11

The Big Bang

The elephant's trunk is six feet long and one foot thick and contains sixty thousand muscles. Elephants can use their trunks to uproot trees, stack timber, or carefully place huge logs in position when recruited to build bridges. An elephant can curl its trunk around a pencil and draw characters on letter-size paper. With the two muscular extensions at the tip, it can remove a thorn, pick up a pin or a dime, uncork a bottle, slide the bolt off a cage door and hide it on a ledge, or grip a cup so firmly, without breaking it, that only another elephant can pull it away. The tip is sensitive enough for a blindfolded elephant to ascertain the shape and texture of objects. In the wild, elephants use their trunks to pull up clumps of grass and tap them against their knees to knock off the dirt, to shake coconuts out of palm trees, and to powder their bodies with dust. They use their trunks to probe the ground as they walk, avoiding pit traps, and to dig wells and siphon water from them. Elephants can walk underwater on the beds of deep rivers or swim like submarines for miles, using their trunks as snorkels. They communicate through their trunks by trumpeting, humming, roaring, piping, purring, rumbling, and making a crumpling-metal sound by rapping the trunk against the ground. The trunk is lined with chemoreceptors that allow the elephant to smell python hidden in the grass or food a mile away.

Elephants are the only living animals that possess this extraordinary organ. Their closest living terrestrial relative is the hyrax, a mammal that you would probably not be able to tell from a large guinea pig. Until now you have probably not given the uniqueness of the elephant's trunk a moment's thought. Certainly no biologist has made a fuss about it. But now imagine what might happen if some biologists were elephants. Obsessed with the unique place of the trunk in nature, they might ask how it could have evolved, given that no other organism has a trunk or anything like it. One school might try to think up ways to narrow the gap. They would first point out that the elephant and the hyrax share about 90% of their DNA and thus could not be all that different. They might say that the trunk must not be as complex as everyone thought; perhaps the number of muscles had been miscounted. They might further note that the hyrax really does have a trunk, but somehow it has been overlooked; after all, the hyrax does have nostrils. Though their attempts to train hyraxes to pick up objects with their nostrils have failed, some might trumpet their success at training the hyraxes to push toothpicks around with their tongues, noting that stacking tree trunks or drawing on blackboards differ from it only in degree. The opposite school, maintaining the uniqueness of the trunk, might insist that it appeared all at once in the offspring of a particular trunkless elephant ancestor, the product of a single dramatic mutation. Or they might say that the trunk somehow arose as an automatic by-product of the elephant's having evolved a large head. They might add another paradox for trunk evolution: the trunk is absurdly more intricate and well coordinated than any ancestral elephant would have needed.

These arguments might strike us as peculiar, but every one of them has been made by scientists of a different species about a complex organ that that species alone possesses, language. As we shall see in this chapter, Chomsky and some of his fiercest opponents agree on one thing: that a uniquely human language instinct seems to be incompatible with the modern Darwinian theory of evolution, in which complex biological systems arise by the gradual accumulation over generations of random genetic mutations that enhance reproductive success. Either there is no language instinct, or it must have evolved by other means. Since I have been trying to convince you that there is a language instinct but would certainly forgive you if you would rather believe Darwin than believe me, I would also like to convince you that you need not make that choice. Though we know few details about how the language instinct evolved, there is no reason to doubt that the principal explanation is the same as for any other complex instinct or organ, Darwin's theory of natural selection.

Language is obviously as different from other animals' communication systems as the elephant's trunk is different from other animals' nostrils. Nonhuman communication systems are based on one of three designs: a finite repertory of calls (one for warnings of predators, one for claims to territory, and so on), a continuous analog signal that registers the magnitude of some state (the livelier the dance of the bee, the richer the food source that it is telling its hivemates about), or a series of random variations on a theme (a birdsong repeated with a new twist each time: Charlie Parker with feathers). As we have seen, human language has a very different design. The discrete combinatorial system called "grammar" makes human language infinite (there is no limit to the number of complex words or sentence in a language), digital (this infinity is achieved by rearranging discrete elements in particular orders and combinations, not by varying some signal along a continuum like the mercury in a thermometer), and compositional (each of the infinite combinations has a different meaning predictable from the meanings of its parts and the rules and principles arranging them).

Even the seat of human language in the brain is special. The vocal calls of primates are controlled not by their cerebral cortex but by phylogenetically older neural structures in the brain stem and limbic systems, structures that are heavily involved in emotion. Human vocalizations other than language, like sobbing, laughing, moaning, and shouting in pain, are also controlled subcortically. Subcortical structures even control the swearing that follows the arrival of a hammer on a thumb, that emerges as an involuntary tic in Tourette's syndrome, and that can survive as Broca's aphasics' only speech. Genuine language, as we saw in the preceding chapter, is seated in the cerebral cortex, primarily the left perisylvian region.

Some psychologists believe that changes in the vocal organs and in the neural circuitry that produces and perceives speech sounds are the *only* aspects of language that evolved in our species. On this view, there are a few general learning abilities found throughout the animal kingdom, and they work most efficiently in humans. At some point in history language was invented and refined, and we have been learning it ever since. The idea that species-specific behavior is caused by anatomy and general intelligence is captured in the Gary Larson *Far Side* cartoon in which two bears hide behind a tree near a human couple relaxing on a blanket. One says: "C'mon! Look at these fangs! . . . Look at these claws! . . . You think we're supposed to eat just honey and berries?"

According to this view, chimpanzees are the second-best learners in the animal kingdom, so they should be able to acquire a language too, albeit a simpler one. All it takes is a teacher. In the 1930s and 1940s two psychologist couples adopted baby chimpanzees. The chimps became part of the family and learned to dress, use the toilet, brush their teeth, and wash the dishes. One of them, Gua, was raised alongside a boy of the same age but never spoke a word. The other, Viki, was given arduous training in speech, mainly by the foster parents' moulding the puzzled chimp's lips and tongue into the right shapes. With a lot of practice, and often with the help of her own hands, Viki learned to make three utterances that charitable listeners could hear as *papa, mama,* and *cup,* though she often confused them when she got excited. She could respond to some stereotyped formulas, like *Kiss me* and *Bring me the dog,* but stared blankly when asked to act out a novel combination like *Kiss the dog.*

But Gua and Viki were at a disadvantage: they were forced to use their vocal apparatus, which was not designed for speech and which they could not voluntarily control. Beginning in the late 1960s, several famous projects claimed to have taught language to baby chimpanzees with the help of more user-friendly media. (Baby chimps are used because the adults are not the hairy clowns in overalls you see on television, but strong, vicious wild animals who have bitten fingers off several well-known psychologists.) Sarah learned to string magnetized plastic shapes on a board. Lana and Kanzi learned to press buttons with symbols on a large computer console or point to them on a portable tablet. Washoe and Koko (a gorilla) were said to have acquired American Sign Language. According to their trainers, these apes learned hundreds of words, strung them together in meaningful sentence, and coined new phrases, like *water bird* for a swan and *cookie rock* for a stale Danish. "Language is no longer the exclusive domain of man," said Koko's trainer, Francine (Penny) Patterson.

These claims quickly captured the public's imagination and were played up in popular science books and magazines and television programs like *National Geographic, Nova, Sixty Minutes,* and *20/20.* Not only did the projects seem to consummate our age-old yearning to talk to the animals, but the photo opportunities of attractive women communing with apes, evocative of the beauty-and-the-beast archetype, were not lost on the popular media. Some of the projects were covered by *People, Life,* and *Penthouse* magazines, and they were fictionalized in a bad movie starring Holly Hunter called *Animal Behavior* and in a famous Pepsi commercial.

Many scientists have also been captivated, seeing the projects as a healthy deflation of our species' arrogant chauvinism. I have seen popular-science columns that list the acquisition of language by chimpanzees as one of the major scientific discoveries of the century. In a recent, widely excerpted book, Carl Sagan and Ann Druyan have used the ape language experiments as part of a call for us to reassess our place in nature:

> A sharp distinction between human beings and "animals" is essential if we are to bend them to our will, make them work for us, wear them, eat them—without any disquieting tinges of guilt or regret. With untroubled consciences, we can render whole species extinct—as we do today to the tune of 100 speces a day. Their loss is of little import: Those beings, we tell ourselves, are not like us. An unbridgeable gap has thus a practical role to play beyond the mere stroking of human egos. Isn't there much to be proud of in the lives of monkeys and apes? Shouldn't we be glad to acknowledge a connection with Leakey, Imo, or Kanzi? Remember those macaques who would rather go hungry then profit from harming their fellows; might we have a more optimistic view of the human future if we were sure our ethics were up to their standards? And, viewed from this perspective, how shall we judge our treatment of monkeys and apes?

This well-meaning but misguided reasoning could only have come from writers who are not biologists. Is it really "humility" for us to save species from extinction because we think they are like us? Or because they seem like a bunch of nice guys? What about all the creepy, nasty, selfish animals who do not remind us of ourselves, or our image of what we would like to be—can we go ahead and wipe them out? And Sagan and Druyan are no friends of the apes if they think the reason we should treat the apes fairly is that they can be taught human language. Like many other writers, Sagan and Druyan are far too credulous about the claims of the chimpanzee trainers.

