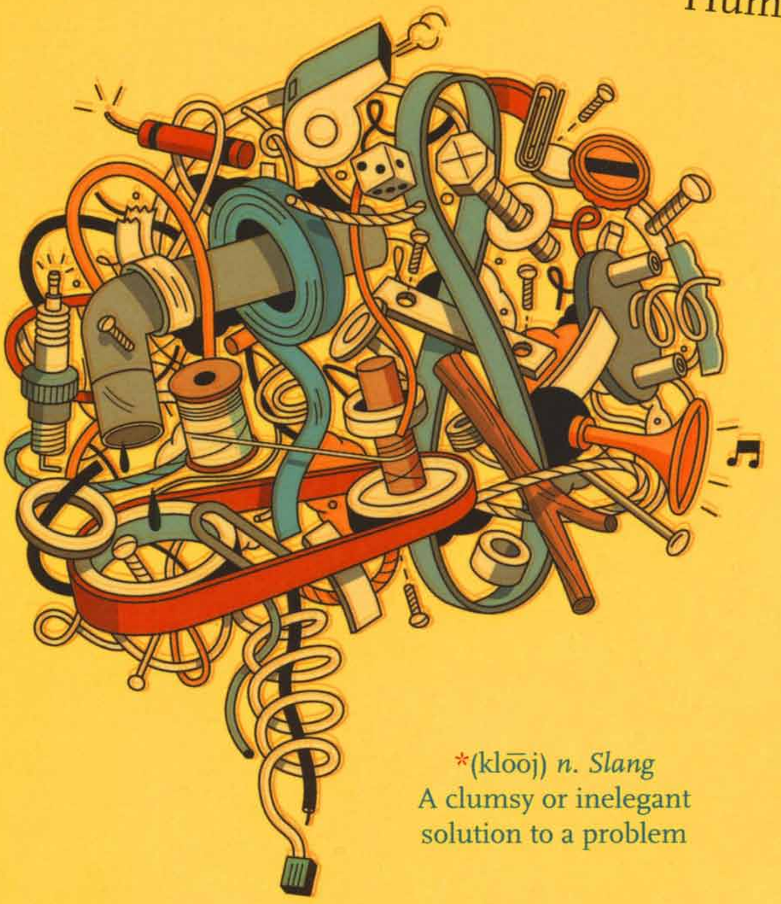
Kluge*

The Haphazard Construction of the Human Mind



*(klōōj) *n. Slang*
A clumsy or inelegant
solution to a problem

GARY MARCUS

$24.00

How the accidents of evolution created our quirky, imperfect minds—and what we can do about it

Are we "noble in reason"? Perfect, in God's image? Far from it, says the New York University psychologist Gary Marcus. In this lucid and revealing book, Marcus argues that the mind is not an elegantly designed organ but rather a "kluge," a clumsy, cobbled-together contraption. He unveils a fundamentally new way of looking at the human mind—think duct tape, not supercomputer—that sheds light on some of the most mysterious aspects of human nature.

Taking us on a tour of the fundamental areas of human experience—memory, belief, decision making, language, and happiness—Marcus reveals the myriad ways our minds fall short. He examines why people often vote against their own interests, why money can't buy happiness, why leaders often stick to bad decisions, and why a sentence like "People people left left" ties us in knots even though it's only four words long.

Marcus also offers surprisingly effective ways to outwit our inner kluge, for the betterment of ourselves and society. Throughout, he shows how only evolution—haphazard and undirected—could have produced the minds we humans have, while making a brilliant case for the power of imperfection.

0408

GARY MARCUS is a professor of psychology at New York University and director of the NYU Infant Language Learning Center. The author of *The Birth of the Mind* and editor of the *Norton Psychology Reader,* he has been a fellow at the prestigious Center for Advanced Study in the Behavioral Sciences at Stanford. His writing has appeared in the *New York Times*, the *Philadelphia Inquirer, Newsday,* the *Los Angeles Times*, and other major publications.

Jacket design by Martha Kennedy
Jacket illustration © Harry Campbell
Author photo © Nina Subin

Houghton Mifflin Company
222 Berkeley Street, Boston, Massachusetts 02116
www.houghtonmifflinbooks.com

Praise for **KLUGE** 

"Evolution, Darwin wrote, is 'descent with modification,' and any understanding of the origins of the human mind must take both aspects into account. In this informative and engaging book, Gary Marcus provides the most thorough argument to date that the design of the mind includes constraints and compromises imposed by its evolutionary origins."

