

Meiosis Is Not Gender Neutral

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In the past, when writing about an unidentified individual, be it a human or other animal, writers often used masculine as the default gender. Scientists, policymakers, and animals were referred to as *he*, regardless of the sex of the individual. “Prominent naturalists in the past wrote as though the oceans were stocked with male fish only or the skies filled with ganders but no geese” (Kevles 1986, p. vii). Nowadays, we try to be gender neutral but still slip into old ways, thereby hindering scientific progress. For example, infanticide was really understood only when it was approached from the perspective of the maternal parent (Hrdy 1999), nesting success in some birds was understood only after bonding by pairs of females was recognized (Young et al. 2008), and sexual selection was rendered a fully operational theory only once we understood the active role of females and their variability (Gowaty 1997). Here, I highlight a specific but still pervasive male-centric bias in biology, with the hope that we remedy this proximate problem and ultimately become more sensitive to gender bias in biology.

In describing *meiosis*, the process by which diploid cells are converted into haploid cells, every introductory biology textbook that I have ever seen describes the process that occurs in males but omits any description or even mention of meiosis in females. Textbooks in zoology, botany, genetics, and evolution depict meiosis—both in words and pictures—as the following set of events: (a) A diploid cell duplicates all its chromosomes. (b) Crossing-over recombination occurs (in prophase I). (c) Sister chromatids are independently segregated. (d) Meiosis I is completed, with two daughter cells—each with a diploid number of chromosomes. (e) Meiosis II occurs, in which both products of

meiosis I undergo a second reduction division to produce a pair of haploid cells. All four products of meiosis are portrayed as being of the same size and shape, and they are all functional.

Textbooks describe these five steps as proceeding sequentially without other intervening steps. Although my examination of first- and second-year university biology textbooks has not been exhaustive, I have found no exceptions. Therefore, textbooks beautifully describe meiosis in males and meiosis in isogamous taxa, in which there is only one size of gametes. But these textbooks fail to describe meiosis in females in anisogamic taxa, in which there are two different sizes of gametes (e.g., eggs and sperm).

In all animals except sea urchins and cnidarians (e.g., jellyfish, corals, anemones, hydras), female meiosis is halted and resumed only once a sperm nucleus has entered the meiotic female cell. The vernacular is that female meiosis is “arrested,” but this term is loaded with pejorative connotations (females, but not males, are arrested). Meiosis can be halted at virtually any step, from just after the duplication of all chromosomes to meiosis II. In humans, female meiosis is halted at the end of meiosis I. Human eggs, when they are fertilized, have twice as many chromosomes as do the sperm that fertilize them. Although halted female meiosis is a shared evolutionary innovation in most animals (*synapomorphy*; i.e., it is not ancestral in eukaryotes), it is still shocking that only male meiosis is depicted in textbooks, except for a handful of third- and fourth-year textbooks, at least some of which were written by feminist biologists.

Even more insidious, in all animals and plants, female meiosis is asymmetrical, whereas male meiosis is symmetrical. The symmetry of male meiosis seems to be universal in eukaryotes,

with all four meiotic products having the potential to be passed on to the next generation, as is depicted in all commonly used first- and second-year university textbooks. Although on average, most sperm have virtually no chance of having their chromosomes passed on to the next generation, all four products of male meiosis seem to be equally viable.

By contrast, only one of the products of female meiosis goes on to form a functional egg cell (which, in plants, may be after several intervening mitotic divisions) and has the opportunity to pass its DNA on to the next generation. In animals, the remaining products of female meiosis are discarded as polar bodies. In many animals, one of the products of meiosis I is discarded as a diploid (more accurately, 2C) polar body that never undergoes meiosis II, whereas the other product of meiosis I undergoes a second reduction to form a haploid egg and a haploid polar body. Thus, in animals, there are often three, not four, products of female meiosis, all but one of which degenerate. Many textbooks mention polar bodies while antithetically depicting female meiosis as being symmetrical, with four equally viable haploid products. Curiously, the asymmetry in female meiosis is usually mentioned only by feminist biologists, such as Ruth Hubbard. In many flowering plants, three of the four haploid products of female meiosis are discarded as polar bodies. In other flowering plants, either two or four of the haploid products of meiosis are retained in the haploid organism, which are called *bisporic* or *tetrasporic female gametophytes*. Ultimately, only one of the four products of flowering plant female meiosis contributes DNA to the egg cell and subsequent generations, even in bisporic or tetrasporic gametophytes. The other products of

female meiosis form the central cell, which itself grows into endosperm, and possibly also form the antipodal cells. The only exception for plants or animals contributing more than one of the haploid products of female meiosis to the next generation is in individuals with complete automixis (i.e., *central fusion* and *terminal fusion*), in which two of the haploid products of female meiosis immediately fuse with one another to restore diploidy. But even with this extreme form of self-fertilization, female meiosis is asymmetrical in that at most two, and not all, of the meiotic products can have their chromosomes transmitted to the next generation. The asymmetry of female meiosis seems universal, with usually one meiotic product (but occasionally two) having the potential to be passed on to the next generation. Note that the *potential* to be passed on to the next generation is very different from gametes *actually* being passed on to the next generation, which is very unlikely for both eggs and sperm.

Meiosis is a highly conserved form of cell division, with virtually no variation across all eukaryotes (Gorelick and

Carpinone 2009). For instance, although several authors have claimed that one-step meiosis exists (why go through chromosomal duplication only to then need a second reduction division?), all claims of one-step meiosis have been repudiated or are still equivocal. It is a shame that we do not highlight the one ubiquitous form of meiotic variation—symmetry versus asymmetry between the sexes—as well as the variation in most anisogamic animals for when sperm are needed to induce the resumption of halted female meiosis.

Feminist critiques of science have a solid basis, as was alluded to in the first paragraph (Kevles 1986, Gowaty 1997, Hrdy 1999, Young et al. 2008). Note, however, that “radical feminism rejects most scientific theories, data, and experiments not only because they exclude women, but also because they are not women-centered” (Rosser 1997, p. 32). Textbook views of meiosis help fuel such radical notions. Correcting the male-centric bias in meiosis to show sex-specific variation will enrich our appreciation of biological variation and may help persuade skeptical feminists that scientific epistemology

is worthwhile and compatible with feminist perspectives.

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doi:10.1525/bio.2012.62.7.2