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When Hamlet says, “What a piece of work is a man! How noble in reason! How infinite in faculty! In form and moving how express and admirable!” we should direct our awe not at Shakespeare or Mozart of Einstein or Kareem Abdul-Jabbar but at a four-year old carrying out a request to put a toy on a shelf. (4)

The mind, like the Apollo spacecraft, is designed to solve many engineering problems, and thus is packed with high-tech systems each contrived to overcome its own obstacles. (4)

“A common man marvels at uncommon things; a wise man marvels at the commonplace” [Confucius] (12)

... there's nothing common about common sense. Somehow it must find its way into a human or robot brain. And common sense is not simply an almanac about life that can be dictated by a teacher or downloaded like an enormous database. No database could list all the facts we tacitly know, and no one ever taught them to us. (13)

An intelligent system [...] cannot be stuffed with trillions of facts. It must be equipped with a smaller list of core truths and a set of rules to deduce their implications. But the rules of common sense, like the categories of common sense, are frustratingly hard to set down. (14)

Man's capacity for evil is never far from our minds, and it is easy to think that evil just comes along with intelligence as part of its very essence. It is a recurring theme in our cultural tradition. (16)

Aggression, like every other part of human behavior we take for granted, is a challenging engineering problem! (17)

Hidden behind the panels of consciousness must lie fantastically complex machinery – optical analyzers, motion guidance systems, simulations of the world, databases on people and things, goal-schedulers, conflict-resolvers, and many others. (19)

When the visual areas of the brain are damaged, for example, the visual world is not simply blurred or riddled with holes. Selected aspects of visual experience are removed while others are left intact. Some patients see a complete world but pay attention only to half of it. They eat food from the right side of the plate, shave only the right cheek, and draw a clock with twelve digits squished into the right half. Other patients lose their sensation of color, but they do not see the world as an arty black-and-white movie. Surfaces look grimy and rat-colored to them, killing their appetite and their libido. Still others can see objects change their positions but cannot see them move – a syndrome that a philosopher once tried to convince me was logically impossible! The stream from a teapot does not flow but looks like an icicle; the cup does not gradually fill with tea but is empty and then suddenly full. Other patients cannot recognize the objects they see: their world is like handwriting they cannot decipher. They copy a bird faithfully but identify it as a tree stump. A cigarette lighter is a mystery until it is lit. When they try to weed the garden, they pull out the roses. Some patients can recognize inanimate objects but cannot recognize faces. The patient deduces that the visage in the mirror must be his, but does not viscerally recognize himself. He identifies John F. Kennedy as Martin Luther King, and asks his wife to wear a ribbon at a party so he can find her when it is time to leave. Stranger still is the patient who recognizes the face but not the person: he sees his wife as an amazingly convincing impostor. These syndromes are caused by an injury, usually a stroke, to one or more of the thirty brain areas that compose the primate visual system. Some areas specialize in color and form, others in where an object is, others in what an object is, still others in how it moves. A seeing robot cannot be built with just the fish-eye viewfinder of the movies, and it is not surprise to discover that humans were not built that way either. When we gaze at the world, we do not fathom the many layers of apparatus that underlie our unified visual experience, until neurological disease dissects them for us. (19-20)

The mind is a system of organs of computation, designed by natural selection to solve the kinds of problems tha tour ancestors faced in their foraging way of life, in particular, understanding and outmaneuvering objects, animals, plants, and other people. [...] The mind is what the brain does; specifically, the brain processes information, and thinking is a kind of computation. The mind is organized into modules or mental organs, each with a specialized design that makes it an expert in one are of interaction with the world. The modules' basic logic is specified by our genetic program. Their operation was shaped by natural selection to solve the problem of the hunting and gathering life led by our ancestors in most of our evolutionary history. The various problems for our ancestors were subtasks of one big problem for their genes, maximizing the number of copies that made it into the next generation. (21)

Cognitive science helps us to understand how a mind is possible and what kind of mind we have. Evolutionary biology helps us to understand *why* we have the kind of mind we have. (23)

We evolved from apes, but that does not mean we have the same minds as apes. And the ultimate goal of natural selection is to propagate genes, but that does not mean that the ultimate goal of a people is to propagate genes (23-24)

... the mind is not the brain but what the brain does. (24)

Information and computation reside in patters of data and in relations of logic that are independent of the physical medium that carries them. (24)

It [computational theory of mind] is one of the great ideas in intellectual history, for it solves one of the puzzles that make up the “mind-body problem”: how to connect the ethereal world of meaning and intention, the stuff of our mental lives, with the physical hunk of matter like the brain. (24)

The computation theory of mind resolves the paradox [why did Bill get on the bus]. It says that beliefs and desires are *information*, incarnated as configurations of symbols. The symbols are the physical states of bits of matter, like chips in a computer of neurons in the brain. They symbolize things in the world because they are triggered by those things via our sense organs, and because of what they do once they are triggered. If the bits of matter that constituting another symbol in just the right way, the symbols corresponding to one belief can give rise to new symbols corresponding to another belief logically related to it. Which can give rise to symbols corresponding to other beliefs, and so on. Eventually the bits of matter constituting a symbol bump into bits of matter connected to the muscles, and behavior happens. The computation theory of mind thus allows us to keep beliefs and desires in our explanations of behavior while planting them squarely in the physical universe. It allows meaning to cause and be caused. (25)

... we cannot simply look at a patch of brain and read out the logic in the intricate pattern of connectivity that makes each part of its separate thing. [...] The content of a book or a movie lies in the *pattern* of ink marks or magnetic charges, and is apparent only when the piece is read or seen. Similarly, the content of brain activity lies in the patters of connections and patters of activity among neurons. (25)

The mind, I claim, is not a single organ but a system or organs, which we can think of as psychological faculties or mental modules. The entities now commonly evoked to explain the mind – such as general intelligence, a capacity to form culture, and multipurpose learning strategies – will surely go the way of protoplasm in biology and of earth, air, fire, and water in physics. (27)

The difference between Einstein and a high school dropout is trivial compared to the difference between the high school dropout and the best robot in existence, or between the high school dropout and a chimpanzee. (34)

The genetic assembly instructions for a mental organ do not specify every connection in the brain as if they were wiring schematic for a Heathkit radio. [...] Every part of the body, from the toenails to the cerebral cortex, takes on its particular shape and substance when its cells respond to some kind of information in its neighborhood that unlocks a different part of the genetic program. (35)

Since the brain is destined to be an organ of computation, it would be surprising if the genome did not exploit the capacity of neural tissue to process information during brain assembly.

In the sensory areas of the brain, where we can best keep track of what is going on, we know that early in fetal development neurons are wired according to a rough genetic recipe. The neurons are born in appropriate numbers at the right times, migrate to their resting places, send out connections to their targets, and hook up to appropriate cell types in the right general regions, all under the guidance of chemical trails and molecular locks and keys. To make precise connections, though, the baby neurons must begin to function, and their firing pattern carries information downstream about their pinpoint connections. This isn't "experience," as it all can take place in the pitch-black womb, sometimes before the rods and cones are functioning, and many mammals can see almost perfectly as soon as they are born. It is more like a kind of genetic data compression or a set of internally generated test patterns. These patterns can trigger the cortex at the receiving end to differentiate, at least one step of the way, into the kind of cortex that is appropriate to processing the incoming information. (For example, in animals that have been cross-wired so that the eyes are connected to the auditory brain, that area shows a few hints of the properties of the visual brain). How the genes control brain development is still unknown, but a reasonable summary of what we know so far is that brain modules assume their identity by a combination of what kind of tissue they start out as, where they are in the brain, and what patterns of triggering input they get during critical periods in development. (35-36)

[There] is a new theory of pregnancy sickness (traditionally called "morning sickness"_ by the biologist Margie Profet. Many pregnant women become nauseated and avoid certain foods. Though their sickness is usually explained away as a side effect of hormones, there is no reason that hormones should induce nausea and food aversion rather than, say, hyperactivity, aggressiveness, or lust. The Freudian explanation is equally unsatisfying: that pregnancy sickness represents the woman's loathing of her husband and her unconscious desire to abort the fetus orally.

Profet predicted that pregnancy sickness should confer some benefit that offsets the cost of lowering nutrition and productivity. Ordinarily, nausea is a protection against eating toxins: the poisonous food is ejected from the stomach before it can do much harm, and our appetite for similar foods is reduced in the future. Perhaps pregnancy sickness protects women against eating or digesting foods with toxins that might harm the developing fetus. Your local Happy Carrot Health Food Store notwithstanding, there is nothing particularly healthy about natural foods. Your cabbage, a Darwinian creature, has no more desire to be eaten than you do, and since it can't very well defend itself through behavior, it resorts to chemical warfare. Most plants have evolved dozens of toxins in their tissues: insecticides, insect repellents, irritants, paralytics, poisons, and other sand to throw in herbivores' gears. Herbivores have in turn evolved countermeasures, such as a liver to detoxify the poisonos and the taste sensation we call bitterness to deter any further desire to ingest them. But the usual defenses may not be enough to protect a tiny embryo.

