistical versions.

In the following passages, Mayr (1994) distinguishes between two versions of natural selection. If one ignores the "typologist" label in the description of the first version of natural selection and pays attention to the statistical language in the second, then we get an accurate description of the distinction between Darwin's theory and the statistical theories of twentieth-century biology.

> For the typologist everything in nature is either "good" or "bad," "useful" or "detrimental." Natural selection is an all-or-none phenomena [*sic*]. It either selects or rejects, with rejection being by far more obvious and conspicuous. Evolution to him consists of the testing of newly arisen "types." Every new type is put through a screening test and is either kept or, more probably, rejected. Evolution is defined as the preservation of superior types and the rejection of inferior ones, "survival of the fittest" as Spencer put it. . . . The populationist, on the other hand, does not interpret natural selection as an all-or-none phenomenon. Every individual has thousands or tens of thousands of traits in which it may be under a given set of conditions selectively superior or inferior in comparison with the mean of the population. The greater the number of superior traits an individual has, the greater the probability that it will not only survive but also reproduce. But this is merely a probability, because under certain environmental conditions and temporary circumstances, even a "superior" individual may fail to survive or reproduce. This statistical view of natural selection permits an operational definition of "selective superiority" in terms of the contribution to the gene pool of the next generation. (Mayr 1994, 159–60)

Mayr's first definition is a rather concise statement of Darwin's own version of natural selection. Compare it with Darwin's statement of natural selection (above) and with the following:

> Let us take the case of a wolf, which preys on various animals, securing some by craft, some by strength, and some by fleetness; and let us suppose that the fleetest prey, a deer for instance, had from any change in the country increased in numbers, or that other prey had decreased in numbers, during that season of the year when the wolf was hardest pressed for food. Under such circumstances the swiftest and slimmest wolves have the best chance of surviving, and so be preserved or selected, provided always that they retained strength to master their prey at this or some other period of the year, when they were compelled to prey on other animals. I can see no more reason to doubt that this would be the result, than that man should be able to improve the fleetness of his greyhounds by careful and methodical selection, or by that kind of unconscious selection which follows from each man trying to keep the best dogs without any thought of modifying the breed. (Darwin 1859, 90)

Darwin treats the swift and slim wolves rather like a type whose trait is rather useful and hence passes the screen of selection when the occasion arises that fleet deer are its source of food. The evolution of the wolf population will favor the swift and slim types while the unfortunate variants will be screened out. Yes, Darwin does employ the concept "chance," but as I argued before in agreement with Gigerenzer et al., there is little evidence that Darwin meant to imply that fitness guarantees reproductive success.

Consider Mayr's second definition, which employs the concepts that Darwin doesn't, including a "population mean." Chance is described (implicitly with reference to large numbers) in the context of the law of large numbers. Even if you don't accept my argument that Darwin's version of selection is exclusively that of Mayr's typologist version of natural selection, I think at least I've given good reasons to think, on a matter-of-degree scale where Mayr's versions are at the extremes, that Darwin's natural selection is closer to that of Mayr's typological thinking than it is to Mayr's second definition, representing population thinking.

Mayr's second definition is a concise statement of neo-Darwinism, or what Darwin's theory might have looked like had he incorporated the statistical concepts pioneered by Quetelet and developed by people like Galton. Notice, ironically, that the reasons Mayr cites for why the second definition represents population thinking have little to do with antiessentialism. The gist of Mayr's populationist version of natural selection is that it employs the language of statistics to analyze Darwin's central concept, "superiority." For instance, superiority is not ascribed to particular or token traits, as it is in Darwin's version of natural selection, but to a cluster of traits.[2] Further, "chance" in the second definition represents the deviation from the average survivability of those possessing overall superior traits.

Perhaps one could interpret the second definition in ways that support antitypological thinking, saving Mayr's metaphysical account of population thinking. But, since Mayr's definition of population thinking invokes the "reality of the individual," while no such concept is mentioned in the second definition, I think the metaphysical interpretation of population thinking is a real stretch. So, if Sober and Mayr (implicitly understood in the context of the second definition above) are correct that population thinking entails statistical thinking about natural selection, should we conclude that Darwin was not a population thinker? No, that would be too blunt. According to historian Theodore Porter (1986, 134), Darwin's theory is statistical "only in retrospect," meaning that Darwin's theory was ripe for Galton and others to reinterpret in terms of the statistical method. Perhaps Porter's sentiment explains why Sober and Mayr are so keen on attributing statistics to Darwin. What about Darwin's theory makes it so ripe? I will offer an alternative account of population thinking.