—**Steven Pinker,** author of *The Stuff of Thought*

"None of us can stay on diets, and we can't solve the kinds of logic problems that a TRS-80 would sneeze at. Now we know why: it's the brain's fault. If you want serious science in a book that's engaging enough to read on a plane, *Kluge* is for you. Get yourself a copy and behold the beautiful mess of your own brain."

—**Dan Heath,** coauthor of *Made to Stick: Why Some Ideas Survive and Others Die*

"A fascinating inventory of the mental errors we all make, illustrating that the brain is nothing more than a jury-rigged set of independent problem solvers, not perfect but good enough most of the time."

—**Daniel J. Levitin,** author of *This Is Your Brain on Music*

"Gary Marcus can explain the most complex scientific questions so well that you not only understand him while you're reading him, but you actually remember his metaphors years later. This book is a treat, one that will give pleasure and insight long after you're done with it."

—**Jonathan Haidt,** author of *The Happiness Hypothesis*

ISBN 978-0-618-87964-9
52400
9 780618 879649
6-94266

KLUGE

BOOKS BY GARY MARCUS

The Algebraic Mind

The Birth of the Mind

The Norton Psychology Reader

Kluge

KLUGE

THE HAPHAZARD CONSTRUCTION OF THE HUMAN MIND

GARY MARCUS

HOUGHTON MIFFLIN COMPANY
BOSTON · NEW YORK 2008

www.houghtonmifflinbooks.com

Library of Congress Cataloging-in-Publication Data
Marcus, Gary F. (Gary Fred)
Kluge : the haphazard construction of the human mind / Gary Marcus.
p. cm.
Includes bibliographical references (p.) and index.
ISBN 978-0-618-87964-9
1. Psychology. 2. Cognitive psychology. 3. Cognitive neuroscience. I. Title.
BF38.M355 2008 153 — dc22

Printed in the United States of America

MP 10 9 8 7 6 5 4 3 2 1

For my father,
who taught me the word

CONTENTS

Living organisms are historical structures: literally creations of history. They represent not a perfect product of engineering, but a patchwork of odd sets pieced together when and where opportunities arose.

— François Jacob

Bad luck is better than no luck at all.

— Traditional

KLUGE

1

Remnants of History

> It has been said that man is a rational animal. All my life I have been searching for evidence which could support this.
>
> — Bertrand Russell

Are human beings "noble in reason" and "infinite in faculty" as William Shakespeare famously wrote? Perfect, "in God's image," as some biblical scholars have asserted? Hardly.

If mankind were the product of some intelligent, compassionate designer, our thoughts would be rational, our logic impeccable. Our memory would be robust, our recollections reliable. Our sentences would be crisp, our words precise, our languages systematic and regular, not besodden with irregular verbs (*sing-sang, ring-rang,* yet *bring-brought*) and other peculiar inconsistencies. As the language maven Richard Lederer has noted, there would be ham in hamburger, egg in eggplant. English speakers would park in parkways and drive on driveways, and not the other way around.

At the same time, we humans are the only species smart enough to systematically plan for the future — yet dumb enough to ditch our most carefully made plans in favor of short-term gratification. ("Did I say I was on a diet? *Mmm,* but three-layer chocolate mousse is my favorite . . . Maybe I'll start my diet *tomorrow.*") We happily drive across town to save $25 on a $100 microwave but refuse to drive the same distance to save exactly the same $25 on a $1,000 flat-screen TV. We can barely tell the difference between a valid syllogism, such as *All men are mortal, Socrates is a man, therefore Socrates is mortal,* and a fallacious counterpart, such as *All living things need water, roses need* *water, therefore roses are living things* (which seems fine until you substitute *car batteries* for *roses*). If I tell you that "Every sailor loves a girl," you have no idea whether I mean one girl in particular (say, Betty Sue) or whether I'm really saying "to each his own." And don't even get me started on eyewitness testimony, which is based on the absurd premise that we humans can accurately remember the details of a briefly witnessed accident or crime, years after the fact, when the average person is hard pressed to keep a list of a dozen words straight for half an hour.