So far this may not sound much better than the barf-up-your-baby theory, but Profet synthesized hundreds of studies, done independently of each other and of her hypothesis, that support it. She meticulously documented that (1) plant toxins in dosages that adults tolerate can cause birth defects and induce abortion when ingested by pregnant women; (2) pregnancy sickness begins at the point when the embryo's organ systems are being laid down and the embryo is most vulnerable to teratogens (birth defect – inducing chemicals) but is growing slowly and has only a modest need for nutrients; (3) pregnancy sickness wanes at the stage when the embryo's organ systems are nearly complete and its biggest need is for nutrients to allow it to grow; (4) women with pregnancy sickness selective avoid bitter, pungent, highly flavored, and novel foods, which are in fact the ones most likely to contain toxins; (5) women's sense of smell becomes hypersensitive during the window of pregnancy sickness and less sensitive than usual thereafter; (6) foraging peoples (including, presumably, our ancestors) are at even higher risk of ingesting plan toxins, because they eat wild plants rather than domesticated crops bred for palatability; (7) pregnancy sickness is universal across human cultures; (8) women with more severe pregnancy sickness are less likely to miscarry; (9) women with more severe pregnancy sickness are less likely to bear babies with birth defects. The fit between how a baby-making system in a natural ecosystem ought to work and how the feelings of modern women do work is impressive, and gives a measure of confidence that Profet's hypothesis is correct. (39-40)

Three hundred thousand generations and up to ten megabytes of potential genetic information are enough to revamp a mind considerably [the difference of chimpanzee and homo sapient DNA]. Indeed, minds are probably easier to revamp than bodies because software is easier to modify than hardware. We should not be surprised to discover impressive new cognitive abilities in humans, language being just the most obvious one. (41)

For ninety-nine percent of human existence, people lived as foragers in small nomadic bands. Our brains are adapted to that long-vanished way of life, not to brand-new agricultural and industrial civilizations. They are not wired to cope with anonymous crowds, schooling, written language, government, police, courts, armies, modern medicine, formal social institutions, high technology, and other newcomers to human experience. [...] It [natural selection] acts by designing the generator of behavior: the package of information-processing and goal-pursuing mechanisms called the mind. Our minds are designed to generate behavior that would have been adaptive, on average, in our ancestral environment, but any particular deed done today is the effect of dozens of causes. Behavior is the outcome of an internal struggle among many mental modules, and it is played out on the chessboard of opportunities and constraints defined by *other* people's behavior. A recent cover story in *Time* asked, “Adultery: Is It in Our Genes?” The question makes no sense because neither adultery nor any other behavior can be in our genes. Conceivably a *desire* for adultery can be an indirect product of our genes, but the desire may be overridden by *other* desires that are also indirect products of our genes, such as the desire to have a trusting spouse. And the desire, even if it prevails in the rough-and-tumble mind, cannot be consummated as overt behavior unless there is a partner around in whom that desire has also prevailed. Behavior itself did not evolve; what evolved was the mind. (42)

The ultimate goal that the mind was designed to attain is maximizing the number of copies of the genes that created it. Natural selection cares only about the long-term fate of entities that replicate, that is, entities that retain a stable identity across many generations of copying. It predicts only that replicators whose effects tend to enhance the probability of their own replication come to predominate. When we ask questions like "Who or what is supposed to benefit from an adaptation?" and "What is a design in living things a design *for*?" the theory of natural selection provides the answer: the long-term stable replicators, genes. Even our bodies, our selves, are not the ultimate beneficiary of our design. As Gould has said, "What is the 'individual reproductive success' of which Darwin speaks? It cannot be the passage of one's body into the next generation – for, truly, you can't take it with you in the sense above all!" The criterion by which genes get selected is the quality of the bodies they build, but it is the genes making it into the next generation, not the perishable bodies, that are selected to live and fight another day.

[...] Contrary to the popular belief, the gene-centered theory of evolution does *not* imply that the point of all human striving is to spread our genes. With the exception of the fertility doctor who artificially inseminated patients with his own semen, the donors to the sperm bank for Nobel Prize winners, and other kooks, *no* human being (or animal) strives to spread his or her genes. Dawkins explained the theory in his book called *The Selfish Gene*, and the metaphor was chosen carefully. People don't selfishly spread their genes; genes selfishly spread themselves. They do it by the way they build our brains. By making us enjoy life, health, sex, friends, and children, the genes buy a lottery ticket for representation in the next generation, with odds that were favorable in the environment in which we evolved. Our goals are subgoals of the ultimate goal of the genes, replicating themselves. But the two are different. As far as *we* are concerned, our goals, conscious or unconscious, are not about genes at all, but about health and lovers and children and friends.

The confusion between our goals and our genes' goals has spawned one muddle after another. A reviewer of a book about the evolution of sexuality protests that human adultery, unlike the animal equivalent, cannot be a strategy to spread the genes because adulterers take steps to prevent pregnancy. But whose strategy are we talking about? Sexual desire is *not* people's strategy to propagate their genes. It's people's strategy to propagate themselves. If the genes don't get propagated, it's because we are smarter than they are. A book on the emotional life of animals complains that if altruism according to biologists is just helping kin or exchanging favors, both of which serve the interests of one's genes, it would not *really* be altruism after all, but some kind of hypocrisy. This too is a mixup. Just as blueprints don't necessarily specify blue buildings, selfish genes don't necessarily specify selfish organism. As we shall see, sometimes the most selfish thing a gene can do is to build a selfless brain. Genes are a play within a play, not the interior monologue of the players. (43-44)

The !Kung San of the Kalahari Desert are often held out as a relatively peaceful people, and so they are, compared with other foragers: their murder rate is only as high as Detroit's. A linguist friend o mine who studied the Wari in the Amazon rainforest learned that their language has a term for edible things, which includes anyone who isn't a Wari. (51)

Well into my procreating years I am, so far voluntarily childless, having squandered my biological resources reading and writing, doing research, helping out friends and students, and jogging in circles, ingnoring the solemn imperative to spread my gens. By Darwinian standards I am a horrible mistake, a pathetic loser, not one iota less than if I were a card-carrying member of Queer Nation. But I am happy to be that way, and if my genes don't like it, they can go jump in the lake. (52)

I believe that science and ethics are two self-contained systems played out among the same entities in the world, just as poker and bridge are different games played with the same fifty-two-card deck. The science game treats people as material objects, and its rules are the physical processes that cause behavior through natural selection and neurophysiology. The ethics game treats people as equivalent, sentient, rational, free-willed agents, and its rules are the calculus that assigns moral value to behavior through the behavior's inherent nature or its consequences. (55)

In the latest twist in the human-nature morality play, a chromosomal marker for homosexuality in some men, the so-called gay gene, was identified by the geneticist Dean Hamer. To the bemusement of Science for the People, this time it is the genetic explanation that is politically correct. Supposedly it refutes right-wingers like Dan Quayle, who had said that homosexuality “is more of a choice than a biological situation. It is a wrong choice.” The gay gene has been used to argue that homosexuality is not a choice for which gay people can be held responsible but an involuntary orientation they just can't help. But the reasoning is dangerous. The gay gene could just as easily be said to influence some people to *choose* homosexuality. And like all good science, Hamer's result might be falsified someday, and then where would we be? Conceding that bigotry against gay people is OK after all? The argument against persecuting gay people must be made not in terms of the gay gene or the gay brain but in terms of the people's right to engage in private consensual acts without discrimination or harassment. (56)

Intelligence [...] is the ability to attain goals in the face of obstacles by means of decision based on rational (truth-obeying) rules. [...] intelligence consists of specifying a goal, assessing the current situation to see how it differs from the goal, and applying a set of operation s that reduce the difference. (62)

The ability of a human to respond to something as physically nebulous as praise is part of the puzzle we are trying to solve, not part of the solution to the puzzle. Praise, danger, English, and all the other things we respond to, no less than beauty, are in the eye of the beholder, and the eye of the beholder is what we want to explain. The chasm between what can be measured by a physicist and what can cause behavior is the reason we must credit people with beliefs and desires. (63)

... intelligence [comes from] a different commodity, *information*. Information is a correlation between two things that is produced by a lawful process (as opposed to coming about by sheer chance).[...] Information itself is nothing special; it is found wherever causes leave effects. What is special is information *processing*. (65-66)

The blossoming came from a central agenda for psychology set by the computational theory: discovering the form of mental representations (they symbol inscriptions used by the mind) and the processes (the demons) that access them. Plato said that we are trapped inside a cave and know the world only through the shadows it casts on the wall. The skull is our cave, and mental representations are the shadows. The information in an internal representation is all that we can know about the world. Consider, as an analogy, how *external* representations work. My bank statement lists each deposit as a single sum. If I deposited several checks and some cash, I cannot verify whether a particular check was among them; that information was obliterated in the representation. What's more, the *form* of a representation determines what can easily be inferred from it, because the symbols and their arrangements are the only things a homunculus stupid enough to be replaced by a machine can respond to. Our representation of number is valuable because addition can be performed on the numbers with a few dronelike operations: looking up entries in the addition table and carrying digits. (84-85)

But if we drop down to the level of representations, we find a firmer sort of entity, which can be rigorously counted and matched. If a theory of psychology is any good, it should predict that the representations required by the “difficult” task contain more symbols (count 'em) or trigger a longer chain of demons than those of the “easy” task. It should predict that the representation of two “similar” things have more shared symbols and fewer nonshared symbols than the representations of “dissimilar” things. The “salient” entities should have different representations from their neighbor; the “nonsalient” entities should have the same ones.

Research in cognitive psychology has tried to triangulate on the mind's internal representations by measuring people's reports, reaction times, and errors as they remember, solve problems, recognize objects, and generalize from experience. The way people generalize is perhaps the most telltale sign that the mind uses mental representations, and lots of them.

Suppose it takes a while for you to learn to read a fancy new typeface, festooned with curlicues. You have practiced with some words and are now as quick as you are for any other typeface. Now you see a familiar word that was not in you practice set – say, *elk*. Do you have to relearn that the world is a noun? Do you have to relearn how to pronounce it? Relearn that the referent is an animal? What the referent looks like? That it has mass and breathes and suckles its young? Surely not. But this banal talent of yours tells a story. Your knowledge about the word *elk* could not have been connected directly to the physical shapes of printed letters. If it had, then when new letters were introduces, your knowledge would have no connection tot them and would be unavailable until you learned the connections anew. In reality, your knowledge must have been connected to a node, a number, an address in memory, or an entry in a mental dictionary representing the abstract word *elk*, and that entry must be neutral with respect to how it is printed or pronounced. When you learned the new typeface, you created a new visual trigger for the letters of the alphabet, which in turn triggered the old *elk* entry, and everything hooked up to the entry was instantly available, without your having to reconnect, piece by piece, everything you know about elks to the new way of printing *elk*. This is how we know that your mind contains mental representations specific to abstract entries for words, not just the shapes of the words when they are printed. (85-86)

Our everyday ease in generalizing our knowledge is one class of evidence that we have several kinds of data representations inside our heads. Mental representations also reveal themselves in the psychology laboratory. With clever techniques, psychologists can catch a mind in the act of flipping from representation to representation. A nice demonstration comes from the psychologist Michael Posner and colleagues. Volunteers sit in a front of a video screen and see pairs of letters flashed briefly: *A A*, for example. They are asked to press one button if the letters are the same, another button if they are different (say, *A B*). Sometimes the matching letters are both uppercase or both lowercase (*A A* or *a a*); that is, they are physically identical. Sometimes one is uppercase and one is lowercase (*A a* or *a A*); they are the same letter of the alphabet, but physically different. When the letters are physically identical, people press the buttons more quickly and accurately than when they are physically different, presumably because the people are processing the letters as visual forms and can simply match them by their geometry, template-style. When one letter is *A* and the other letter is *a*, people have to convert them into a format in which they are equivalent, namely "the letter *a*"; this conversion adds about a tenth of a second to the reaction time. But if one letter is flashed and the other follows seconds later, it doesn't matter whether they were physically identical or not; *A*-then-*A* is as slow as *A*-then-*a*. Quick template-matching is no longer possible. Apparently after a few seconds the mind automatically converts a visual representation into an alphabetic one, discarding the information about its geometry.