2. Population Thinking as a Methodological Doctrine

My account of population thinking differs from Mayr's and Sober's in several important (yet related) respects. First, for Sober and Mayr, population thinking is concerned with answering the question: What is real about the world? For me, population thinking answers a completely different question, one concerning what I'll call a biological instance of a "population phenomenon." Population phenomena are population-level regularities that give lie to individual differences, or, as Porter puts it, regularities that appear to be true at the level of populations but not necessarily true for any particular individual (Porter 1986). Examples of population phenomena come largely from demography, including stable death rates, birth rates, population growth rates, and crime rates for a population over long periods of time. The puzzle about these stable rates was well expressed by André Guerry, as he reflected on the emergence of stable crime rates out of multiple causes. He asked: If we consider the infinite number of circumstances that lead to a crime, how can we fathom that their conjunction reveals a constant effect? ("Essai sur la statistique morale de la France," 1883, 11, quoted in Porter 1986, 49). Darwin was concerned with a biological instance of population phenomena, namely, how extinction, speciation, and adaptation—as population events—emerge out of a wide variety of individual lives and deaths. The question is: How do species extinction, speciation, and adaptation occur despite the wide variety of ways in which individuals live and die? This is a very different question from what Sober and Mayr have Darwin asking.

Second, for Mayr and Sober, population thinking is a metaphysical doctrine, emphasizing the reality either of individuals or of populations (if you are like me, you are still a little confused about which one, individuals or populations, is real). For me, population thinking is a *methodological* doctrine. It tells you that regularities that occur in populations, such as extinction, speciation, and adaptation, emerge from the collective activities of individuals. Here is my thesis about Darwin's innovation: Darwin was a biological population thinker because he believed that speciation, extinction, and adaptation—events that occur to populations—emerge from the lives, deaths, and reproductive activities of individuals, despite the great variety of ways that individuals live and die, and the variety of numbers of offspring they produce. How could such population regularities emerge from the chaos of individual activity? Darwin's answer was in terms of a natural "fixed law" that he got from Malthus (the law of excessive reproduction): All organisms undergo a struggle for existence due to their general tendencies to produce more offspring than can survive their local environmental conditions. I will discuss this in more detail below, but it should be clear that my version of population thinking concerns a methodological issue: to explain how out of the great variety of individual life histories emerge population patterns such as extinction, speciation, and adaptation.

For a third difference, Mayr and Sober contrast population thinking with essentialism. For me, population thinkers are a radical departure from "divine interventionists," who believe that law-like population events are the direct result of an agent imposing a constraint on the otherwise chaotic behavior of individuals. Darwin, like other population thinkers of his day, rejected the agency or the higher-level impositions in favor of the view that population order emerges despite the apparent chaos of individual activity. On my view, population thinkers adopt a bottom-up approach to the cause of population-level regularity while interventionists adopt a top-down approach. Interventionists believe that God intervenes from on high, causing an order. The bottom-up methodology I associate with population thinkers implies that there is nothing more to population-level regularity than what emerges from individual-level action.

Sober/Mayr: My account
Central questions

Metaphysics: What is real: individuals or populations?
Methodology: How to explain population-level phenomena that emerge from individual variation?

Interlocutors

Population thinking vs. essentialism/typological thinking
Population thinking vs. divine intervention

An advantage to my version of Darwin's population thinking is that it accounts for Darwin's innovation, while, as I have been arguing, Mayr's and Sober's do not. Sober's and Mayr's historical assertion that Darwin's theory was aimed at a debunking of the metaphysics of essentialism is wrong. The general consensus among Darwin biographers is that Darwin was motivated to debunk a particular brand of natural theology that provided interventionistic explanations for adaptations (Ospovat 1981). While some natural theologists were essentialists, metaphysics was of secondary importance. The main aim of philosophers like William Paley was to provide the best explanation for the existence of the harmony of ecosystems and the existence of organs of extreme perfection (Gould 2002). By the time Darwin wrote his *Origin,* he was convinced that natural selection provided an alternative account of the same phenomena, without resorting to divine intervention (Schweber 1977, 233).

