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CHAPTER 9: God and the Limbic System

> It is very difficult to elucidate this [cosmic religious] feeling to anyone who is entirely without it.... The religious geniuses of all ages have been distinguished by this kind of religious feeling, which knows no dogma.... In my view, it is the most important function of art and science to awaken this feeling and keep it alive in those who are receptive to it. ALBERT EINSTEIN

> [God] is the greatest democrat the world knows, for He leaves us "unfettered" to make our own choice between evil and good. He is the greatest tyrant ever known, for He often dashes the cup from our lips and under cover of free will leaves us a margin so wholly inadequate as to provide only mirth for Himself ar our expense. Therefore it is that Hinduism calls it all His sport (Lila), or calls it all an illusion (Maya).... Let us dance to the tune of his bansi (flute), and all would be well.
> MOHANDAS K. GANDHI

Imagine you had a machine, a helmet of sorts that you could simply put on your head and stimulate any small region of your brain without causing permanent damage. What would you use the device for?

This is not science fiction. Such a device, called a transcranial magnetic stimulator, already exists and is relatively easy to construct. When applied to the scalp, it shoots a rapidly fluctuating and extremely powerful magnetic field onto a small patch of brain tissue, thereby activating it and providing hints about its function. For example, if you were to stimulate certain parts of your motor cortex, different muscles would contract. Your finger might twitch or you'd feel a sudden involuntary, puppet-like shrugging of one shoulder.

So, if you had access to this device, what part of your brain would you stimulate? If you happened to be familiar with reports from the early days of neurosurgery about the septum—a cluster of cells located near the front of the thalamus in the middle of your brain—you might be tempted to apply the magnet there.[1] Patients "zapped" in this region claim to experience intense pleasure, "like a thousand orgasms rolled into one." If you were blind from birth and the visual areas in your brain had not degenerated, you might stimulate bits of your own visual cortex to find out what people mean by color or "seeing." Or, given the well known clinical observation that the left frontal lobe seems to be involved in feeling "good," maybe you'd want to stimulate a region over your left eye to see whether you could induce a natural high.

When the Canadian psychologist Dr. Michael Persinger got hold of a similar device a few years ago, he chose instead to stimulate parts of his temporal lobes. And he found to his amazement that he experienced God for the first time in his life.

I first heard about Dr. Persinger's strange experiment from my colleague, Patricia Churchland, who spotted an account of it in a popular Canadian science magazine. She phoned me right away. "Rama, you're not going to believe this. There's a man in Canada who stimulated his temporal lobe and experienced God. What do you make of it?"

"Does he have temporal lobe seizures?" I asked.

"No, not at all. He's a normal guy."

"But he stimulated his own temporal lobes?"

"That's what the article said."

"Hmmmm, I wonder what would happen if you tried stimulating an atheist's brain. Would he experience God?" I smiled to myself and said, "Hey, maybe we should try the device on Francis Crick."

Dr. Persinger's observation was not a complete surprise as I've always suspected that the temporal lobes, especially the left lobe, are somehow involved in religious experience. Every medical student is taught that patients with epileptic seizures originating in this part of the brain can have intense, spiritual experiences during the seizures and sometimes become preoccupied with religious and moral issues even during the seizure-free or interictal periods.

But does this syndrome imply that our brains contain some sort of circuitry that is actually specialized for religious experience? Is there a "God module" in our heads? And if such a circuit exists, where did it come from? Could it be a product of natural selection, a human trait as natural in the biological sense as language or stereoscopic vision? Or is there a deeper mystery at play, as a philosopher, epistemologist or theologian might argue?

Many traits make us uniquely human, but none is more enigmatic than religion—our propensity to believe in God or in some higher power that transcends mere appearances. It seems very unlikely that any creature other than humans can ponder the infinite or wonder about "the meaning of it all." Listen to John Milton in *Paradise Lost*:

> For who would lose, though full of pain
> This intellectual being
> Those thoughts that wander through eternity to be swallowed up and lost
> In the wide womb of uncreated night.

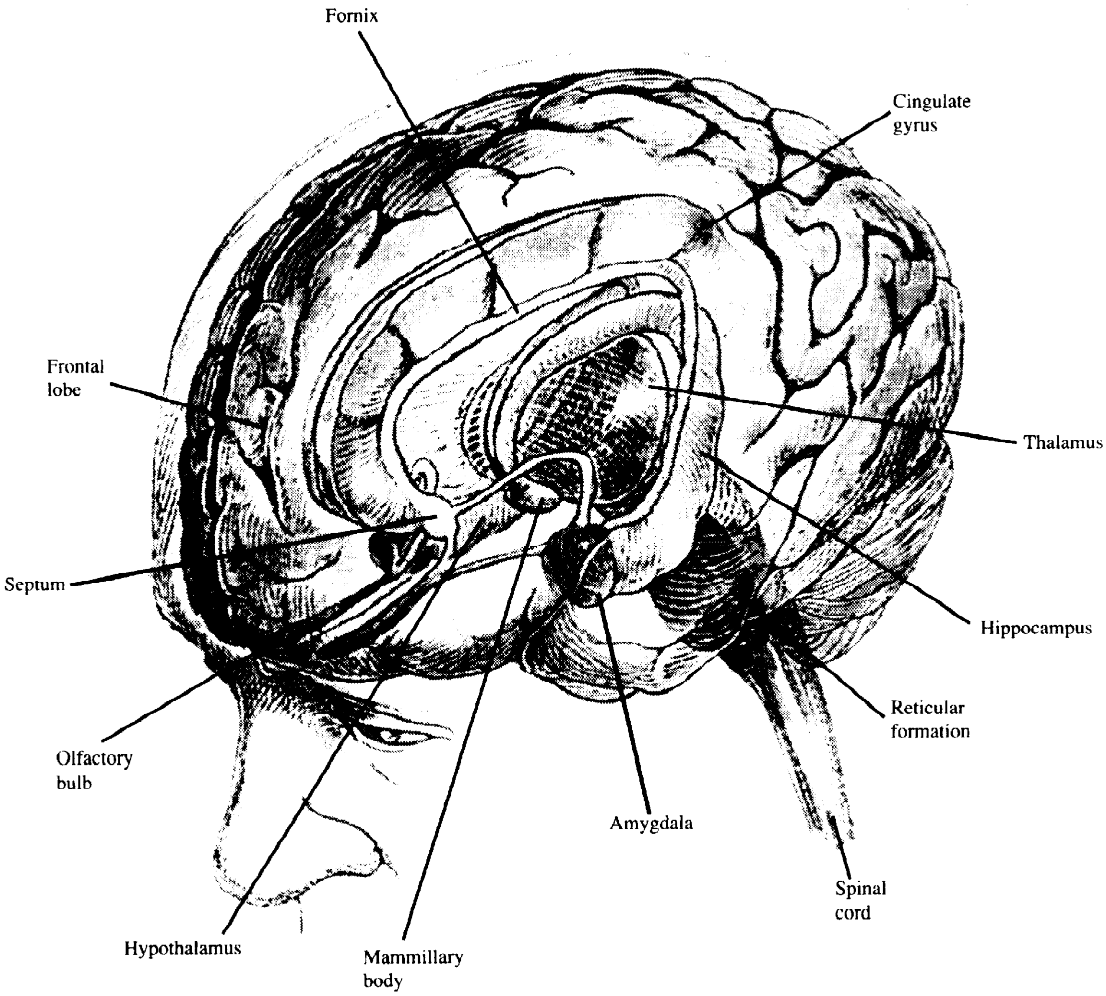
But where do such feelings come from? It may be that any intelligent sentient being that can look into its own future and confront its own mortality will sooner or later begin to engage in such disquieting ruminations. Does my little life have any real significance in the grand scheme of things? If my father's sperm had not fertilized that particular egg on that fateful night, would I not have existed, and in what real sense then would the universe have existed? Would it not then, as Erwin Schrödinger said, have been a mere "play before empty benches"? What if my dad had coughed at that critical moment so that a different sperm had fertilized the ovum? Our minds start reeling when pondering such possibilities. We are bedeviled by paradox: On the one hand our lives seem so important—with all those cherished highly personal memories—and yet we know that in the cosmic scheme of things, our brief existence amounts to nothing at all. So how do people make sense of this dilemma? For many the answer is straightforward: They seek solace in religion.