Such laboratory legerdemian has revealed that human brain uses at least four major formats of representation. One format is the visual image, which is like a template in a two-dimensional, picturelike mosaid. [...] Another is a phonological representation, a stretch of syllables that we play in our minds like a tapeloop, planning out the mouth movements and imagining what the syllables sound like. This stringlike representation is an important component of our short-term memory, as when we look up a phone-number and silently repeat it to ourselves just long enough to dial the number. Phonological short-term memory lasts between one and five seconds and can hold four to seven “chunks.” (Short-term memory is measured in chunks rather than sounds because each item can be a label that points to a much bigger information structure in long-term memory, such as the content of a phrase or sentence.) A third format is the grammatical representation: nouns and verbs, phrases and clauses, stems and roots, phonemes and syllables, all arranged into hierarchical trees. In *The Language Instinct* I explained how these representations determine what goes into a sentence and how people communicate and play with language.

The fourth format is mentalese, the language of thought in which our conceptual knowledge is couched. When you put down a book, you forget almost everything about the wording and typeface of the sentences and where they sat on the page. What you take away is their content or gist. (In memory tests, people confidently “recognize” sentences they never saw if they are paraphrases of the sentences they did see.) Mentalese is the medium in which content or gist is captured. [...] Mentalese is also the mind's lingua franca, the traffic of information among mental modules that allows us to describe what we see, imagine what is described to us, carry out instructions, and so on. This traffic can actually be seen in the anatomy of the brain. The hippocampus and connected structures, which put our memories into long-term storage, and the frontal lobes, which house the circuitry for decision making, are not directly connected to the brain areas that process raw sensory input (the mosaic of edges and colors and the ribbon of changing pitches). Instead, most of their input fibers carry what neuroscientists call “highly processed” input coming from regions one or more stops downstream from the first sensory areas. The input consists of codes for objects, words, and other complex concepts. (89-90)

The activation level of each incoming axon is multiplied by the strength of they synapse [connection weight]. (99)

Where do the rules and representation sin mentalese leave off and the neural networks begin? Most cognitive scientists agree on the extremes. At the highest levels of cognition, where we consciously plod through steps and invoke rules we learned in school or discovered ourselves, the mind is something like a production system, with symbolic inscriptions in memory and demons that carry out procedures. At a lower level, the inscriptions and rules are implemented in something like neural networks, which respond to familiar patterns and associate them with other patterns. (112)

... those neural networks alone cannot do the job. It is the *structuring* of networks into programs for manipulating symbols that explains much of human intelligence. In particular, symbol manipulation underlies human language and the parts of reasoning that interact with it. That's not all of cognition, but it's a lot of it; it's everything we can talk about to ourselves and others. (112)

... our thoughts have a delicate logical structuring that no simple network of homogeneous layers of units can handle. (113)

... thought is governed by two laws. One is contiguity: ideas that are frequently experienced together get associated in the mind. Thereafter, when one is activated, the other is activated too. The other law is resemblance: when ideas are similar, whatever has been associated with the first idea is automatically associated with the second. (113)

Recent thinking about zebra stripes is that they are not for blending in with stripey tall grass – always a dubious explanation – but for turning the zebras into a living shell game, baffling lions and other predators as they try to keep their attention on just one zebra. (118)

The psychologists David Sherry and Dan Schacter [...] note that the different engineering demands on a memory system are often at cross-purposes. Natural selection, they argue, responded by giving organisms *specialized* memory systems. Each has a computational structure optimized for the demands of one of the tasks the mind of the animal must fulfill. For example, birds that cache seeds to retrieve in leaner times have evolved a capacious memory for the hiding places (ten thousand places, in the case of the Clark's Nutcracker). Birds whose males sing to impress the females or to intimidate other males have evolved a capacious memory for songs (two hundred, in the case of the nightingale). The memory for caches and the memory for songs are in different brain structures and have different patters of wiring. We humans place two very different demands on our memory system at the same time. We have to remember individual episodes of who did what to whom, when, where, and why, and that requires stamping each episode with a time, a date, and a serial number. But we also must extract generic knowledge about how people work and how the world works. Sherry and Schacter suggest that nature gave us one memory system for each requirement; an "episodic" or autobiographical memory, and a "semantic" or generic-knowledge memory, following a distinction first made by the psychologist Endel Tulving. (124)

The trick that multiplies human thoughts into truly astronomical numbers is not the slotting of concepts into three or four roles but a kind of mental fecundity called recursion. A fixed set of units for each role is not enough. We humans can take an entire proposition and give it a role in some larger proposition. Then we can take the larger proposition and embed it in a still-larger one, creating a hierarchical tree structure of propositions inside propositions. (124)

Each simple structure (for a person, an action, a proposition, and so on) is represented in long-term memory *once*, and a processor shuttles its attention from one structure to another, storing the itinerary of visits in short-term memory to thread the proposition together. This dynamic processor, called a recursive transition network, is especially plausible for sentence understanding, because we hear and read words one at a time rather than inhaling an entire sentence at once. We also seem to chew our complex thoughts piece by piece rather swallowing or regurgitating them whole, and that suggests that the mind is equipped with a recursive proposition-cruncher for thoughts, not just for sentence. (125)

... unless neural networks are specially assembled into a recursive processor, they cannot handle oru recursive thoughts. (125)

People think in two modes. They can form fuzzy stereotypes by uninsightfully soaking up correlations among properties, taking advantage of the fact that things in the world tend to fall into clusters (things that bark also bite and lift their legs at hydrants). But people can also create systems of rules – intuitive theories – that define categories in terms of the rules that apply to them, and that treat all the members of the category equally. All cultures have systems of formal kinship rules, often so precise that one can prove theorems in them. Our own kinship system gives us a crisp version of "grandmother"; the mother of a parent, muffins be damned. Law, arithmetic, folk science, and social conventions (with their rites of passage sharply delineating adults from children and husbands from bachelors) are other rules systems in which people all over the planet reckon. The grammar of language is yet another. (127)

In associationism and its implementation in connectoplasm, the way an object is represented (namely, as a set of properties) automaticallycommits the system to generalizing in a certain way (unless it is strained out of the generalization with specially provided contrary examples). The alternative I am pushing is that humans can mentally *symbolize* kinds of objects, and those symbols can be referred to in a number of rule systems we carry around in our heads. (In artificial intelligence, this technique is called explanation-based generalization, and connectionist designs are an example of the technique called similarity-based generalization.) Our rule systems couch knowledge in compositional, quantified, recursive propositions, and collections of these propositions interlock to form modules or intuitive psychology, number, language, law. (128)

... the mass of information processing in the nervous system falls into two pools. One pool, which includes the products of vision and the contents of short-term memory, can be accessed by the systems underlying verbal reports, rational though, and deliberate decision making. The other pool, which includes automatic (gut-level) responses, the internal calculations behind vision, language, and movement, and repressed desires or memories (if there are any), cannot be accessed by those systems. Sometimes information can pass from the first pool to the second or vice-versa. When we first learn how to use a stick shift, every motion has to be thought out, but with practice the skill becomes automatic. With intense concentration and biofeedback, we can focus on a hidden sensation like our heartbeat. (135)

... conscious information is inferentially *promiscuous*; it makes itself available to a large number of information-processing agents rather than committing itself to one alone. (137)

The technique of functional imaging of brain activity (PET and MRI) depends on the fact that working brain tissue calls more blood its way and consumes more glucose. (138)

Access-consciousness has four obvious features. First, we are aware to varying degree, of a rich field of sensation: the colors and shapes of the world in front of us, the sounds and smells we are bathed in, the pressures and aches of our skin, bone, and muscles. Second, portions of this information can fall under the spotlight of attention, get rotated into and out of short-term memory, and feed our deliberative cogitation. Third, sensations and thoughts come with an emotional flavoring: pleasant or unpleasant, interesting or repellent, exciting or soothing. Finally, an executive, the “I,” appears to make choice and pull the levers of behavior. Each of these features discards some information in the nervous system, defining the highways of access-consciousness. And each has a clear role in the adaptive organization of thought and perception to serve rational decision making and action. (138-139)

Every organism alive today has had the same amount of time to evolve since the origin of life – the amoeba, the platypus, the rhesus macaque, and yes, Larry on the answering machine asking for another date. (153)

Evolution is about ends, not means; becoming smart is just one option. (153)

Neural tissue is metabolically greedy; our brains take up to two percent of our body weight but consume twenty percent of our energy and nutrients. (154)

The fallacy that intelligence is some exalted ambition of evolution is part of the same fallacy that treats it as a divine essence or wonder tissue or all-encompassing mathematical principle. (155)

Small cold-blooded animals like insects struggle to regulate their temperature. Their high ratio of surface area to volume makes them heat up and cool down quickly. (That's why there are no bugs outside cold months; winter is the best insecticide.) Perhaps the incipient wings of insects first evolved as adjustable solar panels, which soak up the sun's energy when it is colder out and dissipate heat when it's warmer. Using thermodynamic and aerodynamic analyses, Kingsolver and Koehl showed that proto-wings too small for flight are effective heat exchangers. The larger they grow, the more effective they become at heat regulation, though they reach a point of diminishing returns. That point is in the range of sizes in which the panels could serve as effective wings. Beyond that point, they become more and more useful for flying as they grow larger and larger, up to their present size. Natural selection could have pushed for bigger wings throughout the range from no wings to current wings, with a gradual change of function in the middle sizes. (170-171)

... a population of networks that is allowed to evolve innate connection weights often does better than a single neural network that is allowed to learn them. That is especially true for networks with multiple hidden layers, which complex animals, especially humans, surely have. If a network can only learn, not evolve, the environmental teaching signal gets diluted as it is propagated backward to the hidden layer and can only nudge the connection weights up and down by minuscule amounts. But if a population of networks can evolve, even if they cannot learn, mutations and recombinations can reprogram the hidden layers directly, and can catapult the network into a combination of innate connections that is much closer to the optimum. Innate structure is selected for. (177)

... consider a population of animals whose connections can come in three forms; innately on, innately off, or settable to on or off by learning. Mutations determine which of the three possibilities (on, off, learnable) a given connection has at the animal's birth. In an average animal in these simulations, about half the connections are learnable, the other half on or off. Learning works like this. Each animal, as it lives its life, tries out settings for the learnable connections at random until it hits upon the magic combination. In real life this might be figuring out how to catch prey or crack a nut; whatever it is, the animal senses its good fortune and retains those settings, ceasing the trial and error. From then on it enjoys a higher rate of reproduction. The earlier in life the animal acquires the right setting, the longer it will have to reproduce at the higher rate.