What about Darwin's theory being "ripe for statistics," as Porter puts it? As I mentioned before, population phenomena were known to occur in human demographic data. Pioneer social scientists like Pierre-Simon LaPlace, Quetelet, and Galton were, like Darwin, motivated to provide non–divine interventionistic explanations of the population phenomena inherent in the demographic data. The difference is that the social scientists of Darwin's day employed the theory of probability to analyze the data to fathom how such large-scale demographic equilibria could emerge from the myriad of ways that humans conduct themselves. Interestingly, the techniques were available to Darwin (see Ariew forthcoming), he was clearly aware of them, but he chose not to adopt the same statistical techniques as Quetelet. Instead, he adopted a fixed-law approach that he imported from Malthus's law of excessive reproduction. So, my view is that Darwin was not a statistical thinker because none of the statistical practices of the nineteenth century are part of Darwin's explanations. With the Malthusian law of population growth serving as a mechanism for evolutionary change, Darwin had no need for statistical thinking. Statistical thinking is a species of population thinking, but not all population thinkers are statistical thinkers. Malthus and Darwin are examples of the latter. In what follows, I want to discuss the differences and similarities between the demographers' and Darwin's approaches to their version of population phenomena. By quickly going through this bit of history, we can clarify what it means for Darwin to have been a population thinker without being a statistical thinker. Further, it is important to understand how neo-Darwinism, the statistical version of Darwin's theory of natural selection, differs from Darwin's own version. I have already suggested that Mayr's two versions of natural selection exemplify the difference between Darwin's version of natural selection (as the all-or-none version) and the statistical version of natural selection. I think one of the biggest errors in contemporary history and philosophy of biology is misunderstanding how different Darwin's theory is from the twentieth- and twenty-first-century versions of Darwin's theory.

3. History: Population Phenomena

Demographers as early as the eighteenth century discovered that birth and death rates in Europe were nearly constant from year to year. They also discovered that, across Europe, a higher proportion of boys than girls was born every year. The results were surprising because, first, they could not be the result of chance; they were too consistent for that. As Herschel puts it, the preponderance of data in favor of there being a nonaccidental cause for the skewed sex ratio in favor of boys is equivalent to the unlikelihood of expecting a one to come up 643 times in succession on throws of a fair, six-sided die (Herschel 1850, 33). Second, the statistical results could not have been predicted on the evidence of the practices of particular individuals or families. Aggregating the activity of a single individual would not produce the same skewed sex ratio. The sex-ratio skew revealed itself only through a statistical sample of a large number of individuals. The existence of this population phenomenon was taken as evidence for population-level natural laws imposed by a benevolent God. Mathematician John Arbuthnot argued that sex ratios skewed in favor of males were arranged by God to compensate for young men killed in war and at sea (Hacking 1990, 21). Demographer Johann Peter Süssmilch argued that the skewed sex ratio taken in conjunction with a higher mortality rate among men provided a perfect balance of sexes at the time of marriage, thus facilitating the great goal of human activity, maximal population increase (Porter 1986, 50).

But, the necessity of natural law conflicts with the Christian doctrine of free will. As Kant put it, "[S]ince the free will of man has obvious influence upon marriages, births, and deaths, they seem to be subject to no rule by which the number of them could be reckoned in advance. Yet the annual tables of them in the major countries prove that they occur according to laws as stable as [those of] the unstable weather" (quoted in Porter 1986, 51). It appeared to Kant that humans are guided by two forces, the force of their own will and the force of a natural goal, "as if following some guiding thread."[3] Or, perhaps, free will was merely constrained by a loving God who interfered on our behalf by, as it were, corralling populations into conforming to the natural population-level laws. Nevertheless, the explanation from divine intervention seemed problematic for those who held the doctrine of free will to be sacred.

Then, in 1827, the French government released long-run statistics on the number of criminal incidents categorized by types. Astonishingly, the number of criminal incidents turned out to be relatively invariant from year to year. The data further contradicted the expectation from free will. Free individuals sometimes err in judgment, but how could acts so immoral, antisocial, and irrational exhibit the constant effect? Reports soon followed that suicide rates also exhibit a statistical constancy (Hacking 1990, 65). For the frequency of thefts, murder, and suicide, the regularity defied chance, and the immorality of the acts defied the benevolence and wisdom of the design.

But if divine intervention could not explain statistical constancy, what could? For those who reject divine interventionist explanations, the conflict between population-level regularity and the scatterings of individual activity is confounding. I already quoted Guerry's expression of the problem: If we consider the infinite number of circumstances that lead to a crime, how can we fathom that their conjunction reveals a constant effect?[4] The population-level phenomena that belie individual differences suggest that the study of human nature has to employ a distinct strategy from that of physics. Newton's laws of motion apply universally to objects, because objects all share common properties to which the laws apply. Human behaviors and actions are too variegated for that; they are neither universalized nor do they all necessarily share common features. That is why the population phenomena arise for humans and not for falling bodies. Not all people commit a crime the same way; whether they do or not and how they do it depend on multiple contingencies.

The population phenomena were unknown until the statistical measures introduced by Laplace, among others, provided the proper resolution to detect them among the chaos of individual activity. As Quetelet put it, just as a person examining an odd arrangement of irregular dots will fail from her point of view to see the immense circle of which the dots are a part, the knowledge of an examiner content to observe only individuals "would be limited to a series of incoherent facts, leading to a total misapprehension of the laws of nature" (Quetelet 1842, 5).