People who spend a lot of time with animals are prone to developing indulgent attitudes about their powers of communication. My great-aunt Bella insisted in all sincerity that her Siamese cat Rusty understood English. Many of the claims of the ape trainers were not much more scientific. Most of the trainers were schooled in the behaviorist tradition of B. F. Skinner and are ignorant of the study of language; they latched on to the most tenuous resemblance between chimp and child and proclaimed that their abilities are fundamentally the same. The more enthusiastic trainers went over the heads of scientists and made their engaging case directly to the public on the *Tonight Show* and *National Geographic.* Patterson in particular has found ways to excuse Koko's performance on the grounds that the gorilla is fond of puns, jokes, metaphors, and mischievous lies. Generally the stronger the claims about the animal's abilities, the skimpier the data made available to the scientific community for evaluation. Most of the trainers have refused all requests to share their raw data, and Washoe's trainers, Beatrice and Alan Gardner, threatened to sue another researcher because he used frames of one of their films (the only raw data available to him) in a critical scientific article. That researcher, Herbert Terrance, together with the psychologists Lara Ann Petitto, Richard Sanders, and Tom Bever, had tried to teach ASL to one of Washoe's relatives, whom they named Nim Chimpsky. They carefully tabulated and analyzed his signs, and Petitto, with the psychologist Mark Seidenberg, also scrutinized the videotapes and what published data there were on the other signing apes, whose abilities were similar to Nim's. More recently, Joel Wallman has written a history of the topic called *Aping Language*. The moral of their investigation is: Don't believe everything you hear on the *Tonight Show*.

To begin with, the apes did *not* "learn American Sign Language." This preposterous claim is based on the myth that ASL is a crude system of pantomimes and gestures rather than a full language with complex phonology, morphology, and syntax. In fact the apes had not learned *any* true ASL signs. The one deaf native signer on the Washoe team later made these candid remarks:

> Every time the chimp made a sign, we were supposed to write it down in the log. . . . They were always complaining because my log didn't show enough signs. All the hearing people turned in logs with long lists of signs. They always saw more signs than I did. . . . I watched really carefully. The chimp's hands were moving constantly. Maybe I missed something, but I don't think so. I just wasn't seeing any signs. The hearing people were logging every movement the chimp made as a sign. Every time the chimp put his finger in his mouth, they'd say "Oh, he's making the sign for *drink*," and they'd give him some milk. . . . When the chimp scratched itself, they'd record it as the sign for *scratch*. . . . When [the chimps] want something, they reach. Sometimes [the trainers would] say, "Oh, amazing, look at that, it's exactly like the ASL sign for *give*!" It wasn't.

To arrive at their vocabulary counts in the hundreds, the investigators would also "translate" the chimps' pointing as a sign for *you*, their hugging as a sign for *hug*, their picking, tickling, and kissing as signs for *pick*, *tickle*, and *kiss*. Often the same movement would be credited to the chimps as different "words," depending on what the observers thought the appropriate word would be in the context. In the experiments in which the chimps interacted with a computer console, the key that the chimp had to press to initialize the computer was translated as the word *please*. Petitto estimates that with more standard criteria the true vocabulary count would be closer to 25 than 125.

Actually, what the chimps were really doing was more interesting than what they were claimed to be doing. Jane Goodall, visiting the project, remarked to Terrace and Petitto that every one of Nim's so-called signs was familiar to her from her observations of chimps in the wild. The chimps were relying heavily on the gestures in their natural repertoire, rather than learning true arbitrary ASL signs with their combinatorial phonological structure of hand shapes, motions, locations, and orientations. Such backsliding is common when humans train animals. Two enterprising students of B. F. Skinner, Keller and Marian Breland, took his principles for shaping the behavior of rats and pigeons with schedules of reward and turned them into a lucrative career of training circus animals. They recounted their experiences in a famous article called "The Misbehavior of Organisms," a play on Skinner's book *The Behavior of Organisms*. In some of their acts the animals were trained to insert poker chips in little juke boxes and vending machines for a food reward. Though the training schedules were the same for the various animals, their species-specific instincts bled through. The chickens spontaneously pecked at the chips, the pigs tossed and rooted them with their snouts, and the raccoons rubbed and washed them.

The chimp's abilities at anything one would want to call grammar were next to nil. Signs were not coordinated into the well-defined motion contours of ASL and were not inflected for aspect, agreement, and so on—a striking omission, since inflection is the primary means in ASL of conveying who did what to whom and many other kinds of information. The trainers frequently claim that the chimps have syntax, because pairs of signs are sometimes placed in one order more often than chance would predict, and because the brighter chimps can act out sequences like *Would you please carry the cooler to Penny.* But remember from the Loebner Prize competition (for the most convincing computer simulation of a conversational partner) how easy it is to fool people into thinking that their interlocutors have humanlike talents. To understand the request, the chimp could ignore the symbols *would, you, please, carry, the,* and *to;* all the chimp had to notice was the order of the two nouns (and in most of the tests, not even that, because it is more natural to carry a cooler to a person than a person to a cooler). True, some of the chimps can carry out these commands more reliably than a two-year-old child, but this says more about temperament than about grammar: the chimps are highly trained animal acts, and a two-year-old is a two-year-old.

As far as spontaneous output is concerned, there is no comparison. Over several years of intensive training, the average length of the chimps' "sentences" remains constant. With nothing more than exposure to speakers, the average length of a child's sentences shoots off like a rocket. Recall that typical sentences from a two-year-old child are *Look at that train Ursula brought* and *We going turn light on so you can't see.* Typical sentences from a language-trained chimp are:

Nim eat Nim eat.
Drink eat me Nim.
Me gum me gum.
Tickle me Nim play.
Me eat me eat.
Me banana you banana me you give.
You me banana me banana you.
Banana me me me eat.
Give orange me give eat orange me eat orange give me eat orange give me you.

These jumbles bear scant resemblance to children's sentences. (By watching long enough, of course, one is bound to find random combinations in the chimps' gesturing that can be given sensible interpretations, like *water bird*). But the strings *do* resemble animal behavior in the wild. The zoologist E. O. Wilson, summing up a survey of animal communication, remarked on its most striking property: animals, he said, are "repetitious to the point of inanity."

Even putting aside vocabulary, phonology, morphology, and syntax, what impresses one the most about chimpanzee signing is that fundamentally, deep down, chimps just don't "get it." They know that the trainers like them to sign and that signing often gets them what they want, but they never seem to feel in their bones what language is and how to use it. They do not take turns in conversation but instead blithely sign simultaneously with their partner, frequently off to the side or under a table rather than in the standardized signing space in front of the body. (Chimps also like to sign with their feet, but no one blames them for taking advantage of this anatomical gift.) The chimps seldom sign spontaneously; they have to be molded, drilled, and coerced. Many of their "sentences," especially the ones showing systematic ordering, are direct imitations of what the trainer has just signed, or minor variants of a small number of formulas that they have been trained on thousands of times. They do not even clearly get the idea that a particular sign might refer to a kind of object. Most of the chimps' object signs can refer to any aspect of the situation with which an object is typically associated. *Toothbrush* can mean "toothbrush," "toothpaste," "brushing teeth," "I want my toothbrush," or "It's time for bed." *Juice* can mean "juice," "where juice is usually kept," or "Take me to where the juice is kept." Recall from Ellen Markman's experiments in Chapter 5 that children use these "thematic" associations when sorting pictures into groups, but they ignore them when learning word meanings: to them, a *dax* is a dog or another dog, not a dog or its bone. Also, the chimps rarely make statements that comment on interesting objects or actions; virtually all their signs are demands for something they want, usually food or tickling. I cannot help but think of a moment with my two-year-old niece Eva that captures how different are the minds of child and chimp. One night the family was driving on an expressway, and when the adult conversation died down, a tiny voice from the back seat said, "Pink." I followed her gaze, and on the horizon several miles away I could make out a pink neon sign. She was commenting on its color, just for the sake of commenting on its color.

Within the field of psychology, most of the ambitious claims about chimpanzee language are a thing of the past. Nim's trainer Herbert Terrace, as mentioned, turned from enthusiast to whistle-blower. David Premack, Sarah's trainer, does not claim that what she acquired is comparable to human language; he uses the symbol system as a tool to do chimpanzee cognitive psychology. The Gardners and Patterson have distanced themselves from the community of scientific discourse for over a decade. Only one team is currently making claims about language. Sue Savage-Rumbaugh and Duane Rumbaugh concede that the chimps they trained at the computer console did not learn much. But they are now claiming that a different variety of chimpanzee does much better. Chimpanzees come from some half a dozen mutually isolated "islands" of forest in the west African continent, and the groups have diverged over the past million years to the point where some of the groups are sometimes classified as belonging to different species. Most of the trained chimps were "common chimps"; Kanzi is a "pygmy chimp" or "bonobo," and he learned to bang on visual symbols on a portable tablet. Kanzi, says Savage-Rumbaugh, does substantially better at learning symbols (and at understanding spoken language) than common chimps. Why he would be expected to do so much better than members of his sibling species is not clear; contrary to some reports in the press, pygmy chimps are no more closely related to humans than common chimps are. Kanzi is said to have learned his graphic symbols without having been laboriously trained on them—but he was at his mother's side watching while *she* was laboriously trained on them (unsuccessfully). He is said to use the symbols for purposes other than requesting—but at best only four percent of the time. He is said to use three-symbol "sentences"—but they are really fixed formulas with no internal structure and are not even three symbols long. The so-called sentences are all chains like the symbol for chase followed by the symbol for hide followed by a point to the person Kanzi wants to do the chasing and hiding. Kanzi's language abilities, if one is being charitable, are above those of his common cousins by a just-noticeable difference, but no more.