But surely there's more to it than that. If religious beliefs are merely the combined result of wishful thinking and a longing for immortality, how do you explain the flights of intense religious ecstasy experienced by patients with temporal lobe seizures or their claim that God speaks directly to them? Many a patient has told me of a "divine light that illuminates all things," or of an "ultimate truth that iies completely beyond the reach of ordinary minds who are too immersed in the hustle and bustle of daily life to notice the beauty and grandeur of it all." Of course, they might simply be suffering from hallucinations and delusions of the kind that a schizophrenic might experience, but if that's the case, why do such hallucinations occur mainly when the temporal lobes are involved? Even more puzzling, why do they take this particular form? Why don't these patients hallucinate pigs or donkeys?

In 1935, the anatomist James Papez noticed that patients who died of rabies often experienced fits of extreme rage and terror in the hours before death. He knew that the disease was transmitted by dog bites and reasoned that something in the dog's saliva—the rabies virus—traveled along the victim's peripheral nerves located next to the bite, up the spinal cord and into the brain. Upon dissecting victims' brains, Papez found the destination of the virus—clusters of nerve cells or nuclei connected by large C-shaped fiber tracts deep in the brain (Figure 9.1). A century earlier, the famous French neurologist Pierre Paul Broca had named this structure the limbic system. Because rabies patients suffered violent emotional fits, Papez reasoned that these limbic structures must be intimately involved in human emotional behavior.[2]

The limbic system gets its input from all sensory systems—vision, touch, hearing, taste and smell. The latter sense is in fact directly wired to the limbic system, going straight to the amygdala (an almond-shaped structure that serves as a gateway into the limbic system). This is hardly surprising given that in lower mammals, smell is intimately linked with emotion, territorial behavior, aggression and sexuality.

[Figure 9.1: Another view of the limbic system. The limbic system is made up of a series of interconnected structures surrounding a central fluid-filled ventricle of the forebrain and forming an inner border of the cerebral cortex. The structures include the hippocampus, amygdala, septum, anterior thalamic nuclei, mammillary bodies and cingulate cortex. The fornix is a long fibre bundle joining the hippocampus to the mammillary bodies. Pictured also are the corpus callosum, a fibre tract joining right and left neocortex, the cerebellum, a structure involved in modulating movement, and the brainstem. The limbic system is neither directly sensory nor motor but constitutes a central core processing system of the brain that deals with information derived from events, memories of events and emotional associations to these events. This processing is essential if experience is to guide future behaviour. Reprinted from Brain, Mind and Behaviour by Bloom and Laserson (1988) by Educational Broadcasting Corporation. Used with permission from W.H. Freeman and Company.]



The limbic system's output, as Papez realized, is geared mainly toward the experience and expression of emotions. The experience of emotions is mediated by back-and-forth connections with the frontal lobes, and much of the richness of your inner emotional life probably depends on these interactions. The outward expression of these emotions, on the other hand, requires the participation of a small cluster of densely packed cells called the hypothalamus, a control center with three major outputs of its own. First, hypothalamic nuclei send hormonal and neural signals to the pituitary gland, which is often described as the "conductor" of the endocrine orchestra. Hormones released through this system influence almost every part of the human body, a biological tour de force we shall consider in the analysis of mind-body interactions (Chapter 11). Second, the hypothalamus sends commands to the autonomic nervous system, which controls various vegetative or bodily functions, including the production of tears, saliva and sweat and the control of blood pressure, heart rate, body temperature, respiration, bladder function, defecation and so on. The hypothalamus can be regarded, then, as the "brain" of this archaic, ancillary nervous system. The third output drives actual behaviors, often remembered by the mnemonic the "four F's"— fighting, fleeing, feeding and sexual behavior. In short, the hypothalamus is the body's "survival center," preparing the body for dire emergencies or, sometimes, for the passing on of its genes.

Much of our knlowledge about the functions of the limbic system comes from patients who have epileptic seizures originating in this part of the brain. When you hear the word "epilepsy," you usually think of someone having fits or a seizure—the powerful involuntary contraction of all muscles of the body—and falling to the ground. Indeed, these symptoms characterize the most well-known form of epilepsy, called a grand mal seizure. Such seizures usually arise because a tiny cluster of neurons somewhere in the brain is misbehaving, firing chaotically until activity spreads like wildfire to engulf the entire brain. But seizures can also be "focal"; that is, they can remain confined largely to a single small patch of the brain. If such focal seizures are mainly in the motor cortex, the result is a sequential march of muscle twitching—or the so-called jacksonian seizures. But if they happen to be in the limbic system, then the most striking symptoms are emotional. Patients say that their "feelings are on fire," ranging from intense ecstasy to profound despair, a sense of impending doom or even fits of extreme rage and terror. Women sometimes experience orgasms during seizures, although for some obscure reason men never do. But most remarkable of all are those patients who have deeply moving spiritual experiences, including a feeling of divine presence and the sense that they are in direct communion with God. Everything around them is imbued with cosmic significance. They may say, "I finally understand what it's all about. This is the moment I've been waiting for all my life. Suddenly it all makes sense." Or, "Finally I have insight into the true nature of the cosmos." I find it ironic that this sense of enlightenment, this absolute conviction that Truth is revealed at last, should derive from limbic structures concerned with emotions rather than from the thinking, rational parts of the brain that take so much pride in their ability to discern truth and falsehood.

God has vouchsafed for us "normal" people only occasional glimpses of a deeper truth (for me they can occur when listening to some especially moving passage of music or when I look at Jupiter's moon through a telescope), but these patients enjoy the unique privilege of gazing directly into God's eyes every time they have a seizure. Who is to say whether such experiences are "genuine" (whatever that might mean) or "pathological"? Would you, the physician, really want to medicate such a patient and deny visitation rights to the Almighty?

The seizures—and visitations—last usually only for a few seconds each time. But these brief temporal lobe storms can sometimes permanently alter the patient's personality so that even between seizures he is different from other people.[3] No one knows why this happens, but it's as though the repeated electrical bursts inside the patient's brain (the frequent passage of massive volleys of nerve impulses within the limbic system) permanently "facilitate" certain pathways or may even open new channels, much as water from a storm might pour downhill, opening new rivulets, furrows and passages along the hillside. This process, called kindling, might permanently alter—and sometimes enrich—the patient's inner emotional life.

These changes give rise to what some neurologists havo called "temporal lobe personality." Patients have heightened emotions and see cosmic significance in trivial events. It is claimed that they tend to be humorless, full of self-importance, and to maintain elaborate diaries that record quotidian events in elaborate detail—a trait called hypergraphia. Patients have on occasion given me hundreds of pages of written text filled with mystical symbols and notations. Some of these patients are sticky in conversation, argumentative, pedantic and egocentric (although less so than many of my scientific colleagues), and they are obsessively preoccupied with philosophical and theological issues.

Every medical student is taught that he shouldn't ever expect to see a "textbook case" in the wards, for these are merely composites concocted by the authors of medical tomes. But when Paul, the thirty-two-year-old assistant manager of a local Goodwill store, walked into our lab not long ago, I felt that he had strolled straight out of Brain's Textbook of Neurology—the Bible of all practicing neurologists. Dressed in a green Nehru shirt and white duck trousers, he held himself in a regal posture and wore a magnificent jeweled cross at his neck.

There is a soft armchair in our laboratory, but Paul seemed unwilling to relax. Many patients I interview are initially uneasy, but Paul was not nervous in that sense—rather, he seemed to see himself as an expert witness called to offer testimony about himself and his relationship with God. He was intense and self-absorbed and had the arrogance of a believer but none of the humility of the deeply religious. With very little prompting, he launched into his tale.