LaPlace's explanation for the existence of population-level laws is nearly the opposite of the teleologists'. There are no higher-order goals constraining human activity. There are no population forces constraining individual activity toward some God-given goal. Rather, population stability is what emerges from a collection of common individual events.

To better understand the basic idea, consider the astronomical problem and solution that grounded Quetelet's and Laplace's investigations of the large-scale regularities in human activity. The pressing problem for astronomy was how to construct a single theory of the transit of, say, a planet from the various observations made by different astronomers at different times and places, and with a variety of observational techniques (many fraught with error). The key is to attend to the aggregate of the observations, not any subset. The larger the number of observations, the more likely the observational errors will, as it were, get swamped by the preponderance of the data, which tend to reflect the planet's true trajectory. Quetelet defined his "fundamental principle" of social statistics accordingly: "*the greater the number of individuals observed, the more do individual peculiarities, whether physical or moral, become effaced, and leave in a prominent point of view the general facts, by virtue of which society exists and is preserved*" (1842, 6, his italics). In the earlier formulations, Quetelet's *l'homme moyen* was defined in terms of the application of the law of large numbers to social statistics. In later formulations, Quetelet defined the average man in terms of a distribution rather than an average. The appearance of a Gaussian distribution curve in the data indicates the existence of numerous "constant causes" perturbed by many accidental causes. In other words, the large-scale distribution pattern is what we should expect to see if individuals in a population share some common causal features even if these features aren't experienced by all individuals or aren't experienced all in the same way. The characteristics of the average man are useful, says Quetelet, for us to understand the laws of human development.

The main value of the average-man concept is to identify group differences. As Stigler puts it:

> Quetelet's use of the average man was founded upon the belief that if there is no change in any underlying causal relationship—if there is a "persistence of causes"—then there will be a tendency for the average of large aggregates of even unhomogenous data to be stable. Thus if there is instability or differences between averages, this is evidence of . . . differences of causes [between groups]. (1986, 171)

Distinct group averages suggest real causal differences between two groups; the differences might be contingent factors, including distinct shared group experiences, geography, or biology. To illustrate, suppose the average French citizen commits 0.4 crimes on average per year while the average Norwegian commits 0.17. From this fact, we can glean the following information: (a) the average is not a reflection of any individual criminal; (b) the crime rate of individual French citizens or Norwegians varies around this average; and (c) nonetheless, assuming that the averages are stable and emerge from a preponderance of data, they indicate something about the differences between the French and the Norwegians. So, crime is not so much a natural state of a French citizen as it is an event that occurs to some individuals given certain local, societal, or personal conditions and situations. Contrary to Sober, and to Quetelet's sometimes misleading rhetoric, criminality for Quetelet is not like Newton's concept of rest or uniform motion. Without perturbing forces, an object will tend to a straight line, its natural state. Criminality is not an invariant natural state of an individual; criminality is a social problem that is caused by a confluence of a number of contingent factors, including both nature and nurture. Today's French criminal placed in a different environment will likely act differently.

Further, Quetelet recognized the distinction between postulating the existence of nonaccidental commonalities between groups and the determination of the "proper degree of influence" (his words) of the constant causes to an effect. Quetelet's conception of the average man served the former project; his analysis of correlation—which Fisher (1953) acknowledges as a precursor to his own "analysis of variance"—served the latter project. By measuring averages for various group features, Quetelet could examine correlations between them. Take, for example, his analysis of skewed sex ratios—a puzzle for theologists and early demographers that led to rather outlandish divine-interventionist explanations. Quetelet compared the average sex ratio for children born to married couples to the average sex ratio for illegitimate children. The excess of males to females that is indicative of the entire European population (5%) is the same as the excess among children from married couples and more than the excess among illegitimate children (3%). If you add the fact that, for married couples and not necessarily for people having unmarried affairs, males tended to be older than females, Quetelet concluded that the relative ages of the parents physiologically influence the sex of the offspring.

Never mind that Quetelet's analysis was, from a contemporary statistician's point of view, woefully insufficient (see Stigler 1986, chap. 5, for an excellent and sympathetic critique). The important point is that Quetelet provided a means for identifying the source of cause for a puzzling population phenomenon that bedeviled thinkers for decades, and a means for testing the degree of influence among many potential causes for the effect. Quetelet's explanation for the population phenomenon is an alternative to the natural theology that invokes an external force impinging a will over and above individual action. Quetelet's explanation is completely opposite to that of the teleologists. It relies on no imposition of a creative will.

