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# The New York Times For Kids

*EDITORS' NOTE: THIS SECTION SHOULD NOT BE READ BY GROWN-UPS*



HOW DID YOU GET YOUR COOL JOB? BY:

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***HIDDEN QUIZ:***
COUNT ALL THE MOSQUITOES IN THIS ISSUE!
ANSWER ON PAGE 14.

## *KILLER* MOSQUITOES!

**BUT NOT FOR LONG!** A new scientific discovery allows humans to make changes to the DNA in the genes of living things. That means we can one day make mosquitoes that don't carry diseases like Zika or malaria, or create a seedless tomato (see Pages 8-9), or engineer a barkless dog, or even maybe bring back an extinct animal like the woolly mammoth. The process of editing DNA to change genes is complicated. Most adults don't understand it. They might say they do, but they probably don't. (You know how adults are.) But after you read about it in this section, you can teach them how it works.

Illustration by Anuj Shrestha

# CRISPR WILL CHANGE THE WORLD

*BY CHELSEA LEU*

You are made of DNA — the not-so-secret code in all living cells that maps out everything from how a tiger's fur is striped to the color of your eyes. If we could precisely edit DNA, scientists have thought, we'd have the power to cure diseases and help end world hunger. Now they've started using Crispr (pronounced "crisper," like the drawer in your fridge), a new method of editing DNA that might open the doors to all that and more — and people are already calling it the biggest scientific discovery of the century.

Think of DNA like two long, long strands of beads twisted together. Each bead is called a base, and each base corresponds to one of four letters: A, G, C or T. Crispr removes bases and inserts others precisely, just like restringing a bracelet. Rearrange those A's, G's, C's and T's, and you change the instructions a cell uses to build the proteins that ultimately make up a fish, or an apple, or your kid brother.

And with Crispr, the possibilities are endless. Take a painful disease called sickle cell anemia: One wrong letter in a certain spot in your DNA ("CAC" instead of "CTC") means your red-blood cells turn out pointy instead of round. Scientists are using Crispr to figure out how to cure diseases like that, as well as afflictions like cancer, H.I.V., liver disease and diseases that cause blindness. They've engineered mosquitoes so that they can't carry malaria — so eventually, many of the worst diseases to plague humanity might be eliminated. And they've created pest-resistant crops — which could someday end world hunger.