I don't mean to suggest that the "design" of the human mind is a total train wreck, but if I were a politician, I'm pretty sure the way I'd put it is "mistakes were made." The goal of this book is to explain what mistakes were made — and why.

Where Shakespeare imagined infinite reason, I see something else, what engineers call a "kluge." A kluge is a clumsy or inelegant — yet surprisingly effective — solution to a problem. Consider, for example, what happened in April 1970 when the CO_2 filters on the already endangered lunar module of *Apollo 13* began to fail. There was no way to send a replacement filter up to the crew — the space shuttle hadn't been invented yet — and no way to bring the capsule home for several more days. Without a filter, the crew would be doomed. The mission control engineer, Ed Smylie, advised his team of the situation, and said, in effect, "Here's what's available on the space capsule; figure something out." Fortunately, the ground crew was able to meet the challenge, quickly cobbling together a crude filter substitute out of a plastic bag, a cardboard box, some duct tape, and a sock. The lives of the three astronauts were saved. As one of them, Jim Lovell, later recalled, "The contraption wasn't very handsome, but it worked."

Not every kluge saves lives. Engineers sometimes devise them for sport, just to show that something — say, building a computer out of Tinkertoys — can be done, or simply because they're too lazy to do something the right way. Others cobble together kluges out of a mixture of desperation and resourcefulness, like the TV character MacGyver, who, needing to make a quick getaway, jerry-built a pair of shoes from duct tape and rubber mats. Other kluges are created just for laughs, like Wallace and Gromit's "launch and activate" alarm clock/coffeemaker/Murphy bed and Rube Goldberg's "simplified pencil sharpener" (a kite attached to a string lifts a door, which allows moths to escape, culminating in the lifting of a cage, which frees a woodpecker to gnaw the wood that surrounds a pencil's graphite core). MacGyver's shoes and Rube Goldberg's pencil sharpeners are nothing, though, compared to perhaps the most fantastic kluge of them all — the human mind, a quirky yet magnificent product of the entirely blind process of evolution.

The origin, and even the spelling, of the word *kluge* is up for grabs. Some spell it with a *d* (*kludge*), which has the virtue of looking as clumsy as the solutions it denotes, but the disadvantage of suggesting the wrong pronunciation. (Properly pronounced, *kluge* rhymes with *huge*, not *sludge*.)* Some trace the word to the old Scottish word *cludgie*, which means "an outside toilet." Most believe the origins lie in the German word *Kluge*, which means "clever." *The Hacker's Dictionary of Computer Jargon* traces the term back at least to 1935, to a "Kluge [brand] paper feeder," described as "an adjunct to mechanical printing presses."

> The Kluge feeder was designed before small, cheap electric motors and control electronics; it relied on a fiendishly complex assortment of cams, belts, and linkages to both power and synchronize all its operations from one motive driveshaft. It was accordingly temperamental, subject to frequent breakdowns, and devilishly difficult to repair — but oh, so clever!

---

*One could argue that the spelling *klooge* (rhymes with *stooge*) would even better capture the pronunciation, but I'm not about to foist a third spelling upon the world.

Virtually everybody agrees that the term was first popularized in February 1962, in an article titled "How to Design a Kludge," written, tongue in cheek, by a computer pioneer named Jackson Granholm, who defined a kluge as "an ill-assorted collection of poorly matching parts, forming a distressing whole." He went on to note that "the building of a Kludge . . . is not work for amateurs. There is a certain, indefinable, masochistic finesse that must go into true Kludge building. The professional can spot it instantly. The amateur may readily presume that 'that's the way computers are.'"

The engineering world is filled with kluges. Consider, for example, something known as vacuum-powered windshield wipers, common in most cars until the early 1960s. Modern windshield wipers, like most gizmos on cars, are driven by electricity, but back in the olden days, cars ran on 6 volts rather than 12, barely enough power to keep the spark plugs going and certainly not enough to power luxuries like windshield wipers. So some clever engineer rigged up a kluge that powered windshield-wiper motors with suction, drawn from the engine, rather than electricity. The only problem is that the amount of suction created by the engine varies, depending on how hard the engine is working. The harder it works, the less vacuum it produces. Which meant that when you drove your 1958 Buick Riviera up a hill, or accelerated hard, your wipers slowed to a crawl, or even stopped working altogether. On a rainy day in the mountains, Grandpa was out of luck.

