

NOTES

1. Although archaeologists aren't certain when humanity became self-aware, the origins of myth, ritual, and symbol are clearly traced to more than thirty thousand years ago. See S. Mithen, *The Prehistory of the Mind: A Search for the Origins of Art, Religion and Science* (London: Thames & Hudson, 1996).

2. Although nearly a century old, W. Durant's *The Story of Philosophy* (1926) is still a fresh discussion of the early Greeks. Their approach, based in seeking natural rather than supernatural explanations, is the foundation of science today, and it applies to everyone. Physics and engineering keep planes in the air, not Aeolus, the Greek god of wind. Since physics and biology build from the same base, if you believe in the physics that keeps planes in the air, you must also believe in the system of knowledge that explains evolution. You can't have "a little science": it's all or nothing. See W. Durant, *The Story of Philosophy* (New York: Simon & Schuster, 1926).

3. See C. Sullivan and C. M. Smith, "Getting the Monkey off Darwin's Back: Four Common Myths about Evolution," *Skeptical Inquirer* (May/June 2005): 43–48.

4. National Science Foundation, Division of Science Resources and Statistics, "Science and Technology: Public Attitudes and Understanding," in *Science and Engineering Indicators*, chap. 7, pp. 15–16 (2004), <http://www.nsf.gov/statistics/seind04/pdf/c07.pdf> (accessed May 5, 2005).

5. E. Mayr, *What Evolution Is* (New York: Basic Books, 2001).



Myth One

Survival of the Fittest

“Survival of the fittest” is the most commonly used phrase drafted into everyday speech from the theory of evolution. Flipping through television channels, we see a lion bearing down on a gazelle, a boxer pummeling his opponent,

bighorn sheep clashing horns: we nod and smugly think, "There, see? *Survival of the fittest*; the order of nature." And it seems clear enough: for all we can tell, the strong *do* survive. It would be crazy to think otherwise, considering what we've learned about the natural world from mass media.

But mass media, of course, is about drama and unfolding stories, and every dramatist knows that without conflict, you have no story. And so the natural world has been dressed up as a vast and violent landscape of competition—the ultimate reality show, where real blood can be shed. Can the antelope corner tighter than the lion? Can the species survive? Will the "balance of nature" be upset? Television has taken Tennyson to heart, portraying nature as "red in tooth and claw," a world of savage predation, where survival of the fittest is the primary law.¹

This is all very exciting, but it's a vision of the natural world focused almost entirely on dramatic competition. If we shift our focus, though, it's clear that there's an entire world of plant and animal relationships that aren't dominated by violent competition. For example, aside from the obvious eating of prey by predators, most animals generally leave each other alone, particularly if they're after different kinds of food. And of course there's symbiosis, in which species interactions are mutually beneficial. Nevertheless, on tonight's Animal Planet schedule, we have plenty of shows on big, scary, ferocious animals (polar bears, lions, and spitting cobras), while only one herbivore is getting airtime—the poor old wildebeest. And what about plants? Their lack of bloody teeth and claws might account for the lack of a "Plant Planet" channel.²

Clearly, the popular focus on competition has led to a portrayal of nature as a metaphorical battlefield, where all that matters is your ability to wage war, outstrip your opponent, and beat down your immediate peers: the "survival of the fittest."³ But, as usual, nature is far too complex to be reduced to this absolute, bumper-sticker slogan. Let's see if we can clear up the confusion caused by the survival of the fittest myth, starting with Darwin himself.

WHAT DID DARWIN MEAN BY "SURVIVAL OF THE FITTEST"?

We know how popular culture portrays survival of the fittest, but what did Darwin himself have to say about it? In 1872 he wrote: "[The] preservation of favourable individual differences and variations, and the destruction of those which are injurious, I have called Natural Selection, or the Survival of the Fittest."⁴

So, according to Darwin himself, "survival of the fittest" and "natural selection" are basically the same thing—both phrases tell us that in any population, those individuals with characteristics well suited to their environment tend to be preserved, while those less well suited tend to die off. What's most important is that Darwin doesn't specify anything here about the characteristics we often casually associate with the idea that only the strong survive, such as brute force. In fact, Darwin doesn't mention *any specific characteristics* (like bulging muscles, sharp teeth, or a keen sense for smelling blood) equating to fitness. That should raise the first red flag when people speak casually about survival of the fittest, because we can immediately ask, *fittest in what sense* or *fittest in what environment*? Clearly, no single ability or physical characteristic makes any life-form "fit" in every environment.