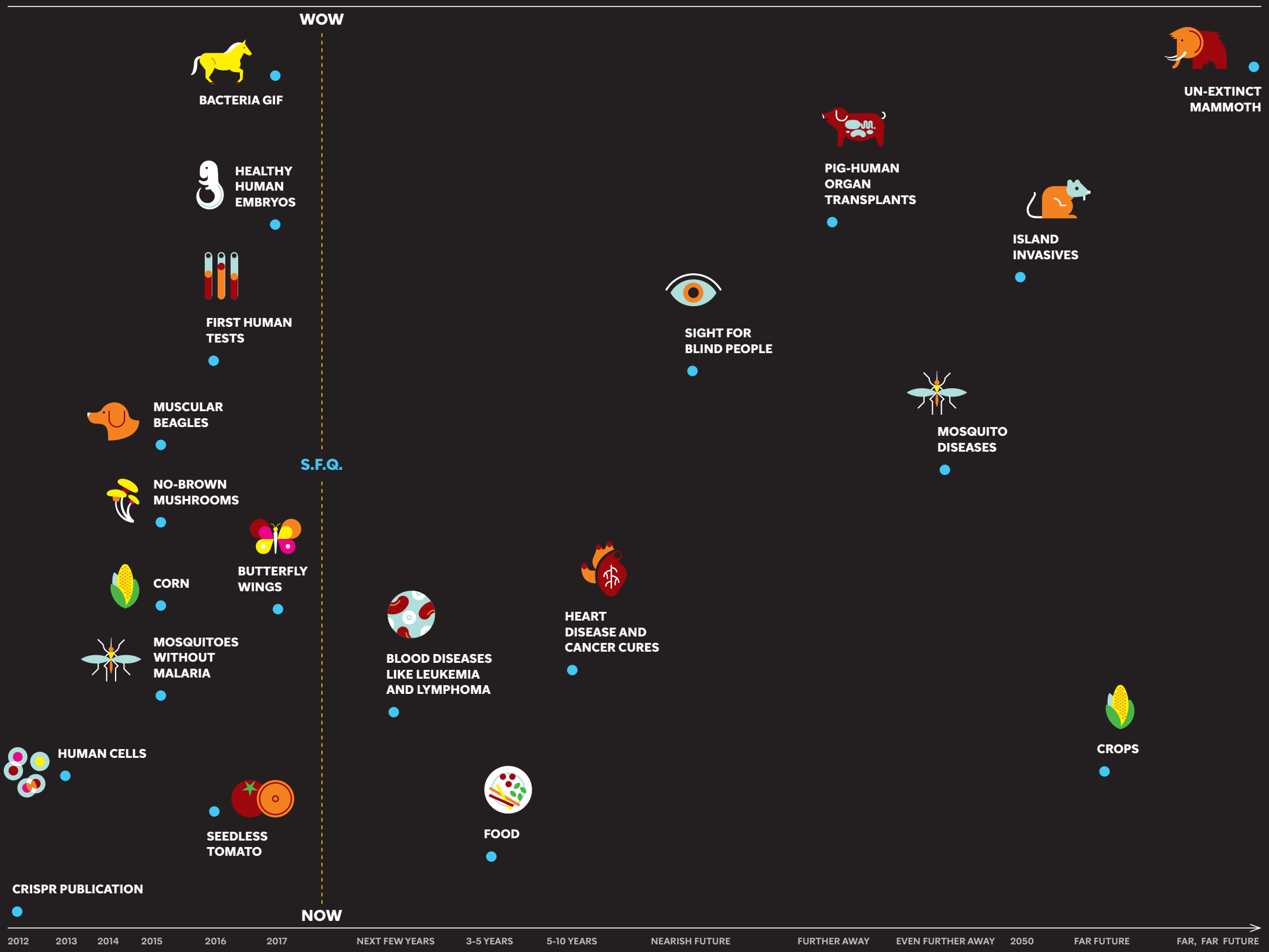
Using Crispr to edit genes has been around for only five years, so scientists are using it mostly to figure out exactly how small changes in DNA translate to effects in actual living creatures. The technique is also cheap, which means that almost any scientist can use it. "Before, you'd have to pay a company tens of thousands of dollars to edit a gene — and it might have taken months," says Sam Sternberg, a biochemist. "With Crispr, we're talking a few days in the laboratory and a hundred bucks to run the experiment." That means more biologists can use it to tackle questions about how life works — speeding up the very pace of science.

You know what they say: With great power comes great responsibility. Some scientists are starting to edit human embryos — the cells that eventually turn into babies and then kids. "If you can make a Crispr'd mouse or a Crispr'd monkey, you can make a Crispr'd person," says Paul Knoepfler, a cell biologist at the University of California, Davis. "For better or worse, we could change the course of our own evolution." And that has some scientists worried about the possibilities: What should people be allowed to change about their babies? Fixing a disease before it even develops is great. But is it O.K. to give them blond hair, or somehow make them smarter than average?

Thankfully, we're still far from that point. Scientists right now just don't know enough to truly manipulate traits, and they want to avoid mistakes or unintended consequences. "The genome is very complicated," Knoepfler says. "Sometimes one gene might have an on-off switch for some other gene inside of it." And it's not important just when it comes to editing humans. If you put mosquitoes or mice changed with Crispr out in the wild, how might they affect other animals or their complicated ecosystems? (For now, scientists are thinking about doing experiments like these on islands — that way, at least the animals can't run off too far.)

There's still so much scientists need to figure out, like how to actually get Crispr into sick people to heal them. But it's hard to overstate Crispr's potential. It turns everything alive — plant, animal or bacterium — into an open book, its innermost secrets ready to be pulled out and decoded and, potentially, improved. ◆

## How Crispr Has Changed, and Will Change, the World




Since the editing technique was first used by scientists in 2012, Crispr has been used in thousands of experiments — some straight from the fantastic imagined worlds of science fiction. So we've mapped out some of the highlights of Crispr's accomplishments and scientists' wildest hopes for its future.
*Chelsea Leu*

**S.F.Q. =** Science-fiction quotient. The more likely you'd find the Crispr breakthrough in a sci-fi movie, the higher its S.F.Q.