What an irony it is that the supposed attempt to bring *Homo sapiens* down a few notches in the natural order has taken the form of us humans hectoring another species into emulating our instinctive form of communication, or some artificial form we have invented, as if that were the measure of biological worth. The chimpanzees' resistance is no shame on them; a human would surely do no better if trained to hoot and shriek like a chimp, a symmetrical project that makes about as much scientific sense. In fact, the idea that some species needs our intervention before its members can display a useful skill, like some bird that could not fly until given a human education, is far from humble!

So human language differs dramatically from natural and artificial animal communication. What of it? Some people, recalling Darwin's insistence on the gradualness of evolutionary change, seem to believe that a detailed examination of chimps' behavior is unnecessary: they must have some form of language, as a matter of principle. Elizabeth Bates, a vociferous critic of Chomskyan approaches to language, writes:

> If the basic structural principles of language cannot be learned (bottom up) or derived (top down), there are only two possible explanations for their existence: either Universal Grammar was endowed to us directly by the Creator, or else our species has undergone a mutation of unprecedented magnitude, a cognitive equivalent of the Big Bang. . . . We have to abandon any strong version of the discontinuity claim that has characterized generative grammar for thirty years. We have to find some way to ground symbols and syntax in the mental material that we share with other species.

But, in fact, if human language is unique in the modern animal kingdom, as it appears to be, the implications for a Darwinian account of its evolution would be as follows: none. A language instinct unique to modern humans poses no more of a paradox than a trunk unique to modern elephants. No contradiction, no Creator, no big bang.

Modern evolutionary biologists are alternately amused and annoyed by a curious fact. Though most educated people profess to believe in Darwin's theory, what they really believe in is a modified version of the ancient theological notion of the Great Chain of Being: that all species are arrayed in a linear hierarchy with humans at the top. Darwin's contribution, according to this belief, was showing that each species on the ladder evolved from the species one rung down, instead of being allotted its rung by God. Dimly remembering their high school biology classes that took them on a tour of the phyla from "primitive" to "modern," people think roughly as follows: amoebas begat sponges which begat jellyfish which begat flatworms which begat trout which begat frogs which begat lizards which begat dinosaurs which begat anteaters which begat monkeys which begat chimpanzees which begat us. (I have skipped a few steps for the sake of brevity.)

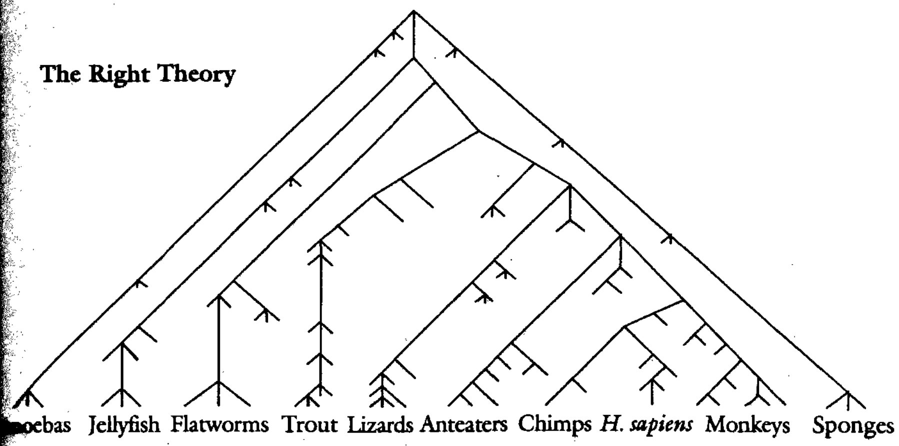
The Wrong Theory

Amoebas
|
Sponges
|
Jellyfish
|
Flatworms
|
Trout
|
Frogs
|
Lizards
|
Dinosaurs
|
Anteaters
|
Monkeys
|
Chimpanzees
|
Homo sapiens

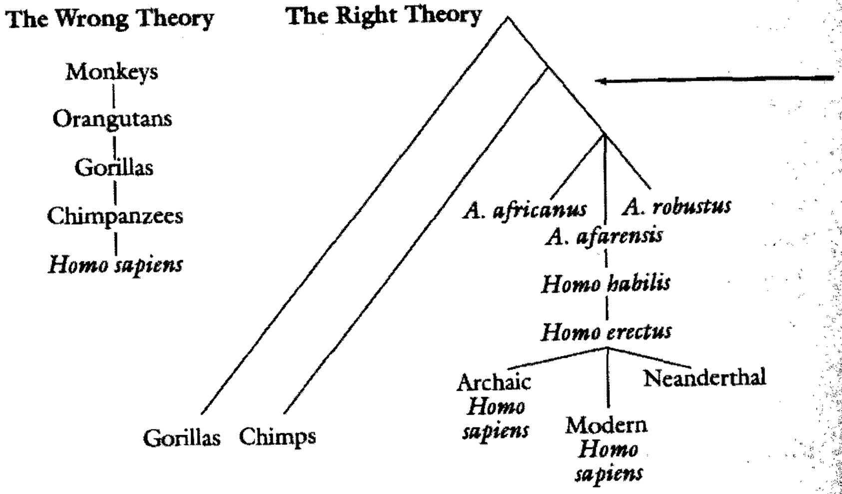
Hence the paradox: humans enjoy language while their neighbors on the adjacent rung have nothing of the kind. We expect a fade-in, but we see a big bang.

But evolution did not make a ladder; it made a bush. We did not evolve from chimpanzees. We and chimpanzees evolved from a common ancestor, now extinct. The human-chimp ancestor evolved not from monkeys but from an even older ancestor of the two, also extinct. And so on, back to our single-celled forebears. Paleontologists like to say that to a first approximation, all species are extinct (ninety-nine percent is the usual estimate). The organisms we see around us are distant cousins, not great-grandparents; they are a few scattered twig-tips of an enormous tree whose branches and trunk are no longer with us. Simplifying a lot:

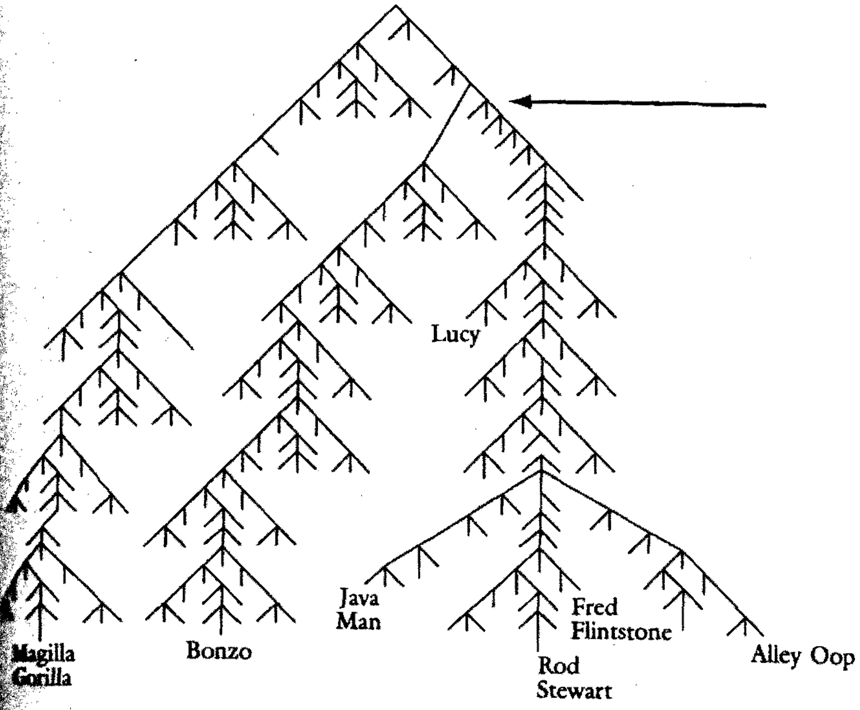
The Right Theory



Zooming in on our branch, we see chimpanzees off on a separate sub-branch, not sitting on top of us.



