BRAIN EVOLUTION AND HUMAN COGNITION: THE ACCIDENTAL MIND*

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I'd like to speak with you about brain evolution. You are probably thinking, "Why should I care about brain evolution? Sure, I might care about brain function and human cognition as it impacts legal and societal thought. But why should I care about *how* the brain got that way? I just care about the way it is now." I hope to convince you that you can only care about the way it is now, and the most human and central aspects of the way it is now through an evolutionary story.

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It's 1975 and we're in the laboratory of Dr. Larry Weiskrantz at the University of Oxford. Larry is studying a population of patients who are blind, not as a result of direct damage to their eyes, but because, at some point in life, they had a blow or a stroke that impacted the visual cortex, the region at the back of the brain that processes visual information. These folks are utterly blind in their daily life. They report no perceptual abilities.

Weiskrantz did what was, on the face of it, a useless experiment. He put a letter in the hands of these folks, and in front of them was a mail slot. The mail slot was oriented either horizontally or vertically, and he asked them to insert the letters into the slot. The subjects replied, "What are you talking about? We are completely blind; what a waste of time; I do not have any idea; I would just be utterly guessing." He said, "Just go with your gut and we will see what happens." He ran the experiment with a number of subjects, and not all of them, but a very large fraction of them were able to orient the

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letter into the slot correctly. Not every time, but a much larger fraction of time than chance; a very statistically significant increase.

So, to explain this result, do we have to invoke ESP or fairies or something odd? No. The explanation is an evolutionary one.

Here are two key evolutionary points that I would like to make: point one, nerve cells, which are called neurons and are the building blocks of the brain, in terms of their ability to process information, suck. They are very inefficient processors of information; the second point is that the brain is built like an ice cream cone—through evolution, new abilities are added on top.

I would like to convince you, ultimately, that big, fat, inefficiently-evolved human brains have given us the core features of our humanity, including things like our mating system and our individuality as conferred through memory. I have just promised a lot. When I was in gym class in the eighth grade, the kid next to me said, "Linden, your mouth just wrote a check your ass can't cash." I hope to convince you that every aspect of our transcendent human experience—from love to memory to our dreams to our pre-disposition for religious thought—ultimately derives from our inefficient and bizarre brains, which are a weird agglomeration of ad hoc solutions that have been piled on through millions of years of evolutionary history.

When I say that neurons suck, what do I mean? The brain is often compared to a computer. Your computer, circa 2008, might have one, or at the most four, central processing units that run at a very high speed and perform computations very efficiently and reliably. A neuron by comparison, is a very lousy computer. It has a very limited signaling range (up to a maximum of about one thousand impulses per second). It leaks signals to its neighbors. It is slow. It conveys information at one-one millionth of the rate of electricity moving through a copper wire, and amazingly, it does not even work all the time.

Many of you may be aware that neurons send electrical signals from the information-receiving end called the dendrite, to the information-sending end called their axon. When these electrical signals invade the axon, they trigger the release of chemical signals called neurotransmitters that diffuse across a narrow gap and activate the next neuron on the chain. This is the central act of neurons and is thereby crucial for our mental function. You would imagine then, that when an electrical signal got to the end of the axon and it was time to release a neurotransmitter, it would be an utterly reliable process—that is, it would occur every single time. Not so. On average, it occurs about one-third of the time. It is probabilistic. Neurons are lousy processors. We, as cognitive entities, on the other hand, are very good. We are much better than computers at a lot of real world tasks. For example, it is trivial for us to see a picture of a Rottweiler from the front, and a Teacup Poodle from the back, and instantly know that these are both dogs. This is a very difficult problem for today's computers.

So how can we build clever brains out of lousy parts? The solution is to have an extraordinarily large number of these crummy parts and to make them massively interconnected. Our human brains have about a hundred billion neurons. Each neuron, on average, receives about five thousand connections from other neurons, and if you do the multiplication, you wind up with this very impressive number of 500 trillion connections, which is astonishing. The way we build clever brains is by massively interconnecting large numbers of lousy parts. It turns out that these parts, the neurons, have not really changed their design fundamentally from 600 million years ago when they first appeared in jellyfish-like animals, which are probably the oldest animals in the fossil record to have neurons.

