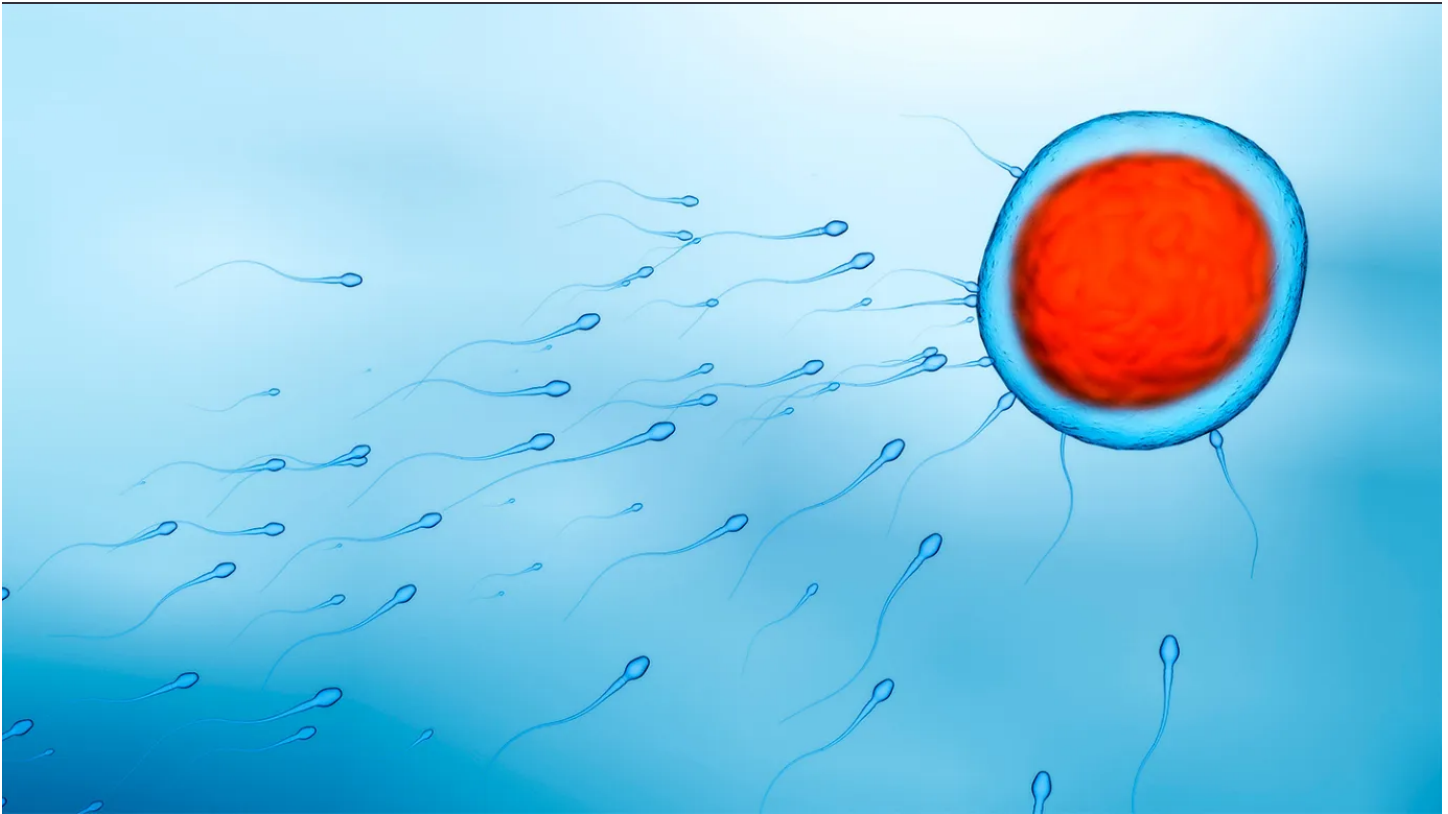


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Egg cells are many times the size of sperm, as shown in this illustration of fertilization. Some people, including President Trump, say people's sexes should be defined by the size of the reproductive cells they make.

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HUMANS

Biological sex is not as simple as male or female

Defining sex as a binary excludes many biological realities, scientists say

By **Tina Hesman Saey**

13 HOURS AGO

Sex is messy.

