America's Leading Animal Geneticist Wants to Talk to You About GMOs

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Alison Van Eenennaam has spent the last decade explaining gene editing to critics who find fear more compelling than data. Is anybody listening?

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(Illustration: Imogen Todd)

At 11 a.m. on a Thursday morning, Alison Van Eenennaam is sitting in a harshly lit lab room, surrounded by her graduate students, talking about cattle sex—sex that, unfortunately, has not gotten anything pregnant. With the gene-editing techniques she's using, there could be many factors to blame: the location in the DNA strand of the edit, the biopsy performed to check the results of the edit, the freezing and the thawing of the embryo, the embryo's journey from lab to farm in a thermos. Now, Van Eenennaam floats another idea. "No foreplay, the poor guy," she says, a cheeky grin on her face. "The candle and the lighting wasn't right."

It's a crucial morning for the team, one of the only public-sector animal genetic-engineering labs left in the country. Inside the animal science building at the University of California–Davis, the scientists gather around the table in a small, beige-colored conference room decorated by pastoral illustrations of farm animals. The meeting has taken on a frenetic kind of gallows humor, the team joking like a bunch of giddy kids before a big test. Seated near the front of the table, Van Eenennaam runs a hand through her silvery-blond hair and leans back in her chair, commanding the room with ease. Her newest doctoral student, 24-year-old Maci Mueller, pulls up a PowerPoint slide intended to bring their lab manager up to speed. Her slides outline plans to make a "surrogate sire," a gene-edited bull with the ability to pass on superior traits through generations.

One slide features a pair of diagrams: the first of artificial insemination, and another of a bull and a cow doing it, well, the old-fashioned way. The latter is highly inefficient, and the first—a routine breeding practice that presents a wealth of possibilities for gene editors—was giving the whole department some problems. "Thank you for the visual," Van Eenennaam says dryly. "I wasn't sure that's how that happened."

Already scientists have developed pigs resistant to disease and cows without horns—all with the snip (and sometimes insertion) of genetic material—but this new project, three years in the making, is especially tricky because the team is pioneering a technique that involves editing directly in the embryo, instead of the typical process of cloning. The team wants to create cows that only sire males, using the sex-determining gene *Sry*, which triggers male development.The geneticists have duplicated and then inserted this gene into the X chromosome of an embryo later implanted in a surrogate mother, ensuring that she gives birth to a phenotypic boy—even if that calf is born with XX chromosomes.

Alison Van Eenennaam feeds the offspring of one of her gene-edited cows in the UC–Davis feedlot. *The lab worked with the start-up Recombinetics to introduce a naturally occurring mutation in Angus beef that produces cows with no horns, eliminating the need for the painful process of dehorning dairy cows.*

(Photo: Emily Moon)

On a commercial level, this innovation makes sense. The ranchers with whom Van Eenennaam works want males, or steers—which are bigger than cows—for more efficient beef production, and they already do something similar by sorting sperm cells carrying X and Y chromosomes in bull semen. It could also reduce the agriculture industry's environmental footprint: More beef from fewer cows means less methane, water pollution, and overall land-use.

But first, of course, Van Eenennaam has to produce a calf. Other researchers have done *Sry* editing in mice, but the bovines have been less cooperative: The team is transferring the embryos into a mammal that takes nine months to give birth, as opposed to the three weeks a mouse takes—and, even then, the cow's fertility could trip them up. It's gotten to a point where, sure, you might as well factor in mood lighting. I hear Van Eenennaam say what will soon become a familiar phrase during my visit: "We might have to go in with a Hail Mary."

Blind belief and science are very different things. Van Eenennaam knows this personally, having spent many of her 25 years in agriculture science explaining her work to critics of genetically modified organisms (GMOs), who find fear more compelling than data showing GMO crops aren't harmful. Lately, though, Van Eenennaam is beginning to rely more on faith. Recent failures and a chronic lack of investment have made it hard to plan for future projects, especially under the specter of new regulation from the United States Food and Drug Administration.

Facing a tide of anti-GMO activism, Van Eenennaam has taken it upon herself to advocate for the agritech industry. "If we don't speak up and we lose access to editing," she says, "we will have lost access to innovation, and that has these huge environmental consequences that the people who work in agriculture understand. But then the general public never hears from us, and so they get their agricultural information from Dr. Oz." (To address this problem, she went on *The Dr. Oz Show* herself.) As a result of her public face, she's become a polarizing figure: Pro-biotech groups call her "the science advocate anti-GMO groups love to hate"; anti-GMO groups say her work is "marred by bias and scientific shortcomings."

