# Power, Sex, Suicide

## Mitochondria and the Meaning of Life

### Part 6. Battle of the Sexes: Human Prehistory and the Nature of Gender

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# About

**Dr Nick Lane** is a British biochemist and writer. He was awarded the first Provost's Venture Research Prize in the Department of Genetics, Evolution and Environment at **University College London**, where he is now a Reader in Evolutionary Biochemistry. Dr Lane's research deals with evolutionary biochemistry and bioenergetics, focusing on the origin of life and the evolution of complex cells. Dr Lane was a founding member of the UCL Consortium for Mitochondrial Research, and is leading the UCL Research Frontiers Origins of Life programme. He was awarded the 2011 BMC Research Award for Genetics, Genomics, Bioinformatics and Evolution, and the 2015 Biochemical Society Award for his sustained and diverse contribution to the molecular life sciences and the public understanding of science.

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What is the deepest biological difference between the sexes? Most of us, I imagine, would venture the Y chromosome, but this isn't actually the case. The Y chromosome is allegedly pivotal to our sexual development, yet its presence is far from categorical, even for us. About 1 in 60,000 women are known to carry a Y chromosome, giving them the typical masculine chromosome combination of XY, yet they are nonetheless female. One unfortunate example was the Spanish 60-metre hurdles champion Maria Patino, who was publicly humiliated and stripped of her medals in 1985 after failing a mandatory sex test, despite the fact she was plainly not a man, nor a drugs cheat. She was in fact 'androgen resistant' – her body could not respond to the natural presence of testosterone, and so she developed by default as a woman. She had no 'unfair' hormonal or muscular advantage. After a legal battle she was reinstated by the International Amateur Athletics Federation nearly three years later. The IAAF abolished the tests altogether in 1992, and in May 2004, in time for the Athens Olympics, the International Olympic Committee ruled that even transsexuals would be permitted to compete in the Games, as they, too, do not gain a hormonal advantage.

Interestingly, 1 in 500 female Olympic athletes carry a Y chromosome, substantially more than the general population, implying there might be some kind of physical advantage, albeit not hormonal. A relatively high proportion of models and actresses also carry a single Y chromosome. It seems to promote a long, leggy physique, ironically attractive to heterosexual men. Conversely, some men carry two X chromosomes but no Y chromosome; in their case, one X chromosome usually incorporates a tiny fragment of the Y chromosome, bearing a critical sex-determining gene, which stimulates development as a man, but this is not always the case: it's possible to develop as a man without any Y chromosome genes at all. Rather more common (about 1 in 500 male births) is the XXY combination, known as Klinefelter's syndrome. Strangely enough, men with this combination would once have qualified for the women's Olympic Games by the same test that disqualified Maria Patino – the second X chromosome marks them histologically as women, even though they are not. Various other unusual combinations are also possible, some giving rise to hermaphroditism, in which the organs of both sexes are present, for example both ovaries and testes.

The superficiality of the Y chromosome is exposed if we consider sex determination more widely across species. Essentially all mammals share the familiar X/Y chromosome system, but there are some exceptions. As regularly publicised in the media, the Y chromosome is in perpetual decline. With no possibility of recombination between Y chromosomes (men usually only have one copy), it is difficult to correct mutations, as there is no 'clean' copy that can act as a template, so mutations accumulate over many generations, potentially leading to a mutational melt-down. The Y chromosome has duly degenerated completely in some species, such as the Asiatic 'mole voles' Ellobius tancrei and E. lutescens. In one of these species, both sexes have unpaired X chromosomes; in the other, the females and males both carry two X chromosomes. Exactly how their sexes are determined remains an enigma, but it is reassuring to know that the decay of the Y chromosome does not inevitably herald the demise of men.

If we venture further afield the X and Y chromosomes soon begin to look parochial. The sex chromosomes of birds, for example, contain a different set of genes to the mammalian chromosomes, implying that they evolved independently; accordingly, they are denoted W and Z. Their inheritance reverses the mammalian pattern: males carry two Z chromosomes making them chromosomally equivalent to female mammals, whereas females carry a single copy of the W and Z chromosomes. Interestingly, in reptiles, the evolutionary ancestors of birds and mammals, both chromosomal systems exist, along with other variations. Most startlingly, sex determination in the cold-blooded reptiles often depends not on sex chromosomes at all, but on the temperature at which the eggs are incubated. In alligators, for example, males are produced from eggs incubated above about 34°C, and females from eggs cooler than about 30°C; if the temperature is intermediate, a mixture is produced. This relationship is reversed in other reptiles; in sea turtles, the females develop from eggs incubated at higher temperatures.

Even reptiles fail to exhaust the cornucopia of sex determinators. In Hymenoptera, such as ants, wasps and bees, the males often develop from an unfertilised egg, whereas the females develop from fertilised eggs. So if a queen bee mates with a drone, the daughters share three quarters of their genes, rather than half, as in the X/Y or W/Z systems. Such genetic similarities might have favoured selection at the level of the colony over that of individuals, facilitating the evolution of eusocial structures (in which reproduction is carried out by a specialised caste in a colony of non-reproductive individuals).

In some crustaceans, sex is not fixed but plastic: individuals can undergo a sex-change. Perhaps the most peculiar example is furnished by the diverse range of arthropods that become infected with the reproductive bacteria Wolbachia, which converts males into females, thus ensuring its own transmission in the egg (they are not passed on in sperm). In other words, sex is determined by infection. Other examples of sexual plasticity are unrelated to infection. For example, many tropical fish change sex, notably the colourful teleosts (the most common type of bony fish) that dwell in coral reefs – a source of confusion that could have added a whole new dimension to Finding Nemo. In fact, most reef fish switch sex at some point in their lives, and the few shrinking violets that don't are contemptuously labelled gonochoristic. The rest are ardently transsexual: males change to females and vice versa; some change sex in both directions, and others manage to be both sexes at the same time (hermaphrodites).

If any order emerges from this sexual cacophony, it's certainly not the Y chromosome. From an evolutionary point of view, sex seems as accidental and shifting as a kaleidoscope. One of the few enduring pillars is the occurrence of two sexes. With the exception of some fungi (which we'll come to later) there are few unequivocal examples of more than two sexes. What is rather more curious, though, is the need for any sexes at all. The trouble is that having two sexes halves the number of possible mates. This begs the question what's wrong with having only one sex, which amounts to having no sexes at all? That would give everyone twice the choice of partners, and indeed would spirit away the distinction between homosexuals and heterosexuals; couldn't everyone be happy? Unfortunately not. In this Part, we shall see that, for better or worse, we are generally doomed to two sexes. The culprits, need I say it, are mitochondria.

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