

Darwin's retraction on natural selection and sexes in the *Descent of Man*: a case study
of Darwin's use of statistical methodology to advance his evolutionary ideas

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FORWARD

About ten years ago Jean presented on “Darwin and Statistics” at an IHPST workshop on “Evolution and Ecology.” At the time, I was starting a project about how Darwin used a variety of techniques to analyze statistical data in order to develop evolutionary ideas. So, I was keen on what Jean had to say. My interest was the same as Jean's, to rebuff the common claim among historians and philosophers (including Jean) that through Darwin's emphasis on variation and chance he made evolution “ripe” for statistical methods, though he lacked the abilities to apply statistical methods himself. Like me, Jean had discovered in Darwin's private notebooks and correspondences (1856-58) that Darwin was applying the botanical arithmetic in creative ways, and that this work “deeply affected central pieces of Darwin's evolutionary thinking: varieties as « incipient species », principle of divergence, and the « diagram » (OS, Chap. 4)”

A few years later, I contacted Jean to share some of my additional discoveries and ask him if he would like to collaborate on an essay. He agreed and sent me his PowerPoint. Regretfully, I set the project aside to work on other things.

Several years later, I met Jean for lunch where mentioned that I was writing a manuscript on Darwin and statistics and he expressed interest in reading a draft as well as rekindling the joint project of fleshing out his 2012 presentation on the botanical arithmetic. At the end of the lunch Jean warned me to “hurry up” because the cancer he was battling shifted to a more aggressive form.

There is no good end to this story. Regretfully, I did not complete the project and my future attempt will be without Jean's guidance. The focus of this workshop, in July 2022, dedicated to Jean's memory, concerns the *Descent of Man* which contains no application of the botanical arithmetic. So, our joint project will have to wait another occasion...

Yet Darwin's discussion of “the proportion of sexes in relation to natural selection” in Chapter Eight of the *Descent of Man* contains an extensive analysis of statistical information about sex ratios for a variety of species. So, it fits within the overall theme of our project and is suitable for the present volume and, I hope, Jean would have enjoyed discussing it (whether he would have agreed with what I have to say is another story altogether)

“During the three years which I spent at Cambridge my time was wasted.... I attempted mathematics, and even went during the summer of 1828 with a private tutor (a very dull man) to Barmouth, but I got on very slowly. The work was repugnant to me, chiefly from my not being able to see any meaning in the early steps in algebra. This impatience was very foolish, and in after years I have deeply regretted that I did not proceed far enough at least to understand something of the great leading principles of mathematics; for men thus endowed seem to have an extra sense. But I do not believe that I should ever have succeeded beyond a very low grade.”

[The Autobiography of Charles Darwin](#), p. 58.

Darwin’s penchant for self-deprecation has endeared him to many of today’s historians and philosophers of science. But, his modesty is also deceiving. His reports of dyscalculia (like in the passage cited in the epigraph) have misled commentators into thinking that he could not have possibly applied mathematical reasoning to develop his ideas about evolution. The consequences are not good for his posterity.

R.A. Fisher, in his 1953 Presidential Address to the Royal Statistical Society blamed Darwin’s ignorance in statistics and mathematical probabilities for causing generations of confusion over his evolutionary ideas. Fisher was incredulous that any well-educated man could be “quite unaware” that they had anything to learn from the efforts of the early statistics educator Adolphe Quetelet. Quetelet (1796-1874) was an astronomer-turned-social scientist who wrote popular treatises in the 1830s and 1840s about the statistical method and the Doctrine of Chances which inspired scientists and like James Clerk Maxwell and Francis Galton in furthering his pioneering work.

Fisher was wrong. Darwin was not only aware of Quetelet’s pioneering statistical methods, he applied it on several occasions throughout his career to advance his ideas about evolution. Darwin’s earliest recorded encounter with Quetelet’s statistical work dates to 1838, over two decades before the publication of the *Origin of Species*, and right around the time Darwin was thinking about Malthus’s laws of human populations. In his diaries, Darwin wrote that he was seeking “where M. Quetelet has published his laws about sexes relative to age of Marriages”.¹ A few months later, Darwin confirmed that he found Quetelet’s papers which “contain facts there mentioned about proportion of sexes, at birth & causes”.²

Three and a half decades later Darwin again referred to Quetelet’s views on human sex ratios; but on this occasion he did more than report on Quetelet’s conclusions, he applied a statistical technique that Quetelet pioneered. Let’s call it “the method of