We need big, fat brains to be clever. How do these big fat brains get built? Imagine that someone said to you, "How would you like to build the latest Formula One race car?" and you would say, "Oh cool, that would be a really fun project. I'll sign up." "Now that you have signed up, we are going to tell you the details. The deal is that we're going to give you a Model-T Ford, and the way you make the race car is that you can only add stuff on top of it, and you cannot take anything away." That's how evolution works in building brains. The brain is built like an ice cream cone. There is never any point in evolutionary history where you get to wipe the slate clean and do a complete re-design from the ground up. Everything is added on bit by bit by bit.

What I mean when I compare the brain to an ice cream cone is that the lowest part of our brain has circuitry that we share with, for example, lizards and amphibians. When I say "lowest", I mean both metaphorically lowest in terms of the most primitive, and literally lowest in terms of a location closest to the spinal cord. Our brainstem and our midbrain are not fundamentally different from the lizard's brainstem and midbrain. Now, let's move up the evolutionary ladder. How do you build a mouse brain? You do not completely revamp the design of the lizard brain. Rather, you take the lizard brain and you add some stuff on top. In addition to this midbrain, now you elaborate what's called a limbic system, some emotional centers, some memory centers, and you add a little bit of what we call neocortex, which is the rind that's on the top of the brain. If you want to build a monkey, then you expand the neocortex enormously. If you want to build a human, then you expand the neocortex more so, particularly the most frontal parts of the neocortex.

As a consequence of the brain's ice-cream-cone-like design, it's very inefficient. What this means, for example, is that in our brains we have two auditory systems: an evolutionarily ancient one that we share with lizards, and an evolutionarily modern one that we share with mice and monkeys. We also have two visual systems; the information from our eyes bifurcates, and some of it goes to our ancient visual system, and some of it to our modern visual system.

So, to return to Larry Weiskrantz's lab, what happened to our cortically blind people who were putting their letter in the slot properly? The answer is that they had damage only to their modern visual system. Their ancient midbrain visual system was intact, but information flowing to this system is not something of which we are consciously aware, even though it can help guide our actions. As a consequence, the conscious mind of those cortically blind folks reported that they were guessing randomly, but the information in their intact ancient visual system was available—subconsciously—to help them guide their decisions. This is an example of a neurological result that can only be understood in terms of considering the evolution of the brain.

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How do we get human memory and individuality out of all this? A brain has to develop. You have a little ball of cells in the womb. It is dividing, and it needs the information that specifies this enormously complicated wiring diagram for the brain. How is that going to occur? We possess about twenty-three thousand genes in our genome. Can our DNA encode the information for this horrifically complicated brain wiring diagram? The answer turns out to be: no, it cannot. A worm has about three hundred neurons in its nervous system, and so it is not difficult for the wiring diagram to be completely specified in the DNA. In contrast, human DNA only has instructions for a rough map of the brain structure. We can say, "Oh, well the retina has to send information to places in the brain that process visual information, and the cells from the cochlea in our inner ear have to go to other places in the brain to process auditory information." The general wiring diagram is encoded genetically, but at the finest level, the wiring diagram is driven by sensory experience.

Brains are not all neatly wired up at birth. In short, they are very crudely wired up, and you need experience to sort out the fine details of wiring. Interestingly, that experience starts in the womb. You need experience starting in late fetal life and continuing up until about age five to wire up the brain properly. That means that your brain cells have to be malleable. They have to have the ability to take sensory information, and based upon the patterns of that sensory information, produce lasting changes to the wiring diagram and the efficiency of communication between neurons and the brain. Once you have that ability to wire up the brain guided by experience, what have you achieved? You have the substrate of memory. You have the ability to become an individual. You have the ability for your experiences to mold your brain and write those memories that make you unique.

However, we have crummy neurons as processors. We have to build this big, fat, horrifically large interconnected brain to be cognitively clever with those awkward, inefficient processors. Then, we cannot specify the wiring diagram of this big, massively interconnected brain in the DNA, so the only way we can build it is have the wiring be partially experience-driven. Then, when we have the ability of experience to modify our neural circuits, this gives us memory and the individuality that it confers. A centrally human aspect of our lives comes from the fact that evolution is a kludgy, tinkering process. Our memories and our individuality are not the latest perfectly engineered feature of an impeccably designed brain. They are what have emerged from an ad hoc, work-around solution to try to design a clever brain with lousy jellyfish neurons, almost Rube-Goldberg-esque in its so-called complexity.