We also see that a form of language could first have emerged at the position of the arrow, after the branch leading to humans split off from the one leading to chimpanzees. The result would be languageless chimps and approximately five to seven million years in which language could have gradually evolved. Indeed, we should zoom in even closer, because species do not mate and produce baby species; organisms mate and produce baby organisms. Species are an abbreviation for chunks of a vast family tree composed of individuals, such as the *particular* gorilla, chimp, australopithecine, *erectus,* archaic *sapiens,* Neanderthal, and modern *sapiens* I have named in this family tree:



So if the first trace of a proto-language ability appeared in the ancestor at the arrow, there could have been on the order of 350,000 generations between then and now for the ability to have been elaborated and fine-tuned to the Universal Grammar we see today. For all we know, language could have had a gradual fade-in, even if no extant species, not even our closest living relatives the chimpanzees, have it. There were plenty of organisms with intermediate language abilities, but they are all dead.

Here is another way to think about it. People see chimpanzees, the living species closest to us, and are tempted to conclude that they, at the very least, must have some ability that is ancestral to language. But because the evolutionary tree is a tree of individuals, not species, "the living species closest to us" has no special status; what that species is depends on the accidents of extinction. Try the following thought experiment. Imagine that anthropologists discover a relict population of *Homo habilis* in some remote highland. *Habilis* would now be our closest living relatives. Would that take the pressure off chimps, so it is not so important that they have something like language after all? Or do it the other way around. Imagine that some epidemic wiped out all the apes several thousand years ago. Would Darwin be in danger unless we showed that monkeys had language? If you are inclined to answer yes, just push the thought experiment one branch up: imagine that in the past some extraterrestrials developed a craze for primate fur coats, and hunted and trapped all the primates to extinction except hairless us. Would insectivores like anteaters have to shoulder the proto-language burden? What if the aliens went for mammals in general? Or developed a taste for vertebrate flesh, sparing us because they like the sitcom reruns that we inadvertently broadcast into space? Would we then have to look for talking starfish? Or ground syntax in the mental material we share with sea cucumbers?

Obviously not. Our brains, and chimpanzee brains, and anteater brains, have whatever wiring they have; the wiring cannot change depending on which other species a continent away happen to survive or go extinct. The point of these thought experiments is that the gradualness that Darwin made so much about applies to lineages of individual organisms in a bushy family tree, not to entire living species in a great chain. For reasons that we will cover soon, an ancestral ape with nothing but hoots and grunts is unlikely to have given birth to a baby who could learn English or Kivunjo. But it did not have to; there was a chain of several hundred thousand generations of grandchildren in which such abilities could gradually blossom. To determine when in fact language began, we have to look at people, and look at animals, and note what we see; we cannot use the idea of phyletic continuity to legislate the answer from the armchair.

The difference between bush and ladder also allows us to put a lid on a fruitless and boring debate. That debate is over what qualifies as True Language. One side lists some qualities that human language has but that no animal has yet demonstrated: reference, use of symbols displaced in time and space from their referents, creativity, categorical

speech perception, consistent ordering, hierarchical structure, infinity, recursion, and so on. The other side finds some counterexample in the animal kingdom (perhaps budgies can discriminate speech sounds, or dolphins or parrots can attend to word order when carrying out commands, or some songbird can improvise indefinitely without repeating itself) and then gloats that the citadel of human uniqueness has been breached. The Human Uniqueness team relinquishes that criterion but emphasizes others or adds new ones to the list, provoking angry objections that they are moving the goalposts. To see how silly this all is, imagine a debate over whether flatworms have True Vision or houseflies have True Hands. Is an iris critical? Eyelashes? Fingernails? Who cares? This is a debate for dictionary-writers, not scientists. Plato and Diogenes were not doing biology when Plato defined man as a "featherless biped" and Diogenes refuted him with a plucked chicken.

The fallacy in all this is that there is some line to be drawn across the ladder, the species on the rungs above it being credited with some glorious trait, those below lacking it. In the tree of life, traits like eyes or hands or infinite vocalizations can arise on any branch, or several times on different branches, some leading to humans, some not. There is an important scientific issue at stake, but it is not whether some species possesses the true version of a trait as opposed to some pale imitation or vile impostor. The issue is which traits are ***homologous*** to which other ones.

Biologists distinguish two kinds of similarity. "Analogous" traits are ones that have a common function but arose on different branches of the evolutionary tree and are in an important sense not "the same" organ. The wings of birds and the wings of bees are a textbook example; they are both used for flight and are similar in some ways because anything used for flight has to be built in those ways, but they arose independently in evolution and have nothing in common beyond their use in flight. "Homologous" traits, in contrast, may or may not have a common function, but they descended from a common ancestor and hence have some common structure that bespeaks their being "the same" organ. The wing of a bat, the front leg of a horse, the flipper of a seal, the claw of a mole, and the hand of a human have very different functions, but they are all modifications of the forelimb of the ancestor of all mammals, and as a result they share nonfunctional traits like the number of bones and the ways they are connected. To distinguish analogy from homology, biologists usually look at the overall architecture of the organs and focus on their most useless properties—the useful ones could have arisen independently in two lineages *because* they are useful (a nuisance to taxonomists called convergent evolution). We deduce that bat wings are really hands because we can see the wrist and count the joints in the fingers, and because that is not the only way that nature could have built a wing.

The interesting question is whether human language is homologous to—biologically "the same thing" as—anything in the modern animal kingdom. Discovering a similarity like sequential ordering is pointless, especially when it is found on a remote branch that is surely not ancestral to humans (birds, for example). Here primates are relevant, but the ape-trainers and their fans are playing by the wrong rules. Imagine that their wildest dreams are realized and some chimpanzees can be taught to produce real signs, to group and order them consistently to convey meaning, to use them spontaneously to describe events, and so on. Does that show that the human ability to learn language evolved from the chimp ability to learn the artificial sign system? Of course not, any more than a seagull's wings show that it evolved from mosquitos. Any resemblance between the chimps' symbol system and human language would not be a legacy of their common ancestor; the features of the symbol system were deliberately designed by the scientists and acquired by the chimps because it was useful to them then and there. To check for homology, one would have to find some signature trait that reliably emerges both in ape symbol systems and in human language, and that is not so indispensable to communication that it was likely to have emerged twice, once in the course of human evolution and once in the lab meetings of the psychologists as they contrived the system to teach their apes. One could look for such signatures in development, checking the apes for some echo of the standard human sequence from syllable babbling to jargon babbling to first words to two-word sequences to a grammar explosion. One could look at the developed grammar, seeing if apes invent or favor some specimen of nouns and verbs, inflections, X-bar syntax, roots and stems, auxiliaries in second position inverting to form questions, or other distinctive aspects of universal human grammar. (These structures are not so abstract as to be undetectable; they leapt out of the data when linguists first looked at American Sign Language and creoles, for example.) And one could look at neuroanatomy, checking for control by the left perisylvian regions of the cortex, with grammar more anterior, dictionary more posterior. This line of questioning, routine in biology since the nineteenth century, has never been applied to chimp signing, though one can make a good prediction of what the answers would be.

How plausible is it that the ancestor to language first appeared after the branch leading to humans split off from the branch leading to chimps? Not very, says Philip Lieberman, one of the scientists who believe that vocal tract anatomy and speech control are the only things that were modified in evolution, not a grammar module: "Since Darwinian natural selection involves small incremental steps that enhance the present function of the specialized module, the evolution of a 'new' module is logically impossible." Now, something has gone seriously awry in this argument. Humans evolved from single-celled ancestors. Single-celled ancestors had no arms, legs, heart, eyes, liver, and so on. Therefore eyes and livers are logically impossible.

The point that the argument misses is that although natural selection involves incremental steps that enhance functioning, the enhancements do not have to be an existing module. They can slowly build a module out of some previously nondescript stretch of anatomy, or out of the nooks and crannies between existing modules, which the biologists Stephen Jay Gould and Richard Lewontin call "spandrels," from the architectural term for the space between two arches. An example of a new module is the eye, which has arisen de novo some forty separate times in animal evolution. It can begin in an eyeless organism with a patch of skin whose cells are sensitive to light.

The patch can deepen into a pit, cinch up into a sphere with a hole in front, grow a translucent cover over the hole, and so on, each step allowing the owner to detect events a bit better. An example of a module growing out of bits that were not originally a module is the elephant's trunk. It is a brand-new organ, but homologies suggest that it evolved from a fusion of the nostrils and some of the upper lip muscles of the extinct elephant-hyrax common ancestor, followed by radical complications and refinements.

Language could have arisen, and probably did arise, in a similar way: by a revamping of primate brain circuits that originally had no role in vocal communication, and by the addition of some new ones. The neuroanatomists Al Galaburda and Terrence Deacon have discovered areas in monkey brains that correspond in location, input-output cabling, and cellular composition to the human language areas. For example, there are homologues to Wernicke's and Broca's areas and a band of fibers connecting the two, just as in humans. The regions are not involved in producing the monkeys' calls, nor are they involved in producing their gestures. The monkey seems to use the regions corresponding to Wernicke's area and its neighbors to recognize sound sequences and to discriminate the calls of other monkeys from its own calls. The Broca's homologues are involved in control over the muscles of the face, mouth, tongue, and larynx, and various subregions of these homologues receive inputs from the parts of the brain dedicated to hearing, the sense of touch in the mouth, tongue, and larynx, and areas in which streams of information from all the senses converge. No one knows exactly why this arrangement is found in monkeys and, presumably, their common ancestor with humans, but the arrangement would have given evolution some parts it could tinker with to produce the human language circuitry, perhaps exploiting the confluence of vocal, auditory, and other signals there.