Now with these evolving learners, or learning evolvers, there *is* an advantage to having less than one hundred percent of the correct network. Take all the animals with ten innate connections. About one in a thousand (2^{10}) will have all ten correct. (Remember that only one in a million *non*learning animals had all twenty of its innate connections correct.) That well-endowed animal will have some probability of attaining the completely correct network by learning the other ten connections; if it has a thousand occasions to learn, success is fairly likely. The successful animal will reproduce earlier, hence more often. And amount its descendants, there are advantages to mutations that make more and more of the connections innately correct, because with more good connections to begin with, it takes less time to learn the rest, and the chances of going through life without having learned them get smaller. In Hinton and Nowland's simulations, the network thus evolved more and more innate connections. The connections never became completely innate, however. As more and more of the connections were fixed, the selection pressure to fix the remaining ones tapered off, because with only a few connections to learn, every organism was guaranteed to learn them quickly. Learning leads to the evolution of innateness, but not complete innateness. (178_179)

Our brains are about three times too big for a generic monkey or ape of our body size. The inflation is accomplished by prolonging fetal brain growth for a year after birth. If our bodies grew proportionally during that period, we would be ten feet tall and weight half a ton.

The major lobes and patches of the brain have been revamped as well. The olfactory bulbs, which underlie the sense of smell, have shriveled to a third of the expected primate size (already puny by mammalian standards), and the main cortical areas for vision and movement have shrunk proportionally as well. Within the visual system, the first stop for information, the primary visual cortex takes up a smaller proportion of the whole brain, while the later areas for complex-form processing expands, as do the temporo-parietal areas that shunt visual information to the language and conceptual regions. The areas for hearing, especially for understanding speech, have grown, and the prefrontal lobes, the seat of deliberate thought and planning, have ballooned to twice what a primate our size should have. While the brains of monkeys and apes are subtly asymmetrical, the human brain, especially in the areas devoted to language, is so lopsided that the two hemispheres can be distinguished by shape in the jar. And there have been takeovers of primate brain areas for new functions. Broca's area, involved in speech, has a homologue (evolutionary counterpart) in monkeys, but they obviously don't use it for speech, and they don't even seem to use it to produce shrieks, barks, and other calls. (183-184)

Across the mammals, carnivores have larger brains for their body size than herbivores, partly because of the greater skill it takes to subdue a rabbit than to subdue grass, and partly because meat can better feed ravenous brain tissue. (195)

The sexes come to differ less in size, suggesting that males spent less of their resources beating each other up and perhaps more on their children and the children's mothers.

The stepwise growth of the brain, propelled by hands and feet and manifested in tools, butchered bones, and increased range, is good evidence, if evidence were needed, that intelligence is a product of natural selection for exploitation of the cognitive niche. (200)

Well after Eve's day, some geneticists think, our ancestors passed through a population bottleneck. According to their scenario, which is based on the remarkable sameness of genes across modern human populations, around 65,000 years ago our ancestors dwindled to a mere ten thousand people, perhaps because of a global cooling triggered by a volcano in Sumatra. The human race was as endangered as mountain gorillas are today. The population then exploded in Africa and spun off small band that moved to other corners of the world, possibly mating now and again with other early humans in their path. Many geneticists believe that evolution is especially rapid when scattered populations exchange occasional migrants. Natural selection can quickly adapt each group to local conditions, so one or more can cope with any new challenge that arises, and their handy genes will then be imported by the neighbors. Perhaps this period saw a final flowering in the evolution of the human mind. (205)

People do not divine what is adaptive for them or their genes; their genes give them thoughts and feelings that were adaptive in the environment in which the genes were selected. (208)

The geneticist Theodosius Dobzhansky famously wrote that nothing in biology makes sense except in the light of evolution. We can add that nothing in culture makes sense except in the light of psychology. Evolution created psychology, and that is how it explains culture. The most important relic of early human is the modern mind. (210)

Vision, he [David Marr] said, "is a process that produces from images of the external world a description that is useful to the viewer and not cluttered with irrelevant information." (213)

A familiar example is the notorious red-and-green cardboard eyeglasses associated with the 3-D movie craze of the early 1950s. The left eye's image is projected in red and the right eye's image is projected in green onto a single white screen. The left eye peers at the screen through a green filter, which makes the white background look green and the green lines intended for the other eye invisible; the red lines intended for the left eye stand out as black. Similarly, the red filter over th e right eye makes the background red, the red lines invisible, and the green lines black. Each eye gets its own image, and the sludge Monster from alpha Centauri rise our of the screen. An unfortunate side effect is that when the two eyes see very different patters like the red and green backgrounds, the brain cannot fuse them. It carves the visual field into a patchwork and seesaws between seeing each patch as green or red, a disconcerting effect called binocular rivalry. You can experience a milder case by holding a finger a few inches in front of you with both eyes open gazing into the distance so you get a double image. If you pay attention to one of the double images, you will notice that portions slowly become opaque, dissolve into transparency, fill in again, and so on.

A better kind of anaglyph puts polarizing filters, rather than colored filters, over two projector lenses and in the cardboard glasses. The image intended for the left eye is projected from the left projector in light waves that oscillate in a diagonal plane, like this: /. The light can pass thorugh a filter in front of the left eye which has microscopic slits that are also in that orientation, but cannot pas through a filter in front of the right eye with slits in the opposite orientation, like this: \. conversely, the filter in front of the right eye allows in only the light coming from the right projector. The superimposed images can be in color, and they do not incite rivalry between the eyes. (223-224)

When the neurobiologists David Hubel and Torsten Wiesel raised kittens and baby monkeys with one eye covered, the input neurons of the cortex all tuned themselves to the other eye making the animal functionally blind in the eye that was covered. The damage was permanent, even with only brief deprivation, if the eye was covered in a critical period in the animal's development. In monkeys, the visual system is especially vulnerable dring the first two weeks of life, and the vulnerability tapers off during the first year. Covering the eye of an adult monkey, even for four years, does no harm.

At first this all looked like a case of "use it or lose it," but a surprise was in store. When Hubel and Wiesel covered *both* eyes, the brain did not show twice the damage; half the cells showed no damage at all. The havoc in the single-eyepatch experiment came about not because of neuron destined for the covered eye was starved of input but because the input signals from the *uncovered* eye elbowed the covered eye's inputs out of the way. The eyes compete for real estate in the input layer of the cortex. Each neuron begins with a slight bias for one eye or the other, and the input from that eye exaggerates the bias until the neuron responds to it alone. The inputs do not even have to originate in the world; waves of activation from intermediate way-stations, a kind of internally generated test pattern, can do the trick. The developmental saga, thought it is sensitive to changes in the animals' experience, is not exactly "learning," in the sense of registering information from the world. Like an architect who hands a rough sketch to a low-level draftsman to straighten out the lines, the genes build eye-specific neurons crudely and then kick off a process that is guaranteed to sharpen them unless a neurobiologist meddles. (239)

In kittens, monkeys, and human babies, the face keeps growing after birth, and the eyes get pushed farther apart. Their relative vantage points change, and the neurons must keep up by retuning the range of intereye disparities they detect. Genes cannot anticipate the degree of spreading of the vantage points, because it depends on other genes, nutrition, and various accidents. So the neurons track the drifting eyes during the window of growth. When the eyes arrive at their grownup separation in the skull, the need disappears, and that is when the critical period ends. Some animals, like rabbits, have precocious babies whose eyes are set in adult positions within faces that grow very little. (These tend to be prey animals, which don't have the luxury of a long, helpless childhood.) The neurons that receive inputs from the two eyes don't need to retune themselves, and in fact these animals are wired at birth and do without a critical period of sensitivity to the input.