¹ <http://darwin-online.org.uk/content/frameset?itemID=CUL-DAR123.-&viewtype=text&pageseq=1>

² I have written elsewhere (Ariew 2007) about the significance of the timing of Darwin’s early encounter with Quetelet in relation to Malthus.

group differences”.³ It involves inferring causal differences between human groups from different group averages in large data sets of human features. Quetelet showcased the technique in his work on human sex ratios that Darwin referenced back in 1838. Children born from parents of the same age tend to exhibit a 1:1 male to female sex ratio while children born from relatively older fathers (which represented the vast majority of human matings) tended to skew towards male births. It is reasonable to infer, Quetelet concluded, that relative age of marriage is an important cause for sex production in humans.

In the second edition of the *Descent of Man* Darwin reports Quetelet’s conclusion (though he attributes the theory to “Dr. Faye” and relegates references to Quetelet to footnotes). More importantly, Darwin himself applies the method of group differences to “trace out the complication of causes” and settle a question about whether organisms themselves, by selection, could “tend to modify the sex-producing power of the species” (1874, p. 259). Darwin includes the statistical analysis of the sex ratio data in the second but not the first edition of the *Descent of Man*. Why?

In the first edition (1871) Darwin proclaims that “natural selection will always tend, though sometimes inefficiently, to equalise the relative number of the two sexes” (1871, p. 318). But in the second edition Darwin retracts his conclusion: “I formerly thought that when a tendency to produce the two sexes in equal numbers was advantageous to the species, it would follow from natural selection, but I now see that the whole problem is so intricate that it is safer to leave its solution for the future” (1874: p. 259). Elliott Sober (2011) calls the retraction a mistake and Darwin’s reasons for it “a mystery”. However, Darwin’s retraction is not mysterious. The argument in the first edition is based largely on conjecture, analogies, and untested assumptions about the power of natural selection to alter sex producing powers. Darwin jettisons these arguments in the second edition and replaces them with empirical arguments based upon data collected in the wild which, among other things, tests Darwin’s previously held assumption that natural selection alters sex ratios. Darwin concludes that natural selection does indeed have the power to alter sex ratios, though “indirectly” (p. 255). Nevertheless, Darwin finds no conclusive evidence in the data that natural selection always tends to equalize the sexes.

The immediate goal of the essay is to expound on Darwin’s statistical arguments which provided him the evidence to retract his view about natural selection always equalizing the sexes. But, my ultimate purpose is to extend the work I began with Jean Gayon about the role statistics played in the development of his evolutionary ideas and to provide insights into Darwin’s rich scientific methodology. I’m not going to argue that Darwin was a brilliant mathematician. He wasn’t, as his autobiographical remarks

³ See Stigler 1986 for longer discussion.

support. But Darwin didn't need to be a brilliant mathematician to apply his statistical techniques to his investigations of sex ratio skews. There are no mathematical equations used in Quetelet's or Darwin's application of the method of group differences.

1871: Descent of Man, first edition.

Darwin begins his section "On the Power of Natural Selection to regulate the proportional Numbers of the Sexes, and General Fertility" asserting that *inequality* of sexes provides no selective advantage to a group. Any such inequality, then, must be due to non-selective causes. In such cases, Darwin asks, "Could the sexes be equalised through natural selection?" (p. 316). Darwin's answer is yes ("we may feel sure") and he offers two scenarios, both involving populations which initially consist of an excess of one sex over another. In one scenario, the overall population continues to increase in numbers and, in the other, the overall population remains constant. Neither can be sustained over the course of generations because they are susceptible against variants that are "subjected to the least waste of organized matter and force", and in both scenarios, the variant is at advantage, hence, natural selection directly or indirectly favors the equality of sexes.

In the first scenario, Darwin begins with populations that vary in the number of excess males they produce, some "produce a somewhat less excess of males over females than other pairs" (p. 316).⁴ Assuming population numbers remain constant from generation to generation, those populations with fewer excess of males will, by proportion, produce more females which produce more mating pairs, "and would therefore be more productive". By "the doctrine of chances", the more productive pairs will produce a greater number of surviving offspring than the populations containing more superfluous males. Assuming that sex determination is heritable, the more productive pairs "would inherit a tendency to procreate fewer males and more females", thereby driving the equalization of sexes (or as Darwin put it "Thus a tendency towards the equalization of the sexes would be brought about").