Brand-new circuits in this general territory could have arisen, too. Neuroscientists charting the cortex with electrodes have occasionally found mutant monkeys who have one extra visual map in their brains compared to standard monkeys (visual maps are the postage-stamp-sized brain areas that are a bit like internal graphics buffers, registering the contours and motions of the visible world in a distorted picture). A sequence of genetic changes that duplicate a brain map or circuit, reroute its inputs and outputs, and frob, twiddle, and tweak its internal connections could manufacture a genuinely new brain module.

Brains can be rewired only if the genes that control their wiring have changed. This brings up another bad argument about why chimp signing must be like human language. The argument is based on the finding that chimpanzees and humans share 98% to 99% of their DNA, a factoid that has become as widely circulated as the supposed four hundred Eskimo words for snow (the comic strip *Zippy* recently quoted the figure as "99.9%"). The implication is that we must be 99% similar to chimpanzees.

But geneticists are appalled at such reasoning and take pains to stifle it in the same breath that they report their results. The recipe for the embryological soufflé is so baroque that small genetic changes can have enormous effects on the final product. And a 1% difference is not even so small. In terms of the information content in the DNA it is 10 megabytes, big enough for the Universal Grammar with lots of room left over for the rest of the instructions on how to turn a chimp into a human. Indeed, a 1% difference in total DNA does not even mean that only 1% of human and chimpanzee genes are different. It could, in theory, mean that 100% of human and chimpanzee genes are different, each by 1%. DNA is a discrete combinatorial code, so a 1% difference in the DNA for a gene can be as significant as a 100% difference, just as changing one bit in every byte, or one letter in every word, can result in a new text that is 100% different, not 10% or 20% different. The reason, for DNA, is that even a single amino-acid substitution can change the shape of a protein enough to alter its function completely; this is what happens in many fatal genetic diseases. Data on genetic similarity are useful in figuring out how to connect up a family tree (for example, whether gorillas branched off from a common ancestor of humans and chimps or humans branched off from a common ancestor of chimps and gorillas) and perhaps even to date the divergences using a "molecular clock." But they say nothing about how similar the organisms' brains and bodies are.

The ancestral brain could have been rewired only if the new circuits had some effect on perception and behavior. The first steps toward human language are a mystery. This did not stop philosophers in the nineteenth century from offering fanciful speculations, such as that speech arose as imitations of animal sounds or as oral gestures that resembled the objects they represented, and linguists subsequently gave these speculations pejorative names like the bow-wow theory and the ding-dong theory. Sign language has frequently been suggested as an intermediate, but that was before scientists discovered that sign language was every bit as complex as speech. Also, signing seems to depend on Broca's and Wernicke's areas, which are in close proximity to vocal and auditory areas on the cortex, respectively. To the extent that brain areas for abstract computation are placed near the centers that process their inputs and outputs, this would suggest that speech is more basic. If I were forced to think about intermediate steps, I might ponder the vervet monkey alarm calls studied by Cheney and Seyfarth, one of which warns of eagles, one of snakes, and one of leopards. Perhaps a set of quasi-referential calls like these came under the voluntary control of the cerebral cortex, and came to be produced in combination for complicated events; the ability to analyze combinations of calls was then applied to the parts of each call. But I admit that this idea has no more evidence in its favor than the ding-dong theory (or than Lily Tomlin's suggestion that the first human sentence was "What a hairy back!").

Also unknown is when, in the lineage beginning at the chimp-human common ancestor, proto-language first evolved, or the rate at which it developed into the modern language instinct. In the tradition of the drunk looking for his keys under the lamppost because that is where the light is best, many archaeologists have tried to infer our extinct ancestors' language abilities from their tangible remnants such as stone tools and dwellings. Complex artifacts are thought to reflect a complex mind which could benefit from complex language. Regional

variation in tools is thought to suggest cultural transmission, which depends in turn on generation-to-generation communication, perhaps via language. However, I suspect that any investigation that depends on what an ancient group left behind will seriously underestimate the antiquity of language. There are many modern hunter-gatherer peoples with sophisticated language and technology, but their baskets, clothing, baby slings, boomerangs, tents, traps, bows and arrows, and poisoned spears are not made of stone and would rot into nothing quickly after their departure, obscuring their linguistic competence from future archaeologists.

Thus the first traces of language could have appeared as early as *Australopithecus afarensis* (first discovered as the famous "Lucy" fossil), at 4 million years old our most ancient fossilized ancestor. Or perhaps even earlier; there are few fossils from the time between the human-chimp split 5 to 7 million years ago and *A. afarensis*. Evidence for a lifestyle into which language could plausibly be woven gets better with later species. *Homo habilis*, which lived about 2.5 to 2 million years ago, left behind caches of stone tools that may have been home bases or local butchering stations; in either case they suggest some degree of cooperation and acquired technology. *Habilis* was also considerate enough to have left us some of their skulls, which bear faint imprints of the wrinkle patterns of their brains. Broca's area is large and prominent enough to be visible, as are the supramarginal and angular gyri (the language areas shown in the brain diagram in Chapter 10), and these areas are larger in the left hemisphere. We do not, however, know whether habilines used them for language; remember that even monkeys have a small homologue to Broca's area. *Homo erectus*, which spread from Africa across much of the old world from 1.5 million to 500,000 years ago (all the way to China and Indonesia), controlled fire and almost everywhere used the same symmetrical, well-crafted stone hand-axes. It is easy to imagine some form of language contributing to such successes, though again we cannot be sure.

Modern *Homo sapiens*, which is thought to have appeared about 200,000 years ago and to have spread out of Africa 100,000 years ago, had skulls like ours and much more elegant and complex tools, showing considerable regional variation. It is hard to believe that they lacked language, given that biologically they *were* us, and all biologically modern humans have language. This elementary fact, by the way, demolishes the date most commonly given in magazine articles and textbooks for the origin of language: 30,000 years ago, the age of the gorgeous cave art and decorated artifacts of Cro-Magnon humans in the Upper Paleolithic. The major branches of humanity diverged well before then, and all their descendants have identical language abilities; therefore the language instinct was probably in place well before the cultural fads of the Upper Paleolithic emerged in Europe. Indeed, the logic used by archaeologists (who are largely unaware of psycholinguistics) to pin language to that date is faulty. It depends on there being a single "symbolic" capacity underlying art, religion, decorated tools, and language, which we now know is false (just think of linguistic idiot savants like Denyse and Crystal from Chapter 2, or, for that matter, any normal three-year-old).

One other ingenious bit of evidence has been applied to language origins. Newborn babies, like other mammals, have a larynx that can rise up and engage the rear opening of the nasal cavity, allowing air to pass from nose to lungs avoiding the mouth and throat. Babies become human at three months when their larynx descends to a position low in their throats. This gives the tongue the space to move both up and down and back and forth, changing the shape of two resonant cavities and defining a large number of possible vowels. But it comes at a price. In *The Origin of Species* Darwin noted "the strange fact that every particle of food and drink which we swallow has to pass over the orifice of the trachea, with some risk of falling into the lungs." Until the recent invention of the Heimlich maneuver, choking on food was the sixth leading cause of accidental death in the United States, claiming six thousand victims a year. The positioning of the larynx deep in the throat, and the tongue far enough low and back to articulate a range of vowels, also compromised breathing and chewing. Presumably the communicative benefits outweighed the physiological costs.

Lieberman and his colleagues have tried to reconstruct the vocal tracts of extinct hominids by deducing where the larynx and its associated muscles could have fit into the space at the base of their fossilized skulls. They argue that all species prior to modern *Homo sapiens*, including Neanderthals, had a standard mammalian airway with its reduced space of possible vowels. Lieberman suggests that until modern *Homo sapiens*, language must have been quite rudimentary. But Neanderthals have their loyal defenders and Lieberman's claim remains controversial. In any case, e lengeege weth e smell nember ef vewels cen remeen quete expresseve, so we cannot conclude that a hominid with a restricted vowel space had little language.

So far I have talked about when and how the language instinct might have evolved, but not why. In a chapter of *The Origin of Species*, Darwin painstakingly argued that his theory of natural selection could account for the evolution of instincts as well as bodies. If language is like other instincts, presumably it evolved by natural selection, the only successful scientific explanation of complex biological traits.

Chomsky, one might think, would have everything to gain by grounding his controversial theory about a language origin in the firm foundation of evolutionary theory, and in some of his writings he has hinted at a connection. But more often he is skeptical:

> It is perfectly safe to attribute this development [of innate mental structure] to "natural selection," so long as we realize that there is no substance to this assertion, that it amounts to nothing more than a belief that there is some naturalistic explanation for these phenomena. . . . In studying the evolution of mind, we cannot guess to what extent there are physically possible alternatives to, say, transformational generative grammar, for an organism meeting certain other physical conditions characteristic of humans. Conceivably, there are none—or very few—in which case talk about evolution of the language capacity is beside the point.