The discoveries about the tunability of binocular vision in different species offers a new way of thinking about learning in general. Learning is often described as indispensable shaper of amorphous brain tissue. Instead it might be an innate adaptation to the project-scheduling demands of a self-assembling animal. The genome builds as much of the animal as it can, and for the parts of the animal that cannot be specified in advance (such as the proper wiring for two eyes that are moving apart at an unpredictable rate), the genome turns on an information-gathering mechanism at the time in development at which it is most needed. In *The Language Instinct* I develop a similar explanation for the critical period for learning language in childhood. (240-241)

A camera's meter, which controls the amount of light reaching the film, embodies two assumptions. The first is that lighting is uniform: the whole scene is in sun, or in shade, or under a lightbulb. When the assumption is violated, the snap-shooter is disappointed. Aunt Mimi is a muddy silhouette against the blue sky because the camera is fooled by her face being in the shade while the sky is lit directly by the sun. The second assumption is that the secene is, on average, medium gray. If you throw together a random collection of objects, their many colors and lightnesses will usually average out to a medium shade of gray that reflects back 18% of the light. The camera “assumes” it is looking at an average scene and lets in just enough light to make the middle of the range of lightnesses in the scene come out as medium gray on the film. Patches that are lighter than the middle are rendered pale gray and white; patches that are darker, deep gray and black. But when the assumption is wrong and the scene does not really average out to gray, the camera is fooled. A picture of a black cat on black velvet comes out medium gray, a picture of a polar bear on the snow comes out medium gray, and so on. A skilled photographer analyzes how a scene differs from the average scene and uses various tricks to compensate. A crude but effective one is to carry around a standard medium gray card (which reflects back exactly 18% of the light), lean it on the subject, and aim the meter at the card. The camera's assumption about the world is now satisfied, and its estimate of the ambient illumination level (made by dividing the light reflecting off the card by 18%) is guaranteed to be correct. (246)

Light from lightbulbs is orange; light from fluorescent is olive; light from the sun is yellow; light from the sky is blue. Our brain somehow factors out the color of the illumination, just as it factors out the intensity of the illumination, and sees an object in its correct color in all those lights. Cameras don't. Unless they send out their *own* white light from a flash, they render an indoor scene with a thick rusty cast, a shady scene as pasty blue, and so on. A knowledgeable photographer can buy special film or screw a filter on the lens to compensate, and a good lab technician can correct the color when printing the photograph, but an instant camera obviously cannot. (247)

Makeup is another example. When applied in sub-Tammy Faye Bakker amounts, pigment on the skin can fool the beholder into seeing the flesh and bone as having a more ideal shape. Dark blush on the sides of the nose makes them look as if they are at a shallower angle to the light, which makes the nose appear narrower. White powder on the upper lip works in the other way: the lip seems to intercept the light source head-on as if it were fuller, bestowing that desirable pouty look. (248-249)

Why do we see in two and a half dimensions? Why not a model in the head? The costs and benefits of storage give part of the answer. Any computer user knows that graphics files are voracious consumers of storage space. Rather than agglomerating the incoming gigabytes into a composite model, which would be obsolete as soon as anything moved, the brain lets the world itself store the information that falls outside a glance. Our heads crane, our eyes flit, and a new, up-to-date sketch is loaded in. As for the second-class status of the third dimension, it is almost inevitable. Unlike the other two dimensions, which announce themselves in the rods and cones that are currently active, depth must be painstakingly wrung out of the data. The stereo, contour, shading, and motion experts that work on computing depth are equipped to send along information about distance, slant, tilt, and occlusion relative to the viewr, not 3-D coordinates in the world, The best they can do is to pool their efforts to give us a two-and-a-half-dimensional acquaintance with the surface in front of our eyes. It's up to the rest of the brain to figure out how to use it. (261)

The coordination of the retina's frame with the inner ear's frame affects our lives in a surprising way: it causes motion sickness. Ordinarily, when you move about, two signals work in synchrony: the swoops of texture and color in the visual field, and the messages about gravity and inertia sent by the inner ear. But if you are moving inside a container like a car, a boat, or a sedan chair – evolutionarily, unprecedented ways to get around – the inner ear says, “You're moving,” but the walls and floor say, “you're staying put.” Motion sickness is triggered by this mismatch, and the standard treatments have you eliminate it: don't read; look out the window; stare at the horizon.

Many astronauts are chronically space-sick, because there *is* no gravitational signal, a rather extreme mismatch between gravity and vision. (Space-sickness is measured in *garns*, a unit named after the Republican senator from Utah, Jake garn, who parlayed his position on the NASA appropriations subcommittee into the ultimate junket, a trip into space. Space Cadet Garn made history as the all-time champion upchucker.) Worse, spacecraft interiors do not give the astronauts a world-aligned frame of reference, because the designers figure that without gravity the cencepts “floor,” “ceiling,” and “walls” are meaningless, so they might as well put instruments on all six surfaces. The astronauts, unfortunately, carry their terrestrial brains with them and literally get lost unless they stop and say to themselves, “I'm gong to pretend that thataway is 'up,' thataway is 'forward,'” and so on. It works for a while, but if they look out the window and see terra firma above them, or catch sight of a crewmate floating upside down, a wave of nausea slams them. Space sickness is a concert to NASA, and not only because of the decline in productivity during expensive flight time; you can well imagine the complications of vomiting in zero gravity. It will also affect the burgeoning technology of virtual reality, in which a person wears a wide-field helmet showing a synthetic world whizzing by. *Newsweek's* assessment: “The most barfogenic invention since the Tilt-a-Whirl. We prefer Budweiser.”

Why on earth – or space – should a mismatch between vision and gravity or inertia lead, of all things, to nausea? What does up-and-down have to do with the gut? The psychologist Michel Treisman has come up with a plausible though still unproven explanation. Animals vomit to expel toxins they have eaten before the toxins do further harm. Many naturally occurring toxins act on the nervous system. This raises the problem faced by Ingrid Bergman in *Notorious*: how do you know when you have been poisoned? Your judgment would be addled, but that would affect your judgment about whether you judgment has been addled! More generally, how could a malfunctioning detector distinguish between the brain's malfunctioning and its accurately registering an unusual situation? (Old bumper sticker: "The world is experiencing technical difficulties. Do not adjust your mind.") Gravity, of course, is the most stable, predictable feature of the world. If two parts of the brain have different opinions about it, chances are that one or both is malfunctioning or that the signals they are getting have been delayed or garbled. The rule would be: if you think gravity is acting up, you've been poisoned; jettison the rest of the poison, now. (264-266)

The psychologist Irv Biederman has fleshed out Marr's two ideas with an inventory of simple geometric parts that he calls "geons" (by analogy to the protons and electrons making up atoms). Here are five geons along with some combinations:

[picture]

Biederman proposes twenty-four geons altogether, including a cone, a megaphone, a football, a tube, a cube, and a piece of elbow macaroni. (Technically, they are all just different kinds of cones. If an ice cream cone is the surface swept out by an expanding circle as its center is moved along a line, geons are the surfaces swept out by *other* 2-D shapes as they expand or contract while moving along straight or curved lines.) Geons can be assembled into objects with a few attachment relations like "above," "beside," "end to end," "end to off-center," and "parallel." These relations are defined in a frame of reference centered on the object, of course, not the visual field; "above" means "above the main geon," not "above the fovea." so the relations stay the same when the object or viewer moves.

Geons are combinatorial, like grammar. Obviously we don't describe shapes to ourselves in words, but geon assemblies are a kind of internal language, a dialect of mentalese. Elements from a fixed vocabulary are fitted together into larger structures, like words in a phrase or sentence. A sentence is not the sum of its words but depends on their syntactic arrangement; *A man bites a dog* is not the same as *A dog bites a man*. Likewise, an object is not the sum of its geons but depends on their spatial arrangement; a cylinder with an elbow on the side is a cup, while a cylinder with an elbow at the top is a pail. And just a small number of words and rules combine into an astronomical number of sentences, a small number of geons and attachments combine into an astronomical number of objects. According to Biederman, each of the twenty-four geons comes in fifteen sizes and builds (a bit fatter, a bit skinnier), and there are eighty-one ways to join them. That allows for 10,497,600 objects build out of two geons, and 306 billion objects made of three geons. In theory, that should be more than enough to fit the tens of thousands of shapes we know. In practice, it's easy to build instantly recognizable models of everyday objects out of three, and often only two, geons.

Language and complex shapes even seem to be neighbors in the brain.

The left hemisphere is not only the seat of language but also the seat of the ability to recognize and imagine shapes defined by arrangements of parts. [...] The right hemisphere, in contrast, is good for measuring whole shapes; it can easily judge whether a rectangle is taller than it is wide or whether a dot lies more or less than an inch from an object. (270-271)

Geons are not good for everything. Many natural objects, such as mountains and trees, have complicated fractal shapes, but geons turn them into pyramids and lollipops. And though geons can be built into a passable generic human face, like a snowman or Mr. Potato head, it is almost impossible to build a model of a *particular* face – John's face, your grandmother's face – that is different enough from other faces not to confuse them, but stable enough across smiles, frowns, weight gains, and aging to identify that person every time. Many psychologists believe that face recognition is special. In a social species like ours, faces are so important that natural selection gave us a processor that registers the kinds of geometric contours and ratios needed to tell them apart. Babies lock onto facelike patters, but not onto other complex and symmetrical arrangements, when they are only thirty minutes old, and quickly learn to recognize their mothers, perhaps as early as the second day of life. (272)

Our obviousness to left-and-right stands in stark contrast to our hypersensitivity to up-and-down and front-and-back. Apparently the human mind does not have a preexisting label for the third dimension of its object-centered reference frame. When it sees a hand, it can aligh the wrist-fingertip axis with "down-up," and the back-palm axis with "backward-forward," but the direction of the pinkie-thumb axis is up for grabs. The mind calls it, say, "thumbward," and the left and right hand become mental synonyms. (277)

... mirror-image confusions come naturally to a bilaterally symmetrical animal. A perfectly symmetrical creature is logically incapable of telling left from right [...]. Natural selection had little incentive to build animals asymmetrically so that they could mentally represent shapes differently from their reflections. Actually, this puts in backwards: natural selection had every incentive to buiild animals symmetrically so that they would *not* represent shapes differently from their reflections. In the intermediate-size world in which animals spend their days (bigger than subatomic particles and organic molecules, smaller than a weather front), left and right make no difference. Objects from dandelions to mountains have tops that differ conspicuously from the bottoms, and most things that move have fronts that differ conspicuously from their behinds. But no natural object has a left side that differs nonrandomly from its right, making its mirror image version behave differently. If a predator comes from the right, next time it might come from the left. Anything learned from the first encounter should generalize to the mirror-image version. Another way of putting it is that if you took a photographic slide of any natural scene, it would be obvious if someone had turned it upside down, but you wouldn't notice if someone had flipped it left-to-right, unless the scene countained a human-made object like a car or writing.