However, as Darwin is quick to point out, these productive groups are not necessarily at a selective advantage, especially where there is a limit on the amount of food able to sustain the increasing number of offspring. In that case "increased fertility will lead to severer competition and to most of the survivors being badly fed." This selective scenario will lead to an overall decrease in the total number of offspring. Darwin puts it this way:

"In this case, if the sexes were equalised by an increase in the number of the females, a simultaneous decrease in the total number of the offspring would be beneficial, or even necessary, for the existence of

4. At the end of the section Darwin notes that the same conclusion will apply in cases where the females are in excess, or in polygamous species.

the species; and this, I believe, could be effected through natural selection in the manner hereafter to be described (p. 316-17)."

In the second scenario, equalization of sexes does not lead to an overall increase of population numbers, for instance, when male numbers are decreased without a corresponding decrease in females. In such cases, Darwin argues that while there would be no direct selective advantage for groups containing fewer superfluous males, there could be an indirect effect--better quality of embryos or better nurturing of young in the womb:

"Those [variants] that produced few superfluous males would have one great indirect advantage, namely that their ova or embryos would probably be larger and finer, or their young better nurtured in the womb and afterwards."

Darwin has in mind a comparison between plants which produce vast numbers of small seeds versus plants like the *Primula* which produce fewer number of larger seeds. The advantage of the larger seeds is that they are "well-stocked with nutriment" (p. 317) and hence enjoy a greater chance of "retaining full fertility" from the larger nurturing environment compared to those plants which produce smaller seeds and which contain the greater number of superfluous males. Darwin concludes:

"Hence the offspring of the parents which had wasted least force in producing superfluous males would be the most likely to survive, and would inherit the same tendency *not* to produce superfluous males, whilst retaining their full fertility in the production of females."

The aggregate outcome over the course of generations is a tendency towards equalization of the sexes.⁵

Darwin's argument is almost entirely based upon thought experiments ranging over hypothetical scenarios. His reference to *Primula* served only to demonstrate the plausibility that a larger seed could be at an advantage in the battle for life over smaller seeds. It did not serve as real world evidence that natural selection favors equality of sexes, let alone that it always does. To put the criticism another way, Darwin's conclusion about natural selection favoring equality of sexes is expressed as a categorical generalization about the natural world, "*natural selection will always tend to equalize the relative number of the two sexes*". Yet, his supporting argument is based upon hypothetical (albeit plausible) scenarios where evolution obeys the doctrine of chances and either increases in overall number (in scenario one) or remains constant (scenario

5. Darwin issues a caveat, the tendency towards equalization does not always lead to actual equalization. Slight excesses likely don't suffer great selective advantage, and in cases where inequalities are large the causes might overwhelm the indirect effects of selection towards equalization.

two). At best Darwin is warranted to the conclusion that it is reasonable to imagine natural selection favoring equality of sexes. He presents no real-world evidence that natural selection actually does, let alone that it always does.

So, it is no wonder that Darwin felt compelled to eliminate the entire section and replace it in the second edition with an analysis of real-world statistical data of sex ratios. In the second edition Darwin's intent was to test a speculative generalization with a well-supported one. The problem is, as Darwin reports in the second edition, he failed to find sufficient empirical evidence; in fact he found evidence to the contrary. Hence, his retraction.

1874: Descent of Man second edition

Darwin's revisions in the second edition are significant because they mark a shift in his methods for theory confirmation. As opposed to relying on thought experiments, he sought evidence from real world population data on whether natural selection is responsible for the sex producing powers of a species. For the retraction Darwin depended on data drawn from human demographic and the statistical "method of group differences" to analyze them. Ultimately, he found insufficient evidence that sex ratios are inherited, that human preferences (including sexual selection) can alter sex producing powers of the species, and that equalization among humans would confer advantages in the battle for life.

Darwin's first major revision (of two) occurs in the section entitled (in both editions) "Supplement on the proportional numbers of the two sexes in animals belonging to various classes" where he reports on data collected on the relative numbers of the two sexes throughout the animal kingdom with summary statistics for man, birds, fish, and insects. The section on "man" is expanded in the second edition by 550 words and includes an interesting argument (not found in the first edition) for why sexual selection is in part responsible for the more frequent deaths of males among illegitimate births (we will discuss it below). In both editions Darwin admitted that the data for humans is sufficiently large and hence reliable, and that proportions between males and females are "known with certainty". But while in the first edition the supplemental data appears as an isolated curiosity, in the second Darwin add a statement of purpose for the existence of the section, to "briefly discuss how far selection has come into play in determining the result". This is key to understanding Darwin's retraction--the extensive human data did not support his previous conclusion that natural selection tends to equalize the sexes. For one, it did not account for the curious, but robust finding in human demography that there exists a world-wide sex ratio towards boy births (103 to 100). Darwin's argument for his retraction in the second edition is made clear when we consider that (as opposed to the first edition's version of the "supplement") Darwin is using the additional data collected on "man" as a basis for his reasoning.

