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SEX AND JUSTICE[1]

> Some have not hesitated to attribute to men in that state of nature the concept of just and unjust, without bothering to show that they must have had such a concept, or even that it would be useful to them.
>
> – Jean-Jacques Rousseau, *A Discourse on Inequality*

IN 1710 there appeared in the *Philosophical Transactions of the Royal Society of London* a note entitled "An argument for Divine Providence, taken from the constant Regularity observ'd in the Births of both Sexes." The author, Dr. John Arbuthnot, was identified as "Physitian in Ordinary to Her Majesty, and Fellow of the College of Physitians and the Royal Society." Arbuthnot was not only the Queen's physician. He had a keen enough interest in the emerging theory of probability to have translated the first textbook on probability, Christian Huygens's *De Ratiociniis in Ludo Aleae*, into English – and to have extended the treatment to a few games of chance not considered by Huygens.

Arbuthnot argued that the balance between the numbers of the men and women was a mark of Divine Providence "for by this means it is provided that the Species shall never fail, since every Male shall have its Female, and of a Proportionable Age." The argument is not simply from approximate equality of the number of sexes at birth. Arbuthnot notes that males suffer a greater mortality than females, so that exact equality of numbers at birth would lead to a deficiency of males at reproductive age. A closer look at birth statistics shows that "to repair that loss, provident Nature, by the disposal of its wise Creator, brings forth more Males than Females; and that in almost constant proportion." Arbuthnot supports the claim with a table of christenings in London from 1629 to 1710 that shows a regular excess of males and with a calculation to show that the probability of getting such a regular excess of males by chance alone was exceedingly small. (The calculation has been repeated throughout the history of probability[2] with larger data sets, and with the conclusion that the male-biased sex ratio at birth in humans is real.) Arbuthnot encapsulates his conclusion in this scholium:

> From hence it follows that Polygamy is contrary to the Law of Nature and Justice, and to the Propagation of Human Race; for where Males and Females are in equal number, if one Man takes Twenty Wives, Nineteen Men must live in Celibacy, which is repugnant to the Design of Nature; nor is it probable that Twenty Women will be so well impregnated by one Man as by Twenty.[3]

Arbuthnot's note raises two important questions. The fundamental question – which emerges in full force in the scholium – asks why the sex ratio should be anywhere near equality. The answer leads to a more subtle puzzle: Why should there be a slight excess of males? Arbuthnot's answer to the fundamental question is that the Creator favors monogamy, and this leads to his answer to the second question. Given the excess mortality of males – for other reasons in the divine plan – a slight excess of males at birth is required to provide for monogamy. Statistical verification of the excess of males – for which there is no plausible alternative explanation – is taken as confirmation of the theory.

The reasoning seems to me somewhat better than commentators make it out to be, but it runs into difficulties when confronted with a wider range of biological data. The sex ratio of mammals in general, even harem-forming species, is close to 1/2. In some such species twenty females *are* well impregnated by one male. A significant proportion of males never breed and appear to serve no useful function. What did the creator have in mind when he made antelope and elephant seals?

If theology does not offer a ready answer to such questions, does biology do any better? In the second edition of *The Descent of Man*, Darwin could not give an affirmative answer:

> In no case, as far as we can see, would an inherited tendency to produce both sexes in equal numbers or to produce one sex in excess, be a direct advantage or disadvantage to certain individuals more than to others; for instance, an individual with a tendency to produce more males than females would not succeed better in the battle for life than an individual with an opposite tendency; and therefore a tendency of this kind could not be gained through natural selection . . . 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.[4]

Nevertheless, in the first edition, Darwin had already cracked the fundamental problem of approximate equality – but not the problem of the slight excess of males that excited Arbuthnot – only to withdraw this insight in the second. The full explanation, as we shall see, was given later by the great geneticist and statistician Ronald Fisher.

THE PROBLEM OF JUSTICE

Here we start with a very simple problem: we are to divide a chocolate cake between us. Neither of us has any special claim as against the other. Our positions are entirely symmetric. The cake is a windfall for us, and it is up to us to divide it. But if we cannot agree how to divide it, the cake will spoil and we will get nothing. What we ought to do seems obvious. We should share alike.

One might imagine some preliminary haggling: "How about 2/3 for me, 1/3 for you? No, I'll take 60% and you get 40% . . ." but in the end each of us has a bottom line. We focus on the bottom line, and simplify even more by considering a model game.[5] Each of us writes a final claim to a percentage of the cake on a piece of paper, folds it, and hands it to a referee. If the claims total more than 100%, the referee eats the cake. Otherwise we get what we claim. (We may suppose that if we claim less than 100% the referee gets the difference. You may well think of interesting variations, but for now we will stick to the problem as stated. We will touch on more general bargaining situations in the postscript.)