"I had my first seizure when I was eight years old," he began. "I remember seeing a bright light before I fell on the ground and wondering where it came from." A few years later, he had several additional seizures that transformed his whole life. "Suddenly, it was all crystal clear to me, doctor," he continued. "There was no longer any doubt anymore." He experienced a rapture beside which everything else paled. In the rapture was a clarity, an apprehension of the divine—no categories, no boundaries, just a Oneness with the Creator. All of this he recounted in elaborate detail and with great persistence, apparently determined to leave nothing out.

Intrigued by all this, I asked him to continue. "Can you be a little more specific?"

"Well, it's not easy, doctor. It's like trying to explain the rapture of sex to a child who has not yet reached puberty. Does that make any sense to you?"

I nodded. "What do you think of the rapture of sex?"

"Well, to be honest," he said, "I'm not interested in it anymore. It doesn't mean much to me. It pales completely beside the divine light that I have seen." But later that afternoon, Paul flirted shamelessly with two of my female graduate students and tried to get their home telephone numbers. This paradoxical combination of loss of libido and a preoccupation with sexual rituals is not unusual in patients with temporal lobe epilepsy.

The next day Paul returned to my office carrying an enormous manuscript bound in an ornate green dust jacket—a project he had been working on for several months. It set out his views on philosophy, mysticism and religion; the nature of the trinity; the iconography of the Star of David; elaborate drawings depicting spiritual themes, strange mystical symbols and maps. I was fascinated, but baffled. This was not the kind of material I usually referee.

When I finally looked up, there was a strange light in Paul's eyes. He clasped his hands and stroked his chin with his index fingers. "There's one other thing I should mention," he said. "I have these amazing flashbacks."

"What kind of flashbacks?"

"Well, the other day, during a seizure, I could remember every little detail from a book I read many years ago. Line after line, page after page word for word."

"Are you sure of this? Did you get the book and compare your memories with the original?"

"No, I lost the book. But this sort of thing happens to me a lot. It's not just that one book."

I was fascinated by Paul's claim. It corroborated similar assertions I had heard many times before from other patients and physicians. One of these days I plan to conduct an "objective test" of Paul's astonishing mnemonic abilities. Does he simply imagine he's reliving every minute detail? Or, when he has a seizure, does he lack the censoring or editing that occurs in normal memory so that he is forced to record every trivial detail—resulting in a paradoxical improvement in his memory? The only way to be sure would be to retrieve the original book or passage that he was talking about and test him on it. The results could offer important insights about how memory traces are formed in the brain.

Once, when Paul was reminiscing about his flashbacks, I interjected, "Paul, do you believe in God?" He looked puzzled. "But what else *is* there?" he said.

But why do patients like Paul have religious experiences? I can think of four possibilities. One is that God really does visit these people. If that is true, so be it. Who are we to question God's infinite wisdom? Unfortunately, this can be neither proved nor ruled out on empirical grounds.

The second possibility is that because these patients experience all sorts of odd, inexplicable emotions, as if a cauldron had boiled over, perhaps their only recourse is to seek ablution in the calm waters of religious tranquility. Or the emotional hodgepodge may be misinterpreted as mystical messages from another world.

I find the latter explanation unlikely for two reasons. First, there are other neurological and psychiatric disorders such as frontal lobe syndrome, schizophrenia, manic depressive illness or just depression in which the emotions are disturbed, but one rarely sees religious preoccupations in such patients to the same degree. Second, even though schizophrenics may occasionally talk about God, the feelings are usually fleeting, they don't have the same intense fervor or the obsessive and stereotyped quality that one sees in temporal lobe epileptics. Hence emotional changes alone cannot provide a complete explanation for religious preoccupation.[4]

The third explanation invokes connections between sensory centers (vision and hearing) and the amygdala, that part of the limbic system specialized in recognizing the emotional significance of events in the external world. Obviously, not every person or event you encounter throughout a typical day sets off alarm bells; that would be maladaptive and you'd soon go mad. To cope with the world's uncertainties, you need a way of gauging the salience of events before you relay a message to the rest of the limbic system and to the hypothalamus telling them to assist you in fighting or fleeing.

But consider what might happen if spurious signals stemming from limbic seizure activity were to travel these pathways. You'd get the sort of kindling I described earlier. These "salience" pathways would become strengthened, increasing communication between brain structures. Sensory brain areas that see people and events and hear voices and noises would become more closely linked to emotional centers. The result? Every object and event—not just salient ones—would become imbued with deep significance, so that the patient would see "the universe in a grain of sand" and "hold[s] infinity in the palm of his hand." He would float on an ocean of religious ecstasy, carried by a universal tide to the shores of Nirvana.

The fourth hypothesis is even more speculative. Could it be that human beings have actually evolved specialized neural circuitry for the sole purpose of mediating religious experience? The human belief in the supernatural is so widespread in all societies all over the world that it's tempting to ask whether the propensity for such beliefs might have a biological basis.[5] If so, you'd have to answer a key question: What sorts of Darwinian selection pressures could lead to such a mechanism? And if there is such a mechanism, is there a gene or set of genes concerned mainly with religiosity and spiritual leanings—a gene that atheists might lack or have learned to circumvent (just kidding!)?

These kinds of arguments are popular within a relatively new discipline called evolutionary psychology. (It used to be called sociobiology, a term that fell into disrepute for political reasons.) According to its central tenets, many human traits and propensities, even ones we might ordinarily be tempted to attribute to "culture," may in fact have been specifically chosen by the guiding hand of natural selection because of their adaptive value.

One good example is the tendency for men to be polygamous and promiscuous whereas women tend to be more monogamous. Of the hundreds of human cultures throughout the world, only one, the Thodas of South India, have officially endorsed polyandry (the practice of having more than one husband or male mate). Indeed, the old adage "Higamous hogamous, women are monogamous; hogamous higamous, men are polygamous" reflects this state of affairs. It all makes good evolutionary sense, since a woman invests a good deal more time and effort—a nine-month-long, risky, arduous pregnancy—in each offspring, so that she has to be very discerning in her choice of sexual partners. For a man, the optimal evolutionary strategy is to disseminate his genes as widely as possible, given his few minutes (or, alas, seconds) of investment in each encounter. These behavioral propensities are unlikely to be cultural. If anything, culture tends to forbid or minimize them rather than encourage them, as we all know.

On the other hand, we must be careful not to carry these "evolutionary psychology" arguments too far. Just because a trait is universal— present in all cultures including cultures that have never been in contact—it doesn't follow that the trait is genetically specified. For instance, almost every culture that we know of has some form of cooking, however primitive. (Yes, even the English.) Yet one would never argue from this that there is a cooking module in the brain specified by cooking genes that were honed by natural selection. The ability to cook is almost certainly an offshoot of a number of other unrelated skills such as a good sense of smell and taste and the ability to follow a recipe step-by-step, as well as a generous dose of patience.

So is religion (or at least the belief in God and spirituality) like cooking—with culture playing by far the dominant role—or is it more like polygamy, for which there appears to be a strong genetic basis? How would an evolutionary psychologist account for the origin of religion? One possibility is that the universal human tendency to seek authority figures—giving rise to an organized priesthood, the participation in rituals, chanting and dancing, sacrificial rites and adherence to a moral code—encourages conformist behavior and contributes to the stability of one's own social group—or "kin"—who share the same genes. Genes that encourage the cultivation of such conformist traits would therefore tend to flourish and multiply, and people who lacked them would be ostracized and punished for their socially deviant behavior. Perhaps the easiest way to ensure such stability and conformity is to believe in some transcendent higher power that controls our destiny. No wonder temporal lobe epilepsy patients experience a sense of omnipotence and grandeur, as if to say, "I am the chosen one. It is my duty and privilege to transmit God's work to you lesser beings."

This is admittedly a speculative argument even by the rather lax standards of evolutionary psychology. But whether or not one believes in religious conformity "genes," it's clear that certain parts of the temporal lobe play a more direct role in the genesis of such experiences than any other part of the brain. And if the personal experiences of Dr. Persinger are anything to go by, then this must be true not just of epileptics but also of you and me.