Revisions to the "Supplement on the proportional numbers of the two sexes in animals belonging to various classes"

Darwin uses the human demographic data because, as he puts it, "the proportion [of sexes] are known with certainty only in mankind" (p. 242). Darwin is referring to the well supported finding in human demography (that I mentioned in the introduction) that world-wide more boys are born than girls. First discovered by the pioneering demographer, John Graunt in 1662, and first shown to be statistically significant by John Arbuthnot in 1710, (see Sober 2011 for a discussion) by the time Quetelet published *Sur L'homme* in 1835 the skew towards male births was well supported by tens of millions of census data all over the world. In the supplement, Darwin reports on data in a variety of districts throughout England (between 1857 and 1866) citing a variety of human statistical surveys, paying particular attention to variation between the overall English ratio of 104.5 males for every 100 females and the ratios for separate districts and over separate years. Darwin reports that that the overall English disproportion of males decreased between the census taken at 1857 (105.2) and 1865 (104.0). Darwin continues:

Looking to separate districts, in Buckinghamshire (where about 5000 children are annually born) the mean proportion of male to female births, during the whole period of the above ten years, was as 102.8 to 100; whilst in N. Wales (where the average annual births are 12,873) it was as high as 106.2 to 100. Taking a still smaller district, viz., Rutlandshire (where the annual births average only 739), in 1864 the male births were as 114.6, and in 1862 as only 97.0 to 100; but even in this small district the average of the 7385 births during the whole ten years, was as 104.5 to 100; that is in the same ratio as throughout England." (1874, p. 242).

Next, Darwin provides data outside of England, showing that "the proportions are sometimes slightly disturbed by unknown causes". Darwin's report continues as before to look at variations in the proportion of male to females among certain groups of people.

"Faye states "that in some districts of Norway there has been "during a decennial period a steady deficiency of boys, whilst in others the opposite condition has existed." In France during forty-four years the male to the female births have been as 106.2 to 100; but during this period it has occurred five times in one department, and six times in another, that the female births have exceeded the males. In Russia the average proportion is as high as 108.9, and in Philadelphia in the United States as 110.5 to 100.49 The average for Europe, deduced by Bickes from about seventy million births, is 106 males to 100 females. On the other hand, with white children born at the Cape of Good Hope, the proportion of males is so low as to fluctuate during successive years

between 90 and 99 males for every 100 females. It is a singular fact that with Jews the proportion of male births is decidedly larger than with Christians: thus in Prussia the proportion is as 113, in Breslau as 114, and in Livonia as 120 to 100; the Christian births in these countries being the same as usual, for instance, in Livonia as 104 to 100” (p. 243).

To understand why Darwin is interested in variation in group averages some historical background is in order. For early Natural theologians, the sex ratio skew towards male births was evidence for the existence of a population-level natural law imposed by a benevolent God. 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). Yet, soon demographers revealed a multitude of such aggregate laws among humans including stable death rates, birth rates, population growth rates. In 1827 Quetelet and André Guerry discovered frightful stable regularities in a variety of non-benevolent features of humans, including regional crime rates (27 years of stable crime rates in Paris), divorce rates, suicide rates and jury conviction rates. If divine intervention is not a suitable explanation for non-benevolent statistical constancy, what is?

For advocates of Quetelet’s “social physics” the presence of stable averages in the population data was evidence of a persistence of causes—as opposed to divine causes—that reveal themselves in the aggregate⁶ statistical data. Stable averages are what we should expect to see if individuals in a population share some common causal feature, even if these features aren’t experienced by all individuals or aren’t experienced all in the same way. Quetelet coined the term “average man”—based upon the law of large numbers—to capture the idea. This is the basis of what we’ve been calling the “method of group differences”. Different group averages revealed in very large samples suggest real causal differences between groups. Average height differences between Belgian and French conscripts suggests that developmental causal differences exist between the Belgians and French awaiting further analysis for their details. The task for social physicists was to determine the “proper degree of influence” of the various causes that correlate with different group averages.