What's really amazing — in hindsight — is that most people probably didn't even realize it was possible to do better. And this, I think, is a great metaphor for our everyday acceptance of the idiosyncrasies of the human mind. The mind is inarguably impressive, a lot better than any available alternative. But it's still flawed, often in ways we scarcely recognize. For the most part, we simply accept our faults — such as our emotional outbursts, our mediocre memories, and our vulnerability to prejudice — as standard equipment. Which is exactly why recognizing a kluge, and how it might be improved upon, sometimes requires thinking outside the box. The best science, like the best engineering, often comes from understanding not just how things are, but how else they could have been.

If engineers build kluges mostly to save money or to save time, why does nature build them? Evolution is neither clever nor penny-pinching. There's no money involved, no foresight, and if it takes a billion years, who's going to complain? Yet a careful look at biology reveals kluge after kluge. The human spine, for example, is a lousy solution to the problem of supporting the load in an upright, two-legged creature. It would have made a lot more sense to distribute our weight across four equal cross-braced columns. Instead, all our weight is borne by a single column, putting enormous stress on the spine. We manage to survive upright (freeing our hands), but the cost for many people is agonizing back pain. We are stuck with this barely adequate solution not because it is the best possible way to support the weight of a biped, but because the spine's structure evolved from that of four-legged creatures, and standing up poorly is (for creatures like us, who use tools) better than not standing up at all.

Meanwhile, the light-sensitive part of our eye (the retina) is installed backward, facing the back of the head rather than the front. As a result, all kinds of stuff gets in its way, including a bunch of wiring that passes through the eye and leaves us with a pair of blind spots, one in each eye.

Another well-known example of an evolutionary kluge comes from a rather intimate detail of male anatomy. The tubing that runs from the testis to the urethra (the vas deferens) is much longer than necessary: it runs back to front, loops around, and does a 180-degree turn back to the penis. A parsimonious designer interested in conserving materials (or in efficiency of delivery) would have connected the testis directly to the penis with just a short length of tubing; only because biology builds on what has come before is the system set up so haphazardly. In the words of one scientist, "The [human] body is a bundle of imperfections, with . . . useless protuberances above the nostrils, rotting teeth with trouble-prone third molars, aching feet . . . , easily strained backs, and naked tender skin, subject to cuts, bites, and, for many, sunburn. We are poor runners and are only about a third as strong as chimpanzees smaller than ourselves."

To this litany of human-specific imperfections, we might add dozens more that are widely shared across the animal world, such as the byzantine system by which DNA strands are separated prior to DNA replication (a key process in allowing one cell to become two). One molecule of DNA polymerase does its job in a perfectly straightforward fashion, but the other does so in a back-and-forth, herky-jerky way that would drive any rational engineer insane.

Nature is prone to making kluges because it doesn't "care" whether its products are perfect or elegant. If something works, it spreads. If it doesn't work, it dies out. Genes that lead to successful outcomes tend to propagate; genes that produce creatures that can't cut it tend to fade away; all else is metaphor. Adequacy, not beauty, is the name of the game.

Nobody would doubt this when it comes to the body, but somehow, when it comes to the mind, many people draw the line. Sure, my spine is a kluge, maybe my retina too, but my *mind*? It's one thing to accept that our body is flawed, quite another to accept that our mind is too.

Indeed, there is a long tradition in thinking otherwise. Aristotle saw man as "the rational animal," and economists going back to John Stuart Mill and Adam Smith have supposed that people make decisions based on their own self-interest, preferring wherever possible to buy low and sell high, maximizing their "utility" wherever they can.

In the past decade, a number of academics have started to argue that humans reason in a "Bayesian"* fashion, which is mathemati-

---

*The term *Bayesian* comes from a particular mathematical theorem stemming from the work of the Reverend Thomas Bayes (1702–1761), although he himself did not propose it as a model for human reasoning. In rough terms, the theorem states that the probability of some event is proportional to the product of the likelihood of that event and its prior probability. For a clear (though somewhat technical) introduction, point your browser to http://en.wikipedia.org/wiki/Bayesian_statistics.

cally optimal. One prestigious journal recently devoted an entire issue to this possibility, with a trio of prominent cognitive scientists from MIT, UCLA, and University College London arguing that "it seems increasingly plausible that human cognition may be explicable in rational probabilistic terms . . . in core domains, human cognition approaches an optimal level of performance."