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What about love? I hope to prove to you that our human mating system also derives from the fact that neurons are lousy processors. Our adult human brains are about twelve hundred cubic centimeters in volume. When we are born, our brains are about four hundred cubic centimeters, about the same size as an adult chimp. As women know, it's not trivial for the brain and skull of the newborn to pass through the birth canal. Death during childbirth is almost a uniquely human phenomenon. None of our close primate relatives die in childbirth. We are already maximizing the volume that the brain can be at birth.

Then, we have the situation where humans have, by far, the longest childhood of any animal. There is no other animal where a five-year-old cannot make its way in the world independently. The human brain is developing at a furious pace from birth to age five, and then at a much slower rate from age five to about age twenty. How does this play out in our love lives? For this, I refer to a little segment of my book:[1]

> Humans are truly the all-time twisted sex deviants of the mammalian world. I'm not saying this because some of us get turned on by the sight of automobile exhaust systems, the smell of unwashed feet, or the idea of traffic cops in bondage. After all, other species are at a disadvantage in expressing their kinks by not having reliable access to the Internet. Rather, I mean that the more prosaic aspects of sexual activity in humans are far outside the mainstream of behavior for most of our closest animal relatives.
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> The spectrum of human amorous and sexual behavior is wide and deeply influenced by culture (and I will consider these issues shortly), but let's first talk about the generic presumed norm: regular, old-fashioned monogamous heterosexual practice. Then we can see how it compares with the practices of most other mammals. The simplified human story, stripped of all the romance, is something like this. Once upon a time, a man and woman met and felt mutual attraction that they codified in a ceremony (marriage). They liked privacy for their sexual acts and they declined opportunities for sex with others. They had sex, including intercourse, many times, in most phases of the woman's ovulatory cycle, until she became pregnant. Once it was known that the woman was pregnant, they continued to have sexual intercourse for some time thereafter. After the baby was born, the man helped the woman to provide resources and sometimes care for the child (and for the other children that followed). The woman and man continued their monogamous relationship and remained sexually active well beyond the woman's childbearing years, as marked by her menopause.
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> Now let's hear another perspective. The comedian Margaret Cho uses the line "Monogamy is sooo weird . . . like . . . when you know their name and stuff?" This brings down the house in a comedy club, but the idea is actually the dominant one in the nonhuman world: more than 95 percent of mammalian species do not form lasting pair bonds,

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or even pair bonds of any kind. In fact, rampant sexual promiscuity is the norm for both males and females, and this promiscuous sex is typically conducted in the open, for everyone in the social group to see. One-night stands and public sex are the rule, not the exception. One consequence of all this public promiscuity is that in most nonhuman mammals the father makes little or no contribution to rearing the young. In some cases, the male does not stay in a social group following mating, but rather drifts away. In others, the male stays in the social group but does not appear to recognize his own offspring.

This arrangement may give the impression that most nonhuman animals are libertines, but in another sense they are deeply conservative. Humans often have sex when it is either unlikely or impossible for conception to occur (during the wrong part of the ovulatory cycle, during pregnancy or after menopause),but most nonhuman mammals have sex that is very accurately timed to match ovulation. Human females have concealed ovulation: it is almost impossible for a male to detect directly the female's most fertile days. Although women are able to train themselves to detect ovulation, there is no evidence of an instinctive knowledge of ovulation like that possessed by other female primates. In fact, while many studies have been done on this topic, it is not clear that women are most interested in sexual intercourse during the preovulatory (fertile) phase of their cycle.

In contrast, most nonhuman females in the mammalian world advertise their impending ovulation with sexual swellings, specific odors, or stereotyped sounds and gestures (such as a posture that presents the genitals) indicating sexual interest. Typically, neither males nor females will approach each other for sex during nonfertile times. Sex after menopause is not an issue because although nonhuman females do show gradually declining fertility after a certain age, there is no point where they become absolutely infertile. Indeed, menopause may be a uniquely human phenomenon.

Of course, these human sexual distinctions are based on a broad generalization. There are some nonhuman species such as gibbons and prairie voles that form long-term pair bonds in which the father helps rear the young. There are also a few animals, such as dolphins and bonobos, that seem to share the human proclivity for recreational sex, and some others, such as vervet monkeys and orangutans, where the females have concealed ovulation. On the human side, it is not all Ozzie-and-Harriet either: clearly, humans are not all monogamous (or even serially monogamous), and in some cultures or subgroups polygyny (multiple wives) or polyandry (multiple husbands) is an established practice. Nonetheless, it is clear that the dominant human practice, across cultures, is monogamy, or at least serial monogamy.