For example, the long-finned eel is expert at snapping up dragonfly larvae, snails, and small fish that live in New Zealand's lakes, and it's in these lakes where they grow fat (up to eighty pounds) and happy, with few predators. They're kings of their cool, clear-water environment. But before they can grow fat and happy, they have to survive a perilous migration from their birthplace in the Pacific Ocean, and that often requires them to squirm across dry land; most make it, but dry spells occasionally strand armies of them in sticky mudflats. Slightly less rainfall than average can make carcasses of these would-be kings.

Humans, it's often thought, are immune to the rigors of nature—the "selective pressures" that any life-form must endure to survive—because we've mastered living in so many environments. But

newborns can't walk or crawl, have no teeth or claws, and can only really eat breast milk, so actually there are many selective pressures that can quickly kill our offspring. At birth, in fact, we're among the most helpless of animals, entirely dependent on our parents. Our specialty as a species isn't *brawn* but *brain*.

Obviously, then, we need to refine our concept of the survival of the fittest. It's pretty clear what "survival" refers to. For the individual, it means staying alive. For a species, it means that enough individuals stay alive long enough to have offspring, and perhaps long enough to care for those offspring. The problem here is the word *fittest*. Fittest, of course, means the most fit, so let's examine the concept of *fitness* itself.

FITNESS

What is fitness? From the perspective of population genetics, fitness is basically the statistical likelihood that you'll have offspring, a cosmic wager on your genetic prospects as an individual.⁵ Fitness isn't any single physical characteristic of an organism, like musculature or tooth size; it's a *measure of an individual's reproductive potential*, whether that individual is bat, buffalo, or bamboo.

While population geneticists calculate theoretical fitness for lab studies, calculating that exact probability for any individual in the real world would take a bank of supercomputers going full-tilt, 24/7. Why? Because the probability that you'll have offspring can be affected by so many factors—each called a *selective pressure*—that your fitness score is constantly changing.⁶ An individual's fitness fluctuates so much that no bookie would dare wager on it, and that's because no bookie, or supercomputer, could ever estimate the range and the effects of selective agents that modify your fitness score from one moment to the next.

For example, imagine that you're a male Neanderthal living with your family group about one hundred thousand years ago.⁷ You inhabit a cave overlooking a broad mountain valley in a place that

will one day be called France. What are the selective agents that affect your fitness, your likelihood of having offspring? Brute force is an asset (you don't know it, but you have twice the strength of a modern human), but is brute strength really enough to keep you alive? You have a lot of concerns. You have to find water and food, and since storage hasn't really been invented yet, every day you hike down from your cave, embarking on the food quest. You know that around the time certain plants begin to bloom, herds of reindeer usually cross the river that runs down your valley; perhaps today it's time to lay in wait for them. But sometimes they don't come at the right time (maybe they've been intercepted by wolves, or diverted by other Neanderthals), and that can be disastrous; your fitness score might plummet. There's also the danger that *you'll* become lunch; cave lions, five-hundred-pound predators bigger than modern lions, are out there, and they know what you do—they're smart, they remember. And of course there's the danger of running into other Neanderthals, who might not like your intruding into their hunting ground. There's also the fire to worry about; it's been raining for a week, and if the fire dies, you're going to have a hard time restarting it. And you need to find a mate, but at twenty-eight, you're already pretty old. Your fitness, in fact, decreases daily now, as the likelihood of your death increases simply as a function of time. And what about the unknowns in your world? What if you get sick for a reason you'll never fathom? And could you predict that one day a new and different variety of people (modern humans) is going to appear at the foot of your valley with better tools and smarter brains? Sometimes, selective pressures leap at you from the abyss of ignorance.

It's clear that at any given time the selective pressures impinging on Neanderthals—or any species—are numerous, complexly interconnected, and largely unpredictable. Objectively, it's easy to *define* fitness as "an organism's likelihood of reproduction," but our Neanderthal example has shown us that this likelihood is a probability figure—perhaps with an infinitely long decimal—that *changes from moment to moment*. Fitness is fluid, not concrete.