(278)

So people use all the tricks. If a shape's sides are not too different, they store it as a 3-D geon model centered on the object's own axes. If the shape is more complicated, they store a copy of what it looks like at each orientation they see it in. When the shape appears at an unfamiliar orientation, they mentally rotate it into the nearest familiar one. Perhaps we shouldn't be surprised. Shape recognition is such a hard problem that a single, general-purpose algorithm may not work for every shape under every viewing angle. (281)

One can even make an educated guess about the anatomy of mental imagery. The incarnation of a 2½ -
D sketch in neurons is called a topographically organized cortical map: a patch of cortex in which each neuron responds to contours in one part of the visual field, and in which neighboring neurons respond to neighboring parts. The primate brain has at least fifteen of these maps, and in a very real sense they are pictures in the head. Neuroscientists can inject a monkey with a radioactive isotope of glucose while it stares at a bull's-eye. The glucose is taken up by the active neurons, and one can literally *develop the monkey's brain* as if it were a piece of film. It comes out of the darkroom with a distorted bull's-eye laid out over the visual cortex. Of course, nothing “looks at” the cortex from above; connectivity is all that matters, and the activity pattern is interpreted by networks of neurons plugged into each cortical map. Presumably space in the world is represented by space on the cortex because neurons are connected to their neighbors, and it is handy for nearby bits of the world to be analyzed together. For example, edges are not scattered across the visual field like rice but snake along a line, and most surfaces are nto archipelagos but cohesive masses. In a cortical map, lines and surfaces can be handled by neurons that are highly interconnected. (287)

... images capture the geometry of an object, not just its meaning. The surefire way of getting people to experience imagery is to ask them about obscure details of an object's shape or coloring – the beagle's ears, the curves in the B, the shade of frozen peas. When a feature is noteworthy – cats have claws, bees have stingers – we file it away as an explicit statement in our conceptual database, available later for instant lookup. But when it is not, we call up a memory of the appearance of the object and run our shape analyzers over the image. Checking for previously unnoticed geometric properties of absent objects in one of the main functions of imagery, and Kosslyn has shown that this mental process differs from dredging up explicit facts. When he asked people questions about well-rehearsed facts, like whether a cat has claws or a lobster has a tail, the speed of the answer depended on how strongly the object and its part were associated in memory. People must have retrieved the answer from a mental database. But when the questions were more unusual, like wheter a cat has a head or a lobster has a mouth, and people consulted a mental image, the speed of the answer depended on the *size* of the part; the smaller parts were slower to verify. Since size and shape are mixed together in an image, smaller shape details are harder to resolve. (292)

Wallace's paradox, the apparent evolutionary uselessness of human intelligence, is central problem of psychology, biology, and the scientific worldview. Even today, scientists such as the astronomoer Paul Davies think that the “overkill” of human intelligence refutes Darwinism and calls for some other agent of a “progressive evolutionary trend,” perhaps a self-organizing process that will be explained someday by complexity theory. Unfortunately this is barely more satisfying than Wallace's idea of a superior intelligence guiding the development of man in a definite direction. (300)

Natural selection [...] did not shape us to earn good grades in science class or to publish in refereed journals. It shaped us to master the local environment, and that led to discrepancies between how we naturally think and what is demanded in the academy. (302)

A ground rule when you solve a problem as schools is to base your reasoning on the premises mentioned in a question, ignoring everything else you know. The attitude is important in modern schooling. In the few thousand years since the emergence of civilizations, a division of labor has allowed a clas of knowledge professionals to develop methods of inference that are widely applicable and can be disseminated by writing and formal instructions. (303)

In a large society with writing and institutionalized science, the cost of an exponential number of tests is repaid by the benefit of the resulting laws to a large number of people. That is why taxpayers are willing to fund scientific research. But for the provincial interests of a single individual or even a small band, good science isn't worth the trouble. [...] Sometimes the truth is adaptive, but sometimes it is not. Conflicts of interest are inherent to the human conditions [...] and we are apt to want *our version* of the truth, rather than the truth itself, to prevail. (304-305)

Infants divide the world into the animate and the inert early in life. Three-months-olds are upset by a face that suddenly goes still but not by an object that suddenly stops moving. They try to bring objects toward them by pushing things, but try to bring people toward them by making noise. By six or seven months, babies distinguish between how hands act upon objects and how other objects act upon objects. They have opposite expectations about what makes people move and what makes objects move: objects launch each other by collisions; people start and stop on their own. By twelve months, babies interpret cartoons of moving dots as if the dots were seeking goals. For example, the babies are not surprised when a dot that hops over a barrier on its way to another dot makes a beeline after the barrier is removed. Three-year-olds describe dot cartoons much as we do, and have no trouble distinguishing things that move on their own, like animals, from things that don't, like dolls, statues, and lifelike animal figurines. (322)

We mortals can't read other people's minds directly. But we make good guesses from what they say, what we read between the lines, what they show in their faces and eyes, and what best explains their behavior. It is our species' most remarkable talent. [...] The skills behind mind reading are first exercised in the crib. Two-month-olds stare at eyes; six-month-olds know when they're staring back; one-year-olds look at what a parent is staring at, and check a parent's eyes when they are uncertain why the parent is doing something. Between eighteen and twenty-four months, children begin to separate the contents of other people's minds from their own beliefs. They show that ability off in a deceptively simple feat: pretending. When a toddler plays along with his mother who tells him the phone is ringing and hands him a banana, he is separating the contents of their pretense (the banana is a telephone) from the contents of his own belief (the banana is a banana). Two-year-olds use mental verbs like *see* and *want*, and three-year-olds use verbs like *think*, *know*, and *remember*. They know that a looker generally wants what he is looking at. And they grasp the idea of "idea." For example, they know that you can't eat the memory of an apple and that a person can tell what's in a box only by looking into it.

By four, children pass a very stringent test of knowledge about other minds: they can attribute to others beliefs they themselves know to be false. In a typical experiment, children open a Smarties box and are surprised to find pencils inside. (Smarties, the British psychologists explain to American audiences, are like M&M's, only better.) Then the children are asked what a person coming into the room expects to find. Though the children know that the box contains pencils, they sequester the knowledge, put themselves in the newcomer's shoes, and say, "Smarties." Three-year-olds have more trouble keeping their knowledge out of the picture; they insist that the newcomer will expect to find pencils in the candy box. But it's unlikely that they lack the very idea of other minds; when the wrong answer is made less alluring or the children are induced to think a bit harder, they attribute false beliefs to other's too. The results come out the same in every country in which children have been tested. (330-331)

Any selfish behavior in the natural world needs a special explanation. One explanation is reciprocation: a creature can extend help in return for help expected in the future. But favor-trading is always vulnerable to cheaters. For it to have evolved, it must be accompanied by a cognitive apparatus that remembers who has taken and that ensures that they give in return. The evolutionary biologist Robert Trivers had predicted that humans, the most conspicuous altruists in the animal kingdom, should have evolved a hypertrophied cheater-detector algorithm. (337)

Mathematics is part of our brithright. One-week-old babies perk up when a scene changes from two to three items or vice-versa. Infants in their first ten months notice how many items (up to four) are in a display, and it doesn't matter whether the items are homogeneous or heterogeneous, bunch together or spread out, dots or household objects, even whether they are objects or sounds.

According to recent experiments by the psychologist Karen Wynn, five-month-old infants even do simple arithmetic. They are shown Mickey Mouse, a screen covers him up, and a second Mickey is placed behind it. The babies expect to see two Mickeys when the screen falls and are surprised if it reveals only one. Other babies are shown two Mickeys and one is removed from behind the screen. These babies expect to see one Mickey and are surprised to find two. By eighteen months children know that numbers not only differ but fall into an order; for example, the children can be taught to choose the picture with fewer dots. Some of these abilities are found in, or can be taught to, some kinds of animals. (338)

Calculus teachers lament that students find the subjects difficult not because derivatives and integrals are abstruse concepts – they're just rate and accumulation – but because you can't do calculus unless algebraic operations are second nature, and most students enter the course without having learned the algebra properly and need to concentrate every drop of mental energy on that. Mathematics is ruthlessly cumulative, all the way back to counting to ten. (341)

Amok is a Malay word for the homicidal sprees occasionally undertaken by lonely Indochinese men who have suffered a loss of love, a loss of money, or a loss of face. The syndrome has been described in a culture even more remote from the West; the stone-age forages of Papua New Guinea. (364)

... another observation by Darwin has been corroborated; children who are blind and deaf from birth display virtually the full gamut of emotions on their faces. (366)

Ekman has shown that cultures differ the most in how the emotions are expressed in public. He secretly filmed the expressions of American and Japanese students as they watched gruesome footage of a primitive puberty rite. (Emotion researchers have extensive collections of gross-out material.) If a white-coated experimenter was in the room interviewing them, the Japanese students smiled politely during scenes that made the Americans recoil in horror. But when the subjects were alone, the Japanese and American faces were equally horrified. (369)

The Romantic movement in philosophy, literature, and art began about two hundred years ago, and since then the emotions and the intellect have been assigned to different realms. The emotions come from nature and live in the body. They are hot, irrational impulses and intuitions, which follow the imperatives of biology. The intellect comes from civilization and lives in the mind. It is a cool deliberator that follows the interests of self and society by keeping the emotions in check. [...] In this chapter I present a distinctly unromantic theory of the emotions. It combines the computation theory of mind, which says that the lifeblood of the psyche is information rather than energy, with the modern theory of evolution, which calls for reverse-engineering the complex design of biological systems. I will show that the emotions are adaptations, well-engineered software modules that work in harmony with the intellect and are indispensable to the functioning of the whole mind. The problem with the emotions is not that they are untamed forces or vestiges of our animal past; it is that they were designed to propagate copies of the genes that built them rather than to promote happiness, wisdom, or moral values. We often call an act “emotional” when it is harmful to the social group, damaging to the actor's happiness in the long run, uncontrollable and impervious to persuasion, or a product of self-delusion. Sad to say, these outcomes are not malfunctions but precisely what we would expect from well-engineered emotions. (369-370)

The emotions are another part of the mind that has been prematurely written off as nonadaptive baggage. The neuroscientist Paul MacLean took the Romantic doctrine of the emotions and translated it into a famous but incorrect theory known as the Triune Brain. He described the human cerebrum as an evolutionary palimpsest of three layers. At the bottom are the basal ganglia or Reptilian Brain, the seat of the primitive and selfish emotions driving the “Four Fs”: feeding, fighting, fleeing, and sexual behavior. Grafted onto it is the limbic system or Primitive Mammalian Brain, which is dedicated to the kinder, gentler, social emotions, like those behind parenting. Wrapped around that is the Modern Mammalian Brain, the neocortex that grew wild in human evolution and that houses the intellect. The belief that the emotions are animal legacies is also familiar from pop ethology documentaries in which snarling baboons segue into rioting soccer hooligans as the voice-over frets about whether we will rise above our instincts and stave off nuclear doom. (370-371)