> The critical point here is that in humans, most females have a single sexual partner in a given ovulatory cycle. In studies where paternity has been evaluated with genetic tests across large numbers of children, the vast majority (over 90 percent) of children are indeed found to be the offspring of the mother's husband or long-term partner, and most fathers provide some form of care and support for their children (although this may take the form of providing food, protection from others, shelter, and money rather than direct child care).
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> So, why have humans evolved such a distinct cluster of sexual behaviors with concealed ovulation, recreational sex, long-term pair bonding, and prolonged paternal involvement? Though a few of our close simian cousins share some of these traits—the bonobos with their penchant for recreational sex and gibbons with their long-term pair bonding—none of these species has the complete cluster of behaviors. Thus these aspects of human sexual behavior are likely to be recent evolutionary developments in our primate lineage.
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> What I will argue here is that our normative human sexual practices follow directly from inelegant brain design. Let's work backward to try to explore this question. Why do humans have concealed ovulation and recreational sex? One persuasive evolutionary hypothesis, from Katherine Noonan and Richard Alexander of the University of Michigan, is that concealed ovulation functions to keep the male around. Let's first consider the counterexample: When ovulation is clearly advertised, the male can maximize his reproductive success by mating with a given female in her fertile time and then, when her fertile time is over, leaving to try to find a another fertile female to impregnate. In this system, the male does not have to worry that some other male will come along and impregnate the first female while he is away because he knows that she is no longer fertile. This is the mating system found in many species, including baboons and geese. With concealed ovulation, however, the couple has to mate all through the woman's cycle to have a reasonable chance of conceiving. Not only that, but if the male decides to stray and try his luck with another female, he cannot be sure that another male will not sneak in the back door and mate with the first female on her fertile days. Furthermore, his chance of finding another ovulating female is low. Hence, with concealed ovulation, the best male strategy is to stick with one female and mate with her all the time.
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> Enough about the male. What does the female get out of this arrangement? Isn't her best reproductive strategy to play the field in the hope of getting the best-quality male genetic contribution to her

offspring? Indeed, the females of many species, including many mammalian species, do exactly that. The crucial difference is that although a female orangutan, for example, easily rears her off spring alone, human females don't have it so easy. Most other animals are able to find their own food immediately after weaning, but human children do not achieve this level of independence for many more years. As a consequence, the reproductive success of a female human is much greater if she can establish a long-term pair bond with a male and he contributes in some form to child rearing. Males tend to buy into this arrangement for two reasons. One is that if the male plays along he can be confident of paternity: he won't be wasting his resources supporting the offspring of another male. Another is that he, and the female, will enjoy the bonding that comes from frequent sex. This bonding and reward is enough to keep humans having sex even when conception is impossible (during pregnancy or after menopause).

In this story, the key point is that human females need male help in certain aspects of childrearing much more than females of other species because human infants are totally helpless and even toddlers and small children are incapable of fending for themselves. Why is that? Recall that the human brain at birth has only about one third of its mature volume and that early life is crucial for the experience-dependent wiring and growth of the brain. The human brain grows at an explosive rate until age 5 and it is not completely mature until about age 20. Unlike the 5-year-olds of most other species, human 5-year-olds simply do not have sufficiently mature brains to find their own food and protect themselves from predators.

Let's summarize by telling the story back in the other direction. Human brains are never designed from the ground up. Rather, as we have seen, new systems are just added on top of the evolutionarily older ones below. This means that the brain must grow in size as it evolves new features. Even more important, the brain is made of neurons that haven't changed substantially in their design since the days of prehistoric jellyfish: as a consequence, neurons are slow, leaky, unreliable, and have a severely limited signaling range. So, the way to build sophisticated computation in a brain with these suboptimal parts has been to create an enormous, massively interconnected network of 100 billion neurons and 500 trillion synapses. This network is too big to have its point-to-point wiring diagram explicitly encoded in the genome, so experience-driven "use it or lose it" rules for wiring must come into play to actively construct this huge network. This necessitates extensive sensory activity, which mostly proceeds after birth, and this requires an unusually protracted childhood during which the brain matures. In addition, the physical constraints of the birth canal make it impossible for a human baby to be born with a more mature

> brain—it just wouldn't fit. As it is, death during childbirth is a significant human phenomenon, particularly in traditional societies, whereas it is almost unknown among our closest primate relatives.
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> As a consequence of all this, human females are uniquely dependent on male support to raise their offspring. They secure their reproductive success by having concealed ovulation, which compels males to adopt a strategy of mating with one female repeatedly throughout her cycle. This monogamous, mostly recreational sex has two effects: it gives a high probability of accurately knowing paternity of the resultant offspring and it helps to reinforce a lasting pair bond, both of which promote continued care of the offspring by both parents. Or, to reduce it to an extreme level of speculation: if human neurons were much more efficient processors, then heterosexual marriage might not exist as a dominant cross-cultural human institution.