Imagine a Cosmic Computer tracking your fitness score, a single probability figure, from 0–100 percent on a little red display that flutters and flashes from moment to moment as selective pressures increase or decrease your chances of passing your genes on to the next generation of your offspring. As the properties of your selective environment shift and slide, riding seasonal tides or being jarred by catastrophes, your fitness score, blinking away on the Cosmic Computer, shows their effects. Sometimes you're favored by a change in your environment (as when our Neanderthal comes across a dying mammoth), other times you're not (as when our Neanderthal is driven away from a kill by a pack of hyenas). No single characteristic, like brute strength or agility or even intelligence, is a savior, because the pressures on you can differ from moment to moment, from place to place, or even from one generation to the next.

Clearly, then, fitness is relative to any life-form's environment at large, and this leads us to the term *selective environment*. Let's see if examining the selective environment can help us sharpen focus on the fuzzy phrase "survival of the fittest."

SELECTIVE ENVIRONMENTS

Another way to envision fitness is to think of it as a measure of the *closeness of fit* between you (and "you" may be a sunflower, a slime mold, a rabbit, or a wren) and your selective environment. Among your seedy, slimy, furry, or feathered counterparts, everyone has a slightly different fit to their environment, because it's very rare that individuals of any population are exact clones; there is almost always some variation, however slight, between individuals.⁸ Clearly, the fittest of your population is the one *best suited* to that environment (and therefore more likely to reproduce), and the one with a poor fit—for example, a fly born without wings—is less fit, and less likely to have offspring. This way of envisioning fitness is only a little less nebulous than the Cosmic Computer's ever-changing readout, but it's

somehow a little more concrete. You can *see it*, for example, in the poor, wingless fly, as you can in many cases in the natural world.⁹

Consider cheetahs. They appear to have had a catastrophic population crash around ten thousand years ago, after which extensive inbreeding of the surviving population created a number of problems, including abnormalities in their sperm, high infant mortality, and susceptibility to a variety of diseases.¹⁰ Most visibly, some cheetahs are born with slightly kinked or curled tails, which is a big problem because normally, the cheetah's tail is used as a sort of rudder, or counterbalance, during its seventy-mile-per-hour sprints in pursuit of prey. Cheetahs born with an abnormal tail simply won't have as much control, or hunting success, as those with a sleek, controllable tail. The difference in fitness here, in *fit between individual cheetahs and their selective environment*, is obvious, and it has nothing to do with one-on-one combat between cheetahs, or with their ability to slay each other in some television producer's gory arena of competition. Here, an important factor tinkering with the fitness score is simply whether a cheetah is born with a kinked or straight tail.

We can see selection at work in even less outwardly competitive realms. Let's say you're a woodpecker, equipped with a stout beak and a compact skull that firmly cups your brain, preventing a chronic migraine. But you're a little hungry because, sometimes, when you listen for grubs after jackhammering a tree with your beak, you don't hear anything. Off you fly, hungry and disappointed; it's only happened twice today, but that's enough to be frustrating. You have no idea that this is a simple hearing defect, and that your neighbor has better hearing; all you know is you see him getting fat on the grubs you can't find. The blunt facts are that, simply because of a hearing defect, your chances of finding grubs are reduced, and that your health may suffer and your chances of finding a mate—for instance, by hammering long and hard at a tree to attract one—is lower than your neighbor's. In this case, an apparently minute factor of the environment—the level of noise produced by burrowing under-bark grubs—is an important aspect of the woodpecker's selective environ-

ment. The subtlety of this particular selective pressure hints at the breathtaking complexity of selective environments.