In *Sur L’homme* (which Darwin references in 1838) Quetelet’s analysis of the human

6. Quetelet defined his “fundamental principle” of social physics 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).

sex ratio data served as a showcase of his statistical method of differences (see Ariew 2007, 2008, and under review, for longer discussions). To determine potential causes of the world-wide skew toward male births, Quetelet reports on tables that count sex ratios for families under a variety of conditions, looking for skews in these sub-groups that vary from the overall proportion. Quetelet rules out climate as a potential factor on the basis of tables that report similar sex ratio skews towards boys for hotter regions in the south of France (105.95 to 100) and states and providences for a variety of locations in the principle European states (which average 106 to 100). Data from white families living near the equator in the Cape of Good Hope are an exception, showing a slight skew towards female births (6604 to 6789). However, that is counter-balanced by data from slave families where the sex ratio towards boys reappears, albeit slightly (2936 to 2826).

There is little doubt that Darwin was applying the same technique in the supplement. Following his report of the stable sex ratio skew towards boys, he shifts to an exposition of “the proportions [of the sex ratio data] are sometimes slightly disturbed by unknown causes” (p. 242). Looking back at the various data Darwin reports (cited above) in Norway, some departments in France, Philadelphia, Jews in Prussia, etc—Darwin cites Quetelet’s data on white children born at the Cape of Good Hope. In the corresponding footnote, Darwin writes: “For the Cape of Good Hope, Quetelet as quoted by Dr. H. H. Zouteveen, in the Dutch Translation of this work (vol. i. p. 417), where much information is given on the proportion of the sexes” (p. 243).

This is not the only occasion where Darwin re-reports Quetelet’s data. According to Quetelet, tables that compare illegitimate vs. legitimate births in a sample of states and provinces all over Europe show that overall proportion of male births decreases when the births are “illegitimate” (101.55) as opposed to “legitimate” (106.07). Quetelet’s cites Poisson and Charles Babbage as sources on his data. Darwin does too. Citing a survey from Babbage in 1828, Darwin reports: “It seems at first sight a mysterious fact that in different nations, under different conditions and climates, in Naples, Prussia, Westphalia, Holland, France, England and the United States, the excess of male over female births is less when they are illegitimate than when legitimate. In the next section Darwin reports that “It has often been supposed that the relative age of the two parents determines the sex of the offspring”. While Darwin cites a “Prof. Leuckart” as his source, in two diary entries of 1838 (cited in the Intro) Darwin correctly reports Quetelet’s conclusion that ‘differential age of parents’ to be the major contributing factor for the sex ratio skew for it appears to underlie in much of the other variational data. As Quetelet wrote, the proportion of male births is not so great in manufacturing towns and in the English countryside because in those places, men tend to marry at a later age and “present a greater difference of age to the women whom they espouse”. Quetelet reported on tables that demonstrate that age of either fathers or mothers taken separately makes no difference in the proportions of males and females of their children. Quetelet also

reproduced a chart showing that widowers tend to produce more female children—in fact, the shift of the skew is dramatic with an average of 79.7 males for 100 females and a trend that shows the skew towards females increases as the age of the widowers is increased. Quetelet concluded: “the age of the parents will be the principal regulator which determines the magnitude of the ratio between the births of the two sexes” (p. 14). This is what Darwin was referring to in his two diary entries in 1838.

In the final paragraph on data collected about human male and female ratios, Darwin considers a variety of extant accounts for sex determination, including the relative age of the two parents (as we saw, above, was Quetelet’s theory), “the period of impregnation relative to the state of the female”, the season of the year, the economic status of the parents, residence (city or country), immigration status, and the number of mates per person. Darwin challenges a few of these with reports of failed tests. For example, against number of mates as a factor, Darwin cites “Dr. J. Cambell’s” work that shows that male to female proportions do not change between practitioners of polygamy and monogamy. This is an instance of the method of group differences in action. If there is no change in the averages between groups, then, the factors that distinguish the groups (polygamy, monogamy) are not causal developmental factors in the trait in question (sex ratios).

In the supplement, Darwin is constantly looking for evidence that sex ratio can be altered by selection. In the second edition he hones in on data revealing the grim fact that a large disproportion of males are still born or die in the infant years:

“The fact is, that for every 100 still-born females, we have in several countries from 134.6 to 144.9 still-born males. During the first four or five years of life, also, more male children die than females; for example in England, during the first year, 126 boys die for every 100 girls—a proportion which in France is still more unfavourable.”

