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Darwin's Rib

Robert S. Root-Bernstein

In this selection, Professor Robert Root-Bernstein, a 1981 MacArthur Fellowship winner, recounts the story of a student who told him that males have one fewer pair of ribs than females. Taken aback by her statement, it soon occurred to him that her comment was based on the biblical story of God creating Eve from one of Adam's ribs. He then notes the challenge of teaching evolution: a 1991 Gallup poll reported that 47 percent of respondents believed that God created humans within the last ten thousand years, and only 9 percent believed that humans evolved without God's direct intervention. At Root-Bernstein's university, only 20 percent of entering students possess enough knowledge about science to evaluate evolution as a valid scientific theory. Root-Bernstein believes just as firmly in religious freedom as he does in scientific research; he never insists that his students blindly accept scientific results. His teaching philosophy encourages students to be skeptical, as long as they apply logic and solid evidence to support their reasoning. Of course, complications still arise. As Root-Bernstein observes, nature evades every generalization humans—even scientists—try to impose on it. He concludes with the admonition "Take nothing for granted . . . that is what makes a scientist."

As all good teachers know, students will work much harder for extra-credit points than at the assigned task. I like to take advantage of this convenient trait in my introductory course on evolution. Once my students—nonscience majors at a midwestern land-grant university—understand the basic terms, I offer additional points for answering the questions I really want them to investigate. Find a dozen differences between the skeletons of a chimpanzee and a human being, I challenge them; tell me how a human female skeleton differs anatomically from a male.

The male and female skeletons I display are exemplary in their difference, and since most students should be able to guess what that difference is if they don't already know, I usually feel confident that the final answer is a giveaway. I say "usually" because seven years ago, the first time I taught the course, I got a surprising answer that still crops up with alarming regularity. Five minutes into the lab period, a young woman announced that she could answer the question without even examining the human skeletons.

I waited silently for her to explain that the female pelvis is shaped slightly differently from the male's, with a larger opening for childbearing. That part was the giveaway. The real purpose of the exercise was to make her prove her conjecture with measurements—to translate the theory to practice. I also wanted her to explain why this sexual dimorphism—that is, this sexually determined physical difference—is not nearly so pronounced in nonhuman primates, such as chimpanzees.

She spoke: "Males have one fewer pair of ribs than females."

I was totally unprepared for her answer. My mandible dropped. After a moment's reflection, I realized she must be referring to the biblical story in which God creates Eve from one of Adam's ribs. My

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student was someone who believed in the literal truth of the Bible, and it was her religious belief, not her previous knowledge of human anatomy, that made her so sure of her answer. This was going to be a challenge.

I believe just as firmly in religious freedom as I do in the scientific search for understanding. Thus, while I adhere rigorously to teaching the best science and showing how scientists recognize it as the best, I never insist that students believe scientific results. On the contrary, I encourage them to be skeptical—as long as their skepticism is based on logic and evidence. Scientific results, in my view, should be compelling because the collected observations and experiments leave room for only one possible rational explanation. To insist that students accept my word (or the word of any scientist) about any fact would undermine the one thing that makes science different from all other belief systems. The acid test of science is the personal one of convincing yourself that you perceive what everyone else perceives, whatever reservations you may start with. The evidence should be so compelling that it convinces even the most serious skeptic—as long as that skeptic retains an open mind. Even more important, science must admit what it does not or cannot know. Questions are what drive science, not answers. A teacher who insists on blind faith might well crush some budding Darwin who sees a higher and more compelling truth about nature than the current dogma admits.

But in this instance, I was dealing with a pretty bare-bones case. The skeletons stood there as mute models of reality. Pedagogical ideals notwithstanding, I saw little hope of enlightening my young friend without attacking her religion outright.

I stalled for time. "Have you actually counted the ribs?" I asked. She admitted that she had not. "Well, since this is a science class," I admonished, "let's treat your statement as a hypothesis. Now you need to test it." So off she went to the back of the room, full of confidence that God would not let her down. The breather gave me a chance to plot out what I hoped would be an enlightened, and enlightening, approach to the crisis her assumption had precipitated.

I began by reviewing my lesson plans to see where I had gone wrong. After all, comparative anatomy lab exercises should be fairly straightforward stuff. The body of the work consists in finding and describing the usual anatomic features essential to understanding basic evolutionary theory. We look for homologies (body parts that spring from the same embryological parts but may have different functions, such as a whale's flipper, a human hand, and a bat's wing) and analogies (body parts that serve the same function but have very different developmental origins, such as the wings of birds and insects).

We go on to examine the evidence for transitional forms, using casts of the series of modifications that begins with the four-toed *Hyracotherium* and ends with the modern one-toed horse. The students generally get a few surprises while learning about divergent evolution—how living things become more and more different through geologic time. Imagine the ribs of a reptile broadening and fusing to become the bony back-plate of a tortoise. If you turn the skeleton over and look at the inside, you can even figure out how the shell evolved.