But this 55-year-old Australian geneticist, who dreams of saving the world with a more efficient food system, only takes shit from one thing: her cows. Tomorrow is the first pregnancy check at the university's barn, which requires putting a full arm into a cow's rectum. As with many of her projects, she says, "It's going to be messy."

Alison Van Eenennaam could just as easily be herding cattle on a ranch as sitting in her cramped office in Davis, where the walls are plastered with science awards and family photos. Having grown up in the rural country outside Melbourne, Australia, she remembers bush-riding horses through the forest behind her aunt's house, the smell of eucalyptus sharp on the air. She also remembers, a little less fondly, showing off her horses at dressage competitions and Pony Club meetings. The other kids had nice saddles and expensive animals, and then there was Van Eenennaam, in "not very nice jumpers, and my ratty old horse that didn't have good papers."

That didn't stop her from falling in love with farm animals: From horses, she moved on to shearing sheep at an animal health company,after taking agriculture science classes at the University of Melbourne. Then, while on exchange at a cattle ranch in San Marcos, Texas, she collected semen from Santa Gertrudis cattle to use for artificial insemination, a breeding practice that lets farmers select for and pass down favorable traits without having to own a bull. Just as Van Eenennaam was learning to breed cattle conventionally, scientists were beginning to explore genetic-engineering techniques that could revolutionize this practice.

Van Eenennaam was determined to join them. After earning her doctorate in genetics at UC–Davis in the 1990s, she entered the private sector. At Calgene, the first company in the U.S. to commercialize a GMO—the Flavr Savr tomato—she began boosting nutrients in

plants using a precursor to CRISPR-Cas9, a scissor-like tool that lets scientists insert and remove genetic material. Within a few years of her starting there, Calgene was bought by Monsanto, whose GMO monopoly and lack of transparency riled conservationists. As a result, Van Eenennaam now holds several patents for the controversial agrichemical company—something her enemies often trot out to demonize her.

Five unnamed bulls and their only sister, Princess—the second generation of an earlier project—idle in the feedlot. "They don't look remarkable," Van Eenennaam says. "You can't tell in a feedlot."

(Photos: Emily Moon)

"Oh my god, Monsanto, it's like invoking the devil,"she quips. "It's true, I mean, I did work there, and I was a bartender too. And I worked as a peach packer when I was young, and I used to collect semen from bulls. I've done a lot of jobs. And so that's going to tarnish me for the rest of my life?"

In 2002, Van Eenennaam returned to UC–Davis, this time to helm her own lab. As a public-sector researcher, she could green-light risky projects that don't always appeal to investors. She says she runs her lab like *Shark Tank*, only with a 90 percent failure rate: Only 10 percent of grants get funded.

Her first project was an attempt to make dairy cows that produce their own omega-3 fatty acids, essential fats found to reduce the risk of heart disease. She successfully got mice to produce it, but when she tried to get funding for cattle, the grant reviewers denied her request. One wrote, "Given the 'pure and wholesome' public perception of milk products, it may be particularly difficult to gain widespread public acceptance for transgenic [genetically engineered] milk products—despite their health benefits." Today, this feels prophetic: The pushback on GMO crops has all but killed the commercial application in animals.

Frustrated, Van Eenennaam returned to conventional breeding. It was a common experience for animal geneticists at the time, whose funding began drying up during a regulatory crackdown on genetic engineering from the FDA, which oversees GMOs in animals.

Then in 2012, American biochemist Jennifer Doudna published a groundbreaking paper on CRISPR, one of several tools that have allowed scientists to make precise changes within an animal's genetic material. The technology was suddenly so accessible that many worried that someone might create designer babies in a garage. Until 2017, the FDA spared gene editing from its existing rules on genetic engineering. While gene editing involves tinkering with an animal's own genome, genetic engineering involves introducing DNA from a different species altogether into that genome.

CRISPR "democratized" editing, Van Eenennaam says. It also brought more interest to the field, and, with it, greater scrutiny.

Some scientists would say increased oversight of gene editing is necessary. Fearing ecological consequences, Natalie Kofler, a molecular biologist, founded the initiative Editing Nature at Yale University to put the brakes on controversial genetic-engineering techniques. Most of the debate is focused on wild species, but feelings about domesticated animals can be even more personal. People who oppose gene editing often cite a gut reaction—and nothing's more invasive to your gut than the meat you're eating. "The applications [for this technology] in livestock," Kofler says, "they pull at my heart."

Today, few Americans are exposed to the realities of modern food production, but they still have plenty of opinions about it. Researchers estimate that about half the country—particularly those with low levels of science knowledge—still believe GMOs pose a serious risk to health.