To appreciate this great complexity, imagine trying to sketch out your own selective environment. You could start with local pressures (*Did I cook that chicken well enough?*), then reach out farther (*Is there a contaminant in my city's water supply?*), but how far do you go? Do you include the properties of the sunlight that come to us from ninety-three million miles away? You should, since it's the source of most of the energy in the biosphere, and also because in years of intense solar flare activity (such as the eleven-year cycle that began in 2005), solar radiation doses can be several hundred times higher than in normal years, "slow-cooking" your DNA.¹¹ How do you measure the effects of the microbes that may swarm in the water you drink, microbes that might attack an even slightly depleted immune system? What about the *E. coli* bacteria that multiply in your innards every day? Most aren't harmful, but it just takes one harmful strain to arise, spread to your brain, and produce meningitis, which can kill you in just hours. This normally happens in infants, infants who have no idea that such a selective pressure is upon them. Selective pressures don't care if you're an infant or the pope.

Well, obviously you could drive yourself crazy trying to sketch out your selective environment, and contemplating it can even lead to paranoia. By his fifties, eccentric billionaire Howard Hughes tried to shield himself from selective pressures—namely, germs—by insisting on handling everything with clean paper towels. Maybe he wasn't so crazy after all?¹² Can we hide? Can we isolate ourselves?

It turns out that although we can use our technologies to buffer out some selective pressures (such as wearing clothing to keep us warm), we can't protect ourselves from *everything*.¹³ Nothing, it turns out, lives in a vacuum, unaffected by the rest of the universe. Selective environments are so complex that we may as well consider them infinite.

Consider life ten thousand feet below the surface of the ocean, where the water is nearly freezing and over two tons of pressure press on every square inch of whatever ventures this far down.¹⁴ Except for the ghostly flashes of occasionally glowing fish, there is no light here:

sunlight doesn't reach this deep. But there is life. There are beard worms, red-and-white "living tubes" standing up to ten feet tall, and there are free-floating colonies of bacteria, feeding on sulfurs billowing up from hot-water vents in the seafloor. And a few fish quietly glide by. But it looks bleak to us humans, like the surface of the moon, and it's hard to escape the notion that the beard worm is among the most isolated, lonely forms of life. But even here, there is a selective environment, and that means selective pressures for the beard worm to endure. Beard worms can't stand the cold water just a few feet from the hydrothermal vents, so they need a way of reproducing that keeps them close to the warmth. Their environment is also affected by a steady rain of decaying organic matter—disintegrated plant and fish bits from far above—that descends like slow snowflakes, and affects the chemistry of the seafloor, in which many beard worms are half-buried. Beard worms battle no one in their cold, dark domain, but they still have a selective environment.

No life, then, is an island unto itself. Each individual is immersed in a complex web of selective pressures that requires environment-specific "solutions." No single adaptation assures fitness in every time and place. And this is exactly why geneticists consider gene-pool diversity to be a measure of health in a population; if everyone is identical, a single environmental change, for example, or a single disease, could devastate the whole population. Genetic diversity is genetic health, a hedge against catastrophe.

DO THE FITTEST SURVIVE?

By taking apart the phrase "survival of the fittest," we've been able to see how it masks some important complexity. Yes, it's the fittest that survive. But in an enormously complex world of ever-changing selective pressures, no single characteristic—such as brute strength—ensures survival in every circumstance. What it is to be "fit" depends on what you are, where you are, and when.

NOTES

1. British poet Alfred Lord Tennyson (1809–1892), whose poetic genius leaned toward morbid and violent themes, characterized nature as “red in tooth and claw” in an elegy published nearly a decade before Darwin published *On the Origin of Species*. See M. Demoor, “His Way is thro’ Chaos and the Bottomless and Pathless: The Gender of Madness in Alfred Tennyson’s Poetry,” *Neophilologus* 86, no. 2 (2002): 325–35.
2. But plants deserve some television airtime: most life is supported by plants, which produce both food we can eat and oxygen we can breathe. They also “scrub” our atmosphere of carbon dioxide, which we can’t breathe. We emit carbon dioxide every time we exhale and every time we start a car.
3. The popular focus on competition, among economists, biologists, and sociologists alike, is rooted in mistakenly attributing purposive, violent natural competition to Darwin, while this view actually predates Darwin. See note 1 above.
4. See C. Darwin, *On the Origin of Species*, 6th ed. (London: Murray, 1872), p. 63, http://pages.britishlibrary.net/charles.darwin/texts/origin_6th/origin6th.fm_html (accessed December 10, 2005). Although Darwin says “destruction,” he means it in a sterile, Victorian way, rather than implying purposive violence or combat. Darwin first used the phrase “survival of the fittest” in the title to chapter 4 (“Natural Selection; or The Survival of the Fittest”) of the sixth edition (considered the definitive edition) of *On the Origin of Species*, published in 1872, thirteen years after the first edition. He took the phrase from Herbert Spencer, an early social Darwinist.
5. For a thorough discussion of fitness, see S. Wright, *Evolution and the Genetics of Populations: A Treatise* (Chicago: University of Chicago Press, 1968). A more popular account is found in R. Dawkins, *The Selfish Gene* (New York: Oxford University Press, 1976).
6. Discrete, easily defined selective pressures, such as a major food competitor or a predator, are known as *selective agents*. For many examples of natural selection, see J. Endler, *Natural Selection in the Wild* (Princeton, NJ: Princeton University Press, 1986).
7. Neanderthals were “protohumans” that lived in Europe and the Near East from about two hundred thousand years ago to about thirty thousand years ago. We share a common ancestor with them, but they went