**Crispr, 2012** Several scientists announce an exciting new way to edit genes: Crispr.

**Human cells, 2013** The first papers about using Crispr in human cells are published.

**Beagles, 2015** Crispr is used to create the first gene-edited dogs: extremely muscular beagles.

**Mushrooms, 2015** A scientist changes mushrooms to keep them from turning brown when you cut them.

**Corn, 2015** A company researches Crispr-edited corn that can resist drought.

**Malaria, 2015** Scientists use Crispr to create mosquitoes that can't carry malaria.

**Tomato, 2016** Scientists create a seedless tomato with Crispr.

**Tests, 2016** Crispr used for the first time in living people — lung cancer patients — to test a cure.

**Embryos, 2017** Mutations in healthy human embryos — the cells that develop into people — are first treated with.

**GIF, 2017** A GIF of a running horse is encoded into bacteria with Crispr. Scientists are looking into using DNA as a method of data storage.

**Butterfly, 2017** Scientists use Crispr to change the color of butterfly wings.

**Blood diseases, next few years** Crispr-based cures are developed for blood diseases like leukemia and lymphoma, hemophilia and sickle cell anemia.

**Food, 3-5 years** Food altered with Crispr appears on dinner plates.

**Cures, 5-10 years** Heart diseases and more cancers now have cures, thanks to Crispr.

**Sight, Nearish future** Crispr restores sight to some blind people.

**Organs, Further away** Pigs are successfully altered with Crispr to host human organs for transplants.

**Mosquitoes, Even further away** Diseases like malaria, Zika and dengue are far less common because of mosquitoes altered with Crispr.

**Invasives, About 2050** Crispr helps eliminate the invasive rats, possums and weasels plaguing islands like New Zealand.

**Crops, Far future** Thanks to Crispr, staple crops like rice, wheat and corn resist drought and pests and produce more food.

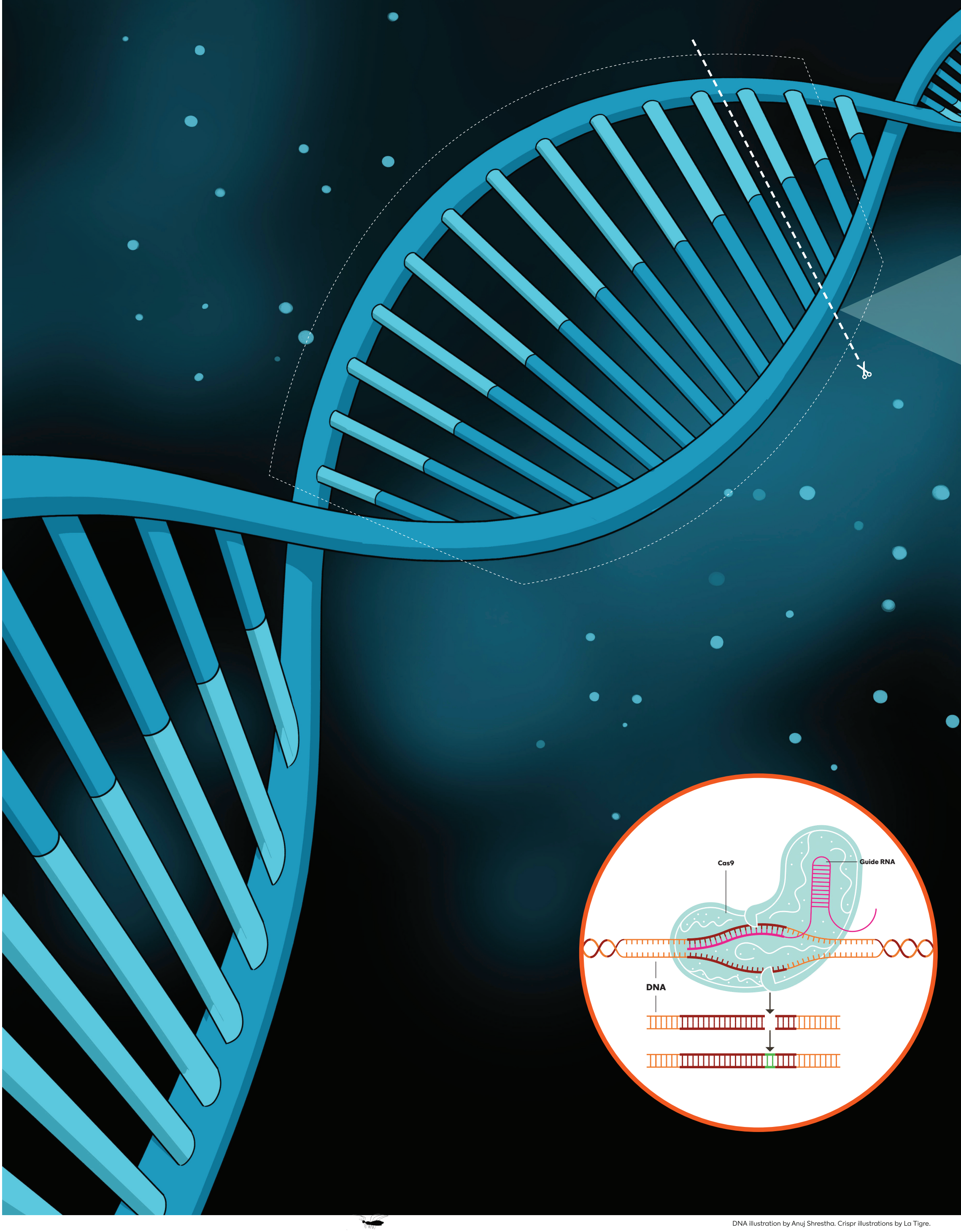
**Mammoth, Far, far future** Scientists "de-extinct" woolly mammoths by changing elephant genes to look more like mammoth genes.