Public fears specifically around genetic engineering began when a French scientist tied GMOs to cancer in a now-retracted study. But even those who know that genetically engineered and gene-edited crops (and animals, if they ever make it to U.S. shelves) are safe to eat still feel somewhat queasy about the existence of GMO food. Kofler notes that scientists have developed pigs resistant to porcine reproductive and respiratory syndrome, which animals are often exposed to in confinement housing. "This seems like a Band-Aid solution," she says. "Gene editing cattle or pigs to be able to be raised in concentrated, large factory-farming situations, that's also concerning because they're using gene editing to perpetuate a system that already needs to be reformed."

And then there are the dystopian scenarios: Last year, Chinese scientist He Jiankui announced that he'd created two gene-edited human babies. He was met with widespread condemnation among the scientific community, some of whom—including CRISPR patent

holders—called for a temporary global ban on editing human embryos.

But powerful opposition voices have worked hard to drown out these more measured concerns with wild theories. Although scientific consensus now says genetically engineered crops are safe to eat, environmental groups have stoked public fears of GMOs, leading over two dozen countries and some U.S. municipalities to ban them. The FDA has taken a harsher approach than the U.S. Department of Agriculture, classifying both genetically engineered and edited animals as "new animal drugs," and not food. In a 2017 announcement, the agency said an animal's intentionally altered DNA is a drug because it is "intended to affect the structure or function of the body of the animal, and, in some cases, intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease in the animal."

Normally, the animal science department's animals are sold at the UC-Davis meat lab or other local slaughterhouses. For Van Eenennaam's cows, however, the FDA classification means the surrogate mothers and edited calves her process creates cannot enter the food supply. "If you say all of a sudden that she's a drug-manufacturing facility, and that a fetus is a drug, then theoretically you'd have to incinerate that cow," she says.This could make costs prohibitive for UC–Davis—as it has at other universities—leaving the work of gene editing to the Monsantos of the world. It's already had a chilling effect on development: So far, the FDA has only approved one genetically engineered food animal for consumption, the AquAdvantage Salmon.

Van Eenennaam's newest doctoral student, 24-year-old Maci Mueller, *extracts eggs from a cow ovary, which she will then place in reproductive hormones to kick-start ovulation so they can be fertilized the next day. T*he lab gets its ovaries from a slaughterhouse in Fresno, California, and its sperm from one particularly potent Holstein named Swordfish.

(Photos: Emily Moon)

Van Eenennaam and her colleagues had hoped gene editing would be spared the costly drug-approval process. But an Obama-era decision, coupled with the new draft plan released last year, will send their animals down the same regulatory path—unless Van Eenennaam gets her way. She's spent the past few years trying to convince anyone who will listen—congressional staff, anti-GMO groups, people on the street—that gene editing poses no risk to food safety.

Van Eenennaam brushes aside critiques of gene editing. She likens the anti-GMO crowd to climate-change deniers or anti-vaxxers, and those who mislead the crowd to tobacco scientists. Researchers who stoked these fears are a small minority, she says, and some of their claims have been publicly discredited. But for years, their findings hogged the spotlight.

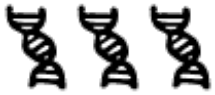
Van Eenennaam has made several media appearances defending GMOs, including one alongside Monsanto's then-chief technology officer, Robert Fraley. She also appeared in the 2016 science documentary *Food Evolution*. In one scene, she confronts anti-GMO protesters at a conference in Des Moines, Iowa, and politely rebuts them. "She's not the face that one might imagine when hearing about a GMO scientist, right?" producer Trace Sheehan asks. "You've got the image of an evil, Monsanto, old white guy in a lab coat. She's not that. She's a vivacious Australian out in the field, talking to everybody she can."

On the week I visited, Van Eenennaam had just given a talk at a retirement community in San Diego, California, which she says involved debunking a lot of myths about GMOs causing food allergies. The next weekend, she did the same thing at the Iowa Pork Congress, one of the biggest agribusiness events of the year. It's second nature for her, so much that, when her kids were young, she found herself wanting to correct the other parents at PTA meetings. "I don't want to be that parent," she says. "But you're just wrong."

In January of 2019, Van Eenennaam launched a petition with the Cornell Alliance for Science, an agriculture biotech group funded by the Bill & Melinda Gates Foundation, calling for a "harmonized" approach to gene-editing regulation, meaning that the FDA would not regulate alterations that can be achieved through conventional breeding, such as the hornless calves or all-male cattle.

