For scientists, there is little doubt that evolution is more than a theory. It’s taken as a fact for anyone researching biology, medicine and almost any other scientific pursuit. But for those who haven’t been versed in human genetics, evolutionary biology or the fossil history of the world, Jerry Coyne lays out a clear case for evolution in his new book, *Why Evolution Is True*. Coyne, a professor of ecology and evolution at the University of Chicago, is known internationally for defending evolution against intelligent design. In this excerpt, he explains how weird bits of human anatomy—the appendix, goose bumps, tailbone and ears—are signs that we have evolved as a species.
We humans have many vestigial features proving that we evolved. The most famous is the appendix. Known medically as the vermiform ("worm-shaped") appendix, it's a thin, pencil-sized cylinder of tissue that forms the end of the pouch, or caecum, that sits at the junction of our large and small intestines. Like many vestigial features, its size and degree of development are highly variable. In humans, its length ranges from about an inch to over a foot. A few people are even born without one.

In herbivorous animals like koalas, rabbits and kangaroos, the caecum and its appendix tip are much larger than ours. This also is true of leaf-eating primates like lemurs, lorises and spider monkeys. The enlarged pouch serves as a fermenting vessel that helps the animal break down cellulose into usable sugars. In primates whose diet includes fewer leaves, like orangutans and macaques, the caecum and appendix are reduced. In humans, who don't eat leaves and can't digest cellulose, the appendix is nearly gone. The less herbivorous the animal, the smaller the caecum and appendix. Our appendix is simply the remnant of an organ that was critically important to our leaf-eating ancestors, but of no real value to us.

Does an appendix do us any good at all? If so, it's not obvious. Removing it doesn't produce any bad side effects or increase mortality (in fact, removal seems to reduce the incidence of colitis). Discussing the appendix in his famous textbook The Vertebrate Body, paleontologist Alfred Romer remarked drily, "it's major importance would appear to be financial support of the surgical profession." To be fair, it may be of some small use. The appendix contains patches of tissue that may function as part of the immune system. It also has been suggested that it provides a refuge for useful gut bacteria when an infection removes them from the rest of our digestive system.

But these minor benefits are surely outweighed by the severe problems that come with the human appendix. Its narrowness makes it easily clogged, which can lead to its infection and inflammation, otherwise known as appendicitis. If not treated, a ruptured appendix can kill you. You have about one chance in 15 of getting appendicitis in your lifetime. Fortunately, thanks to the evolutionarily recent practice of surgery, the chance of dying when you get appendicitis is only 1 percent. But before doctors began to remove inflamed appendices in the late nineteenth century, mortality may have exceeded 26 percent. In other words, before the days of surgical removal, more than one person in a hundred died of appendicitis. That's pretty strong natural selection.

Over the vast period of human evolution—more than 99 percent of it—there were no surgeons, and we lived with a ticking time bomb in our gut. When you weigh the advantages of an appendix against its huge disadvantages, it's clear that on the whole it is simply a bad thing to have. But apart from where it's good or bad, the appendix is still vestigial, for it no longer performs the function for which it evolved.

So why do we still have one? We don't yet know the answer. It may in fact have been on its way out, but surgery has almost eliminated natural selection against people with appendixes. Another possibility is that selection simply can't shrink the appendix any more without it becoming even more harmful: A smaller appendix may run an even higher risk of being blocked. That might be an evolutionary roadblock to its complete disappearance.

Our bodies teem with remnants of primate ancestry. We have a vestigial tail: the coccyx, or the triangular end of our spine that's made of several fused vertebrae hanging below our pelvis. It's what remains of the long, useful tail of our ancestors. Tellingly, some humans have a rudimentary tail muscle (the "extensor coccygei"), identical to the one that moves the tails of monkeys and other mammals. It still attaches to our coccyx, but since the bones can't move, the muscle is useless. You may have one and not even know it.

Other vestigial muscles become apparent in winter, or at horror movies. These are the arrector pili, the tiny muscles that attach to the base of each body hair. When they contract, the hairs stand up, giving us "goose bumps"—so called because of their resemblance to the skin of a plucked goose. Goose bumps and the muscles that make them serve no useful function, at least in humans. In other mammals, however, they raise the fur for insulation when it's cold, and cause the animal to look larger when it's making or receiving threats. Think of a cat, whose fur bushes out when it's cold or angry. Our vestigial goose bumps are produced by exactly the same stimuli—cold or a rush of adrenaline.

And here's a final example: If you can wiggle your ears, you're demonstrating evolution. We have three muscles under our scalp that attach to our ears. In most individuals they're useless, but some people can use them to wiggle their ears. I'm one of the lucky ones, and every year demonstrate this prowess to my evolution class, much to the students' amusement.) These are the same muscles used by other animals, like cats and horses, to move their ears around, helping them localize sounds. In those species, moving the ears helps them detect predators, locate their young and so on. But in humans the muscles are good only for entertainment.

Vestigial traits make sense only in the light of evolution. Sometimes useful, but often not, they're exactly what we'd expect to find if natural selection gradually eliminated useless features or refashioned them into new, more adaptive ones. A dangerous appendix and silly ear muscles simply don't make sense if you think that species were specially created.