I hasten to add that as far as the patient is concerned, whatever changes have occurred are authentic—sometimes even desirable—and the physician has no right, really, to attribute a value label to such esoteric embellishments of personality. On what basis does one decide whether a mystical experience is normal or abnormal? There is a common tendency to equate "unusual" or "rare" with abnormal, but this is a logical fallacy. Genius is a rare but highly valued trait, whereas tooth decay is common but obviously undesirable. Which one of these categories does mystical experience fall into? Why is the revealed truth of such transcendent experiences in any way "inferior" to the more mundane truths that we scientists dabble in? Indeed, if you are ever tempted to jump to this conclusion, just bear in mind that one could use exactly the same evidence—the involvement of the temporal lobes in religion—to argue for, rather than against, the existence of God. By way of analogy, consider the fact that most animals don't have the receptors or neural machinery for color vision. Only a privileged few do, yet would you want to conclude from this that color wasn't real? Obviously not, but if not, then why doesn't the same argument apply to God? Perhaps only the "chosen" ones have the required neural connections. (After all, "God works in mysterious ways.") My goal as a scientist, in other words, is to discover how and why religious sentiments originate in the brain, but this has no bearing one way or the other on whether God really exists or not.

So we now have several competing hypotheses of why temporal lobe epileptics have such experiences. Even though all these theories invoke the same neural structures, they postulate very different mechanisms and it would be nice to find a way to distinguish among them. One of the ideas—the notion that kindling has indiscriminately strengthened all connections from the temporal cortex to the amygdala—can be addressed directly by studying the patient's galvanic skin response. Ordinarily an object is recognized by the visual areas of the temporal lobes. Its emotional salience—is it a friendly face or a fierce lion?—is signalled by the amygdala and transmitted to the limbic system so that you become emotionally aroused and start sweating. But if the kindling has strengthened all the connections within these pathways, then everything becomes salient. No matter what you look at—a nondescript stranger, a chair or a table—it should activate the limbic system strongly and make you perspire. So unlike you and me, who should display a heightened GSR response only for our moms, dads, spouses or lions, or even a loud thud or bang, the patient with temporal lobe epilepsy should show an increased galvanic skin response to everything under the sun.

To test this possibility, I contacted two of my colleagues who specialize in the diagnosis and treatment of epilepsy—Dr. Vincent Iragui and Dr. Evelyn Tecoma. Given the highly controversial nature of the whole concept of "temporal lobe personality" (not everyone agrees that these personality traits are seen more frequently in epileptics), they were quite intrigued by my ideas. A few days later, they recruited two of their patients who manifested obvious "symptoms" of this syndrome—hypergraphia, spiritual leanings and an obsessive need to talk about their feelings and about religious and metaphysical topics. Would they want to volunteer in a research study?

Both were eager to participate. In what may turn out to be the very first scientific experiment ever done on religion directly, I sat them in comfortable chairs and attached harmless electrodes to their hands. Once settled in front of a computer screen, they were shown random samples of several types of words and images—for example, words for ordinary inanimate objects (a shoe, vase, table and the like), familiar faces (parents, siblings), unfamiliar faces, sexually arousing words and pictures (erotic magazine pinups), four-letter words involving sex, extreme violence and horror (an alligator eating a person alive, a man setting himself afire) and religious words and icons (such as the word "God").

If you and I were to undergo this exercise, we would show huge GSR responses to the scenes of violence and to the sexually explicit words and pictures, a fairly large response to familiar faces and usually nothing at all to other categories (unless you have a shoe fetish, in which case you'd respond to one).

What about the patients? The kindling hypothesis would predict a uniform high response to all categories. But to our amazement what we found in the two patients tested was a heightened response mainly to religious words and icons. Their responses to the other categories, including the sexual words and images, which ordinarily evoke a powerful response, was strangely diminished compared to what is seen in normal individuals.[6]

Thus the results show that there has been no general enhancement of all the connections—indeed, if anything, there has been a decrement. But rather surprisingly, there's been a selective amplification of response to religious words. One wonders whether this technique could be useful as a sort of "piety index" to distinguish religious dabblers or frauds ("closet atheists") from true believers. The absolute zero on the scale could be set by measuring Francis Crick's galvanic skin response.

I want to emphasize that not every temporal lobe epilepsy patient becomes religious. There are many parallel neural connections between the temporal cortex and the amygdala. Depending on which particular ones are involved, some patients may have their personalities skewed in other directions, becoming obsessed with writing, drawing, arguing philosophy or, rarely, being preoccupied with sex. It's likely that their GSR responses would shoot upward in response to these stimuli rather than to religious icons, a possibility that is being studied in our laboratory and others.

Was God talking to us directly through the GSR machine? Did we now have a direct hotline to heaven? Whatever one makes of the selective amplification of responses to religious words and icons, the finding eliminates one of the proposed explanations for these experiences—that these people become spiritual simply because *everything* around them becomes so salient and deeply meaningful. On the contrary, the finding suggests that there has been a selective enhancement of responses to some categories of stimuli—such as religious words and images—and an actual reduction in response to other categories such as sexually loaded ones (as is consistent with the diminished libido that some of these patients report).

So do these findings imply that there are neural structures in the temporal lobes that are specialized for religion or spirituality, that are selectively enhanced by the epileptic process? This is a seductive hypothesis, but other interpretations are possible. For all we know, the changes that have triggered these patients' religious fervor could be occurring anywhere, not necessarily in the temporal lobes. Such activity would still eventually cascade into the limbic system and give you exactly the same result—an enhanced GSR for religious images. So strong GSR itself is no guarantee that the temporal lobes are directly involved in religion.[7]

There is, however, another experiment that could be done to resolve this issue once and for all. The experiment takes advantage of the fact that when seizures become seriously disabling, life-threatening and unresponsive to medication, portions of the temporal lobe are often surgically removed. So we can ask, What would happen to the patient's personality— especially his spiritual leanings—if we removed a chunk of his temporal lobe? Would some of his acquired personality changes be "reversed"? Would he suddenly stop having mystical experiences and become an atheist or an agnostic? Would we have performed a "Godectomy"?

We have yet to conduct such a study, but meanwhile we have already learned something from our GSR studies—that the seizures have permanently altered the patients' inner mental life, often producing interesting and highly selective distortions of their personality. After all, one rarely sees such profound emotional upheavals or religious preoccupations in other neurological disorders. The simplest explanation for what happens in the epileptics is that there have been permanent changes in temporal lobe circuitry caused by selective enhancement of some connections and effacement of others—leading to new peaks and valleys in the patients' emotional landscape.

So what's the bottom line? The one clear conclusion that emerges from all this is that there are circuits in the human brain that are involved in religious experience and these become hyperactive in some epileptics. We still don't know whether these circuits evolved specifically for religion (as evolutionary psychologists might argue) or whether they generate other emotions that are merely conducive to such beliefs (although that cannot explain the fervor with which the beliefs are held by many patients). We are therefore still a long way from showing that there is a "God module" in the brain that might be genetically specified, but to me the exciting idea is that one can even begin to address questions about God and spirituality scientifically.

> Then to the rolling Heav'n itself I cried,
> Asking, “What Lamp had Destiny to guide
> Her little Children stumbling in the dark?"
> And—"A blind Understanding!" Heav'n replied.
>
> The Rubáiyát of Omar Khayyám

For many of the topics we've discussed in earlier chapters—phantom limbs, neglect syndrome and Capgras' syndrome—we now have reasonable interpretations as a result of our experiments. But in seeking brain centers concerned with religious experience and God, I realized that I had entered the "twilight zone" of neurology. There are some questions about the brain that are so mysterious, so deeply enigmatic, that most serious scientists simply shy away from them, as if to say, "That would be premature to study" and "I'd be a fool if I embarked on such a quest." And yet these are the very issues that fascinate us most of all. The most obvious one, of course, is religion, a quintessentially human trait, but it is only one unsolved mystery of human nature. What about other uniquely human traits—such as our capacity for music, math, humor and poetry? What allowed Mozart to compose an entire symphony in his head or mathematicians like Fermat or Ramanujan to "discover" flawless conjectures and theorems without ever going through step-by-step formal proofs? And what goes on in the brain of a person like Dylan Thomas that allowed him to write such evocative poetry? Is the creative spark simply an expression of the divine spark that exists in all of us? Ironically clues come from a bizarre condition called "idiot savant syndrome" (or, to use the more politically correct phrase, the savant syndrome). These individuals (retarded and yet highly talented) can give us valuable insights about the evolution of human nature—a topic that became an obsession for some of the greatest scientific minds of the last century.