Convergent evolution is usually an eye-opener, too, since the notion that random mutations might lead to similar outcomes is anything but obvious. We study the point by examining a wonderful display of creatures that eat ants—spiny anteaters, silky anteaters, pangolins, and armadillos—each of which evolved from a different class of animals. Despite their disparate origins, they look generally similar: they all have the same long snouts; long, sticky tongues; and long, sharp claws for prying ants from their nests and eating them, and they all have little eyes and thick fur, spines, or scales to protect them from the bites of their tiny prey. Such examples of convergent evolution are among the best evidence for natural selection, because any animal that is going to eat ants, regardless of its anatomic origins, needs certain adaptations and will therefore end up looking similar to all the other animals that live in the same way.

Finally, we study vestigial traits—leftover parts that seem to serve no present function, such as the useless wings of flightless birds like ostriches and our apparently pointless appendix.

The students are required to understand these terms and be able to use their attendant principles to compare many amphibian, reptile, and mammalian skeletons, as well as a few fossil replicas. Was it really possible to learn all that and still think God created Eve from one of Adam's ribs?

"Are you sure those are male and female skeletons?" My cocksure friend was back, looking a little puzzled.

"They're the bona fide item," I answered. "Not only did they come so labeled from the company from which they were bought, but certain anatomic features that I have verified myself lead me to conclude that the labels are correct. But I'm glad you asked. Skepticism is a very useful scientific tool, and scientists do sometimes make mistakes. Not this time, though."

"Yes, but the skeletons have the same number of ribs," objected my student.

I agreed. "Why did you expect otherwise?" Best to get the argument out in the open. As I had guessed, her information came from the Bible, via Sunday school.

I had a sudden vision of whole classes being taught anatomic nonsense as truth. In my imagination, simple skeletons rose with a clamorous rattle to take on new lives as bones of contention. Wherever they appeared, dozens of Bible-toting students followed, egged on by ossified Sunday school teachers clustering around my desk to demand how I dare question Scripture. I knew my department chair would back me up, but the dean? The board of trustees? Weren't a few of them fundamentalists themselves? The problem was getting more difficult by the minute.

"But what does the Bible actually say?" I asked. Surely there had to be some way out of this mess.

"That God took a rib from Adam to create Eve."

"One rib or two?"

"One," she replied without hesitation.

"Don't forget that ribs come in pairs," I prompted her.

"Oh!" I could almost hear her mind whirring. "So men should be missing only one rib, not a pair—is that what you're saying?"

"I don't know." I shook my head. "Why should they be missing any?"

"Well, if God took a rib from Adam, wouldn't his children also be missing a rib?"

"All his children?" I countered. "Boys and girls?"

My young friend thought for a moment. "Oh, I see," she said. "Why should only males inherit the missing rib—why not females, too? That's a good question."

"I have a better one," I pressed on, a full plan of evolutionary enlightenment now formulated in my mind. "What kind of inheritance would this missing rib represent?"

In class we had discussed the differences between Lamarckian evolution by transmission of inherited somatic modifications and Mendelian inheritance through genes carried in the germ line of reproductive cells, but my student missed the point of my question. I explained. "Essentially, Lamarck maintained that anything that affects your body could affect your offspring. Lift weights regularly, and your daughter could inherit a bigger and stronger body than she would if you never stirred from the sofa. Chop off the tails of generation after generation of mice, and eventually you should end up with tailless mice. Make an antelope put its neck out for high-growing leaves, and its distant descendants will be giraffes.

"The problem is that generations of Jewish and Muslim males have been circumcised, without any effect on the presence or absence of the penile foreskin of later generations. Certain breeds of dogs have had their ears and tails cropped for hundreds of years without affecting the length or shape of the ears and tails of their offspring. In other words, Lamarck was wrong.

"In fact, if you recall from lectures, he couldn't have been right. Lamarckian types of inheritance aren't possible in higher animals. Remember: your egg cells are formed prior to birth and, mutations aside, contain essentially unalterable genetic information. Nothing you do to change your personal physiognomy, from lifting weights to having a nose job, will affect the genetic makeup of your offspring." As I reexplained these basic points, I realized that, lacking a problem to apply the information to, my student had not yet understood the important differences between Lamarck's and Mendel's theories. Information without a problem to which it can be applied is like a body without bones: a shapeless mass of muscle with nothing to work against. With Lamarck and Mendel in their fortuitous, Bible-generated problem context, I tried again.

"Look at it this way. Suppose you had an accident, and your right thumb had to be amputated. Would you expect all your children, assuming you have any, to be born lacking a right thumb?"