The notion of optimality is also a recurrent theme in the increasingly popular field of evolutionary psychology. For example, John Tooby and Leda Cosmides, the cofounders of the field, have written that "because natural selection is a hill-climbing process that tends to choose the best of the variant designs that actually appear, and because of the immense numbers of alternatives that appear over the vast expanse of evolutionary time, natural selection tends to cause the accumulation of *superlatively well engineered* functional designs."

In the same vein, Steven Pinker has argued that "the parts of the mind that allow us to see are indeed well engineered, and there is no reason to think that the quality of engineering progressively deteriorates as the information flows upstream to the faculties that interpret and act on what we see."

This book will present a rather different view. Although no reasonable scholar would doubt the fact that natural selection *can* produce superlatively well engineered functional designs, it is also clear that superlative engineering is by no means *guaranteed.* What I will argue, in contrast to most economists, Bayesians, and evolutionary psychologists, is that the human mind is no less of a kluge than the body. And if that's true, our very understanding of ourselves — of human nature — must be reconsidered.

In the extensive literature on evolutionary psychology, I know of only a few aspects of the human mind that have been attributed to genuine quirks. Although most evolutionary psychologists recognize the possibility of suboptimal evolution *in principle,* in practice, when human errors are discussed, it's almost always to explain why something apparently nonadaptive actually turns out to be *well* engineered.

Take, for example, infanticide. Nobody would argue that infanticide is morally justifiable, but why does it happen at all? From the perspective of evolution, infanticide is not just immoral, but puzzling. If we exist essentially as gene-propagating vessels (as Richard Dawkins has argued), why would any parent murder his or her own child? Martin Daly and Margo Wilson have argued that from the gene's-eye view, infanticide makes sense only in a very limited set of circumstances: when the parent is not actually related by blood to the child (stepparents, for example), when a male parent is in doubt about paternity, or when a mother is not currently in a position to take good care of the child, yet has prospects for taking better care of some future child (say, because the current infant was born hopelessly unhealthy). As Daly and Wilson have shown, patterns of murder and child abuse fit well with these hypotheses.

Or consider the somewhat unsurprising fact that men (but not women) systematically tend to overinterpret the sexual intentions of potential mates.* Is this simply a matter of wishful thinking? Not at all, argue the evolutionary psychologists Martie Haselton and David Buss. Instead, it's a highly efficient strategy shaped by natural selection, a cognitive error reinforced by nature. Strategies that lead to greater reproductive success spread (by definition) widely throughout the population, and ancestral males who tended to read too much into the signals given by possible partners would have more opportunities to reproduce than would their more cautious counterparts, who likely failed to identify bona fide opportunities. From the gene's-eye view, it was well worth it for our male ancestors to take the risk of overinterpretation because gaining an extra reproductive opportunity far outweighs the downside, such as damage to self-esteem or reputation, of perceiving opportunity where there is none. What looks like a bug, a systematic bias in interpreting the motives of other human beings, might in this case actually be a positive feature.

When reading clever, carefully argued examples like this one, it's

*Except, tellingly, those of their sisters.

easy to get caught up in the excitement, to think that behind every human quirk or malfunction is a truly adaptive strategy. Underpinning such examples is a bold premise: that optimization is the inevitable outcome of evolution. But optimization is not an *inevitable* outcome of evolution, just a *possible* one. Some apparent bugs may turn out to be advantages, but — as the spine and inverted retina attest — some bugs may be genuinely suboptimal and remain in place because evolution just didn't find a better way.

Natural selection, the key mechanism of evolution, is only as good as the random mutations that arise. If a given mutation is beneficial, it may propagate, but the most beneficial mutations imaginable sometimes, alas, never appear. As an old saying puts it, "Chance proposes and nature disposes"; a mutation that does not arise cannot be selected for. If the right set of genes falls into place, natural selection will likely promote the spread of those genes, but if they don't happen to occur, all evolution can do is select the next best thing that's available.