4. Darwin and Population Thinking

Sometime between April and July 1838, Darwin wrote in his notebook, "Find out from the Statistical Society—where M. Quetelet has published his laws about sexes relative to age of Marriages" (C 268, Barrett et al. 1987, 324). Then again, around October 16, 1838, Darwin wrote, "In the Atheneum Numbers 406, 407, 409, Quetelet papers are given, & I think facts there mentioned about proportion of sexes, at birth & causes" (379). Clearly, Darwin was aware of Quetelet's statistical method to determine causes of sex ratios, which I have been describing as an instance of a population phenomenon. What is significant about Darwin's curiosity is that shortly before the entries on Quetelet (in late 1837), we find Darwin describing extinction in terms of a population phenomenon. Specifically, Darwin wondered how a species might go extinct without the appearance of a single cause. In the following passage, Darwin considers two "fine families." Both experience the tragedies of life—death, aversion to marriage, disease, accidents—but one lineage propagates and the other goes extinct. The fate of the families is an analogy to species extinction.

> In looking at two fine families one with B successors [for] centuries, the other will become extinct.—Who can analyze causes, dislike to marriage, hereditary disease, effects of contagions & accidents: yet some causes are evident, as for instance one man killing another.—So is it with varying races of man. then races may be overlooked; many variations consequent on climate &c—the whole races act towards each other, and are acted on, just like the two fine families [no doubt a different set of causes must act in the two cases].). (B 147)[5]

"Extinction" describes a population event, something that happens to lineages or species, and it has multiple causes. Each of the possible multiple causes themselves describes events that only individuals experience. It is worth noting that Quetelet's work would have been particularly useful for his analysis of such relations. Quetelet would have provided Darwin a means to investigate and rank the numerous potential causes that, when aggregated, produce the cumulative effect of extinction. Or, Quetelet would have provided a way to analyze the different circumstances of the species analogue of the two fine families to help to determine why one survived and one went extinct. Quetelet would have offered Darwin an analysis devoid of divine interventionism. Reflecting on this missed opportunity, R. A. Fisher writes (implicitly implicating Darwin), "It must seem strange in view of Quetelet's early advocacy of Statistics as an educational discipline, that so many leading, and by the standards of their time, well educated, men were quite unaware that they had anything to learn in this field."(1959, 4)

Instead, Darwin turned to Malthus (in 1838, after reviewing Quetelet) to solve the population phenomena.[6] How does Malthus provide an answer to extinction?

Sprinkled throughout his notebooks, Darwin considered factors that could lead to extinctions, including botanist Augustin de Candolle's idea of a war between organic beings and Lyell's view that rather rapid species changes could result when one species invades another (see Hodge and Kohn 1985, 194). Lyell's idea is, roughly, that in an area already fully stocked with individuals, small changes in ecological conditions can lead to rather dramatic effects, such as some species driving out others to the point of extinction. It isn't until Darwin encounters Malthus, however, that he finds a way to comport Lyell's view of extinction with a theory of how extinction could emerge from multiple causes.

To understand why Malthus would have provided an answer to the question about extinction, we should explore what sort of answer Darwin would have found acceptable. While Darwin sought to undermine divine-interventionist explanations, Darwin was not an atheist, tout court. In the early years before his essay of 1844, Darwin, following Paley, believed in the perfection of adaptation and the harmony of ecosystems (Ospovat 1981). And, following Whewell and Herschel, Darwin believed that God's perfections were mediated through a combination of laws (Brooke 2003, 197). Laws, here, were understood in the model of Newton's laws of motion and theory of universal gravity; they were universal and deterministic (Hull 1989). According to Whewell, the existence of Newtonian laws *necessitated* the existence of God. The perfection and harmony of laws were the hallmark of a benevolent God. Newton held the same view. Confirming references to final causes and laws litter the early, pre-Malthus notebooks. The following is a good example, where Darwin rejects interventionistic explanations for laws without denying that God is ultimately responsible for them. In September or October 1837 (Barrett et al. 1987, B 101), he wrote: "Astronomers might formerly have said that God ordered, each planet to move in its particular destiny.—In same manner God orders each animal created with certain form in certain country, but how much more simple, & sublime power let attraction act according to certain law such are inevitable consequences let animal be created, then by the fixed laws of generation, such will be their successor."

Notice that, in this quote, Darwin describes the distinction between the interventionist and noninterventionist teleology. In the following notebook entry, we see Darwin's commitment to establishing a system of great harmony as a consequence of his theory (D 74): "When I show that island would have no plants were it not for seeds being floated about—I must state that. The mechanism by which seeds are adapted for long transportation, seems? to imply knowledge of whole world—if so doubtless [part of] system of great harmony." So, the pre-Malthus Darwin was a teleologist but not a divine interventionist.