The Victorian era witnessed a vigorous intellectual debate between two brilliant biologists—Charles Darwin and Alfred Russel Wallace. Darwin, of course, is a household name. Everyone associates him with the discovery of natural selection as the main driving force of organic evolution. It is a pity that Wallace is almost completely unknown except among biologists and historians of science, since he was an equally brilliant scholar and independently came up with the same idea. In fact, the very first scientific paper on evolution by natural selection was presented jointly by Darwin and Wallace and communicated to the Linnean Society by Joseph Hooker in 1850. Instead of feuding endlessly over priority, as many of today's scientists do, they cheerfully acknowledged each other's contributions and Wallace even wrote a book called Darminism, championing what he referred to as "Darwin's" theory of natural selection. Upon hearing of this book, Darwin responded, "You should not speak of Darwinism for it can as well be called Wallacism."

What does the theory state? There are three components:[8]

1. Since offspring vastly outnumber the available resources, there must be a constant struggle for existence in the natural world.
2. No two individuals of a species are exactly identical (except in the rare case of identical twins). Indeed, there are always random variations, however minute, in body type that arise from the random shuffling of genes that takes place during cell division—a shuffling that ensures that offspring differ from each other and from their parents, thereby increasing their candidature for evolutionary change.
3. Those fortuitous combinations of genes that cause individuals to be slightly better adapted to a given local environment tend to multiply and propagate within a population since they increase the survival and reproduction of those individuals.

Darwin believed that his principle of natural selection could account not only for the emergence of morphological traits like fingers or noses, but also for the structure of the brain and therefore our mental capacities. In other words, natural selection could explain our talents for music, art, literature and other human intellectual achievements. Wallace disagreed. He conceded that Darwin's principle might explain fingers and toes and maybe even some simple mental traits, but that certain quintessentially human abilities like mathematical and musical talent could not possibly have arisen through the blind workings of chance.

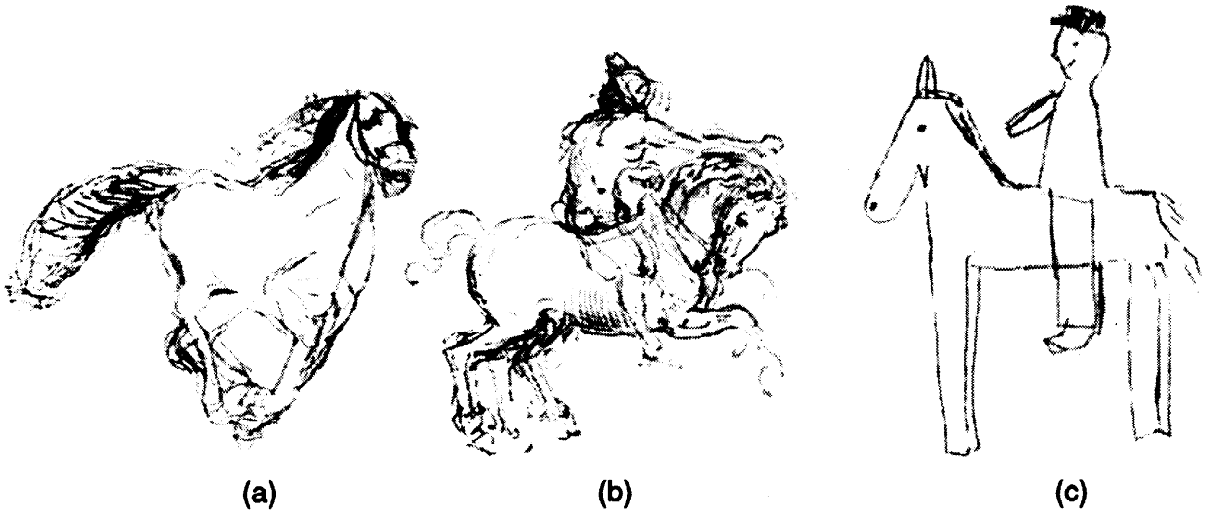
Why not? According to Wallace, as the human brain evolved, it encountered a new and equally powerful force called culture. Once culture, language and writing emerged, he argued, human evolution became Lamarckian—that is, you could pass on the accumulated wisdom of a lifetime to your offspring. These progeny will be much wiser than the offspring of illiterates not because your genes have changed but simply because this knowledge—in the form of culture—has been transferred from your brain to your child's brain. In this way, the brain is symbiotic with culture; the two are as inter-dependent as the naked hermit crab and its shell or the nucleated cell and its mitochondria. For Wallace, culture propels human evolution, making us absolutely unique in the animal kingdom. Isn't it extraordinary, he said, that we are the only animal in which the mind is vastly more important than any bodily organ, assuming a tremendous significance because of what we call "culture." Moreover, our brain actually helps us avoid the need for further specialization.[9] Most organisms evolve to become more and more specialized as they take up new environmental niches, be it a longer neck for the giraffe or sonar for the bat. Humans, on the other hand, have evolved an organ, a brain, that gives us the capacity to evade specialization. We can colonize the Arctic without evolving a fur coat over millions of years like the polar bear because we can go kill one, take its coat and drape it on ourselves. And then we can give it to our children and grandchildren.

Wallace's second argument against "blind chance giving rise to the talents of a Mozart" involves what might be called potential intelligence (a phrase used by Richard Gregory). Say, you take a barely literate young tribesman from a contemporary aboriginal society (or even use a time machine to garner a Cro-Magnon man) and give him a modern public school education in Rio or New York or Tokyo. He will, of course, be no different from any other child reared in those cities. According to Wallace, this means that the aborigine or Cro-Magnon possesses a potential intelligence that vastly exceeds anything that he might need for coping with his natural environment. This kind of potential intelligence can be contrasted with kinetic intelligence, which is realized through formal education. But why the devil did this potential intelligence evolve? It couldn't have arisen for learning Latin in English schools. It couldn't have evolved for learning the calculus, even though almost anyone who tries hard enough can master it. What was the selection pressure for the emergence of these latent abilities? Natural selection can only explain the emergence of actual abilities that are expressed by the organism—never potential ones. When they are useful and promote survival, they are passed on to the next generation. But what to make of a gene for *latent* mathematical ability? What benefit does that confer on a nonliterate person? It seems like overkill.

Wallace wrote, "The lowest savages with the least copious vocabularies [have] the capacity of uttering a variety of distinct articulate sounds and of applying them to an almost infinite amount of modulation and inflection [which] is not in any way inferior to that of the higher [European] races. An instrument has been developed in advance of the needs of its possessor." And the argument holds, with even greater force, for other esoteric human abilities such as mathematics or musical talent.