Illustrations by La Tigre

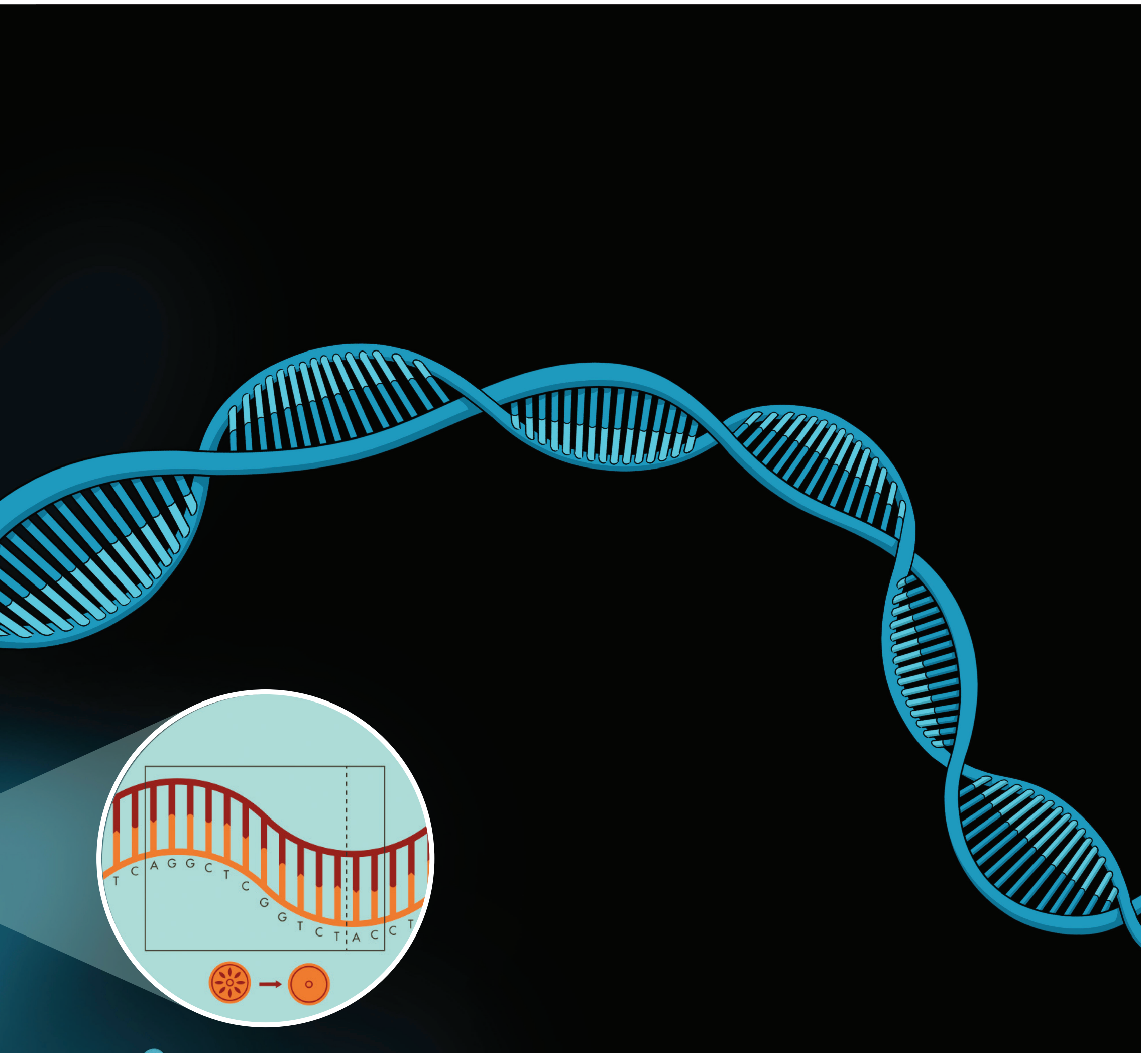
# DNA Is in Every Living Thing

## GET YOUR SCISSORS — IT'S TIME TO MESS WITH IT!

Your DNA determines your height, your hair color, the shape of your nose. It also determines how much your dog drools, or whether your cat is cuddly or claws you if you get too close. DNA also makes some apples sweet and some more sour, and affects the redness of a tomato. The strand shown here is the specific DNA found in a tomato that you might find on your sandwich. Scientists have found a way to use Crispr to make the slippery seeds of this tomato disappear!




DNA illustration by Anuj Shrestha. Crispr illustrations by La Tigre.




## MAKING A SEEDLESS TOMATO

**USING CRISPR,** Japanese scientists were able to cut the DNA sequence where this dotted line appears. (If you want to follow along, that's where you should cut with your scissors!) This caused the DNA to repair itself — and in the process, knocked out the section of DNA shown here in the box. Go ahead and cut that out. Then the two sides linked up (you can tape yours together, though they won't match perfectly), which created a seedless tomato. That means no more pesky seeds, and it could help create plants that don't need to be pollinated — leading to a steady food supply even in a changing climate.