To think about this, it helps to start with the idea of evolution as mountain climbing. Richard Dawkins, for example, has noted that there is little chance that evolution would assemble any complex creature or organ (say, the eye) overnight — too many lucky chance mutations would need to occur simultaneously. But it is possible to achieve perfection incrementally. In the vivid words of Dawkins,

> you don't need to be a mathematician or physicist to calculate that an eye or a hemoglobin molecule would take from here to infinity to self-assemble by sheer higgledy-piggledy luck. Far from being a difficulty peculiar to Darwinism, the astronomic improbability of eyes and knees, enzymes and elbow joints and the other living wonders is precisely the problem that any theory of life must solve, and that Darwinism uniquely does solve. It solves it by breaking the improbability up into small, manageable parts, smearing out the luck needed, going round the back of

> Mount Improbable and crawling up the gentle slopes, inch by million-year inch.

And, to be sure, examples of sublime evolution abound. The human retina, for example, can detect a single photon in a darkened room, and the human cochlea (the hair cell containing the part of the inner ear that vibrates in response to sound waves) can, in an otherwise silent room, detect vibrations measuring less than the diameter of a hydrogen atom. Our visual systems continue, despite remarkable advances in computer power, to far outstrip the visual capacities of any machine. Spider silk is stronger than steel and more elastic than rubber. All else being equal, species (and the organs they depend upon) tend, over time, to become better and better suited to their environment — sometimes even reaching theoretical limits, as in the aforementioned sensitivity of the eye. Hemoglobin (the key ingredient in red blood cells) is exquisitely adapted to the task of transporting oxygen, tuned by slight variations in different species such that it can load and unload its oxygen cargo in a way optimally suited to the prevailing air pressure — one method for creatures that dwell at sea level, another for a species like the bar-headed goose, an inhabitant of the upper reaches of the Himalayas. From the biochemistry of hemoglobin to the intricate focusing systems of the eye, there are thousands of ways in which biology comes startlingly close to perfection.

But perfection is clearly not always the way; the possibility of imperfection too becomes apparent when we realize that what evolution traverses is not just a mountain, but a mountain *range*. What is omitted from the usual metaphor is the fact that it is perfectly possible for evolution to get *stuck* on a peak that is *short of the highest conceivable summit,* what is known as a "local maximum." As Dawkins and many others have noted, evolution tends to take small steps.* If

*Emphasis on "tends to." Strictly speaking, the steps taken by evolution may be of any size, but dramatic mutations rarely survive, whereas small modifications often keep enough core systems in place to have a fighting chance. As a statistical matter, small changes thus appear to have a disproportionately large influence on evolution.

no immediate change leads to an improvement, an organism is likely to stay where it is on the mountain range, even if some distant peak might be better. The kluges I've talked about already — the spine, the inverted retina, and so forth — are examples of just that, of evolution getting stuck on tallish mountains that fall short of the absolute zenith.

In the final analysis, evolution isn't about perfection. It's about what the late Nobel laureate Herb Simon called "satisficing," obtaining an outcome that is good enough. That outcome might be beautiful and elegant, or it might be a kluge. Over time, evolution can lead to both: aspects of biology that are exquisite and aspects of biology that are at best rough-and-ready.

Indeed, sometimes elegance and kluginess coexist, side by side. Highly efficient neurons, for example, are connected to their neighbors by puzzlingly inefficient synaptic gaps, which transform efficient electrical activity into less efficient diffusing chemicals, and these in turn waste heat and lose information. Likewise, the vertebrate eye is, in many respects, tremendously elegant, with its subtle mechanisms for focusing light, adjusting to varied amounts of lighting, and so forth. Though it operates with more sophistication than most digital cameras, it's still hobbled by the backward retina and its attendant blind spot. On the highest peak of evolution, our eyes would work much as they do now, but the retina would face forward (as it does in the octopus), eliminating those blind spots. The human eye is about as good as it could be, given the backward retina, but it could be better — a perfect illustration of how nature occasionally winds up notably short of the highest possible summit.

There are a number of reasons why, at any particular moment, a given creature might have a design that is less than optimal, including random chance (sheer bad luck), rapid environmental change (for example, if there's a major meteor hit, an ice age, or another cataclysmic event, it takes time for evolution to catch up), or the influence that will animate much of this book: history, as encapsulated in our genome. History has a potent — and sometimes detrimental — effect because what can evolve at any given point is heavily constrained by what has evolved before. Just as contemporary political conflicts can in part be traced to the treaties following the world wars, current biology can be traced to the history of earlier creatures. As Darwin put it, all life is the product of "descent with modification"; existing forms are simply altered versions of earlier ones. The human spine, for example, arose not because it was the best possible solution imaginable, but because it was built upon something (the quadruped spine) that already existed.

