

Male, Female and/or —?

How does nature define the sexes?

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Intersex individuals are coming out of the closet. Witness, for example, the 2003 Pulitzer Prize in Fiction for *Middlesex* (Eugenides, 2002). The story follows someone with 5-alpha-reductase deficiency, or late onset virilization (OMIM #607306). Imagine yourself raised as a girl, discovering at puberty (through cryptic, piecemeal clues) that you are male instead. —Or male *also*? —Or male *only now*? —Or “just” newly virile? The condition confounds the conventionally strict dichotomy of male and female, masculine and feminine. It teases a culture preoccupied with gender. What an opportunity for learning more about who we are through biology!

What are male and female, biologically? How does nature define the sexes, and sex itself? The questions seem simple enough! Seeking answers, however, may yield unexpected lessons—about the role of biological definitions; assumptions about universals, rarities and judgments about “normality”; and about the power of even mistaken conceptions of nature to shape culture.

Sorting the Sexes

Conceptualizing sex as male and female seems straightforward. In the standard version (familiar even to those unschooled in biology), females have two X-chromosomes, while males have an X and a Y. They have different gametes: one sessile, one mobile. That

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seems foundational. This seems to explain why male and female organisms have contrasting gonads, contrasting hormone-mediated physiologies, and contrasting secondary sex characteristics. Once-homologous organs follow divergent developmental trajectories. Perhaps even contrasting behaviors express the purported evolutionary imperative of each gamete: the “promiscuous” uncaring male of cheap sperm, and the cunning, protective female of big-investment eggs. The apparent alignment of the two sexes through all levels of biological organization seems to validate scientifically a sound categorization.

Good biologists know better. First, sex may be determined in many ways, from the “reversed” WZ system of birds (where females have the distinctive chromosome) to the haploid-diploid system of many insects. Crocodiles and turtles follow temperature cues, not genes alone; and the spoon worm *Bonellia* responds to the presence or absence of other females (Bainbridge, 2003, pp. 39-56; Roughgarden, 2004, pp. 203-205; Bercé et al., 2005). In humans, widely documented chromosomal rearrangements (XO in Turner’s syndrome and XXY in Klinefelter’s syndrome) are further exceptions to the conventional formula.

More challenging conundrums arise with XY females and XX males. In these rare human cases (~1/20,000), crossing over between the X and Y chromosomes results in the addition or deletion of the critical *Sry* gene, which regulates many other “male”-related genes (Bainbridge, 2003, pp. 17-21, 58; Roughgarden, 2004, pp. 198-202). Of course, these exceptions only seem to affirm another presumed, more fundamental reality: identity as fixed by genes (“Sacred Bovines,” April, 2005).

The fascinating puzzles continue. (Why not playfully challenge students' unquestioned commonplaces—their sacred bovines? The world is so incredible, why stuff it into pigeonholes? Indeed, we must guard against the label “scientifically known,” ironically discouraging any further inquiry.) In intersex humans (exemplified in *Middlesex*), hormonal levels, ineffective hormone receptors or developmental branches lead to mosaics of sexual characters. For example, external genitalia may contrast with internal gonads (Dreger, 1998, pp. 37-39). Bodies may exhibit almost any combination of sexual anatomies: position of gonads, urinary plumbing, large breasts, facial hair, hair loss, invaginations and protuberances, ejaculates and menses, and vocal timbre (pp. 84-106). All these traits do not sort neatly according to chromosomes *or* gonad type. Some such “mixed” patterns are actually typical within other mammal species, from spotted hyenas and kangaroo rats to bush babies and old world moles (Roughgarden, 2004, pp. 35-42). Male and female, one might learn, are suites of characters, not essential comprehensive dichotomies. Imagine the problem: What box do you check on a passport application?

Many fish, including wrasses, parrotfish, and groupers (and others found in tropical aquaria), *change* sex during their lifetimes (Roughgarden, 2004, pp. 30-35). In the cleaner wrasse, for example, a community typically has one male and many females, the male releasing a pheromone that inhibits male development. When the male dies, the largest female begins changing sex in a matter of hours to become the new male. In other species, such as the clown fish, males later become female (a detail not included in the popular film, *Finding Nemo*). Some gobies go even further, changing sex more than once. Organisms develop. Sexed anatomies and physiologies may change. Sex, it seems, need not be viewed as a predetermined or fixed identity. How informative might that be to an adolescent experiencing an emerging sexual body?