There's the rub. *An instrument has been developed in advance of the needs of its possessor*, but we know that evolution has no foresight! Here is an instance in which evolution appears to have fore-knowledge. How is this possible?
Wallace wrestled mightily with this paradox. How can improvement in esoteric mathematical skills—in latent form—affect the survival of one race that has this latent ability and the extinction of another that doesn't ? “It is a somewhat curious fact," he wrote, "that when all modern writers admit the great antiquity of man, most of them maintain the very recent development of intellect, and will hardly contemplate the possibility of men, equal in mental capacity to ourselves, having existed in prehistoric times."
But we know they did. Both the Neanderthal and Cro-Magnon cranial capacities were actually larger than ours, and it's not inconceivable that their latent potential intelligence may have been equal to or even greater than that of Homo sapiens.
So how is it possible that these astonishing, latent abilities emerged in the prehistoric brain but have only been realized in the last one thousand years? Wallace's answer: It was done by God! "Some higher intelligence must have directed the process by which the human nature was developed." Thus human grace is an earthly expression of "divine grace."
This is where Wallace parted company with Darwin, who resolutely maintained that natural selection was the prime force in evolution and could account for the emergence of even the most esoteric mental traits, without the helping hand of a Supreme Being.
How would a modern biologist resolve Wallace's paradox? She would probably argue that esoteric and "advanced" human traits like musical and mathematical ability are specific manifestations of what is usually called "general intelligence"—itself the culmination of a "runaway" brain that exploded in size and complexity within the last three million years.[10] General intelligence evolved, the argument goes, so that one can communicate, hunt game, hoard food in granaries, engage in elaborate social rituals and do the myriad things that humans enjoy and that help them survive. But once this intelligence was in place, you could use it for all sorts of other things, like the calculus, music and the design of scientific instruments to extend the reach of our senses. By way of analogy, consider the human hand: Even though it evolved its amazing versatility for grasping at tree branches, it can now be used to count, write poetry, rock the cradle, wield a scepter and make shadow puppets.
But with respect to the mind, this argument doesn't make much sense to me. I'm not saying it's wrong, but the idea that the ability to spear antelope was then somehow used for the calculus is a bit dubious. I'd like to suggest another explanation, one that takes us back not only to the savant syndrome that I mentioned earlier but also to the more general question of the sporadic emergence of talent and genius in the normal population.
"Savants" are persons whose mental capacity or general intelligence is abysmally low, yet who have islands of astonishing talent. For example, there are savants on record with an IQ of less than 50, barely able to function in normal society, yet they could with ease generate an eight digit prime number, a feat that most tenured mathematics professors cannot match. One savant could come up with the cube root of a six-figure number in seconds and could double 8,388,628 twenty-four times to

obtain 140,737,488,355,328 in several seconds. Such individuals are a living refutation of the argument that specialized talents are merely clever deployments of general intelligence.[11]
The realms of art and music are punctuated with savants whose talents have amazed and delighted audiences through the ages. Oliver Sacks describes Tom, a thirteen-year-old boy who was blind and incapable of tying his own shoes. Although he had never been instructed in music or educated in any way, he learned to play the piano simply by hearing others play. He absorbed arias and tunes from hearing them sung and could play any piece of music on the first try as well as the most accomplished performer. One of his most remarkable feats was to perform three pieces of music all at once. With one hand he played "Fisher's Horn Pipe," with the other he played "Yankee Doodle Dandy" and simultaneously he sang "Dixie." He could also play the piano with his back to the keyboard, his inverted hands racing up and down the ivories. Tom composed his own music, and yet, as a contemporary observer pointed out, "He seems to be an unconscious agent acting as he is acted on and his mind [is] a vacant receptor where nature stores her jewels to recall them at her pleasure."
Nadia, whose IQ measured between 60 and 70, was an artistic genius. At age six, she showed all the signs of severe autism—ritualistic behavior, inability to relate to others and limited language. She could barely put two words together. Yet from this early age, Nadia could draw life-like pictures of people around her, of horses and even of complex visual scenes unlike the "tadpole-like" drawings of other children her age. Her sketches were so animated that they seemed to leap out from the canvas and were good enough to hang in any Madison Avenue gallery (Figure 9.2).



[Figure 9.2 (a) A drawing of a horse made by Nadia, the autistic savant, when she was 5 years old. (b) A horse drawn by Leonardo da Vinci. (c) A drawing of a horse by a normal 8 year old. Notice that Nadia's drawing is vastly superior to that of the normal 8 year old and almost as good as (or perhaps better than!) da Vinci's horse. (a) and (c) reprinted from *Nadia*, by Lorna Selfe, with permission from Academic Press (New York).]

Other savants have incredibly specific talents. One boy can tell you the time of day, to the exact second, without referring to any timepiece. He can do this even in his sleep, sometimes mumbling the exact time while dreaming. The "clock" inside his head is as accurate as any Rolex. Another can estimate the exact width of an object seen from twenty feet away. You or I would give a ballpark figure. She would say, "That rock is exactly two feet, eleven and three-quarter inches wide." And she'd be right.

These examples show that specialized esoteric talents do not emerge spontaneously from general intelligence, for if that were true, how can an "idiot" display them?

Nor do we have to invoke the extreme pathological example of savants to make this point, for there is an element of this syndrome in every talented person or indeed in every genius. "Genius," contrary to popular misconception, is not synonymous with superhuman intelligence. Most of the geniuses whom I have had the privilege of knowing are more like idiot savants than they would care to admit—extraordinarily talented in a few domains but quite ordinary in other respects.

Consider the oft-told story of the Indian mathematical genius Ramanujan, who at the tum of the century worked as a clerk in the Madras seaport, a few miks from where I was born. He had matriculated to the early part of high school, where he performed badly in all his subjects, and he had no formal education in advanced mathematics. Yet he was astonishingly gifted in math and was obsessed by it. So poor that he couldn't afford paper, he would use discarded envelopes to scribble his mathematical equations, discovering several new theorems before the age of twenty-two. Since he was not acquainted with any number theorists in India, he decided to communicate his discoveries to several mathematicians in other parts of the world, including Cambridge, England. One of the world's top number theorists of that time, G.H. Hardy, received his scribbles and immediately thought Ramanujan was a crackpot. Having glanced at them, he went out to play tennis. As the game wore on, Ramanujan's equations kept haunting him. He kept seeing the numbers in his mind. "I had never seen anything in the least like them before," Hardy later wrote. "They must be true because no one would have had the imagination to invent them." So he promptly went back and checked the validity of the elaborate equations on backs of envelopes, saw that most of them were correct and immediately sent a note to his colleague J.E. Littlewood, who also went over the manuscripts. Both luminaries quickly realized that Ramanujan was probably a genius of the highest caliber. They invited him to Cambridge, where he worked for many years, eventually surpassing them in the originality and importance of his contributions.

I mention this story because if you were to go out to dinner with Ramanujan you wouldn't think there was anything unusual about him. He was just like any other person except for the fact that his mathematical skills were way off scale—almost supernatural, some have said. Again, if mathematical ability is simply a function of general intelligence, a result of the brain's getting bigger and better overall, then more intelligent people should be better at math, and vice versa. But if you met Ramanujan, you'd know that that just isn't true.

What is the solution? Ramanujan's own "explanation"—that the fully formed equations were whispered to him in dreams by the presiding village deity, Goddess Namagiri—doesn't really help us very much. But I can think of two other possibilities.

The first, more parsimonious, view is that general intelligence is really a number of different mental traits—with both the genes and the traits themselves influencing each other's expression. Since genes combine randomly in the population, every now and then you will get a fortuitous combination of traits—such as vivid visual imagery combined with excellent numerical skills—and such shuffling can throw up all sores of unexpected interactions. Thus is born that extraordinary flowering of talent we call genius—the gifts of an Albert Einstein who could "visualize" his equations or a Mozart who saw, and did not merely hear, his musical compositions unfold in his mind's eye. Such genius is rare only because the lucky genetic combinations are rare.

But there's a problem with this argument. If genius results from serendipitous genetic combinations, how does one explain the talents of Nadia and Tom, whose general intelligence is abysmal? (Indeed, an autistic savant's social skills may be less than those of a Bonobo ape.) It's difficult, moreover, to see why such unique talent should actually be *more* common among savants than it is among the general population, who, if anything, have a larger number of healthy traits to shuffle around in each generation. (As many as 10 percent of autistic children have perfect pitch, compared with only 1 or 2 percent of the general population.) Furthermore, the traits in that individual would have to "interlock" precisely and interace in such a way that the outcome is something elegant rather than nonsensical, a scenario that is as unlikely as a confederacy of dunces producing a work of artistic or scientific genius.

This brings me to the second explanation for the savant syndrome in particular and for genius in general. How can someone who can't tie shoelaces or carry on a normal conversation calculate prime numbers? The answer might lie in a region of the left hemisphere called the angular gyrus, which, when damaged, leaves some people (like Bill, the Air Force pilot in Chapter 1 who couldn't subtract) with an inability to do simple calculations, such as subtract 7 from 100. This does not mean that the left angular gyrus is the brain's math module, but it's fair to say that this structure is doing something crucial for mathematical computation and is not essential for language, working memory or vision. But you do seem to need the left angular gyrus for math.