This gives rise to a notion that I call "evolutionary inertia," borrowing from Newton's law of inertia (an object at rest tends to stay at rest, and an object in motion tends to stay in motion). Evolution tends to work with what is already in place, making modifications rather than starting from scratch.

Evolutionary inertia occurs because new genes must work in concert with old genes and because evolution is driven by the immediate. Gene-bearing creatures either live and reproduce or they don't. Natural selection therefore tends to favor genes that have immediate advantages, discarding other options that might function better in the long term. Thus the process operates a bit like a product manager who needs his product to ship *now,* even if today's cut corners might lead to problems later.

The net result is, as Nobel laureate François Jacob famously put it, that evolution is like a tinkerer "who . . . often without knowing what he is going to produce . . . uses whatever he finds around him, old cardboards, pieces of strings, fragments of wood or metal, to make some kind of workable object . . . [the result is] a patchwork of odd sets pieced together when and where opportunity arose." If necessity is the mother of invention, tinkering is the geeky grandfather of kluge.

In short, evolution often proceeds by piling new systems on top of old ones. The neuroscientist John Allman has captured this idea nicely with an analogy to a power plant he once visited, where at least three layers of technology were in simultaneous use, stacked on top of one another. The recent computer technology operated not directly, but rather by controlling vacuum tubes (perhaps from the 1940s), which in turn controlled still older pneumatic mechanisms that relied on pressurized gases. If the power plant's engineers could afford the luxury of taking the whole system offline, they would no doubt prefer to start over, getting rid of the older systems altogether. But the continuous need for power precludes such an ambitious redesign.

In the same way, living creatures' continuous need to survive and reproduce often precludes evolution from building genuinely optimal systems; evolution can no more take its products offline than the human engineers could, and the consequences are often equally clumsy, with new technologies piled on top of old. The human midbrain, for example, exists literally on top of the ancient hindbrain, and the forebrain is built top of both. The hindbrain, the oldest of the three (dating from at least half a billion years ago), controls respiration, balance, alertness, and other functions that are as critical to a dinosaur as to a human. The midbrain, layered on soon afterward, coordinates visual and auditory reflexes and controls functions such as eye movements. The forebrain, the final division to come online, governs things such as language and decision making, but in ways that often depend on older systems. As any neuroscience textbook will tell you, language relies heavily on Broca's area, a walnut-sized region of the left forebrain, but it too relies on older systems, such as the cerebellum, and ancestral memory systems that are not particularly well suited to the job. Over the course of evolution our brain has become a bit like a palimpsest, an ancient manuscript with layers of text written over it many times, old bits still hiding behind new.

Allman referred to this awkward process, by which new systems are built on top of old ones rather than begun from scratch, as the "progressive overlay of technologies." The end product tends to be a kluge.

Of course, explaining why evolution can produce kluge-like solutions *in general* is not the same thing as showing that the human mind *in particular* is a kluge. But there are two powerful reasons for thinking that it might be: our relatively recent evolution and the nature of our genome.

Consider, first, the short span of human existence and what it might mean. Bacteria have lived on the planet for three billion years, mammals for three hundred million. Humans, in contrast, have been around for, at most, only a few hundred thousand. Language, complex culture, and the capacity for deliberate thought may have emerged only in the past fifty thousand years. By the standards of evolution, that's not a lot of time for debugging, and a long time for the accumulation of prior evolutionary inertia.

Meanwhile, even though your average human makes its living in ways that are pretty different from those of the average monkey, the human genome and primate genomes scarcely differ. Measured nucleotide by nucleotide, the human genome is 98.5 percent identical to that of the chimpanzee. This suggests that the vast majority of our genetic material evolved *in the context of creatures who didn't have language, didn't have culture, and didn't reason deliberately.* This means that the characteristics we hold most dear, the features that most distinctly define us as human beings — language, culture, explicit thought — must have been built on a genetic bedrock *originally adapted for very different purposes.*

Over the course of this book, we'll travel through some of the most important areas of human mental life: memory, belief, choice, language, and pleasure. And in every case, I will show you that kluges abound.

Humans can be brilliant, but they can be stupid too; they can join cults, get addicted to life-ruining drugs, and fall for the claptrap