Of course, organisms need not be just male *or* female. Some are male *and* female simultaneously. Biology textbooks typically describe hermaphroditism, as found in snails, earthworms, barnacles and many deep sea fishes (Roughgarden, 2004, pp. 30-31). Most plants, too, have both male and female organs. Some mammals develop *ovotesticular* tissue or, rarely, both ovary *and* testis, although none seem to reproduce with both gamete types (Roughgarden, 2004, p. 41; Dreger, 1998, pp. 37, 73-74, 147-149, 159-161; Fausto-Sterling, 2000, pp. 51, 53). Similarly, the set of steroid hormones that contributes to various androgenic and gynoecogenic effects – once popularly envisioned as mutually exclusive “sex” hormones – are produced by male and female alike (Dreger, 1998, pp. 7-8; Fausto-Sterling, 2000, pp. 170-194; Roughgarden, 2004, pp. 215-221). Are we too accustomed to binary, either-or categories?

Finally, one may encounter problems sorting reproductive behaviors. The whiptail lizard is an often cited example, where females engage in pseudocopulation, critically stimulating parthenogenesis (Crews, 1987). Another

case involves the *fruitless* (*fru*) gene in fruit flies. Different mRNA transcripts of this one gene are spliced to produce three proteins in males, none in females. These contribute to developing a circuit of olfactory neurons that respond to pheromones and so control mating behavior. Recently, in a dramatic experiment, females were genetically manipulated to splice the mRNAs. They exhibited mating behavior towards other females. By contrast, males whose splicing was inhibited barely courted (Miller, 2005; Demir & Dickson, 2005). Behaviors, too, are hard to characterize as necessarily exclusively male or exclusively female.

Harvard political philosopher Harvey Mansfield recently characterized what he calls “manly men” (2006). Ironically, his phrase is far from redundant. Indeed, it underscores how behavior and sexed anatomies need *not* align according to any pattern. Remarkably, however, he nonetheless appeals to science to label certain behaviors as “manly,” or associated with only one sexed body: namely, behaviors like his (or perhaps, more tellingly, behaviors he values). In many species—for example, seahorses, some pipefish, and aquatic birds such as the wattled jacana, Wilson’s phalarope, and spotted sandpiper—males are primary protectors and nurturers of offspring (Roughgarden, 2004, pp. 45-48). Does one thus call these males “maternal”? –Or just “parental”? Mansfield’s mere use of the term “manliness” bristles with biological contradictions (on sex-biased behaviors, see Fausto-Sterling, 2000, pp. 115-232).

All these cases exemplify one virtue of comparative biology. They help us perceive who we are by showing us how organisms can be organized otherwise. Sex is not a permanent identity. Sex is not solely genetic, or inherited. Sex is not either/or. The definition of male-and-female is ultimately not so clear-cut as the simple labels might indicate.

In biology, exceptions abound. Absolutes are few. Here, no “one body, one sex” rule holds universally. No single-trait definition applies to all other traits uniformly. An excursion into sorting male and female, then—more than highlighting mere curiosities—can show how some of our most basic assumptions about nature are mistaken. We may also begin learning to check the tendency (all too easy in teaching) to oversimplify nature.

Domesticating Nature

Aristotle surely expressed an ideal when he advocated adopting categories that would “cut nature at her joints.” That goal assumes, of course, that nature has clearly defined joints. Yet in nature, sexed traits do not sort uniformly. Intersex mosaics may combine traits that we conventionally designate as *either* male *or* female. Traits at different levels of organization do not always align according to the popularly imagined dichotomy. Why, then, did the dichotomy emerge, and why does it persist?

Consider two models for human sexual development (Fausto-Sterling 2000, p. 68 [after Milton Diamond]). In one, the body begins as indeterminate—unsexed, perhaps. Each embryo is then assumed to respond to hormonal (or

genetic) “switches” that trigger only one of two available, diverging trajectories: male *or* female. In this model, intersex individuals are anomalous hybrids or deviants. They may even seem “unnatural.” Note, too, that the possibilities this model portrays as scientifically “normal” echo familiar cultural categories.

In the other model, the original mass of cells is multipotential. In a sense, the embryo is *both* male *and* female, because no developmental opportunities have yet been closed off. As the organism develops—both before and after birth—due to local and temporal cues, some potentialities are followed, others foregone (sometimes even lost). A constellation of “male” and “female” traits emerges. In some cases, certain potentials might later be pursued, as in “late” onset virilization, or perhaps even restored, as in intentional surgical or hormonal intervention. In this second model, indigo hamlets (reef fish), which just within a few hours may switch several times from delivering sperm to having their own eggs fertilized, do not change bodily identity at all. Rather, they merely exhibit physiological options—here, related to alternative reproductive functions.