Consider the possibility that savants suffer early brain damage before or shortly after birth. Is it possible that their brains undergo some form of remapping as seen in phantom limb patients? Does the prenatal or neonatal injury lead to unusual rewiring? In savants, one part of the brain may for some obscure reason receive a greater than average input or some other equivalent impetus to become denser and larger—a huge angular gyrus, for example. What would be the consequence for mathematical ability? Would this produce a child who can generate eight-digit prime numbers? In truth, we know so little about how neurons perform such abstract operations that it's difficult to predict what thc effect of such a change might be. An angular gyrus doubled in size could lead not to a mere doubling of mathematical ability but to a logarithmic or hundred-fold increase. You can imagine an explosion of talent resulting from this simple but "anomalous" increase in brain volume. The same argument might hold for drawing, music, language, indeed any human trait.[12]

This argument is zany and unashamedly speculative, but at least it's testable. A math savant should have a large or hypertrophied left angular gyrus, whereas an artistic savant may have a hypertrophied right angular gyrus. Such experiments have not been done, to my knowledge, although we do know that damage to the *right* parietal cortex, where the angular gyrus is located, can profoundly disrupt artistic skills (just as damage to the left disrupts calculation).

A similar argument can be put forth to explain the occasional emergence of genius or extraordinary talent in the normal population, or to answer the especially vexing question of how such abilities cropped up in evolution in the first place. Maybe when the brain reaches a critical mass, new and unforeseen traits, properties that were not specifically chosen by natural selection, emerge. Maybe the brain had to become big for some other more obviously adaptive reason—throwing spears, talking or navigation—and the simplest way to achieve this was to increase one or two growth-related hormones or morphogens (genes that alter size and shape in developing organisms). But since such a hormone- or morphogen-based growth spurt cannot selectively increase the size of some parts while sparing others, the bonus might be an altogether bigger brain, including an enormous angular gyrus and the accompanying ten-fold or hundred-fold enhancement in mathematical ability. Notice that this argument is very different from the widely held belief that you develop some very "general" ability that is then deployed for a specialized skill.

Taking this speculation even further, is it possible that humans find such esoteric talents—be it music, poetry, drawing or math—to be sexually attractive mainly because they serve as an externally visible signature of a giant brain? Just as the peacock's large, iridescent tail or the size of a majestic bull elephant's tusks constitutes "truth in advertising" for the animal's health, so the human ability to croon a tune or pen a sonnet might be a marker for a superior brain. ("Truth in advertising" may play an important role in mate selection. Indeed, Richard Dawkins has suggested, half seriously, that the size and strength of a human male's erection may be markers for general health.)

This line of reasoning raises some fascinating possibilities. For instance, you could inject hormones or morphogens into a fetal human brain or infant to try to increase brain size artificially. Would this result in a race of geniuses with superhuman talents? Needless to say, the experiment would be unethical to do in humans, but an evil genius might be tempted to try it on the great apes. If so, would you see a sudden efflorescence of extraordinary mental talents in these apes? Could you accelerate the pace of simian evolution through a combination of genetic engineering, hormonal intervention and artificial selection?

My basic argument about savants—that some specialized brain regions may have become enlarged at the expense of others—may or may not turn out to be correct. But even if it's valid, bear in mind that no savant is going to be a Picasso or an Einstein. To be a true genius, you need other abilities, not just isolated islands of talent. Most savants are not truly creative. If you look at a drawing by Nadia, you do see creative artistic ability,[13] but among mathematical and musical savants, there are no such examples. What seems to be missing is an ineffable quality called creativity, which brings us face to face with the very essence of what it is to be human. There are those who assert that creativity is simply the ability to randomly link seemingly unrelated ideas, but surely that is not enough. The proverbial monkey with a typewriter will eventually produce a Shakespeare play, but it would need a billion lifetimes before it could generate a single intelligible sentence—let alone a sonnet or a play.

Not long ago when I told a colleague about my interest in creativity, he repeated the well-worn argument that we simply toss ideas around in our heads, producing random combinations until we hit on aesthetically pleasing ones. So I challenged him to "toss around" some words and ideas by coming up with a single evocative metaphor for "taking things to ridiculous extremes" or "over-doing things."

Hc scratched his head and after half an hour confessed that he couldn't think of anything all that original (despite his very high verbal IQ, I might add). I pointed out to him that Shakespeare had crammed five such metaphors in a single sentence:

> To gild refined gold, to paint the lily, to throw a perfume on the violet, to smooth the ice, or add another hue unto the rainbow . . . is wasteful and ridiculous excess.

It sounds so simple. But how come Shakespeare thought of it and nobody else? Each of us has the same words at our command. There's nothing complicated or esoteric about the idea that's being conveyed. In fact, it's crystal clear once it is explained and has that universal "why didn't I think of that?" quality that characterizes the most beautiful and creative insights. Yet you and I would never come up with an equally elegant set of metaphors by simply dredging up and randomly shuffling words in our minds. What's missing is the creative spark of genius, a trait that remains as mysterious to us now as it did to Wallace. No wonder he felt impelled to invoke divine intervention.

Ramachandran's Footnotes (pp. 284-288)

1. At present the device is effective mainly for stimulating parts of the brain near the surface but we may eventually be able to stimulate deeper structures.

2. See Papez, 1937, for the original description and Maclean, 1973, for a comprehensive review full of fascinating speculations.

It's no coincidence that the rabies virus "chooses" to lodge itself mainly in the limbic structures. When dog A bites dog B, the virus moves from the peripheral nerves near the bite into the spinal cord and then eventually up to the victim's limbic system, turning Benji into Damien. Snarling and foaming at the mouth, the once-placid pooch bites another victim and the virus is thus passed on, infecting those very brain structures that drive aggressive biting behavior. And as part of this diabolical strategy, the virus initially leaves other brain structures completely unaffected so that the dog can remain alive just long enough to transmit the virus. But how the devil does a virus travel all the way from peripheral nerves near the bite to cells deep inside the brain while sparing all other brain structures along the way? When I was a student I often wondered whether it might be possible to stain the virus with a fluorescent dye in order to "light up" these brain areas—thereby allowing us to discover pathways specifically concerned with biting and aggression, in much the same way one uses PET scans these days. In any event, it is clear that as far as the rabies virus is concerned, a dog is just another way of making a virus—a temporary vehicle for passing on its genome.

3. Useful descriptions of temporal lobe epilepsy can be found in Trimble, 1992 and Bear and Fedio, 1977. Waxman and Geschwind, 1975, have championed the view that there is a constellation of personality traits more frequently found in temporal lobe epilepsy patients than in age-matched controls. Although this notion is not without its critics, several studies have confirmed such an associahon: Gibbs, 1951; Gastaut, 1956; Bear and Fedio, 1977; Nielsen and Kristensen, 1981; Rodin and Schmaltz, 1984: Adamec, 1989; Wieser, 1983.

The presumed link between "psychiatric disturbances" and epilepsy, of course, goes back to antiquity. and, in the past, there has been an unfortunate stigma attached to the disorder. But as I have stressed repeatedly in this chapter, there is no basis for concluding that any of these traits is "undesirable" or that the patient is worse off because of them. The best way to eliminate the stigma, of course, is to explore the syndrome in greater depth.

Slater and Beard (1963) noted "mystical experiences" in 38 percent of their series of cases, and Bruens (1971) made a similar observation. Frequent religious conversions are also seen in some patients (Dewhurst and Beard, 1970).

It is important to recognize that only a minority of patients display esoteric traits, like religiosity or hypergraphia, but that does not make the association any less real. By way of analogy, consider the fact that kidney or eye changes (complications of diabetes) occur only in a minority of diabetics, but no one would deny that the association exists. As Trimble (1992) has noted, "It is most likely that personality traits such as religiosity and hypergraphia seen in patients with epilepsy represent an all-or-none phenomenon and are seen in a minority of patients. It is not a graded characteristic, for example like obsessionality, and therefore does not emerge as a prominent factor in questionnaire studies unless a sufficiently large number of patients are evaluated."

