Scientists who breed rodents for their desire to run have proven that work ethic is genetically influenced. One of the leaders in that field has been Theodore Garland, a physiologist at UC Riverside. For more than a decade, he has been offering mice a wheel that they may hop on or shun at their discretion.

Normal mice run three to four miles each night. Garland took a group of average mice and separated them into two subgroups: those that chose to run less than average each night, and those that chose to run more than average. Garland then bred "high runners" with other high runners, and "low runners" with other low runners. After just one generation of breeding, the progeny of the high runners were, of their own accord, running even farther on average than their parents. By the sixteenth generation of breeding, the high runners were voluntarily cranking out seven miles each night. "The normal mice are out for a leisurely stroll," Garland says. "They putz around on the wheel, while the high runners are really running."

When mice are bred for endurance capacity—not voluntary running, but when they are forced to run as long as they physically can—successive generations have more symmetrical bones, lower body fat, and larger hearts. In his voluntary-runner breeding program, Garland saw body changes, "but at the same time," he says, "clearly the brains are very different." Like their hearts, the brains of the high runners were larger than those of average mice. "Presumably," Garland says, "the centers of the brain that deal with motivation and reward have gotten larger."

He then dosed the mice with Ritalin, a stimulant that alters levels of dopamine. Dopamine is a neurotransmitter, a chemical that conveys messages between brain cells. The normal mice, once doped, apparently derived a greater sensation of pleasure from running, so they started doing it more. But the high runners, when doped, did not run more. Whatever Ritalin does in the brains of normal mice is already occurring in the brains of the high-running mice. They are, quite literally, running junkies.*

"Who says motivation isn't genetic?" Garland asks, rhetorically. "In these mice, it's absolutely the case that motivation has evolved."

Researchers around the world have begun to explore locations on the genome that differ between marathon mice and their normal counterparts, and specifically to home in on genes related to dopamine processing that might impact the sense of pleasure or reward a mouse gets from a particular behavior.

Of course, they aren't doing this simply to understand why rodents want to run. The ultimate goal is to learn about human gym rats.

232 The genetics of Alaskan huskies:
Huson, Heather J., et al. (2010). "A Genetic Dissection of Breed Composition and Performance Enhancement in the Alaskan Sled Dog." *BMC Genetics*, 11:71.

234 Garland's coauthored work on dopamine, Ritalin, and "running-junkie" mice:
Rhodes, J. S., S. C. Gammie, and T. Garland Jr. (2005). "Neurobiology of Mice Selected for High Voluntary Wheel-Running Activity." *Integrative and Comparative Biology*, 45(3):438–55.

236 The University of Wisconsin mice to which Pam Reed compared herself:
Rhodes, J. S., T. Garland Jr., and S. C. Gammie (2003). "Patterns of Brain Activity Associated with Variation in Voluntary Wheel Running Behavior." *Behavioral Neuroscience*, 117(6):1243–56.

237 Background on the scientific study of dopamine and addiction:
Holden, Constance (2001). "'Behavioral' Addictions: Do They Exist?" *Science*, 294:980–82.
Peirce, R. C., and V. Kumaresan (2006). "The Mesolimbic Dopamine System: The Final Common Pathway for the Reinforcing Effect of Drugs of Abuse?" *Neuroscience & Biobehavioral Reviews*, 30(2):215–38.

238 Every human study conducted has found that voluntary physical activity is significantly heritable:
Lightfoot, J. Timothy (2011). "Current Understanding of the Genetic Basis for Physical Activity." *Journal of Nutrition*, 141(3):526–30.

Reed writes in her book, while noting that she finds peace of mind in extreme activity. "I am certain that *not* running for three hours every day would very quickly make me ill. . . . While nobody's forcing me to do this, it's not really a choice, either. There's something in my nature that makes it really hard for me to sit still . . . being temperamentally attuned to perpetual motion makes me pretty uncomfortable on long car trips or in sedate social settings." (Reed's son Tim contrasts himself to his mother: "I only like to run for maybe two or three hours max.") One of Reed's current goals is to set the women's world record for running across America, which she plans to do at a pace of two marathons a day.

"When I don't do this," Reed says—and by "this" she means running three to five times a day—"I feel horrible. I had C-sections, and three days after them I was running. . . . It's who I am. I totally love it. As I get older, I have to say, I can sit still a bit longer, but it's not comfortable."

In her book, Reed astutely ponders whether she might be the human version of the rodents from an experiment at the University of Wisconsin in which mice bred for voluntary running were restricted from running, and then had their brain activity measured. Brain circuitry similar to that which is active when humans crave food or sex, or when addicts crave drugs, was activated in the high-running mice that were denied the chance to run, and they became agitated. The researchers presumed that when the mice were deprived of running their brain activity would decline. Instead, it went into overdrive, as if the mice needed exercise to feel normal. The longer the distance a particular mouse was used to running, the more frenetic its brain activity became when it was made to sit still. As with Garland's mice, these rodents were genetic junkies for exercise.

Pam Reed is an outlier by any measure. But a seemingly compulsive drive to exercise is hardly unique among distinguished athletes. Consider Ethiopian Haile Gebrselassie, who has set twenty-seven distance running world records: "A day I don't run, I don't feel good," he says. Or Floyd Mayweather Jr., the undefeated boxing champion, who has been known to jolt awake in the middle of the night and force his bloated entourage to meet him at the gym for a workout. Or Steve Mesler, a member of the 2010 Olympic four-man bobsled team that won the first U.S. gold in sixty-two years. He retired afterward, but says he "feels anxious" when he takes a break from working out even now. Or Ironman triathlete Chrissie Wellington or high jumper Stefan Holm, both of whom claim addictive personalities that they channeled to their training.

Or Herschel Walker, best known as the 1982 Heisman Trophy–winning