> Can the problem [the evolution of language] be addressed today? In fact, little is known about these matters. Evolutionary

> theory is informative about many things, but it has little to say, as of now, about questions of this nature. The answers may well lie not so much in the theory of natural selection as in molecular biology, in the study of what kinds of physical systems can develop under the conditions of life on earth and why, ultimately because of physical principles. It surely cannot be assumed that every trait is specifically selected. In the case of such systems as language . . . it is not easy even to imagine a course of selection that might have given rise to them.

What could he possibly mean? Could there be a language organ that evolved by a process different from the one we have always been told is responsible for the other organs? Many psychologists, impatient with arguments that cannot be fit into a slogan, pounce on such statements and ridicule Chomsky as a crypto-creationist. They are wrong, though I think Chomsky is wrong too.

To understand the issues, we first must understand the logic of Darwin's theory of natural selection. Evolution and natural selection are not the same thing. Evolution, the fact that species change over time because of what Darwin called "descent with modification," was already widely accepted in Darwin's time but was attributed to many now-discredited processes such as Lamarck's inheritance of acquired characteristics and some internal urge or drive to develop in a direction of increasing complexity culminating in humans. What Darwin and Alfred Wallace discovered and emphasized was a particular cause of evolution, natural selection. Natural selection applies to any set of entities with the properties of ***multiplication, variation,*** and ***heredity.*** Multiplication means that the entities copy themselves, that the copies are also capable of copying themselves, and so on. Variation means that the copying is not perfect; errors crop up from time to time, and these errors may give an entity traits that enable it to copy itself at higher or lower rates relative to other entities. Heredity means that a variant trait produced by a copying error reappears in subsequent copies, so the trait is perpetuated in the lineage. Natural selection is the mathematically necessary outcome that any traits that foster superior

replication will tend to spread through the population over many generations. As a result, the entities will come to have traits that appear to have been designed for effective replication, including traits that are means to this end, like the ability to gather energy and materials from the environment and to safeguard them from competitors. These replicating entities are what we recognize as "organisms," and the replication-enhancing traits they accumulated by this process are called "adaptations."

At this point many people feel proud of themselves for spotting what they think is a fatal flaw. "Aha! The theory is circular! All it says is that traits that lead to effective replication lead to effective replication. Natural selection is 'the survival of the fittest' and the definition of 'the fittest' is 'those who survive.' " Not!! The power of the theory of natural selection is that it connects two independent and very different ideas. The first idea is the appearance of design. By "appearance of design" I mean something that an engineer could look at and surmise that its parts are shaped and arranged so as to carry out some function. Give an optical engineer an eyeball from an unknown species, and the engineer could immediately tell that it is designed for forming an image of the surroundings: it is built like a camera, with a transparent lens, contractable diaphragm, and so on. Moreover, an image-forming device is not just any old piece of bric-a-brac but a tool that is useful for finding food and mates, escaping from enemies, and so on. Natural selection explains how this design came to be, using a ***second*** idea: the actuarial statistics of reproduction in the organism's ancestors. Take a good look at the two ideas:

1. A part of an organism appears to have been engineered to enhance its reproduction.
2. That organism's ancestors reproduced more effectively than their competitors.

Note that (1) and (2) are logically independent. They are about different things: engineering design, and birth and death rates. They are about different organisms: the one you're interested in, and its ancestors. You can say that an organism has good vision and that good vision should help it reproduce (1), without knowing how well that organism, or any organism, in fact reproduces (2). Since "design" merely implies an enhanced *probability* of reproduction, a particular organism with well-designed vision may, in fact, not reproduce at all. Maybe it will be struck by lightning. Conversely, it may have a myopic sibling that in fact reproduces better, if, for instance, the same lightning bolt killed a predator who had the sibling in its sights. The theory of natural selection says that (2), the ancestors' birth and death rates, is the explanation for (1), the organism's engineering design—so it is not circular in the least.

This means that Chomsky was too flip when he dismissed natural selection as having no substance, as nothing more than a belief that there is some naturalistic explanation for a trait. In fact, it is not so easy to show that a trait is a product of selection. The trait has to be hereditary. It has to enhance the probability of reproduction of the organism, relative to organisms without the trait, in an environment like the one its ancestors lived in. There has to have been a sufficiently long lineage of similar organisms in the past. And because natural selection has no foresight, each intermediate stage in the evolution of an organ must have conferred some reproductive advantage on its possessor. Darwin noted that his theory made strong predictions and could easily be falsified. All it would take is the discovery of a trait that showed signs of design but that appeared somewhere other than at the end of a linage of replicators that could have used it to help in their replication. One example would be the existence of a trait designed only for the beauty of nature, such as a beautiful but cumbersome peacock tail evolving in moles, whose potential mates are too blind to be attracted to it. Another would be a complex organ that can exist in no useful intermediate form, such as a part-wing that could not have been useful for anything until it was one hundred percent of its current size and shape. A third would be an organism that was not produced by an entity that can replicate, such as some insect that spontaneously grew out of rocks, like a crystal. A fourth would be a trait designed to benefit an organism other than the one that caused the trait to appear, such as horses evolving saddles. In the

comic strip *Li'l Abner,* the cartoonist Al Capp featured selfless organisms called shmoos that laid chocolate cakes instead of eggs and that cheerfully barbecued themselves so that people could enjoy their delicious boneless meat. The discovery of a real-life shmoo would instantly refute Darwin.

Hasty dismissals aside, Chomsky raises a real issue when he brings up alternatives to natural selection. Thoughtful evolutionary theorists since Darwin have been adamant that not every beneficial trait is an adaptation to be explained by natural selection. When a flying fish leaves the water, it is extremely adaptive for it to reenter the water. But we do not need natural selection to explain this happy event; gravity will do just fine. Other traits, too, need an explanation different from selection. Sometimes a trait is not an adaptation in itself but a consequence of something else that is an adaptation. There is no advantage to our bones being white instead of green, but there is an advantage to our bones being rigid; building them out of calcium is one way to make them rigid, and calcium happens to be white. Sometimes a trait is constrained by its history, like the S-bend in our spine that we inherited when four legs became bad and two legs good. Many traits may just be impossible to grow within the constraints of a body plan and the way the genes build the body. The biologist J.B.S. Haldane once said that there are two reasons why humans do not turn into angels: moral imperfection and a body plan that cannot accommodate both arms and wings. And sometimes a trait comes about by dumb luck. If enough time passes in a small population of organisms, all kinds of coincidences will be preserved in it, a process called genetic drift. For example, in a particular generation all the stripeless organisms might be hit by lightning or die without issue; stripedness will reign thereafter, whatever its advantages or disadvantages.

Stephen Jay Gould and Richard Lewontin have accused biologists (unfairly, most believe) of ignoring these alternative forces and putting too much stock in natural selection. They ridicule such explanations as "just-so stories," an allusion to Kipling's whimsical tales of how various animals got their body parts. Gould and Lewontin's essays have been influential in the cognitive sciences, and Chomsky's skepticism that natural selection can explain human language is in the spirit of their critique.

But Gould and Lewontin's potshots do not provide a useful model of how to reason about the evolution of a complex trait. One of their goals was to undermine theories of human behavior that they envisioned as having right-wing political implications. The critiques also reflect their day-to-day professional concerns. Gould is a paleontologist, and paleontologists study organisms after they have turned into rocks. They look more at grand patterns in the history of life than at the workings of an individual's long-defunct organs. When they discover, for example, that the dinosaurs were extinguished by an asteroid slamming into the earth and blacking out the sun, small differences in reproductive advantages understandably seem beside the point. Lewontin is a geneticist, and geneticists tend to look at the raw code of the genes and their statistical variation in a population, rather than the complex organs they build. Adaptation can seem like a minor force to them, just as someone examining the 1's and 0's of a computer program in machine language without knowing what the program does might conclude that the patterns are without design. The mainstream in modern evolutionary biology is better represented by biologists like George Williams, John Maynard Smith, and Ernst Mayr, who are concerned with the design of whole living organisms. Their consensus is that natural selection has a very special place in evolution, and that the existence of alternatives does *not* mean that the explanation of a biological trait is up for grabs, depending only on the taste of the explainer.

The biologist Richard Dawkins has explained this reasoning lucidly in his book *The Blind Watchmaker*. Dawkins notes that the fundamental problem of biology is to explain "complex design." The problem was appreciated well before Darwin. The theologian William Paley wrote:

> In crossing a heath, suppose I pitched my foot against a *stone*, and were asked how the stone came to be there; I might possibly answer, that, for anything I knew to the contrary, it had lain there for ever: nor would it perhaps be very easy to show the absurdity of this answer. But suppose I had found a *watch* upon the ground, and it should be inquired how the watch happened to be in that place; I should hardly think of the answer which I had before given, that for anything I knew, the watch might have always been there.