Darwin was also prone to a Newtonian framework for dynamic explanations. Many historians point out the parallels between Darwin's explanatory scheme in the *Origins* and Newton's model (Hull 1989; Waters 2003; Schweber 1985). For instance, Schweber (1985) asserts that Darwin understood natural selection as a law of nature of universal scope. Further, as in the Newtonian scheme, the dynamic response of an organism is determined by selection of its various parts (49).

In Malthus, Darwin found what he was looking for, a noninterventionist teleological explanation of a population-level phenomenon that ascribed laws in the spirit of Newtonian dynamics. Darwin read the following passage in Malthus sometime before September 28, 1838:

> In New Jersey the proportion of births to deaths, on an average of 7 years, ending with 1743, was 300 to 100. In France and England the average proportion cannot be reckoned at more than 120 to 100. Great and astonishing as this difference is, we ought not to be so wonder-struck at it, as to attribute it to the miraculous interposition off [*sic*] Heaven. The causes of it are not remote, latent and mysterious, but near us, round about us, and open to the investigation of every inquiring mind. (cited in Barrett et al. 1987, 397)

Malthus is declaring that stable death rates ought to be explained in terms of internal causes described in the form of fixed natural laws rather than in terms of an external godly force. With obvious elation, Darwin quotes and comments on the passage that directly follows the one I just cited:

> Epidemics—seem intimately related to famines., yet very inexplicable.—do p. 529. "It accords with the most liberal! spirit of philosophy to believe that no stone can fall, or plant rise, without the immediate agency of the deity. But we know from experience! That these operations of what we call nature, have been conducted almost! Invariably according to fixed laws: And since the world began, the causes of population & depopulation have been probably as constant as any of the laws of nature with which we are acquainted."—this applies to one species—I would apply it not only to population & depopulation, but extermination & production of new forms.—the number & correlations. (cited in Barrett et al. 1987, 397)

At the end of the passage, Darwin asserts that the Malthusian theory of population growth can be extended to explain both extinction and the "production of new forms" for all living organisms. This is how it works. Malthus's theory of growth concerns a universal condition of humans that affects both the rate of population growth and the conditions under which individuals live. Humans tend to geometrically increase their number through propagation. However, their tendency is checked by the limited resources available to support the increasing masses. Once the limit is reached, humans either consciously slow down their propagation rates or they experience the hardships and deaths associated with lack of resources (as it were, nature slows the rate down for us). To Darwin, this means that species are at war over resources. Why so dramatic? Because, as Malthus expresses, the tendency of organisms to increase geometrically means that populations grow very fast: "It may safely be pronounced . . . that population, when unchecked, goes on doubling itself [in less than] twenty-five years, or increases in a geometrical ratio" (Malthus 1826, 1:6, cited in Barrett et al. 1987, 375). If every lineage experiences the same tendency for rapid increase and the resources are limited, Darwin reasons, the overall effect is a "warring of the species."

The language to describe the opposing conditions is one of "forces." As Malthus puts it, the tendency of humans to increase geometrically is counteracted by checks that operate "with more or less force in every society" and act to "keep down the number to the level of the means of subsistence" (Malthus 1826, 1:12–13, cited in Barrett et al. 1987, 375). As we shall see below, Darwin uses the same force metaphor.

Now, how does Darwin read from Malthus's theory of population growth an answer to his query about how extinctions come about without the existence of a single cause like famine? The key is that checks themselves describe conditions of a population, not of an individual, as there are multiple causes for each check. Darwin sees this clearly: "take Europe on an average, every species must have same number killed, year with year, by hawks, by cold &c. cited in Barrett et al. 1987, 163) So, while every population experiences the same average death rate, the conditions of death might differ between lineages. As Darwin says, and I quote from where I left off above, "even one species of hawk decreasing in number must effect instantaneously all the rest." So, getting back to our two "fine families," both experience the same force of the check against their inherent tendencies to geometrically increase their numbers, i.e., both are affected by the same average death rate. Yet, each experiences different causes of death. Suppose one family's growth is more likely to be threatened by the cold climate and the other is more likely to be threatened by predator hawks, while both are limited by the same resource constraints. If the number of hawks decreases while the threat of cold remains the same, the hawk-threatened family will likely increase its numbers at the expense of the cold-threatened family. I say "at the expense of" because, you might recall, the increase of one family takes away potential resources from the other. Everyone experiences both the same checks (on average) and everyone experiences the same resource constraints. Darwin evokes the force metaphor (in exchange for his war metaphor) to express the general idea: "One may say there is a force like a hundred thousand wedges trying [to] force into every kind of adapted structure into the gaps of in the economy of Nature, or rather forming gaps by thrusting out weaker ones."[7]