What will people do, when given this problem? I expect that we would all give the same answer – almost everyone will claim half the cake. In fact, the experiment has been done. Nydegger and Owen[6] asked subjects to divide a dollar among themselves. There were no surprises. All agreed to a fifty-fifty split. The experiment is not widely discussed because it is not thought of as an anomaly.[7] Results are just what everyone would have expected. It is this uncontroversial rule of fair division to which I now wish to direct attention.

We think we know the right answer to the problem, but why is it right? In what sense is it right? Let us see whether *informed rational self-interest* will give us an answer. If I want to get as much as possible, the best claim for me to write down depends on what you write down. Likewise, your optimum claim depends on what I write down. We have two interacting optimization problems. A solution to our problem will consist of solutions to each optimization problem that are in *equilibrium*.

We have an equilibrium in informed rational self-interest if each of our claims is optimal given the other's claim. In other words, given my claim you could not do better by changing yours and given your claim I could do no better by changing mine. This equilibrium is the central equilibrium concept in the theory of games. It was used already in the nineteenth century by the philosopher, economist and mathematician Antoine-Augustin Cournot, but it is usually called a *Nash equilibrium* after John Nash,[8] who showed that such equilibria exist in great generality. Such an equilibrium would be even more compelling if it were not only true that one could not gain by unilaterally deviating from it, but also that on such a deviation one would definitely do worse than one would have done at equilibrium. An equilibrium with this additional stability property is a *strict Nash equilibrium*.

If we each claim half of the cake, we are at such a strict Nash equilibrium. If one of us had claimed less, he would have gotten less. If one of us had claimed more, the claims would have exceeded 100% and he would have gotten nothing. However, there are many other strict Nash equilibria as well. Suppose that you claim 2/3 of the cake and I claim 1/3. Then we are again at a strict Nash equilibrium for the same reason. If either of us had claimed more, we would both have gotten nothing, if either of us had claimed less, he would have gotten less. In fact, every pair of positive[9] claims that total 100% is a strict Nash equilibrium. There is a profusion of strict equilibrium solutions to our problem of dividing the cake, but we want to say that only one of them is *just*. Equilibrium in informed rational self-interest, even when strictly construed, does not explain our conception of justice.

Justice is blind, but justice is not completely blind. She is not ignorant. She is not foolish. She is informed and rational, but her interest – in some sense to be made clear – is not self-interest. Much of the history of ethics consists of attempts to pin down this idea. John Harsanyi[10] and John Rawls[11] construe just rules or procedures as those that would be gotten by rational choice behind what Rawls calls a "veil of ignorance": "Somehow we must nullify the effects of specific contingencies which put men at odds and tempt them to exploit social and natural circumstances to their own advantage. In order to do this I assume that parties are situated behind a veil of ignorance."[12] Exactly what the veil is supposed to hide is a surprisingly delicate question, which I will not pursue here. Abstracting from these complexities, imagine that you and I are supposed to decide how to divide the cake between individuals A and B, under the condition that a referee will later decide whether you are A and I am B or conversely. We are supposed to make a rational choice under this veil of ignorance.

Well, who is the referee and how will she choose? I would like to know, in order to make my rational choice. In fact, I don't know how to make a rational choice unless I have some knowledge, or some beliefs, or some degrees of belief about this question. If the referee likes me, I might favor 99% for A, 1% for B, or 99% for B, 1% for A (I don't care which) on the theory that fate will smile upon me. If the referee hates me, I shall favor equal shares.

It might be natural to say, "Don't worry about such things. They have nothing to do with justice. The referee will flip a fair coin." This is essentially Harsanyi's position. Now, *if all I care about is expected amount of cake* – if I am neither risk averse nor a risk seeker – I will judge every combination of portions of cake between A and B that uses up all the cake to be optimal: 99% for A and 1% for B is just as good as 50%–50%, as far as I am concerned. The situation is the same for you. The Harsanyi–Rawls veil of ignorance has not helped at all with this problem (though it would with others.)[13] We are left with all the strict Nash equilibria of the bargaining game.[14]

Rawls doesn't have the referee flip the coin. We don't know anything at all about Ms. Fortuna. In my ignorance, he argues, I should guard myself by acting as if she doesn't like me.[15] So should you. We should follow the decision rule of maximizing minimum gain. Then we will both agree on the 50%–50% split. This gets us the desired conclusion, but on what basis? Why should we both be paranoid? After all, if there is an unequal division between A and B, Fortuna can't very well decide against both of us. This discussion could, obviously, be continued.[16] But, having introduced the problem of explaining our conception of justice, I would like to pause in this discussion and return to the problem of sex ratios.

EVOLUTION AND SEX RATIOS

Darwin, in the first edition of *The Descent of Man*, saw the fundamental answer to the puzzle about the evolution of sex ratios. Let us assume that the inherited tendency to produce both sexes in equal numbers, or to produce one sex in excess, does not affect the expected number of children of an individual with that tendency, and let us assume random mating in the population. Darwin pointed out that the inherited tendency can nevertheless affect the expected number of grandchildren.