Breeders, Van Eenennaam notes, have been selecting for naturally occurring mutations to introduce useful genetic variations into food animals for centuries, now using techniques improved by the advent of artificial insemination in the 1930s. While the rest of the world frets about designer babies, ranchers already shop for beef sires with "elite genetics" (really great bull semen) in glossy catalogues with futuristic names like Genex. They can pick a calf's gender using sex-sorted semen, or predict a cow's weight a generation into the future—without gene editing.

"There are a lot of things we do in animal breeding that don't 'slippery slope' into human reproduction," Van Eenennaam says. "We select our animals to be parents of the next generation based on their genetic merit for milk production. I picked my husband based on how he looked in a pair of blue jeans at a party."



On a cold and gray Friday morning, Van Eenennaam, grad student Maci Mueller, and their lab-manager, project scientist Josephine Trott,drive to the animal science department's beef barn for pregnancy-checks. The barn—a smattering of cattle pens and pastureland—is located off an olive tree-lined gravel road, parallel to the freeway. We wade out into the muddy field, where the cows are queueing up for an ultrasound. Van Eenennaam was right to expect a mess: The process involves immobilizing the animal in a metal chute, while a lucky veterinary student sticks her arm up the rectum, reaching through the rubber-like inner wall to the cervix with a scanner.

The facility houses about 300 cows for research and teaching, but the lab has singled out a lucky few.Last year, Joseph Owen, a fourth year doctoral student on the team, duplicated the sex-determining gene *Sry* onto the X chromosome in 18 cow embryos. He then transferred these embryos into 18 mother cows. In bulls this edit should guarantee all-male offspring, passing along two copies of *Sry*. The lab is also editing females for "proof of concept." They predict that *Sry* alone is enough to make a cow appear male, giving it all the characteristics of maleness (primarily, testicles) with a female genotype. Their infertility would also make them a perfect candidate for genetic containment—a way to keep transgenes—those from a different species—from spreading, to satisfy Van Eenennaam's critics. "Terminator bulls," Owen calls them.

"It's actually a really beautiful piece of work," Van Eenennaam says.Except that, after Owen's last transfer, the only viable pregnancy was reabsorbed. Normal in vitro fertilization has around a 70 percent pregnancy rate, but these blastocysts have been through hell: edited, biopsied, vitrified.

Veterinarian Bret McNabb prepares to pregnancy-check a cow that's (hopefully) carrying an edited embryo. The process involves sticking an ultrasound probe through the rectum to the cervix.

(Photo: Emily Moon)

Bret McNabb, an assistant professor at UC–Davis' school of veterinary medicine, helps two veterinary students corral the first cow into a rusty metal chute. After a few minutes, McNabb sets the cow free, yelling "Open." Bad news: "Open" means "not pregnant." The vets clear two more open cows before Van Eenennaam strides into the barn. Immediately, the mood lightens.

"Alison's presence is gonna spew fertility," McNabb says.

"It's gonna scare them into becoming pregnant," Owen adds, cracking his first real smile all morning.

Van Eenennaam is chipper, more than most people who find themselves ankle-deep in mud. Watching the vet clear shit out of the animal's rectum, she jokes, "Do you have a piss test?"

After a few more disappointments, the group grows tense: The only sounds in the barn are the discontented moos of the open cows and the far-off wails from a caravan of police cars. Van Eenennaam stands directly behind the vet, craning her neck to get a look at the ultrasound monitor, with Owen right behind her. They look like a pair of anxious new parents. "I think I'm more worried about this than when I was getting myself pregnant," Van Eenennaam says. She has two children, both boys.

McNabb and his students search within circles of black fluid on the ultrasound monitor for a flicker of white—the tell-tale sign of a heart. There should be a beat after one month. But there's nothing: zero for four. Owen shakes his head. Turning to the next cow in line, Van Eenennaam peers into its blank eyes and places a hand on its side. "Are you pregnant?" she asks. "Come on, fertility gods, give us a baby."

Don Harper, the *Beef Barn's* natural resource manager, prepares the lab's 18 cows for pregnancy checks.

(Photo: Emily Moon)

The next up is number 401, one of the "Hail Marys," meaning Van Eenennaam doesn't know what genotype to expect. The animal barrels into the chute, stopping short as the bars slam shut around it. The vet plunges a gloved arm into the cow's rectum, the lead-up to the least glamorous gender reveal of all time. Van Eenennaam crosses her fingers as the other

scientists gather around the monitor, radiating a quiet, nervous energy. McNabb probes for what seems like hours. And then, this time he yells out, "Pregnant." The whole group erupts in whoops and clapping.

"I'm gonna have a baby," Van Eenennaam says, beaming.

The others pile on compliments, like it's really hers: *Congrats! You're glowing. Proof of concept.* Van Eenennaam smiles, then repeats, "And a baby."