Paley noted that a watch has a delicate arrangement of tiny gears and springs that function together to indicate the time. Bits of rock do not spontaneously exude metal which forms itself into gears and springs which then hop into an arrangement that keeps time. We are forced to conclude that the watch had an artificer who designed the watch with the goal of timekeeping in mind. But an organ like an eye is even more complexly and purposefully designed than a watch. The eye has a transparent protective cornea, a focusing lens, a light-sensitive retina at the focal plane of the lens, an iris whose diameter changes with the illumination, muscles that move one eye in tandem with the other, and neural circuits that detect edges, color, motion, and depth. It is impossible to make sense of the eye without noting that it appears to have been designed for seeing—if for no other reason than that it displays an uncanny resemblance to the man-made camera. If a watch entails a watchmaker and a camera entails a cameramaker, then an eye entails an eyemaker, namely God. Biologists today do not disagree with Paley's laying out of the problem. They disagree only with his solution. Darwin is history's most important biologist because he showed how such "organs of extreme perfection and complication" could arise from the purely physical process of natural selection.

And here is the key point. Natural selection is not just a scientifically respectable alternative to divine creation. It is the *only* alternative that can explain the evolution of a complex organ like the eye. The reason that the choice is so stark—God or natural selection—is that structures that can do what the eye does are extremely low-probability arrangements of matter. By an unimaginably large margin, most objects thrown together out of generic stuff, even generic animal stuff, cannot bring an image into focus, modulate incoming light, and detect edges and depth boundaries. The animal stuff in an eye seems to have been assembled with the goal of seeing in mind—but in whose mind, if not God's? How else could the mere *goal* of seeing well *cause* something to see well? The very special power of natural selection is to remove the paradox. What causes eyes to see well now is that they descended from a long line of ancestors that saw a bit better than their rivals, which allowed them to out-reproduce those rivals. The small random improvements in seeing were retained and combined and concentrated over the eons, leading to better and better eyes. The ability of *many* ancestors to see a *bit* better in the *past* causes a *single* organism to see *extremely* well *now*.

Another way of putting it is that natural selection is the only process that can steer a lineage of organisms along the path in the astronomically vast space of possible bodies leading from a body with no eye to a body with a functioning eye. The alternatives to natural selection can, in contrast, only grope randomly. The odds that the coincidences of genetic drift would result in just the right genes coming together to build a functioning eye are infinitesimally small. Gravity alone may make a flying fish fall into the ocean, a nice big target, but gravity alone cannot make bits of a flying fish embryo fall into place to make a flying fish eye. When one organ develops, a bulge of tissue or some nook or cranny can come along for free, the way an S-bend accompanies an upright spine. But you can bet that such a cranny will not just happen to have a functioning lens and a diaphragm and a retina all perfectly arranged for seeing. It would be like the proverbial hurricane that blows through a junkyard and assembles a Boeing 747. For these reasons, Dawkins argues that natural selection is not only the correct explanation for life on earth but is bound to be the correct explanation for anything we would be willing to call "life" anywhere in the universe.

And adaptive complexity, by the way, is also the reason that the evolution of complex organs tends to be slow and gradual. It is not that large mutations and rapid change violate some law of evolution. It is only that complex engineering requires precise arrangements of delicate parts, and if the engineering is accomplished by accumulating random changes, those changes had better be small. Complex organs evolve by small steps for the same reason that a watchmaker does not use a sledgehammer and a surgeon does not use a meat cleaver.

So we now know which biological traits to credit to natural selection and which ones to other evolutionary processes. What about language? In my mind, the conclusion is inescapable. Every discussion in this book has underscored the adaptive complexity of the language instinct. It is composed of many parts: syntax, with its discrete combinatorial system building phrase structures; morphology, a second combinatorial system building words; a capacious lexicon; a revamped vocal tract; phonological rules and structures; speech perception; parsing algorithms; learning algorithms. Those parts are physically realized as intricately structured neural circuits, laid down by a cascade of precisely timed genetic events. What these circuits make possible is an extraordinary gift: the ability to dispatch an infinite number of precisely structured thoughts from head to head by modulating exhaled breath. The gift is obviously useful for reproduction—think of Williams' parable of little Hans and Fritz being ordered to stay away from the fire and not to play with the saber-tooth. Randomly jigger a neural network or mangle a vocal tract, and you will not end up with a system with these capabilities. The language instinct, like the eye, is an example of what Darwin called "that perfection of structure and co-adaptation which justly excites our admiration," and as such it bears the unmistakable stamp of nature's designer, natural selection.

If Chomsky maintains that grammar shows signs of complex design but is skeptical that natural selection manufactured it, what alternative does he have in mind? What he repeatedly mentions is physical law. Just as the flying fish is compelled to return to the water and calcium-filled bones are compelled to be white, human brains might, for all we know, be compelled to contain circuits for Universal Grammar. He writes:

> These skills [for example, learning a grammar] may well have arisen as a concomitant of structural properties of the brain that

> developed for other reasons. Suppose that there was selection for bigger brains, more cortical surface, hemispheric specialization for analytic processing, or many other structural properties that can be imagined. The brain that evolved might well have all sorts of special properties that are not individually selected; there would be no miracle in this, but only the normal workings of evolution. We have no idea, at present, how physical laws apply when 10^{10} neurons are placed in an object the size of a basketball, under the special conditions that arose during human evolution.

We may not, just as we don't know how physical laws apply under the special conditions of hurricanes sweeping through junkyards, but the possibility that there is an undiscovered corollary of the laws of physics that causes brains of human size and shape to develop the circuitry for Universal Grammar seems unlikely for many reasons.

At the microscopic level, what set of physical laws could cause a surface molecule guiding an axon along a thicket of glial cells to cooperate with millions of other such molecules to solder together just the kinds of circuits that would compute something as useful to an intelligent social species as grammatical language? The vast majority of the astronomical number of ways of wiring together a large neural network would surely lead to something else: bat sonar, or nest-building, or go-go dancing, or, most likely of all, random neural noise.

At the level of the whole brain, the remark that there has been selection for bigger brains is, to be sure, common in writings about human evolution (especially from paleoanthropologists). Given that premise, one might naturally think that all kinds of computational abilities might come as a by-product. But if you think about it for a minute, you should quickly see that the premise has it backwards. Why would evolution ever have selected for sheer bigness of brain, that bulbous, metabolically greedy organ? A large-brained creature is sentenced to a life that combines all the disadvantages of balancing a watermelon on a broomstick, running in place in a down jacket, and,

for women, passing a large kidney stone every few years. Any selection on brain size itself would surely have favored the pinhead. Selection for more powerful computational abilities (language, perception, reasoning, and so on) must have given us a big brain as a by-product, not the other way around!

But even given a big brain, language does not fall out the way that flying fish fall out of the air. We see language in dwarfs whose heads are much smaller than a basketball. We also see it in hydrocephalics whose cerebral hemispheres have been squashed into grotesque shapes, sometimes a thin layer lining the skull like the flesh of a coconut, but who are intellectually and linguistically normal. Conversely, there are Specific Language Impairment victims with brains of normal size and shape and with intact analytic processing (recall that one of Gopnik's subjects was fine with math and computers). All the evidence suggests that it is the precise wiring of the brain's microcircuitry that makes language happen, not gross size, shape, or neuron packing. The pitiless laws of physics are unlikely to have done us the favor of hooking up that circuitry so that we could communicate with one another in words.

Incidentally, to attribute the basic design of the language instinct to natural selection is not to indulge in just-so storytelling that can spuriously "explain" any trait. The neuroscientist William Calvin, in his book *The Throwing Madonna,* explains the left-brain specialization for hand control, and consequently for language, as follows. Female hominids held their baby on their left side so the baby would be calmed by their heartbeat. This forced the mothers to use their right arm for throwing stones at small prey. Therefore the race became right-handed and left-brained. Now, this really *is* a just-so story. In all human societies that hunt, it is the men who do the hunting, not the women. Moreover, as a former boy I can attest that hitting an animal with a rock is not so easy. Calvin's throwing madonna is about as likely as Roger Clemens hurling split-fingered fastballs over the plate with a squirming infant on his lap. In the second edition to his book Calvin had to explain to readers that he only meant it as a joke; he was trying to show that such stories are no less plausible than serious adaptationist explanations. But such blunt-edged satire misses the point almost as much as if it had been intended as serious. The throwing madonna is qualitatively different from genuine adaptationist explanations, for not only is it instantly falsified by empirical and engineering considerations, but it is a nonstarter for a key theoretical reason: natural selection is an explanation for the extremely improbable. If brains are lateralized at all, lateralization on the left is not extremely improbable—its chances are exactly fifty percent! We do not need a circuitous tracing of left brains to anything else, for here the alternatives to selection are perfectly satisfying. It is a good illustration of how the logic of natural selection allows us to distinguish legitimate selectionist accounts from just-so stories.