Thus, at least two models of sex are possible:

- 1) male *or* female, or
- 2) male *and* female, each in differing degrees.

Why then, given hermaphrodites and intersex conditions, do we typically interpret the duality as “or” rather than “and”? Are we subtly influenced by cultural frameworks—for example, based on the either-or competitive rhetoric that pervades athletics, economics, and academic assessments?

Whether one envisions sex as male *or* female, or male *and* female, at least the options seem reduced to two. Biologically, that seems to reflect the very nature of sexual reproduction. Males mate with females! What would seem more “natural” as a benchmark? Sex seems plainly *binary*.

Comparative biology, once again, may come to the rescue—or to upset the conventional order. Looking beyond humans, one can find sexual reproduction—properly understood—without dimorphic sexes. Moreover, some species may have more than two sexes, or mating types. All these systems nevertheless express the fundamental feature of sex: *genetic recombination*.

For example, gametes need not differentiate into egg and sperm. In the algae *Chlamydomonas* and *Ulva*, as classic textbook cases, the gametes are similar (isogamous). Reproduction is indeed sexual. Meiosis does occur. Gametes do fuse. But *both* gametes are motile. There are no microgametes and macrogametes, hence no identifiable male or female. Other algae, fungi, and protozoa

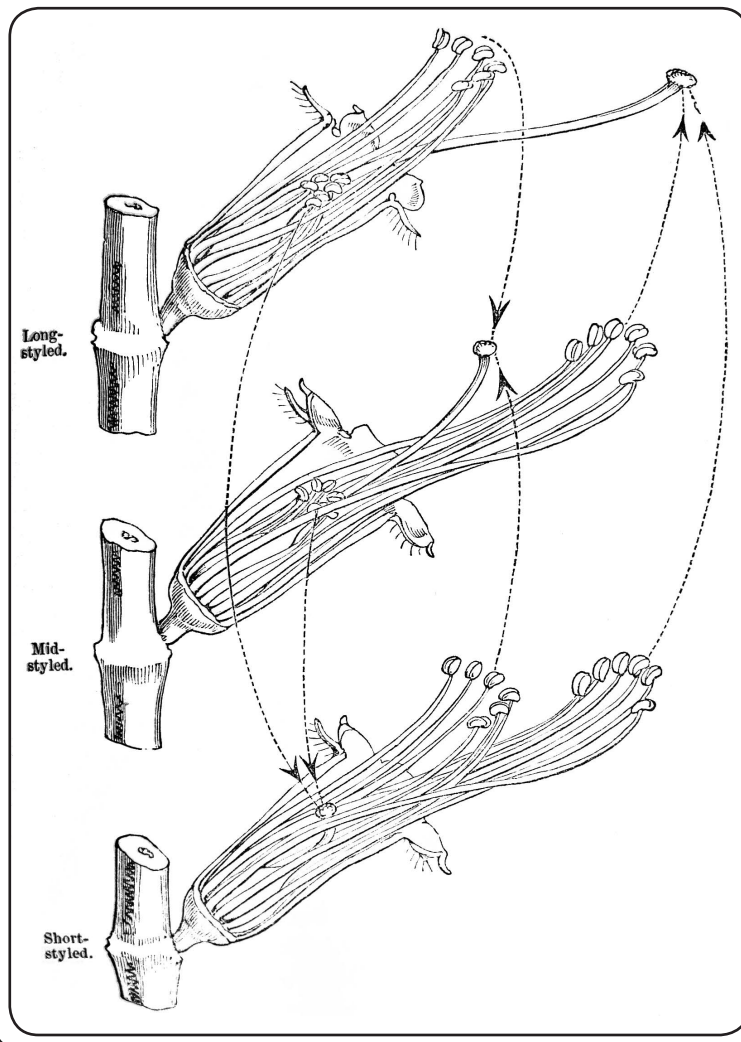
exhibit the same pattern (Hoekstra, 1987; Bell, 1982). Sexual reproduction occurs widely *without sexes*.

Further, sexual reproduction recombines genetic material only when types outcross. Sex alone is no guarantee. Accordingly, further mechanisms may help foster, or ensure, the critical mixing. For example, in many plants, pollen does not germinate unless the host stigma is of a different genetic type, determined by specific *sterility alleles*. Mating strains may regulate inbreeding and promote outcrossing. *Tetrahymena thermophila*, a protozoan, has seven mating strains. *Schizophyllum commune*, a mushroom, has over 28,000 (Whitfield, 2004). If one interprets sex as who-can-mate-with-who for the purpose of recombining genes, then there can be a large number of sexes indeed!