4. To complicate matters, it is entirely possible that some clinically undetectable damage in the temporal lobes also underlies schizophrenia and manic-depressive disorders, so the fact that psychiatric patients sometimes experience religious feelings doesn't negate my argument.

5. Similiar views have been put forward by Crick, 1993; Ridley, 1997, and Wright 1994, although they do not invoke specialized structures in the temporal lobe.

This argument smacks of group selection—a taboo phrase in evolutionary psychology—but it doesn't have to. After all, most religions, even though they pay lip service to the "brotherhood" of mankind, tend mainly to emphasize loyalty to one's own clan or tribe (hence those who probably share many of the same genes).

6. Bear and Fedio (1977) offered the ingenious suggestion that there has been hyperconnectivity in the limbic system that makes the patients see cosmic significance in everything. Their idea predicts a heightened GSR to everything the patient looks at, a prediction that held up in some preliminary studies. But other studies showed either no change or a reduction in GSR to most categories. The picture is complicated also by the extent to which the patient is on medication while the GSR is measured.

Our own preliminaty studies, on the other hand, suggest that there can be a selective enhancement of GSR responses to some categories and not others— thereby altering the patients' emotional landscape permanently (Ramachandran, Hirstein, Armel, Tecoma and Iragui, 1997). But this finding, too, should be taken with a generous scoop of salt until it is confirmed on a large number of patients.

7. Moreover, even if the changes in dhe patient's brain were originally mediated by the temporal lobes—the actual repository of the changes—"a religious outlook" probably involves many different brain areas.

8. For lucid and lively expositions of Darwin's ideas, see Dawkins, 1976; Maynard Smith, 1978; Dennett, 1995.

There is an acrimonious debate going on at the high table of evolotion over whether every trait (or almost every trait) is a direct result of natural selection or whether there are other laws or principles governing evolution. We will take up this debate in Chapter 10, where I discuss the evolution of humor and laughter.
9. Much of this discussion appears in a book by Loren Eisley (1958).
10. This idea is clearly described in a delightful book by Christopher Wills (1993). See also Leakey, 1993, and Johanson and Edward, 1996.
11. The savant who could produce the cube-root is described by Hill, 1978. The idea that savants have learned some simple shortcuts or tricks for discovering primes or for factoring has been around for some time. But it doesn't work. When a professional mathematician learned the appropriate algorithm, he still took almost a minute to generate all primes between 10,037 and 10,133— whereas a nonverbal autistic man, naive to this task, took only ten seconds (Hermelin and O'Connor, 1990).
There are algorithms for generating primes at a high frequency—with occasional rare errors. It would be interesting to see whether prime number savants make exactly the same rare errors that these algorithms do; that would tell us whether the savants were tacitly using the same algorithm.
12. Another possible explanation of the savant syndrome is based on the notion that the absence of certain abilities may actually make it easier to take advantage of what's left over and to focus attention on more esoteric skills. For instance, as you encounter events in the external world, you obviously do not record every trivial detail in your mind; that would be maladaptive. Our brains first gauge the significance of events and engage in an elaborate censoring and editing of the information—before storing it. But what if this mechanism goes awry? Then you might start recording at least some events in needless detail like the words in a book that you read ten years ago. This, to you or me, might seem to be an astounding talent. But in truth, it emerges from a damaged brain that cannot censor daily experience. Similarly, an autistic child is locked in a world where others are not welcome, save one or two channels of interest to the outside. The child's ability to focus all her attention on a single subject to the exclusion of all else can lead to apparently exotic abilities—but, again, her brain is not normal and she remains profoundly retarded.
A related but more ingenious argument is proposed by Snyder and Thomas (1997), who suggest that savants are for some reason less concept-driven because of their retardation and this in turn allows them access to earlier levels of the processing hierarchy, which is not available to most of us (hence the obsessively detailed drawings of Stephen Wiltshire, which contrast sharply with the tadpole figures or the conceptual cartoon-like drawings of normal children).
This idea is not inconsistent with mine. One could argue that the shift in emphasis from concept-driven perception (or conception) to allow access to early processes may depend on the hypertrophy of the "early" modules in precisely the manner I have suggested. Snyder's idea could therefore be seen as being halfway between the traditional attention theory and my theory proposed in this chapter.
One problem is that although drawings of some savants seem excessively detailed (for example, Stephen Wiltshire's, described by Sacks), there are others whose drawings seem genuinely beautiful

(for example, the da Vinci-like drawings of horses produced by Nadia). Her sense of perspective, shading and so on seem hypernormal in a manner predicted by my argument.

What all these ideas have in common is that they imply a shift in emphasis from one set of modules to the other. Whether this results simply from the lack of function of one set (with more attention paid to others) or from actual hypertrophy of what's left remains to be seen.

The attention shift idea also doesn't appeal to me for two other reasons. First, saying that you automatically become skilled at something by deploying attention doesn't really tell us very much unless you know what attention is, and we don't. Second, if this argument is correct, then why don't adult patients with damaged large portions of their brains suddenly become very skilled at other things—by shifting attention? I have yet to come across a dyscalculic who suddenly became a musical savant or a neglect patient who became a calculating prodigy. In other words, the argument doesn't explain why savants are born, not made.

The hypertrophy theory can, of course, be readily tested by using magnetic resonance imaging (MRI) on different types of savants.

13. Patients like Nadia also bring us face-to-face with an even deeper question: What is art? Why are some things pretty, while others are not? Is there a universal grammar underlying all visual aesthetics? An artist is skilled at grasping the essential features (what Hindus call rasa) of an image he is trying to portray and eliminating superfluous detail, and in doing so he is essentially imitating what the brain itself has evolved for. But the real question is: Why should this be aesthetically pleasing?

In my view, all art is "caricature" and hyperbole, so if you understand why caricatures are effective you understand art. If you teach a rat to discriminate a square from, say, a rectangle and reward it for the latter, then it will soon start recognizing the rectangle and show a preference for it. But paradoxically, it will respond even more vigorously to a skinnier "caricature" rectangle (e.g., widh an aspect ratio of 3:1 instead of 2:1) than to the original prototype! The paradox is resolved when you realize that what the rat learns is a rule—"rectangularity"— rather than a particular exemplar of that rule. And the way the visual form area in the brain is structured, amplifying the rule (a skinnier rectangle) is especially reinforcing (pleasing) to the rat, providing an incentive for the rat's visual system to "discover" the rule. In a similar vein, if you subtract a generic average face from Nixon's face and then amplify the differences, you end up with a caricature that is more Nixon-like than the original. In fact, the visual system is constanly struggling to "discover the rule." My hunch is that very early in evolution, many of the extra-striate visual areas that are specialized for extracting correlations and rules and binding features along different dimensions (form, motion, shading, color, etc.) are directly linked to limbic structures to produce a pleasant sensation, since this would enhance dhe animal's survival. Consequently, amplifying a specific rule and eliminating irrelevant detail makes the picture look even more attractive. I would suggest also that these mechanisms and associated limbic connections are more prominent in the right hemisphere. There are many cases in the literature of patients with left-hemisphere stroke whose drawings actually implied after the stroke—perhaps because the right hemisphere is then free to amplify the rule. A great painting is more evocative than a photograph because the photograph's details may actually mask the underlying rule—a masking that is eliminated by the artist's touch (or by a left-hemisphere stroke!).

This is not a complete explanation of art, but it's a good start. We skill need to explain why artists often use incongruous juxtapositions deliberately (as in humor) and why a nude seen behind a shower curtain or a diaphanous veil is more attractive than a nude photograph. It's as though the rule discovered after a struggle is even more reinforcing than one that is instantly obvious, a point that has also been made by the art historian Ernest Gombrich. Perhaps natural selection has wired up the visual areas in such a way that the reinforcement is actually stronger if it obtained after "work"—in order to ensure that the effort itself is pleasant rather than unpleasant. Hence the eternal appeal of puzzle pictures such as the dalmatian dog in Fig. 12.2 or "abstract" pictures of faces with strong shadows. A pleasant feeling occurs when the picture finally clicks and the splotches are correctly linked together to form a figure.