And the human cerebral cortex does not ride piggyback on an ancient limbic system, or serve as the terminus of a processing stream beginning there. The systems work in tandem, integrated by many two-way connections. The amygdala, and almond-shaped organ buried in each temporal lobe, houses the main circuits that color our experience with emotions. It receives not just simple signals (such as of loud noises) from the lower stations of the brain, but abstract, complex information from the brain's highest centers. The amygdala in turn sends signals to virtually every other part of the brain, including the decision-making circuitry of the frontal lobes. (371-372)

The emotions are mechanisms that set the brain's highest-level goals. Once triggered by a propitious moment, an emotion triggers the cascade of subgoals and sub-subgoals that we call thinking and acting. Because the goals and means are woven into a multiply nested control structure of subgoals within subgoals within subgoals, no sharp line divides thinking from feeling, nor does thinking inevitably precede feeling or vice versa (notwithstanding the century of debate within psychology over which comes first). For example, fear is triggered by a signal of impending harm like a predator, a clifftop, or a spoken threat. It lights up the short-term goal of fleeing, subduing, or deflecting the danger, and gives the goal high priority, which we experience as a sense of urgency. It also lights up the long-term goals of avoiding the hazard in the future and remembering how we got out of it this time, triggered by the state we experience as relief. Most artificial intelligence researchers believe that freely behaving robots (as opposed to the ones bolted to the side of an assembly line) will have to be programmed with something like emotions merely for them to know at every moment what to do next. (373-374)

Homo sapiens is adapted to two habitats. One is the African savanna, in which most of our evolution took place. For an omnivore like our ancestors, the savanna is a hospitable place compared with other ecosystems. Deserts have little biomass because they have little water. Temperate forests lock up much of their biomass in wood. Rainforests – or, as they used to be called, jungles – place it high in the canopy, relegating omnivores on the ground to being scavengers who gather the bits that fall from above. But the savanna – grasslands dotted with clumps of trees – is rich in biomass, much of it in the flesh or large animals, because grass replenishes itself quickly when grazed. And most of the biomass is conveniently placed a meter or two from the ground. Savannas also offer expansive views, so predators, water, and paths can be spotted from afar. Its trees provide shade and an escape from carnivores.

Our second-choice habitat is the rest of the world. (375)

Language-lovers know that there is a world for every fear. Are you afraid of wine? Then you have *oenophobia*. Tremulous about train travel? You suffer from *siderodromophobia*. Having misgivings about your mother-in-law is *pentheraphobia*, and being petrified of peanut butter sticking to the roof of your mouth is *arachibutyrophobia*. And then there's Franklin Delano Roosevelt's affliction, the fear of fear itself, or *phobophobia*. (386)

The best evidence that fears are adaptations and not just bugs in the nervous system is that animals that have evolved on islands without predators lose their fear and are sitting ducks for any invader – hence the expression “dead as a dodo.” (387)

... fears can be easily conditioned only when the animal is evolutionarily prepared to make the association. (388)

There are twice as many negative emotions (fear, grief, anxiety, and so on) as positive ones, and losses are more keenly felt than equivalent gains. The tennis star Jimmy Connors once summed up the human condition: “I hate to lose more than I like to win.” The asymmetry has been confirmed in the lab by showing that people will take a bigger gamble to avoid a sure loss than to improve on a sure gain, and by showing that people's mood plummets more when imagining a loss in their lives (for example, in course grades, or in relationships with the opposite sex) than it rises when imaging an equivalent gain. The psychologist timothy Ketelaar notes that happiness tracks the effects of resources on biological fitness. As things get better, increases in fitness show diminishing returns; more food is better, but only up to a point. But as things get worse, decreases in fitness can take you out of the game; not enough food, and you're dead. There are many ways to become infinitely worse off (from an infection, starvation, getting eaten, a fall, ad infinitum) and not many ways to become vastly better off. That makes prospective losses more worthy of attention than gains; there are more things that make us unhappy than things that make us happy. (392)

Though myopic discounting remains unexplained, Schelling captures something important about its psychology when he roots the paradox of self-control in the modularity of the mind. He observes that "people behave sometimes as if they had two selves, one who wants clean lungs and long life and another who adores tobacco, or one who wants a lean body and another who wants dessert, or one who yearns to improve himself by reading Adam Smith on self-command . . . and another who would rather watch an old movie on television. The two are in continual contest for control." When the spirit is willing but the flesh is weak, such as in pondering a diet-busting dessert, we can feel two very different kinds of motives fighting within us, one responding to sights and smells, the other to doctor's advice. (396)

When an animal behaves to benefit another animal at a cost to itself, biologists call it altruism. When altruism evolves because the altruist is related to the beneficiary so the altruism-causing gene benefits itself, they call it kin selection. But when we look into psychology of the animal doing the behaving, we can give the phenomenon another name; love. [...] Many people think that the theory of the selfish gene says that "animals try to spread their genes." That misstates the fact and it misstates the theory. Animals, including most people, know nothing about genetics and care even less. People love their children not because they want to spread their genes (consciously or unconsciously) but because they can't help it. That love makes them try to keep their children warm, fed, and safe. What is selfish is not the real motives of the person but the metaphorical motives of the genes that build the person. Genes "try" to spread *themselves* by wiring animals' brains so the animals love their kind and try to keep warm, fed, and safe. (400-401)

Your toothache simply does not hurt me the way it hurts you. But genes are not imprisoned in bodies; the same gene lives in the bodies of many family members at once. The dispersed copies of a gene call to one another by endowing bodies with emotions. Love, compassion, and empathy are invisible fibers that connect genes in different bodies. They are the closest we wil ever come to feeling someone else's toothache. When a parent wishes she could take the place of a child about to undergo surgery, it is not the species or the group or her body that wants her to have that most unselfish emotion; it is her selfish genes. (401-402)

The lust for revenge is a particularly terrifying emotion. All over the world, relatives of the slain fantasize day and night about the bittersweet moment when they might avenge a life with a life and find peace at last. The emotion strikes us as primitive and dreadful because we have contracted the government to settle our scores for us. But in many societies an irresistible thirst for vengeance is one's only protection against deadly raids. Individuals may differ in the resolve with which they will suffer costs to carry out vengeance. Since that resolve is an effective deterrent only if it is advertised, it is accompanied by the emotion traditionally referred to as honor: the desire to publicly avenge even minor trespasses and insults. The hair-trigger of honor and revenge can be tuned to the degree of threat in the environment. Honor and vengeance are raised to godly virtues in societies that lie beyond the reach of law enforcement, such as remote horticulturalists and herders, the pioneers of the Wild West, street gangs, organized crime families, and entire nation-states when dealing with one another (in which case the emotion is called "patriotism"). But even with in a modern state society where it serves no purpose, the emotion of vengeance cannot easily be turned off. Most legal theories, even from the highest-minded philosophers, acknowledge that retribution is one of the legitimate goals of criminal punishment, over and above the goals of deterring potential criminals and incapacitating, deterring, and rehabilitating the offender. Enraged crime victims, long disenfranchised from the American legal system, have recently pressed for a say in plea-bargaining and sentencing decisions. (413-414)

Somewhere in this world of five billion people [six and a half, as of 2007] there lives the bestlooking, richest, smartest, funniest, kindest person who would settle for you. But your dreamboat is a needle in a haystack, and you may die single if you insist on waiting for him or her to show up. Staying single has costs, such loneliness, childlessness, and playing the dating game with all its awkward drink and dinners (and sometimes breakfasts). At some point it pays to set up house with the best person you have found so far.

But that calculation leaves your partner vulnerable. The laws of probability say that someday you will meet a more desirable person, and if you are always going for the best you can get, on that day you will dump your partner. But your partner has invested money, time, chilreading, and forgone opportunities in the relationship. If your partner was the most desirable person in the world, he or she would have nothing to worry about, because you would never want to desert. But failing that, the partner would have been foolish to enter the relationship. (417)

... we fall in love with the individual, not with the individual's qualities. (418)

Mental life often feels like a parliament within. Thoughts and feelings vie for control as if each were an agent with strategies for taking over the whole person, you. (419)

The neuroscientist Michael Gazzaniga has shown that the brain blithely weaves false explanation about tis motives. Split-brain patients have had their cerebral hemispheres surgically disconnected as a treatment for epilepsy. Language circuitry is in the left hemisphere, and the left half of the visual field is registered in the isolated right hemisphere, so the part of the split-brain person that can talk is unaware of the left half of his world. The right hemisphere is still active, though, and can carry out simple commands presented in the left visual field, like “Walk” or “Laugh.” When the paeient (actually, the patient's left hemisphere) is asked why he walked out (which we know was a response to the command presented to the right hemisphere), he ingenuously replies, “To get a Coke.” When asked why he is laughing, he says, “You guys come up and test us every month. What a way to make a living!” (422)

Everyone has heard of “reducing cognitive dissonance,” in which people invent a new opinion to resolve a contradiction in their minds. For example, a person will recall enjoying a boring task if he had agreed to recommend it to others for paltry pay. (If the person had been enticed to recommend the task for generous pay, he accurately recalls that the task was boring.) (422)

“There's one way to find out if a man is honest: ask him; if he says yes, you know he's crooked. - Mark Twain” (423)

The Woodstock Nation was not the first utopian dream to be shattered. The free-love communes of nineteenth-century America collapsed from sexual jealousy and the resentment of both sexes over the leaders' habit of accumulating young mistresses. The socialist utopias of the twentieth century became repressive empires led by men who collected Cadillacs and concubines. In anthropology, one south Sea island paradise after another has turned out to be nasty and brutish. Margaret Mead said that nonchalant sex made the Samoans satisfied and free of crime; it turned out that the boys tutored one another in rape techniques. She called the Arapesh “gentle”; they were headhunters. She said that the Tshambuli reversed our sex roles, the men wearing curls and makeup. In fact the men beat their wives, exterminated neighboring tribes, and treated homicide as a milestone in a young man's life which entitled him to wear the face paint that mead thought was so effeminate. (426-427)