That is how I believe that brain evolution has given us our most common human mating practices.

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In our lives, and in legal thought, we assume that our senses are giving us the low-down—an accurate representation of the external world—and that we can, if we choose, act upon this pure sensory information dispassionately to make decisions. This is so far from the truth that it is laughable.

We like to think that sensation and emotion are separate, but in truth, they are blended at a very early state. We also like to think of certain sensations as being undeniably and explicitly emotional. What is revealed in certain neurological patients is that this is not true. Physical pain has a negative emotional state associated with it. Recent research has revealed that there are two aspects of pain. There is a purely sensory/discriminative aspect of pain that determines how intense it is and where it is located on your body. Then there is the affective/emotional aspect of pain. There are people who have a condition known as pain asymbolia where their emotional component of pain is not felt, but they still have the discriminative aspect of pain. If you take their thumb and put it in a vise, they will say with a flat affect, "Oh boy, yah that hurts, mmm hmmm.", but a normal person would scream, "*Argh, son of a bitch that hurts!*" There are also people who have the exact opposite syndrome. They have lost the sensory/discriminative aspect of pain, but they only have the emotional aspect of pain. If you put their thumb in a vise, they scream "*Yeeow that hurts!*" If you ask them where it hurts, they will say they do not know, it just does.

In order to have this experience of pain that we think is irreducible, we need one neural center that is processing the emotional aspect and another that is processing the sensory aspect, and they are anatomically distinct. We may say we experience emotional pain, but is this merely metaphoric language? Is the pain of being excluded from some social interaction, for example, really basically the same as the pain from my finger hurting? What is amazing, though, is that when you do brain scanning experiments like those I just discussed, social pain and physical pain have highly overlapping patterns of brain activation. Emotional pain and physical pain share neural substrates in the brain.

What about pleasure? What about, say, orgasm? Orgasm is something that we think of as intrinsically pleasurable. However, just like pain, you can distinguish in the brain the pure sensory/discriminative component of orgasm from the emotional component of orgasm. For example, if I were to put an electrode into a part of your brain called the medial septum and stimulate it, I could produce an orgasm in you that would be more like "whoops!" than like the kind of orgasm you normally would experience. It would be a purely sensory orgasm with no emotional component. There are people who have orgasms that are triggered by seizures, and sometimes those seizures can invade both the emotional center and the sensory center and produce an orgasm that is like a normal behavioral one. Sometimes, they will only affect the sensory center, and they will produce an orgasm that is devoid of the affective component.

We are so used to sensation and emotion being blended in our experience, that it can seem very cognitively dissonant when they are separated. For example, there is a neurological phenomenon called Capgras syndrome, named after the French doctor who originally described it. This is a very odd disease. Afflicted people are convinced that their close relatives, or sometimes even their pets, have been kidnapped and replaced with very accurate replicas. You might at first think that these people are mentally ill or hallucinating, but they are not. They are otherwise psychiatrically normal. Here is what is weird: you have someone who is convinced their parents have been replaced by exact replicates when they see them; however, when they get their parents on the phone, they will act as if they are speaking to their real parents. The problem is solely with visual information. What happens in the brains of people with Capgras syndrome? The visual information that normally drives emotional centers that would be activated by familiar people or animals is not occurring in Capgras syndrome patients. These people are seeing their parents, but they are not feeling emotionally what they would expect to feel. As a consequence, they create an explanation that their loved ones have been kidnapped and replaced with convincing replicates because that is the only thing that makes sense.

Subconscious ancient streams of sensory information are often involved in driving emotional centers. Thinking back to the people who were neocortically blind, they cannot report anything around them. Their visual information is not consciously available. However, if you make a threatening facial expression in front of them, their heart rate will go up. Why is that? It is because the intact evolutionary ancient visual system is wired into their fear center and produces a stereotyped elevation in heart rate through a subconscious process.

