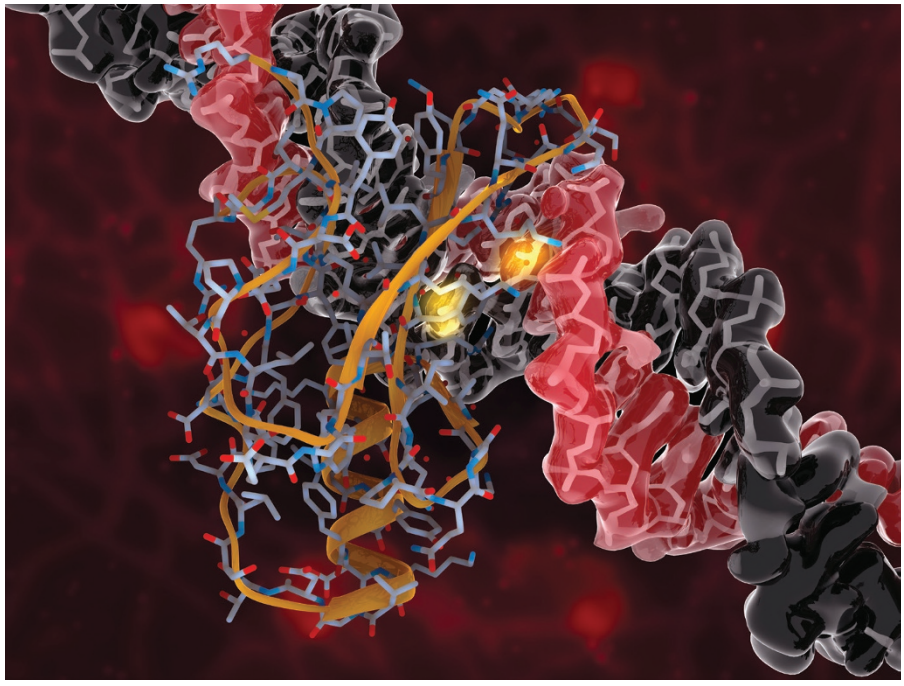
that make them good surrogates for humans also raise ethical concerns. However, the creation of colonies of monkeys and apes with neurological conditions could add other complexities to this type of research. Amaral brought up one example at the NIH workshop: "If you develop an animal model of something like autism, where repetitive behavior and self-injurious behaviors are actually part of the diagnostic features, how do we deal with animal-welfare constraints on maintaining those animals?" he said. "I think this is a really difficult topic."

In the first experiments inserting the *HTT* gene into monkeys to model Huntington's disease, two of the animals did not survive long after birth. However, in the second generation of engineered monkeys, the researchers managed to manipulate the *HTT* gene to make the disease less aggressive.

Amaral also points out that that the way nonhuman primates are reared can have a significant impact on their brain development. Research has shown that monkeys raised in nurseries without their mothers exhibit more anxiety and abnormal behaviors than monkeys raised with their mothers[6]. "I would hope that the monkeys that are produced with these genetic mutations have normal social upbringings," he says. Otherwise, it will be difficult to tease out whether behavioral abnormalities are due to the mutation or the rearing conditions.

Many primate centers allow infants to be with their mothers, says Joyce Cohen, associate director of animal resources at the Yerkes National Primate Research Center, part of Emory University in Atlanta. However, some engineered monkeys might need to be reared in nurseries if the infants develop the disease early in life. Or there might be testing schedules or procedures that require nursery rearing.

None of these issues is new, says Larry Carbone, a veterinarian at the University of California San Francisco. Nonhuman-primate disease models have been around for decades. "You don't need genetic modification to be able to cause human-like diseases in monkeys," he says. However, he suspects that the growing ease of genetically manipulating monkeys will lead to the development of more models. "I think it's opening new doors, and potentially a lot of new doors, really fast."



Ramón Andrade, 3Dciencia/Science Source

Protein of interest: An illustration of the MECP2 protein bound to DNA.

Michael Platt, a neurobiologist at Duke University in Durham, North Carolina, however, is unsure whether there will be a deluge of new models—at least, not immediately. "I think people are going to wait to see how effective these models will be. The few that have come out have shown a lot of promise, in particular, recapitulating some of the aspects of the human phenotype that are often not seen in mice," he says.

Steven Niemi, director of Harvard University's Office of Animal Resources in Cambridge, Massachusetts, says that the new disease models will provide an opportunity to enhance veterinary care for nonhuman primates. "The convention today is to treat an animal of any species solely with the drug of interest or the vaccine of interest and see if that drug or vaccine succeeds on its own," he says. But that is not how it works in the real world. Human patients receive medicines and other therapies to alleviate their symptoms and make them more comfortable. Providing nonhuman primates with similar supportive care is worthwhile "not just for moral reasons," Niemi says, but also because more closely mimicking the human situation will provide better scientific answers.

> "I think CRISPR–Cas9 gives greater opportunity to mimic the real disease condition in large animal models."

The use of new gene-editing technologies to create nonhuman primate disease models is "the cutting edge of science," says Carrie Wolinetz, director of the NIH's Office of Science Policy and the organizer of the NIH workshop on ethics. And it is possible that these models will raise new issues. "That's why we're paying a lot of attention to the conversation in the community," she says. "Science is evolving by its very nature, and ethics is evolving right along with it."

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1. Yang, S.H. *et al. Nature* **453**, 921–924 (2008).
2. Moran, S. *et al. Theriogenology* **84**, 277–285 (2015).
3. Niu, Y. *et al. Cell* **156**, 836–843 (2014).
4. Chen, Y. *et al. Hum. Mol. Genet.* **24**, 3764–3774 (2015).
5. Liu, Z. *et al. Nature* **530**, 98–102 (2016).
6. Sasaki, E. *et al. Nature* **459**, 523–527 (2009).
7. Rommeck, I., Gottlieb, D.H., Strand, S.C. & McCowan, B. *J. Am. Assoc. Lab Anim. Sci.* **48**, 395–401 (2009).

Correction

In the October 2016 issue, the piece "Reservoirs of resistance: To understand why antibiotics fail, geneticists chase the 'resistome'" (*Nat. Med.* **22**, 1069–1071, 2016) neglected to include the full name and affiliation of Evan Jones, one of the sources quoted in the piece. Evan Jones serves as the CEO of OpGen. The error has been corrected in the HTML and PDF versions of this article.