"Of course not," said my student. Then, after a pause, "Oh, I see. You mean that for the same reason

my children would have thumbs even if I didn't, Adam's children would have the normal number of ribs even though God took one of his. Otherwise, it would be Lamarckian inheritance."

"Right!" I said. "And there is no creditable evidence to support Lamarckian inheritance. So you've actually got several problems here. First, Lamarckian inheritance doesn't work. Why should Adam's loss of a rib affect his children? Second, everyone has ribs, men and women alike. Ribs certainly aren't a sex-linked trait like excessive facial hair or a scrotum. So there's no reason I can think of that Adam's male offspring but not his female ones should be missing a rib. If the sons were missing a rib, wouldn't the daughters be missing one, too?

"Third, there is nothing in the Bible that says exactly how many ribs Adam started out with, or how many ribs we should have, is there? So you have no compelling reason to believe that in taking a rib from Adam, God left all his male offspring one short. That's an inference—and a particularly poor one since it relies on an outdated theory of evolutionary change. You don't really want to use a discarded evolutionary theory to prop up the Bible, do you?"

I was pleased to see that my ploy had worked. My student accepted this rebuff of accepted wisdom with good grace and an active intellect. Her religion was intact, but she was learning to think about her assumptions and to reason a bit more like a scientist. She was soon back at the human skeletons counting and measuring other bones. With some help, and a few broad hints ("How can you tell the difference between a man and a woman from behind, if they are the same height and have equal-length hair?"), she finally realized that the reason she wore a different cut of jeans from the men in the class was because she is built slightly differently. *Vive la différence!*

Most human females have a relatively wider pelvis than males because the human brain (even in a newborn) is too large to pass through a narrow birth canal. Thus, one of the reasons sexual dimorphism is so much more pronounced in humans than in most other primates is relative brain size. ("Don't trust me," I told her, "check it—the skeletons are there!") Bigger brains require bigger hips.

By the end of the course, five more students had reported to me that they too knew without having to look at the skeletons that women have more ribs than men. Some of them trotted off to count the ribs and came back to report that they had verified their preconceived notion. I had to stand beside them and count the ribs two or three times before they would believe that there really are the same number in the two skeletons.

These days I'm better prepared than I was that first year. Sometimes I bring in an extra pair of skeletons or a medical textbook with X-ray photographs of the chest, so that the students can count ribs to their hearts' content. I've come to expect at least 10 percent of the students in each class to tell me that men and women differ in rib count. I have conducted surveys of nearly a thousand first-year college students who either are nonscience majors or have not yet declared a major. More than 25 percent report believing that God created the Earth within the last 10,000 years and that man was formed in God's image exactly as described in the Bible. Another 50 percent report being undecided as to whether evolution is a valid scientific theory or a hoax. Only about 20 percent enter my university having learned enough about science and the evidence for evolution to consider it a valid scientific theory.

My college classroom numbers follow fairly closely those reported in recent national polls. A 1991 Gallup poll, for example, found that 47 percent of the respondents believed that God created man within the last 10,000 years. Forty percent believed that man evolved over millions of years but that God had a direct hand in guiding that process. Only 9 percent said man evolved without God's direct intervention. In many communities, such as mine, there are ongoing, active attempts to exclude evolution from the public school curriculum. Lecturing on evolution is an interesting challenge under these circumstances.

But I always have the last laugh. I share it with my classes after they have counted ribs for themselves and know for themselves the correct answer. You see, I really do have one fewer pair of ribs than my mother.

Don't get me wrong: I'm perfectly normal. I have 12 pairs of ribs, just like almost every other human being, male or female. So, as far as we know, do my father and brother. My mother is the unusual one. She has 13 pairs of ribs.

Oh yes, and that 5,300-year-old man they found frozen in a glacier in the Alps a few years back? He's

got only 11 pairs of ribs. It happens. Still, imagine what might happen if the creation "scientists" get hold of a replica of the 5,300-year-old man's skeleton and try to pawn it off as proof of the Bible. Or consider the havoc my mother might wreak if her bones find their way into some science class to be compared with a typical male skeleton.

I chuckle at the thought, but I also check my skeletons twice. You can never be too careful. For example, there's a condition known as polydactyly—literally, "many digits"—in which people have extra fingers or toes. In one town in Spain, there has been so much inbreeding that almost everyone has six or seven fingers on each hand. I don't want any of my students unexpectedly claiming that a significant difference between chimps and us is the number of fingers or toes.

On the other hand, I wouldn't say no to a seven-fingered skeleton with 13 pairs of ribs. What a wonderful extra-credit assignment that would make, and what a wonderful example of how nature evades every generalization we try to impose on it. Take nothing for granted, I counsel my students: that is what makes a scientist. But don't ignore the exceptions, either. I'll make no bones about it: anatomic differences are what drive evolution—and its teaching.