It's not just about chromosomes. Or reproductive cells. Or any other binary metric. Many genetic, environmental and developmental variations can produce what are thought of as masculine and feminine traits in the same person. And so sex, scientists say, should be viewed in all its complex glory.

"Sex is a multifaceted trait that has some components that are present at birth and some components that developed during puberty, and each of these components shows variation," says Sam Sharpe, an evolutionary biologist at Kansas State University in Manhattan.

Yet a definition of biological sex put forth by U.S. President Donald Trump designates people as either male or female based solely on the size of the reproductive cells they make.

Millions of Americans don't fit that narrow definition through no fault of their own — and many don't even know it.

In an [executive order](#) signed January 20, the president asserts that there are two immutable human sexes and that females are defined as persons "belonging, at conception, to the sex that produces the large reproductive cell." Males, according to the order, make the smaller cell.

On February 19, newly instated Health and Human Services secretary Robert F. Kennedy Jr. [announced](#) that the agency, which oversees most federally funded health research, will use these definitions in making policies.

In a slight variation from the executive order, HHS defines males as people "of the sex characterized by a reproductive system with the biological function of producing sperm." And females as people with reproductive systems that make eggs.

"For me, the definition is really painful because it reduces a human being to their chance of reproducing," says Anna Biason-Lauber, a pediatric endocrinologist at the University of Fribourg in Switzerland.

What's more, Trump's definition is not biologically accurate and leaves out people who carry certain genetic variants and don't make any reproductive cells, or gametes. The order makes no exceptions for them. "What does that mean for people who don't have gametes?" Sharpe asks. "That is, as of now, an unanswered question. But it's an important question to answer, because you can't have a definition of sex that doesn't apply to everyone."

Any definition of sex used to determine who can get an identification card or use a public restroom needs to account for variation, they and other researchers say.

Sex is complicated

One thing Trump's order gets right is that there are two sizes of reproductive cells, or gametes, known as eggs and sperm. Egg cells are much larger than sperm. That's about as close to a true binary as nature gets, says Nathan Lents, a molecular evolutionary biologist at the John Jay College of Criminal Justice in New York City.

But sex is much more than the size of reproductive cells, researchers say.

"Biology doesn't operate in binaries very often," Lents says.

Instead, most characteristics ascribed to males and females fall along a spectrum with two peaks, one the average for females and the other the average for males. For instance, on average, males are taller than females and have more muscle mass, more red blood cells and a higher metabolism.

But almost nobody fits in the peak for all those measures for their sex, Lents says. "There's plenty of women who are taller than plenty of men. There are plenty of women who have higher metabolic rates than some men, even though the averages are different.

"If you define biological sex purely on the gametes, you're going to ignore most of what actually matters to your daily life, including in your social life,"

he says. "Reducing sex to a binary really doesn't make a lot of sense for how we actually live."

Sex doesn't start at conception

No sex cells are produced at conception. Fertilized eggs "can't produce gametes, because they're single cells," Sharpe says.

In fact, sex development doesn't start until several weeks after conception. The exact timing is hard to pinpoint in humans, because it happens in the womb, often before people know they're pregnant, Biason-Lauber says. About six weeks into gestation, cells appear that will eventually give rise to the gonads: ovaries to make eggs or testes to produce sperm. But for a couple of weeks, she says, those cells are "absolutely indistinguishable" from each other.

Scientists used to think that embryos automatically developed as female unless there were specific instructions to become male. But in the last decade, researchers found that for embryos to develop as females they need to [actively dismantle male-producing structures](#) and build ones that support female reproduction.

At about eight weeks of gestation, certain cells in what will become the testes begin to make the hormone testosterone, which is important for development of the scrotum and penis and other male reproductive organs. But males still don't produce sperm at this point. That's partially because testosterone production drops around week 20 of pregnancy and doesn't pick back up again until puberty, when it kicks in once more, allowing immature cells to morph into sperm.

Ovaries don't produce any sex hormones in the fetus. And the uterus, fallopian tubes and the vagina develop without any input from hormones, Biason-Lauber says. Females are born with all the eggs they will ever make, though those cells are stuck in suspended animation until puberty, when they can mature and be released.