To be fair, there are genuine problems in reconstructing how the language faculty might have evolved by natural selection, though the psychologist Paul Bloom and I have argued that the problems are all resolvable. As P. B. Medawar noted, language could not have begun in the form it supposedly took in the first recorded utterance of the infant Lord Macaulay, who after having been scalded with hot tea allegedly said to his hostess, "Thank you, madam, the agony is sensibly abated." If language evolved gradually, there must have been a sequence of intermediate forms, each useful to its possessor, and this raises several questions.

First, if language involves, for its true expression, another individual, who did the first grammar mutant talk to? One answer might be: the fifty percent of the brothers and sisters and sons and daughters who shared the new gene by common inheritance. But a more general answer is that the neighbors could have partly understood what the mutant was saying even if they lacked the new-fangled circuitry, just using overall intelligence. Though we cannot parse strings like *skid crash hospital,* we can figure out what they probably mean, and English speakers can often do a reasonably good job understanding Italian newspaper stories based on similar words and background knowledge. If a grammar mutant is making important distinctions that can be decoded by others only with uncertainty and great mental

effort, it could set up a pressure for them to evolve the matching system that allows those distinctions to be recovered reliably by an automatic, unconscious parsing process. As I mentioned in Chapter 8, natural selection can take skills that are acquired with effort and uncertainty and hardwire them into the brain. Selection could have ratcheted up language abilities by favoring the speakers in each generation that the hearers could best decode, and the hearers who could best decode the speakers.

A second problem is what an intermediate grammar would have looked like. Bates asks:

> What protoform can we possibly envision that could have given birth to constraints on the extraction of noun phrases from an embedded clause? What could it conceivably mean for an organism to possess half a symbol, or three quarters of a rule? . . . monadic symbols, absolute rules and modular systems must be acquired as a whole, on a yes-or-no basis—a process that cries out for a Creationist explanation.

The question is rather odd, because it assumes that Darwin literally meant that organs must evolve in successively larger fractions (half, three quarters, and so on). Bates' rhetorical question is like asking what it could conceivably mean for an organism to possess half a head or three quarters of an elbow. Darwin's real claim, of course, is that organs evolve in successively more complex forms. Grammars of intermediate *complexity* are easy to imagine; they could have symbols with a narrower range, rules that are less reliably applied, modules with fewer rules, and so on. In a recent book Derek Bickerton answers Bates even more concretely. He gives the term "protolanguage" to chimp signing, pidgins, child language in the two-word stage, and the unsuccessful partial language acquired after the critical period by Genie and other wolf-children. Bickerton suggests that *Homo erectus* spoke in protolanguage. Obviously there is still a huge gulf between these relatively crude systems and the modern adult language instinct, and here Bickerton makes the jaw-dropping additional suggestion that a single mutation in a single woman, African Eve, simultaneously wired in syntax, resized and reshaped the skull, and reworked the vocal tract. But we can extend the first half of Bickerton's argument without accepting the second half, which is reminiscent of hurricanes assembling jetliners. The languages of children, pidgin speakers, immigrants, tourists, aphasics, telegrams, and headlines show that there is a vast continuum of viable language systems varying in efficiency and expressive power, exactly what the theory of natural selection requires.

A third problem is that each step in the evolution of a language instinct, up to and including the most recent ones, must enhance fitness. David Premack writes:

> I challenge the reader to reconstruct the scenario that would confer selective fitness on recursiveness. Language evolved, it is conjectured, at a time when humans or protohumans were hunting mastodons. . . . Would it be a great advantage for one of our ancestors squatting alongside the embers, to be able to remark: "Beware of the short beast whose front hoof Bob cracked when, having forgotten his own spear back at camp, he got in a glancing blow with the dull spear he borrowed from Jack"?
>
> Human language is an embarrassment for evolutionary theory because it is vastly more powerful than one can account for in terms of selective fitness. A semantic language with simple mapping rules, of a kind one might suppose that the chimpanzee would have, appears to confer all the advantages one normally associates with discussions of mastodon hunting or the like. For discussions of that kind, syntactic classes, structure-dependent rules, recursion and the rest, are overly powerful devices, absurdly so.

I am reminded of a Yiddish expression, "What's the matter, is the bride too beautiful?" The objection is a bit like saying that the cheetah is much faster than it has to be, or that the eagle does not need such good vision, or that the elephant's trunk is an overly powerful device, absurdly so. But it is worth taking up the challenge.

First, bear in mind that selection does not need great advantages.

Given the vastness of time, tiny advantages will do. Imagine a mouse that was subjected to a minuscule selection pressure for increased size—say, a one percent reproductive advantage for offspring that were one percent bigger. Some arithmetic shows that the mouse's descendants would evolve to the size of an elephant in a few thousand generations, an evolutionary eyeblink.

Second, if contemporary hunter-gatherers are any guide, our ancestors were not grunting cave men with little more to talk about than which mastodon to avoid. Hunter-gatherers are accomplished toolmakers and superb amateur biologists with detailed knowledge of the life cycles, ecology, and behavior of the plants and animals they depend on. Language would surely have been useful in anything resembling such a lifestyle. It is possible to imagine a superintelligent species whose isolated members cleverly negotiated their environment without communicating with one another, but what a waste! There is a fantastic payoff in trading hard-won knowledge with kin and friends, and language is obviously a major means of doing so.

And grammatical devices designed for communicating precise information about time, space, objects, and who did what to whom are not like the proverbial thermonuclear fly-swatter. Recursion in particular is extremely useful; it is not, as Premack implies, confined to phrases with tortuous syntax. Without recursion you can't say *the man's hat* or *I think he left*. Recall that all you need for recursion is an ability to embed a noun phrase inside another noun phrase or a clause within a clause, which falls out of rules as simple as "NP → det N PP" and "PP → P NP." With this ability a speaker can pick out an object to an arbitrarily fine level of precision. These abilities can make a big difference. It makes a difference whether a far-off region is reached by taking the trail that is in front of the large tree or the trail that the large tree is in front of. It makes a difference whether that region has animals that you can eat or animals that can eat you. It makes a difference whether it has fruit that is ripe or fruit that was ripe or fruit that will be ripe. It makes a difference whether you can get there if you walk for three days or whether you can get there and walk for three days.

Third, people everywhere depend on cooperative efforts for survival, forming alliances by exchanging information and commitments. This too puts complex grammar to good use. It makes a difference whether you understand me as saying that if you give me some of your fruit I will share meat that I will get, or that you should give me some fruit because I shared meat that I got, or that if you don't give me some fruit I will take back the meat that I got. And once again, recursion is far from being an absurdly powerful device. Recursion allows sentences like ***He knows that she thinks that he is flirting with Mary*** and other means of conveying gossip, an apparently universal human vice.

But could these exchanges really produce the rococo complexity of human grammar? Perhaps. Evolution often produces spectacular abilities when adversaries get locked into an "arms race," like the struggle between cheetahs and gazelles. Some anthropologists believe that human brain evolution was propelled more by a cognitive arms race among social competitors than by mastery of technology and the physical environment. After all, it doesn't take that much brain power to master the ins and outs of a rock or to get the better of a berry. But outwitting and second-guessing an organism of approximately equal mental abilities with non-overlapping interests, at best, and malevolent intentions, at worst, makes formidable and ever-escalating demands on cognition. And a cognitive arms race clearly could propel a linguistic one. In all cultures, social interactions are mediated by persuasion and argument. How a choice is framed plays a large role in determining which alternative people choose. Thus there could easily have been selection for any edge in the ability to frame an offer so that it appears to present maximal benefit and minimal cost to the negotiating partner, and in the ability to see through such attempts and to formulate attractive counterproposals.

Finally, anthropologists have noted that tribal chiefs are often both gifted orators and highly polygynous—a splendid prod to any imagination that cannot conceive of how linguistic skills could make a Darwinian difference. I suspect that evolving humans lived in a world in which language was woven into the intrigues of politics, economics, technology, family, sex, and friendship that played key roles

in individual reproductive success. They could no more live with a Me-Tarzan-you-Jane level of grammar than we could.

The brouhaha raised by the uniqueness of language has many ironies. The spectacle of humans trying to ennoble animals by forcing them to mimic human forms of communication is one. The pains that have been taken to portray language as innate, complex, and useful but not a product of the one force in nature that can make innate complex useful things is another. Why should language be considered such a big deal? It has allowed humans to spread out over the planet and wreak large changes, but is that any more extraordinary than coral that build islands, earthworms that shape the landscape by building soil, or the photosynthesizing bacteria that first released corrosive oxygen into the atmosphere, an ecological catastrophe of its time? Why should talking humans be considered any weirder than elephants, penguins, beavers, camels, rattlesnakes, hummingbirds, electric eels, leaf-mimicking insects, giant sequoias, Venus flytraps, echolocating bats, or deep-sea fish with lanterns growing out of their heads? Some of these creatures have traits unique to their species, others do not, depending only on the accidents of which of their relatives have become extinct. Darwin emphasized the genealogical connectedness of all living things, but evolution is descent ***with modification***, and natural selection has shaped the raw materials of bodies and brains to fit them into countless differentiated niches. For Darwin, such is the "grandeur in this view of life": "that whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and wonderful have been, and are being, evolved."