Van Eenennaam calculates that the baby will be born in eight months with a gestation calendar on her phone: September 19th, 2019. Now a little giddy with relief, she turns to the students huddled around her. "What star sign is that? Sagittarius? Taurus would be best of course." But no: It's Virgo, the symbol of the maiden. The award-winning geneticist admits she doesn't know what Virgos are like. But the symbol proves a fit: If this cow delivers a baby, the result will be up there with immaculate conception.

The calf's personality is not the only mystery. No. 401's embryo was mosaic, meaning that only some of the cells have the edit. If the edits don't take, the result could be crushingly, infuriatingly normal. If it works, however, Van Eenennaam expects that *Sry* will make the embryo a him—a hemizygous calf with the XX-*Sry* combination: female chromosomes, male phenotype. It could also be a perfect male, with two copies of *Sry*, so he's guaranteed to pass one along to the next generation.

Van Eenennaam inspects the monitor for signs of a heartbeat: a flicker of white within spots of black fluid.

(Photo: Emily Moon)

"We often find perfect males in unexpected places," Van Eenennaam says, the way you psych up a friend for a last go at Tinder. If it is a perfect male, the next step would be letting the bull age, collecting its sperm, and using that to produce the next in line. But they can't know for sure until after its birth, and, before that, the embryo needs to survive. "It is pretty remarkable, with what those eggs have been through," Van Eenennaam says.*"And still she persisted."* For a brief moment, she flirts with naming the baby Elizabeth, after Senator Warren. Owen has another name in mind: Birl, a portmanteau of boy and girl, like they expect this calf to be.

The mood this morning, first solemn and then celebratory, has now mellowed into bright relief. The vets are mopping up their shit-strewn clothes. The scientists are already thinking of data to analyze and papers to write. Van Eenennaam is all business, pulling Mueller aside and noting matter-of-factly, "This isn't going to work for commercial." Ranchers can't use a method that only guarantees one out of 18 babies, especially one that stalls under regulation. If Van Eenennaam, Mueller, and Owen want to fix the food system with gene editing, they'll need to find a cheaper way.

Don Harper, the barn's animal-resource manager, is planning what cows to buy next. "I need that one hand-fed," Van Eenennaam warns Harper on her way out, pointing to the one pregnant cow. It's a joke, but he takes her seriously. "We don't treat them any differently," he says. "Just let nature do its work."

"Sometimes nature's a bitch," she retorts. To this, the vets, the geneticists, and the rancher all heartily agree.

A week after my visit, Van Eenennaam calls to tell me that the cow has lost its pregnancy: Birl is no more. It's too early to tell, but she figures the problem may lie with the location on the X chromosome where Owen placed the *Sry* fragment. They'll try it again, this time adding a red fluorescent protein as a kind of tracker, so they can observe the results without doing a biopsy and risking another loss. But the protein is also a transgene: Cow cells don't glow red by themselves. Now, whatever the outcome, the new calf will be genetically engineered, not edited—meaning it will be confined to regulatory limbo forever and, when the experiment is over, will have to be incinerated. You won't be able to find the next Birl at a farmers' market for quite some time.

One Saturday in January, I meet Van Eenennaam and her husband, Joel, who's an animal researcher, at their favorite brunch place near the Davis farmers' market. Along the neat, little streets of downtown Davis, families browse rows of organic produce, while an old-man bluegrass band plays in the background.

In previous interviews, Van Eenennaam has often said she feels caught between the liberal college town that is Davis, and the conservative world of agribusiness. As a result, she can turn neither off. She lapses into political diatribes against the Trump administration, but despises regulation of her field, no matter the party. Even at the Davis farmers' market, where families buy "non-GMO" fruit and sample oat milk, Van Eenennaam sees traps for the ignorant consumer, which she says perpetuate deeply entrenched inequities: While rich shoppers have the money to buy organic, poor people are now avoiding GMO (and all) produce at higher rates.

"I get it because everyone eats," Van Eenennaam says. "Everyone believes they have a good handle on agricultural production systems. ... But that kind of nuance, the grown-up conversation, doesn't happen very much in our society." She's trying to have those conversations: Once, when an activist stumping at the market asked Van Eenennaam to support Proposition 12 (banning small livestock cages in California), she launched into a tirade about the research on chicken health and cage sizes.

"Do you feel like you know too much for this?" I ask as we browse the market after lunch. She doesn't answer, but eyes a bag of satsuma mandarin oranges disapprovingly, organic and expensive—$7 for five pounds. "I don't support inefficient agricultural systems," she

says, pointing to them.

But they're the only oranges here, so she buys them. For now, there's no other option.