Mating strains typically differ chemically. However, morphological differentiation of mating types was also noted by none other than Charles Darwin. Darwin (1877) discussed *heterostyly*, where the lengths of styles and anther positions of even some common garden flowers

Figure 1.

Heterostyly in common flowers: different positions of the stigmas and anthers ensure cross-fertilization between types (Darwin, 1877, p. 139). Courtesy of the Wangenstein Historical Library, University of Minnesota.



varied in discrete morphs, long and short. The position of the structures dictate how pollinators transfer pollen most effectively between different types. Hybrids are also more viable, he found. In some cases Darwin noted *three* discrete lengths (Figure 1), leading to what Darwin profiled as three pairs of males and females, each akin to reproductively separate species. “No little discovery of mine ever gave me so much pleasure as the making out the meaning of heterostyled flowers,” Darwin noted proudly in his autobiography (1958, p. 134). Darwin, of course, well appreciated the evolutionary significance: “We may feel sure that plants have been rendered heterostyled to ensure cross-fertilisation” (1877, p. 258). Functionally, style type seems as important to sexual reproduction as sex itself.

Beyond heterostyly, other systems involve discrete reproductive morphs (Roughgarden, 2004, pp. 75-93). Even gametes may exhibit more than two distinct types (pp. 24-25). Sexual dimorphism, as well, is not a universal rule. One especially striking system was recently discovered among two ant species of the genus *Pogonomyrmex*. Independently of male and female, the ants have two distinct mating types. A queen that mates with a male of her own type produces more queens, essential to the continuity of the colony. However, she must also mate with a male of the alternate type to produce workers, who keep the colony functioning. *Both* matings are necessary for the colony to survive, although each *individual* ant has only two parents. John D. Parker (2004) argues that these ants thus have *four* sexes. For effective reproduction, *three* sexes—one female and *two* male—seem essential (when assessed at the level of the colony). Even if one does not construe these ants as exhibiting polysexes, they certainly illustrate the complexity of reproductive systems and their mating morphs. Sex does not reduce to “simple” mating between dimorphic males and females.

Intersexes, null sexes, mating types, multiply morphed sexes: One may be tempted to dismiss them all as *merely* exceptions. —Or rare, and *hence* insignificant. Here, one may easily confuse “normality” (as a numerical frequency) with “normality” (as a presumed *value*). Indeed, the “exceptions” are not so rare as that label might indicate. Intersex humans occur probably about 1 to 3 times in every 2,000 births (more, if one is liberal in one’s interpretation) (Dreger, 1998, pp. 40-43; Fausto-Sterling, 2000, pp. 51-53; Blackless et al., 2000). (For comparison, the incidence of cystic fibrosis is ~1/2,000, Down’s syndrome ~1/800.) As noted, among plants hermaphroditism is more common than not. Note, too, how prior conceptions define what are “exceptions.” “Normal” is a cultural judgment. Ultimately, the frequencies are peripheral. These cases are important because they challenge the very concept of sex. Viewing sex as dichotomous, or as uniformly male or female, one cannot fully characterize—or fully appreciate—nature.

Reconceptualizing sex is profoundly challenging because the male/female dichotomy seems such a plain biological fact. Far more deeply, however, it permeates our cultural organization, from names and dress to military conscription, career, and athletic opportunities, and vari-

ous other enfranchisements, and even to toys and games. The temptation among many may surely be to cast intersex organisms and other complex cases as *unnatural*—that is, as violating some “scientific” notion of male and female. The inescapable irony, of course, is that all the cases discussed above are products of nature. We would be using culturally laden concepts of nature to incorrectly interpret nature itself—all in the name of science. The challenge for science teachers, therefore, is to help show students how observations and cultural perspectives interact in the making of and use of such scientific concepts. Exploring male and female may thus also yield lessons about the nature of science.

Discussing the biological spectrum of sexed bodies, behaviors, and systems of sexual reproduction is unabashedly sensationalistic. But it can also lead to genuine and profound lessons. The significance of that understanding may perhaps best be measured by reflecting on why we pose, and how we choose to answer, the ubiquitous—and presumably unambiguous—first question about newborns: “Is it a boy or a girl?”

Web Excursions

Intersex Society of North America: www.isna.org

Gonad development (recommended by ISNA): www.sickkids.ca/childphysiology/cpwp/Genital/genitaldevelopment.htm

Videos

Is It a Boy or a Girl? [55 mins.] (Ward & Associates, 2000). Great Falls, VA: Discovery Channel.

Life Stories

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