Sex chromosomes differ

Those developmental processes are partially directed by what are often called sex chromosomes. The name is somewhat of a misnomer because these two chromosomes — dubbed X and Y — have a wide range of responsibilities beyond sex.

The X chromosome contains hundreds of genes including many involved in processes throughout the body such as blood clotting, color vision and brain development. The much smaller Y chromosome contains genes important for male sex development and fertility, but also plays a role in [immunity](#), [heart health](#) and [cancer](#).



Millions of people are intersex, including model Hanne Gaby Odiele, shown walking the runway during Paris Fashion Week in 2022. Such people don't fit typical binary definitions of sex. Odiele, who has androgen insensitivity that prevents the body from responding to testosterone and similar hormones, speaks out against unconsented surgeries on intersex children to make them conform to a sex binary.

JONAS GUSTAVSSON/SIPA USA/ALAMY STOCK PHOTO

Females generally have two X chromosomes, while males typically have an X and a [Y chromosome](#). But there are plenty of variations on that theme, Biason-Lauber says. For instance, in [Turner syndrome](#), women lack one X chromosome. "They do not have gametes," she says. Instead, these women have what are called streak gonads. "They have a piece of collagen instead of ovaries." They do have a uterus.

This leads Biason-Lauber to wonder, "if the definition of a woman is the presence of the big cells, what are these [people]?" Turner syndrome is not so rare, she says, occurring in 1 of every 2,000 to 2,500 female babies born. Some people are not diagnosed until adulthood or may never be diagnosed.

About 1 in every 650 male babies born have two or more X chromosomes and one Y. Those men, who have [Klinefelter syndrome](#), don't produce sperm. Many are unaware that they carry an extra chromosome until they go for fertility treatments, Biason-Lauber says. These people have testes and penises, but they don't make small reproductive cells, and thus don't fit the administration's definition of men.

The Y chromosome contains a gene called *SRY* that is important, [but not essential](#), for male sex development. Sometimes, when chromosomes are divvied up before sperm production, *SRY* jumps out of the Y chromosome and attaches itself to an X or another chromosome. When the hitchhiking *SRY* gene, but not the rest of the Y chromosome, is passed on to offspring it may result in people who have two X chromosomes [plus a stray *SRY* gene](#). Those people often develop as males.

Some people have an X and a Y chromosome but carry a version of [SRY or other genes](#) that don't spur typical male development. Those people develop as females but don't make gametes.

Other people with an X and a Y may have genetic variants that prevent their bodies from responding to testosterone and other male sex hormones, called androgens. Those people with [androgen insensitivity](#) have testes

inside their abdomens, but the rest of their bodies develop as female. "These people would have the small cells, but they're not men," Biason-Lauber says.

Variants in many other genes may also prevent production of either large or small reproductive cells. Some people even have [different combinations of sex chromosomes](#) in different cells in their bodies.

Being intersex isn't all that rare

About 1.7 percent of the population is intersex and [don't fit neatly into male and female boxes](#), according to InterAct, an advocacy organization for intersex youth. That's as common as having naturally red hair. Intersex people may have any of a wide variety of sex development differences including Turner syndrome, androgen insensitivity, Klinefelter syndrome and others.

Some may be born with [both ovarian and testicular tissue](#), and thus might be classified as both male and female under the terms of the executive order, says Sylvan Fraser Anthony, InterAct's legal and policy director.

Intersex individuals often undergo surgeries as infants or young children to make their genitals or internal organs conform to the sex their parents choose. They may also need to take hormones such as estrogen or testosterone to maintain their health, says Sharpe, who worries that a binary definition of sex could be used to deny intersex people access to health care.

Such sex hormones also "play an important role in many facets of development, including whether your skin is painfully dry or not, or how tall you grow during puberty, or whether you're able to maintain bone density," they say.

Choosing any single definer of sex is bound to sow confusion.

"If [they] use chromosomes, there's a whole lot of individuals who will be quite surprised to learn that they're male," Lents says. "If they use gametes,

they're going to exclude some individuals ... but they'll also potentially open the door to including people that they didn't intend." For instance, people who have X and Y chromosomes but make female gametes would be eligible under the definition to compete in women's sports.

"The biology of sex and gender makes it very clear," Lents says. "These are not hard categories with clear definitions."

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