What are the potential causes? According to an account by Dr. Stockton-Hough, there is a greater tendency of males to have developmental defects. Darwin supplements this with his own hypothesis that males have a greater tendency than females to be variable in body structure. Consequently, “variations in important organs would generally be injurious”. For example, greater male head sizes makes “males...more liable to be injured during parturition”.

Darwin will use his hypothesis in the next section when considering the causes of sex ratio unity among illegitimate births.

Argument for sexual selection in illegitimate births.

In 1829 Charles Babbage reported a curious finding that the sex ratio proportion is closer to unity among illegitimate births. In contrast, among legitimate births the sex ratio skews towards males in a proportion that is closer to that of the general

population. As Quetelet noted in 1835, Darwin recognizes that results are consistent across a variety of demographic conditions, “in different nations, under different conditions and climates, in Naples, Prussia, Westphalia, Holland, France, England and the United States” (p. 244). Darwin first dismisses alternative explanations: “This has been explained by different writers in many different ways, as from the mothers being generally young, from the large proportion of first pregnancies, &c.”) and suggests his own explanation which begins with sexual selection: “the stronger males having conquered the weaker in their struggles for the possession of the females” results in males being larger than females at birth. The problem is, as Darwin reported in the previous selection, larger males are more susceptible to injury or death during parturition. This is particularly problematic for illegitimate births because their mothers are more liable to “undergo bad labours” for a variety of reasons, from “attempts at concealment by tight lacing, hard work, distress of mind, &c.” Darwin concludes, “this probably is the most efficient of all the causes of the proportion of males to females born alive being less amongst illegitimate children than amongst the legitimate”, and sums up his argument from sexual selection: “we have the curious fact that we may attribute the more frequent deaths of male than female infants, especially amongst the illegitimate, at least in part to sexual selection” (p. 246).

Recall in the first edition, Darwin’s thought experiments both begin with populational variants that produce fewer excess of one sex over another which, as a result of their hypothetical advantage, either lead to an overall increase in population numbers, or a corresponding decrease in the alternative sex. Argument from sexual selection in the second edition also begins with a population that contains fewer excess of males over females, yet the argument strategy is entirely different. Darwin is trying to find the best explanation for a fact grounded in actual human demographic data that “the excess of male over female births is less when they are illegitimate than when legitimate”. Rather than assuming the existence of a proximate cause that confers reproductive advantage, Darwin seeks a plausible proximate explanation that best fits a range of biological and social facts, including the disproportion of male still births (from the English and French demographic data) and the social pressures on women carrying illegitimate children. Only then does Darwin offer his sexual selection explanation as a speculation.

“The proportion of the sexes in relation to natural selection”.

Perhaps Darwin’s most significant revision of the second edition was to eliminate the entire section “On the Power of Natural Selection to regulate the proportional Numbers of the Sexes, and General Fertility” which contained the thought experiments and famous conclusion about natural selection always favoring the unity of sexes. Darwin replaced it with a new section, “The proportion of the sexes in relation to natural selection” (1760 words) with the primary objective whether humans—through a variety of

social practices—have altered “his own sex-producing power” (p. 255). The revised section is a continuation of Darwin’s strategy in the “supplement” to try to confirm selection hypotheses against real statistical data.

The revised section contains several distinct arguments. To demonstrate that humans can by selection influence its sex producing powers it must be shown that the feature is both inherited and that variants have an advantage in the battle for life. Darwin divides the section accordingly. The first half evaluates two arguments, one by analogy, one from sex ratio data collected among tribes, which purportedly show that the sex-producing power is inherited. Darwin will ultimately conclude that the statistical data is insufficient to confirm them. In the second half Darwin evaluates the evidence that possessing a sex-altering capacity would provide an advantage, first to human communities that possess it, second to individuals. Darwin concludes in this section that given all the various attempts to “trace out the complication of causes” presented in both the supplement and the present section, there is not enough evidence to confirm or disconfirm a selective advantage to either human community or individuals. Darwin compares the human case with that of the paradigmatic cases among non-human animals where either group selection or individual selection best explains the preponderance of one sex over another. Except for tribes where defense is paramount, there are no cases where humans provide the clearcut evidence of selection favoring disproportionate numbers of either sex. And, this ultimately provides him sufficient reason for his retraction.