In the species under consideration, every child has one female and one male parent and gets half its genes from each. Suppose there were a preponderance of females in the population. Then males would have more children on average than females and would contribute more genes to the next generation. An individual who carried a tendency to produce more males would have a higher expected number of grandchildren than the population average, and that genetically based tendency would spread through the population. Likewise, in a population with a preponderance of males, a genetic tendency to produce more females would spread. There is an evolutionary feedback that tends to stabilize at equal proportions of males and females.

Notice that this argument remains good even if a large proportion of males never breed. If only half the males breed, then males that breed are twice as valuable in terms of reproductive fitness. Producing a male offspring is like buying a lottery ticket on a breeding male. Probability one-half of twice as much yields the same expected reproductive value. The argument is general. Even if 90% of the males were eaten before having a chance to breed – as happens to be the case with domestic cattle – evolutionary pressures will still drive the sex ratio to unity.

With this treatment of sex ratio, Darwin introduced strategic – essentially game theoretic – thinking into the theory of evolution. What sex ratio propensity is optimal for an individual depends on what sex ratio propensities are used by the other members of the population. A tendency to produce mostly males would have high fitness in a population that produced mostly females but a low fitness in a population that produced mostly males. The tendency to produce both sexes in equal numbers is an *equilibrium* in the sense that it is optimal relative to a population in which everyone has it.

We now have a dynamic explanation of the general fact that the proportions of the sexes in mammals are approximately equal. But what about Arbuthnot's problem? Why are they not exactly equal in man? Arbuthnot's argument that the excess of males in the human population cannot simply be due to sampling error has been strengthened by subsequent studies. Sir Ronald Fisher[17] has an answer to this problem as well. The simplified argument that I have given so far assumes that the parental cost of producing and rearing a male is equal to that of producing and rearing a female. To take an extreme case, if a parent using the same amount of resources could produce either two males or one female, and the expected reproductive fitness through a male were more than one-half of that through a female, it would pay to produce the two males. Where the costs of producing and rearing different sexes are unequal, the evolutionary feedback leads to a propensity for *equal parental investment* in both sexes, rather than to equal proportions of the sexes.

The way Fisher applies this to humans depends on the fact that here the sex ratio changes during the time of parental care. At conception the ratio of males to females is perhaps as high as 120 to 100. But males experience greater mortality during parental care, with males and females being in about equal proportion at maturity, and females being in the majority later. The correct period to count as the period of parental care is not entirely clear, since parents may care for grandchildren as well as children. Because of the higher mortality of males, the average parental expenditure for a male at the end of parental care will be higher than that for a female, but the expected parental expenditure for a male at birth should be lower. Then it is consistent with the evolutionary argument that there should be an excess of males at conception and birth that changes to an excess of females at the end of the period of parental care. Fisher remarks: "The actual sex ratio in man seems to fulfill these conditions quite closely."[18]

JUSTICE: AN EVOLUTIONARY FABLE

How would evolution affect strategies in the game of dividing a cake? We start by building an evolutionary model. Individuals, paired at random from a large population, play our bargaining game. The cake represents a quantity of Darwinian fitness – expected number of offspring – that can be divided and transferred. Individuals reproduce, on average, according to their fitness and pass along their strategies to their offspring. In this simple model, individuals have strategies programmed in, and the strategies replicate themselves in accord with the evolutionary fitness that they receive in the bargaining interactions.

Notice that in this setting it is the strategies that come to the fore; the individuals that implement them on various occasions recede from view. Although the episodes that drive evolution here are a series of two-person games, the payoffs are determined by what strategy is played against what strategy. The identity of the individuals playing is unimportant and is continually shifting. This is the *Darwinian Veil of Ignorance*. It has striking consequences for the evolution of justice.

Suppose that we have a population of individuals demanding 60% of the cake. Meeting each other they get nothing. If anyone were to demand a positive amount less than 40%, she would get that amount and thus do better than the population average. Likewise, for any population of individuals that demand more than 50% (and less than 100%). Suppose we have a population demanding 30%. Anyone demanding a bit more will do better than the population average. Likewise for any amount less than 50%. This means that the only strategies[19] that can be equilibrium strategies under the Darwinian veil of ignorance are Demand 50% and Demand 100%.

The strategy Demand 100% is an equilibrium, but an unstable one. In a population in which everyone demands 100%, everyone gets nothing, and if a mutant popped up who made a different demand against 100 percenters, she would also get nothing. But suppose that a small proportion of modest mutants arose who demanded, for example, 45%. Most of the time they would be paired with 100 percenters and get nothing, but some of the time they would be paired with each other and get 45%. On average their payoff would be higher than that of the population, and they would increase.