Another way in which our senses are built to mess with sensory information is that we have systems in our brain that are useful for certain kinds of information processing, but which can never be turned off. For example, we are particularly well adapted to ignore information that is self-generated. If you are walking down the street, and your clothes are rubbing against your body, you are probably not thinking about that. However, if you are standing still and you get those same sensations, your reaction will be surprise. Likewise, it is very hard to tickle yourself as a consequence of having a circuit in our brain that tells us to ignore information that is self-generated.

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Your brain cannot resist constructing stories from incomplete information. How is this manifest in higher cognitive function? This tendency is hard to reveal in the normal waking state. It is, however, seen in both dreaming and certain neurological patients. In your left cortex, there is a function (it is not like we can point precisely to any particular anatomical region within the left cortex) but this function is called the “interpreter.” It is a region that creates narrative from streams of sensory information. Some patients have severe amnesia, such that they cannot form new memories for facts and events and have not been able to form new memories for a long time. If you ask these people what happened yesterday, a large fraction of them will not say they cannot remember. Rather, they will dredge up memories from their past, and they will weave them together to make a story. It is an extremely common phenomenon. Amnesiacs believe their own confabulations.

When we dream, what is going on? We have our experiences during the day and we need to consolidate all of this sensory input, to write certain aspects of those experiences into memory. That is best done at night in the absence of competing sensory information. If you take someone who is dreaming, and you put them in a brain scanner, and you ask what parts of the brain are active, someone may be having a highly visual dream, but their main visual cortex that is active in waking vision is shut down. Their visual memory centers however, are extremely active. The regions in the frontal cortex that are normally active with reasoning and logical thought are shut down. That is what allows dreams to be so bizarre. The left cortical regions that are associated with this interpreter function and are stitching disparate things together to make a story, they are very active. So when you dream, why are your dreams not just a flash in your memory that is being consolidated and a flash of that? Why do dreams, particularly in the REM stage of sleep, have to be in the form of stories? The reason is, because your brain cannot help it. It cannot help but make a story out of those disparate scraps of information.

Now, I would like to bring up religion. Religion is a cross-cultural universal. There is no culture that has ever been found that does not have religious thought. If you ask people why all cultures have religion, they come up with explanations like, "Well, religion provides answers to difficult questions," or, "it enforces a societal moral code," or, "it gives promise of an afterlife that is somehow comforting." These explanations are true in some cases, but actually, all of those explanations fail the broad cross-cultural test. There are religions that do not promise an afterlife, and there are religions that do not particularly enforce a moral code, and there are religions that do not have an origin story at all. If you were to ask a question about the universality of religious thought, one way to approach it is through consideration of common brain functions that we share across cultures. It is the narrative creation function that we have that allows for this, and this narrative creation gives rise not just to religious thought, but also to scientific thought.

Our brains have evolved to make us believers. We cannot help but take disparate scraps of information that do not make sense, and make a story. That act of making a story is the first act of science. It is hypothesis creation. In science, we say, "to be a scientific hypothesis, my story has to be falsifiable." For example, we have a story about human evolution. It is a hypothesis. If tomorrow you dig up a hominid skeleton that comes from the time of the dinosaurs, then my evolutionary hypothesis fails and has to be rejected. In religion, we similarly creative a narrative from incomplete fragments of information and call it a sacred text. It is not subject to falsifying experiment or observation and in this way is different from a scientific hypothesis. But, the initial act of narrative creation is shared with scientific hypotheses.

John Brockman, who is the editor of an online journal called EDGE, surveyed a group of scientists and asked, "What do you believe, but cannot prove?" You might think that a significant fraction of scientists would have said, "I'm a hardheaded rational atheist, there is nothing that I believe I cannot prove," but in truth, every single person asked had an answer. Some of the ideas they had were scientific hypotheses. Some of the ideas were narratives that are not falsifiable, and therefore constitute faith. Religion and science in our culture are often put at opposition, but in truth, they are two branches of the same cognitive stream. Both derived from an always-on brain center for narrative creation. The things that we hold most central to our human experience are not the ultimate design features of an impeccable, engineered brain. They were not designed all at once by a genius inventor on a blank sheet of paper. Furthermore, they do not happen in spite of the quirks of evolutionary history. Rather, we have these essential human features precisely because of them.