Female infanticide

Darwin first evaluates an argument by analogy based upon anecdotal evidence. Female cows, cattle, and humans sometimes feature the tendency to produce more children of one sex rather than another. If the sex producing capacity is like any other inherited biological “peculiarity”, then by analogy, the sex producing capacity is inherited. The argument is reinforced by Mr. J. Downing—a “good authority”—who reports that indeed sex production in cattle is inherited. So, by analogy, sex production is likely an inherited feature of horses and humans. Darwin’s evaluation is that while the argument by analogy provides some “reason to suspect that in some cases” humans can by selection alter its own sex producing power, “I have very little evidence on this head”.

Darwin next switches to a more promising argument by Col Marshall involving the practice of female infanticide among the Todas tribe of India. Marshall’s argument relies on actual sex ratio data (196 people of all ages) and a simple application of the method of group differences. While the Todas used to practice female infanticide, it has since been discontinued. Among children born in the later years the overall proportion skews male by a ratio of 124 to 100. Col. Marshall then lays out an “ingenious” selection account to explain the male bias (Darwin quotes Col. Marshall):

"Let us for the purpose of illustration take three families as representing an average of the entire tribe; say that one mother gives birth to six daughters and no sons; a second mother has six sons only, whilst the third mother has three sons and three daughters. The first mother, following the tribal custom, destroys four daughters and preserves two. The second retains her six sons. The third kills two daughters and keeps one, as also her three sons. We have then from the three families, nine sons and three daughters, with which to continue the breed. But whilst the males belong to families in which the tendency to produce sons is great, the females are of those of a converse inclination. Thus the bias strengthens with each generation, until, as we find, families grow to have habitually more sons than daughters." (P. 256).

Darwin critique is swift; Col. Marshall's "numbers are so extremely scanty". That is, the samples are too small (only 196 members of the Todas tribe) to sufficiently demonstrate that the sex producing tendency is inherited. Darwin is right, the method of group differences is an application of the probability law of error which depends on very large samples for its inferential strength. Small sample sizes insufficiently rule out that the effect is coincidental. While Darwin doesn't say it, only those who think Darwin is completely ignorant at math would require Darwin's explicit assent to the law of error to accept the interpretation that Darwin's criticism is based on good statistical methods.

To compensate for Col. Marshall's small samples, Darwin reports that he has "searched for additional evidence" that would support the assumption that that sex producing power is inherited in humans. But, Darwin warns, he "cannot decide whether what I have found is trustworthy". And, this is, I believe, a sufficient reason for Darwin's retraction.

Nevertheless, Darwin provides the data he collected among tribes that once (but no longer) practice female infanticide, including the Maories of New Zealand and the various tribes inhabiting the Sandwich Islands. The data report is roughly two pages long but while various samples suggest a skew towards non-adult males, in each case Darwin indicates problems with the quality of the data. For the Maories Darwin complains: "the number are not large, and as the census was not accurate, uniform results cannot be expected" (p. 257). The data from careful census of males and females in the Sandwich Islands contains larger samples. And Darwin asserts more confidence in the results and admits that the data provides some evidence to believe that infanticide could alter the sex producing power in humans (as Col. Marshall argued).

Yet, in the end Darwin is skeptical:

"From the several foregoing cases we have some reason to believe that infanticide practised in the manner above explained, tends to make a male-producing race; but I am far from supposing that this practice in the case of man, or some analogous process with other species, has been the sole determining cause of an excess of males".

Darwin provides two reasons to be skeptical. First, there are alternative explanations to female infanticide that could explain the male skewing in the tribal data; for instance, “the greater facility of parturition amongst savages, and the less consequent injury to their male infants, would tend to increase the proportion of live-born males to females.” Second, there seems to be no necessary link between the “savage life” and the excess of males. To make the case Darwin refers to an earlier discussion comparing the populations of Norfolk Islanders and Tasmanians. The former was composed of crossed offspring from the Tahitians and English, while the Tasmanians were uncrossed. In each population the sex ratio was identical between males and females (p. 191 for the Norfolk Islanders, p. 184 for the Tasmanians).

The selective advantage of altering sex ratios.