extinct, while we “modern” humans survived. Neanderthal life was not apparently as brutish as Hollywood makes it seem, but it was fundamentally different from the life of “modern” humans, even one hundred thousand years ago. This sketch of Neanderthal life is compiled from O. Bar-Yosef, “Eat What Is There: Hunting and Gathering in the World of Neanderthals and Their Neighbors,” *International Journal of Osteoarchaeology* 14, nos. 3–4 (2004): 333–42; K. V. Boyle, “Reconstructing Middle Paleolithic Subsistence Strategies in the South of France,” *International Journal of Osteoarchaeology* 10, no. 5 (2000): 336–56; C. Gamble, *The Palaeolithic Societies of Europe* (Cambridge: Cambridge University Press, 1999); and E. Trinkaus and M. Zimmerman, “Trauma among the Shanidar Neanderthals,” *American Journal of Physical Anthropology* 57, no. 1 (1982): 61–76.

8. As we will see in “Myth Two: It’s Just a Theory,” sexually reproducing species combine the male and female DNA, creating offspring slightly different from their parents. Clones are more common in asexually reproducing species (which produce legions of offspring, like Xerox copies) but even so, there is variation. Note that some slime molds (including the Dog Vomit slime mold, which looks just like it sounds) reproduce with an unusual form of sexual reproduction. See S. L. Stephensen and H. Stempen, *Myxomycetes: A Handbook of Slime Molds* (Portland, OR: Timber, 2000).

9. For many examples of selection in the natural world, see J. Endler, *Natural Selection in the Wild*.

10. See M. Menotti-Raymond and S. J. O’Brien, “Dating the Genetic Bottleneck of the African Cheetah,” *Proceedings of the National Academy of Sciences USA* 90, no. 8 (1993): 3172–76. See also S. J. O’Brien et al., “Genetic Basis for Species Vulnerability in the Cheetah,” *Science* 227, no. 4693 (1985): 1428–34.

11. Solar Physics Group (NASA), “Sun Facts,” <http://science.msfc.nasa.gov/ssl/pad/solar/sunspots.htm> (accessed August 24, 2005).

12. Hughes may have been somewhat fanatic, but today the Howard Hughes Medical Institute promotes and funds (to the tune of over \$10 billion a year) a wide variety of important biomedical research projects.

13. Although it may seem that our layers of cultural practices (such as incest avoidance) and, especially, technologies (such as modern medicine) have totally buffered humanity from selective pressures, this is partly an illusion. American fetuses, for example, have recently been found to be

24 The Top Ten Myths about Evolution

floating in the womb in an unhealthy broth containing mercury, pesticides, and Teflon; in this case, we're *creating our own selective pressures* by polluting our environment! See the nonprofit Environmental Working Group's report "Bodyburden: The Pollution in Newborns" (which has prompted some members of Congress to tighten pollution regulations), <http://www.ewg.org/reports/bodyburden2/> (accessed December 22, 2005).

14. For an overview of the fascinating world of deep-sea biology, see J. D. Gage and P. A. Tyler, *Deep-Sea Biology: A Natural History of Organisms at the Deep-Sea Floor* (Cambridge: Cambridge University Press, 1996).