## HOW CRISPR WORKS

**THE CRISPR TECHNIQUE** is now the quickest, cheapest way to edit genes — and it's also surprisingly simple. If you were a geneticist in a lab, this is how you'd do it. *Chelsea Leu*

**1. CRISPR** is made up of two parts: a protein from the Cas family (there are dozens, including Cas5, Cas13a, Cas9 and CasX) that cuts DNA like a pair of molecular scissors; and guide RNA, a fragment of 20 genetic "letters" that acts as an instruction manual, telling the Cas protein exactly where to cut by matching up with that area of the gene.

**2. MIX** Cas9 protein, say, and the guide RNA, and the two become linked. Insert the combination into the cell you want to change, and the cell pushes it into the nucleus, where all its genes are kept.

**3. CAS9** and the guide RNA bounce around in the nucleus, randomly colliding with DNA for milliseconds at a time, searching the whole six-billion-letter genome until they find a match.

**4. ONCE** the letters in the DNA line up with the ones in the RNA instruction manual, Cas9 latches on to the DNA, unzips it and then makes a precise cut in the sequence you want to edit.

**5. TWO THINGS** can happen now. If you just want to delete a gene, you're done! The cut will trigger the cell to fix the DNA, closing the strands and deactivating the gene. Or, if you want to edit the gene, you also include with the instructions the snippet of DNA that you want to insert, which the cell uses to change the sequence.