To explain the production of new forms in a population, Darwin relies on both the war between species for resources and the differential reactions (among individuals) to the crush of population growth constrained by limited resources. In addition, the war of species and the differential reactions among individuals to the checks on their tendency to increase explain the production of forms. To demonstrate how, recall the difference between the two fine families, in my example, which concerns their different abilities to utilize resources and to stave off potential fatal threats. Given a change in conditions, say, the decrease of hawks, one family propagates its kind relatively quicker than does the other. The result is a replacement of one kind (defined in terms of adapted abilities) for another in the overall population. In Darwin's mind, this is the "final cause of all this wedgings . . . to sort out proper structure & adapt it to change." Recall that Darwin's teleology here is not one of divine intervention but God's will exerted in the form of a natural universal law, which in this case is Malthus's law of population. Darwin views a God-imposed benefit on the struggle; it contributes to a great harmony in nature. At this point, Darwin is more like Süssmilch than like Laplace. While God may not intervene directly to produce adaptations, he does so through fixed laws with a purpose (Ospovat 1981, 67).

So, from Malthus, Darwin learns to understand how multiple causes might conspire to create large-scale regularities in fixed law-like ways (population phenomena). Darwin is explicit about the importance of this conceptual tool in an entry shortly after September 28, 1838 (E 5): "The difficulty of multiplying effects & to [ponder] conceive the result with that clearness of conviction, absolutely necessary as the [basal] foundation stone of further inductive reasoning is immense." Darwin elaborates his point with examples from geology and political history. Fossils record the large-scale changes, but "without every animal preserved," one cannot infer from the fossil record how it is that the multiple ways that individuals die conspire to cause the dramatic effects. It is the same with political history: We see the revolutionary changes of government but from the study of the steadiness of the laws of government, it is difficult to fathom how such a steady institution can give way to revolutions. The Malthusian law provides a way to link the apparent asymmetry between large-scale patterns and variegated individual activity. Quetelet expresses a similar point when he invokes the metaphor of how free-willed individuals come together and form a perfect circle. The circle is detected only by taking the long view, and the statistical laws of large numbers or the error curve provide a law-like way to connect the asymmetry. Yet, for Darwin and Malthus, the connection is fathomed in terms of identifying the effects of universal laws imposed on everyone equally but whose effects will be felt differently for each individual (think of the two fine families). Extinctions come about when the force of the universal tendency of organisms to increase their numbers is checked by resource limitations and the differential abilities of organisms to survive the hardships that follow. If small changes in local conditions lessen the check on one type over another, the one type will increase its numbers at the expense of the other, driving it out, extinguishing the lineage. Darwin retains Malthus's strategy despite his exposure to Quetelet's statistical method.

In *The Origin of Species*, published decades later, Darwin still retains the language of force[8] and all of the reliance on Malthus when he introduces the struggle for existence that, for Darwin, is at the heart of his explanation for speciation and adaptation as well as extinction.

To summarize: What makes Quetelet, LaPlace, Darwin, Galton, and the like "population thinkers" is that they rejected divine-intervention explanation for population-level phenomena and replaced it with a naturalistic explanation whereby the population patterns are the result of the aggregate of causes at the individual level. Yet, there are two types of population thinkers, statisticians and force theorists. Malthus and Darwin were force theorists. In their view, the population patterns are caused by conditions that every individual, however variegated the individual conditions, undergoes. An increasing population checked by resource limits is a force that is felt by each individual in the same way, as a struggle to survive. Evolution by natural selection, according to Darwin, is caused by this struggle for survival.

5. Darwin's Malthusian Natural Selection vs. Modern Queteletian Natural Selection

R. A. Fisher finds Darwin's reliance on Malthus's law of excessive reproduction to be unfortunate. It paints an unrealistic view of nature:

> [S]omething in Malthus undoubtedly influenced both Darwin and Wallace, for they begin at once to sketch pictures of a very unrealistic world in which animals reproduce, but do not die, at least until after they have reproduced abundantly—pictures in which the planet's land area is overrun with elephants, and in which the volume of the oceans is insufficient to accommodate all the herrings. This is certainly due to Malthus, but it is scarcely his logic but his rhetoric, which has gone to their heads. In truth, when I try to explain the Theory of Natural Selection to students, the phrases I find least helpful are those rather journalistic slogans, "The Struggle for Existence" and "The Survival of the Fittest." (1953, 5)

In the next passage, Fisher argues that there is no need to conceive of the struggle for existence as the cause for evolution by natural selection:

> Now it is very natural to the human race, and very unphilosophical, to imagine that results of towering and majestic importance, such as the evolution of living creatures, must be brought about by equally powerful or violent causes. If we can imagine my winkles, or my primroses, tense with struggle, red in their non-existent teeth and claws, it becomes easier to believe that great things are happening to them, that they are being hammered into shape by cosmic forces. Whereas all we know is that each is living its own quiet life, with the life Table and the rates of reproduction characteristic of its genotype, and that for this

> reason, and for no other, these species are probably changing, imperceptibly slowly, but with a speed sufficient to make them perceptibly different if they keep it up for some millions, or tens of millions, of years. Natural Selection has no need of all this "Sound and Fury, signifying nothing." (ibid.)

Fisher's Queteletian version of selection does not require a universal instigating force to pressure variation through the filter of natural selection. All that is required is that individuals vary in their life histories and reproductive tables and that, for whatever local reason, in the long run, the population will evolve to favor certain life histories or reproductive schedules. The local reasons do not have to include winning a tense struggle for existence. In fact, selection may operate in the absence of a population check (see also Fisher 1959, 46–47).

Rather, the idea is more like what Herschel said, in his favorable review of Quetelet, about why the strong tend to carry off the spoils while the weak get nothing. Herschel's answer is that there may not be a consistent answer for each and every case (there is no external pressure). Nor is the tendency true in every individual case. Rather, in the long run, we see this visible tendency of the weak and strong in a lot of different populations (Herschel 1850, 31). A twentieth-century commentator has suggested that had Darwin read this passage in Herschel, Darwin would have had no need to read Malthus, as the probability calculus would have provided a suitable analysis of tendencies that suggest causes.[9]

6. Population Thinking: A Conclusion

S. J. Gould (2002, following Schweber 1977) offers a wonderful analogy between Darwin's natural selection and Adam Smith's invisible hand that, to me, best illustrates the revolutionary features of population thinking, at least that version of population thinking that I endorse as opposed to the metaphysical version that Sober and Mayr endorse. The analogy is between Darwin's answer to Paley and Adam Smith's theory of laissez-faire. The question for Adam Smith and other economists was: What makes a well-ordered economy? One answer is akin to teleology: Congregate economic experts to create and impose principles and rules on the economic activities of the people. Adam Smith's answer is very different; in fact, it is the opposite of the expert theory: Allow individuals to transact without constraint. From the collective activity of all those unfettered transactions will emerge a well-ordered economy. Accordingly, there are no rules or principles; rather, order emerges as a side consequence of individual activity whose intent is orthogonal to the collective effect. Individuals are acting on their own desire for profit, not for the good of the whole (Gould 2002). Smith invokes the "invisible hand" to describe the distinctive features of this theory: There is no hand of economy creation. Darwin's theory can be viewed in the same light. To achieve good adaptations and harmony in nature, you don't need a hand of God; rather, these phenomena are the result of the collective activity of individuals which are simply striving to survive and reproduce on their own, without a mind to the collective effect. The individuals vary in their features and in their abilities to survive and reproduce in the local environmental conditions. Natural selection is the invisible hand or, to mix metaphors, the blind watchmaker. Emergentism is to Paley-style creationism as Copernicus's sun-centered cosmology is to Ptolemy's earth-centered universe: It stands the conventional biological wisdom on its head.

NOTES

1. See Walsh, Lewens, and Ariew (2004); Matthen and Ariew (2004,);for reasons that the view that natural selection is a force acting on individuals is a misleading view of what natural selection is.

2. Keep in mind that Mayr seems to think that Darwin's own theory is a representation of population thinking. But that is historically inaccurate.

3. Kant was not a Christian teleologist. His teleology was nontheistic. See Cornell (1986), 406.

4. "If we consider now the infinite number of circumstances that can cause the commission of crime, . . . we will not know how to conceive that in the end result, their conjunction leads to such constant effects" ("Essai sur la statistique morale de la France," 1883, 11, quoted in Porter 1986, 49).

5. All citations of Darwin's notebooks refer to notation in Barrett et al. (1987).

6. For more detail on Quetelet, Malthus, and Darwin, see Ariew (forthcoming). Some of the passages that follow are from that article.

7. The force metaphor also conveys a sense that the population pressure is great enough that even a small amount of time or small changes in local conditions might lead to changes in the overall number of species within a certain environmental range. As Darwin writes, "We ought to be far from wondering of changes in number of species, from small sort out proper structure & adapt it to change" (see discussion in Hodge and Kohn 1985, 193).

8. "It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms" (Darwin 1859, 63 chap. 3).

9. Gillespie (1963), 452.

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