Having concluded that the case of female infanticide provides insufficient evidence that sex producing power is inherited among humans, Darwin attends to the issue of whether the selective strategy of destroying one sex in favor of another (as in the case of female infanticide) would modify the sex-producing capacities of any animal species. His answer is that it is unlikely. In paradigmatic cases of selection favoring disproportionate numbers of one sex or another the sex producing tendency arises by the overproduction (rather than the destruction) of one sex, and that the advantage the tendency confers is at the level of groups rather than individuals. He cites several examples.

* Social bees and insects “which produce a vast number of sterile and fertile females”. Communities which “contained females having a strong inherited tendency to produce more and more females” would flourish better than other communities, hence, “an unequal sex-producing tendency would be ultimately gained through natural selection”.

* Animals living in herds or troops, such as “in which the males come to the front and defend the herd, as with the bisons of North America and certain baboons”: Groups that better defend the herds would be a good environment for females who possess male-producing tendencies to thrive. Darwin mentions that one of the reasons some tribes practice female infanticide is for the need of male protection. But, as he has shown above, there is insufficient evidence that among humans the male producing tendency is inherited.

In the last section Darwin considers whether there would be a selective advantage for any individual female to robustly produce any particular ratio—equal or disproportionate. Again, he answers in the negative. Admittedly certain fishes and barnacles in which two or more males are required to fertilize the females there could be a distinctive advantage for the over-production of males (and they do). But, Darwin retorts, no one knows how the male-producing tendency actually arose—if by selection

or chance—so,⁷ fishes and barnacles do not provide sufficient evidence of individual selection favoring the sex producing tendency.

We have a fairly comprehensive answer to the “mystery” of Darwin’s retraction in the second edition of the *Descent of Man*. Darwin’s previous claim—that natural selection always favors equality of sexes—was based on thought experiments without actual evidence of natural selection favoring equality of the sexes. In the second edition Darwin put his claim to the test against actual empirical evidence drawn primarily from human demographic data on sex ratio skews for a range of populations. In the end, Darwin finds no conclusive evidence. In fact, the preponderance of evidence among humans is that there exists a world-wide sex ratio towards male births. Among the likely proximate causes of the human skew that Darwin surveys, including Quetelet’s relative age of marriage and female infanticide among certain tribes, he finds no conclusive evidence that the feature is inherited or would present a selective advantage (either by group or individual selection). So, more than finding reasons to dismiss his previous claims about selection favoring equalization, Darwin in the revision finds no conclusive reasons to believe that selection favors the production of any particular ratio.

Conclusion

The objective of Fisher’s 1953 presidential address was to identify several instances in the 19th and early 20th century where statistical methodology “was responsible for a goodly number of fundamental advances” in science. Fisher offers three examples, none of which include Darwin’s accomplishments (Fisher’s three examples were Charles Lyell’s construction of the geological time scale, James Clerk Maxwell’s contributions to the Kinetic Theory of Gases, and Johannes Schmidt’s discovery of the source of all European freshwater river eelers in the Saragossa Sea.) Fisher’s neglect of Darwin’s published statistical work is unfortunate. He missed out on an opportunity to highlight the several occasions where Darwin applied statistical methodology to advance his ideas about evolution. In previous chapters (Ariew 2022 and Ariew forthcoming) I discuss two instances.

In the first, Darwin applied simple calculations (the “rule of three”) over plant data on ratios of species to genera to predict whether a genera with few species is growing by speciation or shrinking by extinction. The work was instrumental to his idea in the *Origin of Species* that the economy of nature is dynamic, with constant cycles of extinction and adaptive speciation. In turn it helped him construct his principle of divergence to

7. Darwin does in fact address the issue in his article in *Nature* in 1874—the same year the second edition was published. I suspect but do not know whether Darwin had that in mind when he wrote the passage. I suspect he did because the statistical argument he presents in *Nature* is not one of a distinctive advantage to the sex producing tendency but rather a consequence of stunted development and random mating.

explain the process of speciation.

For the second instance, I discuss Darwin's 1873 letter to *Nature*, where Darwin provides a speculative answer to the question, how it is possible for rudimentary structure (like that of the males of certain Cirripedes) to evolve? To answer, Darwin modeled trait variation according to what was "known from the researchers of Quetelet on the height of man" that the variation of biological features are distributed according to the astronomer's law of error. With Darwin's statistical model of trait of trait variation he anticipated Fisher's contributions to the 20th century modern synthesis.

In this essay I expounded upon a third instance where Darwin applied statistical analysis of human sex ratios (including applications of the method of group differences) to disconfirm and retract his previously held conviction that natural selection always tends to equalize the sexes.

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