Daly and wilson who proposed the alternative, believe that Freud's mistake [in Oedipal complex] was to run together two different kinds of parent-offspring conflict. Young children are in conflict with their father over access to their mother, but it is not a sexual rivalry. And older children may have a sexual conflict with their parents, especially their fathers, but it sis not a rivalry over the mother. In many spcieties fathers compete with their sons for sexual partners, explicitly or implicitly. In polygynous societies, where a man can have several wives, they might literally compete for the same women. And in most societies, polygynous or monogamous, a father must subsidize his son's quest for a wife at the expense of his other children or his own aspirations. The son may be impatient for the father to begin diverting resources to him; a still-robust father is a roadblock to his career. Filicides and parricides in most of the world are touched off by such competition. (446)

The other popular theory subverted by parent-offspring conflict is the biology-culture distinction, in which babies are a bundle of uncivilized instincts and parents socialize them into competent, well-adjusted members of society. Personality, in this conventional wisdom, is shaped in the formative years by the parenting process. Parents and children both want the children to prosper in the social milieu, and since children are in no position to shape themselves, socialization represents a confluence of their interests. (447)

Personalities differ in at least five major ways: whether a person is sociable or retiring (extroversion-introversion), whether a person worries constantly or is calm and self-satisfied (neuroticism-stability), whether the person is courteous and trusting or rude and suspicious (agreeableness-antagonism), and whether a person is daring or conforming (openness-nonopenness). (448)

Much of the variation in personality – about fifty percent – has genetic causes. Identical twins separated at birth are alike; biological siblings raised together are more alike than adopted siblings. That means that the other fifty percent must come from the parents and the home, right? Wrong! Being brought up in one home versus another accounts, at most, for *five percent* of the differences among people in personality. Identical twins separated at birth are not only similar; they are virtually as similar as identical twins raised together. Adoptive siblings in the same home are not just different; they are about as different as two children plucked from the population at random. The biggest influence that parents have on their children is at the moment of conception.

(I hasten to add that parents are unimportant only when it comes to *differences* among them and differences among their grown children. Anything that *all* normal parents do that affects all children is not measured in these studies. Young children surely need the love, protection, and tutelage of a sane parent. As the psychologist Judith Harris has put it, the studies imply only that children would turn into the same kinds of adults if you left them in their homes and social milieus but switched all the parents around.)

No one knows where the other forty-five percent of the variation comes from. Perhaps personality is shaped by unique events impinging on the growing brain: how the fetus lay in the womb, how much maternal blood it diverted, how it was squeezed during birth, whether it was dropped on its head or caught certain viruses in the early years. Perhaps personality is shaped by unique experiences, like being chased by a dog or receiving an act of kindness from a teacher. Perhaps the traits of parents and the traits of children interact in complicated ways, so that two children growing up with the same parents really have different environments. One kind of parent may reward a rambunctious child and punish a placid one; another kind of parent may do the opposite. There is no good evidence for these scenarios, and I think two others are more plausible, both of which see personality as an adaptation rooted in the divergence of interests between parents and offspring. One is the child's battle plan for competing with its siblings. [...] The other is the child's battle plan for competing in its peer group.

Judith Harris has amassed evidence that children everywhere are socialized by their peer group, not by their parents. At all ages children join various play groups, circles, gangs, packs, cliques, and salons, and they jockey for status within them. Each is a culture that absorbs some customs from the outside and generates many of its own. Children's cultural heritage – the rules of Ringolevio, the melody and lyrics of the nyah-nyah song, the belief that if you kill someone you legally have to pay for his gravestone – is passed from child to child, sometimes for thousands of years. As children grow up they graduate from group to group and eventually join adult groups. Prestige at one level gives one a leg up at the next; most significantly, the leaders of young adolescent cliques are the first date. At all ages children are driven to figure out what it takes to succeed among their peers and to give these strategies precedence over anything their parents foist on them. Weary parents know they are no match for a child's peers, and rightly obsess over the best neighborhood in which to bring their children up. Many successful people immigrated to this country as children and were not handicapped in the least by culturally inept parents who never learned the language or customs. As a researcher of language development I have always been struck by the way in which children rapidly pick up the language (especially the accent) of their peers, though they spend more time with their parents. (448-450)

Barbara Dafoe Whitehead has reviewed data showing that sex education does not succeed in its advertised function of reducing teenage pregnancies. Today's teens know all about sex and its hazards, but the girls end up pregnant anyway, quite possibly because they don't mind the idea of having babies. If the teens' parents do mind, they may have to enforce their interests by controlling the teenagers (with chaperones and curfews), not just by educating them. (451)

Sulloway analyzed biographical data from 3,894 scientists who had voiced opinions on radical scientific revolutions (such as the Copernican revolution and Darwinism), 893 members of the French National convention during the Terror of 1793 – 1794, more than seven hundred protagonists in the protestant Reformation, and the leaders of sixty-two American reform movements such as the abolition of slavery. In each of these shake-ups, later-borns were more likely to support the revolution, first-borns were more likely to be reactionary. The effects are not byproducts of family size, family attitudes, social class, or other confounding factors. When evolutionary theory was first proposed and still incendiary, later-borns were *ten times* as likely to support it as first-borns. Other alleged causes of radicalism, such as nationality and social class, have only minor effects. (Darwin himself, for example, was upper-class but later-born.) Later-born scientists are also less specialized, trying their hands in a greater number of scientific fields. (454)

Incest avoidance showcases the complicated software engineering behind our emotions for other people. We feel stronger bonds of affection to family members than to acquaintances or strangers. We clearly perceive the sexual attractiveness of family members, and even take pleasure in looking at them. But the affection and appreciation of beauty don't translate into a desire to copulate, though if the same emotions had been elicited by a nonrelative, the urge might be irresistible. (457)

The battle between the sexes is not just a skirmish in the war between unrelated individuals but is fought in a different theater, for reasons first explained by Donald Symons. "With respect to human sexuality," he wrote, "there is a female human nature and a male human nature, and these natures are extraordinarily different. . . . Men and women differ in their sexual natures because throughout the immensely long hunting and gathering phases of human evolutionary history the sexual desires and dispositions that were adaptive for either sex were for the other tickets to reproductive oblivion." (461)

Why is there sex to begin with? Lord Chesterfield noted of sex that "the pleasure is momentary, the position ridiculous, and the expense damnable." [...] The best theory, proposed by John Tooby, William Hamilton, and others, and now supported by several kinds of evidence, is that sex is a defense against parasites and pathogens (disease-causing microorganisms). (461-462)

Why do we come in *two* sexes? Why do we make one big egg and lots of little sperm, instead of two equal blobs that coalesce like mercury? It is because the cell that is to become the baby cannot be just a bag of genes; it needs the metabolic machinery of the rest of a cell. Some of that machinery, the mitochondria, has it own genes, the famous mitochondrial DNA which is so useful in dating evolutionary splits. Like all genes, the ones in mitochondria are selected to replicate ruthlessly. And that is why a cell formed by fusing two equal cells faces trouble. The mitochondria of one parent and the mitochondria of the other parent wage a ferocious war for survival inside it. Mitochondira from each parent will murder their counterparts from the other, leaving the fused cell dangerously underpowered. The genes for the rest of the cell (the ones in the nucleus) suffer from the crippling of the cell, so they evolve a way of heading off the internecine warfare. In each pair of parents, one "agrees" to unilateral disarmament. It contributes a cell that provides no metabolic machinery, just naked DNA for the new nucleus. The species reproduces by fusing a big cell that contains a half-self of genes plus all the necessary machinery with a small cell that contains a half-set of genes and nothing else. The big cell is called an egg and the small cell is called a sperm.

Once an organism has taken that first step, the specialization of its sex cells can only escalate. A sperm is small and cheap, so the organism might as well make many of them, and give them outboard motors to get to the egg quickly and an organ to launch them on their way. The egg is big and precious, so the organism had better give it a head start by packing it with food and a protective cover. That makes it more expensive still, so to protect the investment the organism evolves organs that let the fertilized egg grow inside the body and absorb even more food, and that release the new offspring only when it is large enough to survive. These structures are called male and female reproductive organs. A few animals, hermaphrodites, put both kinds of organs in every individual, but most specialize further and divide up into two kinds, each allocating all their reproductive tissue to one kind of organ or the other. They are called males and females. (462-463)

Sperm can survive in the vagina for several days, so a promiscuous female can have several males' sperm competing inside her for a chance at fertilizing the egg. The more sperm a male produces, the greater the chance that one of his will get there first. That explains why chimpanzees have enormous testicles for the body size. Bigger testes make more sperm, which have a better chance inside promiscuous females. (465)

What kind of animal is *Homo sapiens*? We are mammals, so a woman's minimum parental investment is much larger than a man's. She contributes nine months of pregnancy and (in a natural environment) two to four years of nursing. He contributes a few minutes of sex and a teaspoon of semen. Men are about 1.15 times as large as women, which tells us that they have competed in our evolutionary history, with some men mating with several women and some men mating with none. Unlike gibbons, who are isolated, monogamous, and relatively sexless, and gorillas, who are clustered, harem-forming, and relatively sexless, we are gregarious, with men and women living together in large groups and constantly facing opportunities to couple. Men have smaller testicles for their body size than chimpanzees but bigger ones than gorillas and gibbons, suggesting that ancestral women were not wantonly promiscuous but were not always monogamous either. Children are born helpless and remain dependent on adults for a large chunk of the human lifespan, presumably because knowledge and skills are so important to the human way of life. So children need parental investment, and men, because they get meat from hunting and other resources, have something to invest. Men far exceed the minimum investment that their anatomy would let them get away with: they feed, protect, and teach their children. That should make cuckoldry a concern to men, and a man's willingness and ability to invest in children a concern to women. Because men and women live together in large groups, like chimps, but the males invest in their offspring, like birds, we developed marriage, in which a man and woman form a reproductive alliance that is meant to limit demands from third parties for sexual access and parental investment.

These facts of life have never changed, but others have. Until recently, men hunted and women gathered. Women were married soon after puberty. There was no contraception, no institutionalized adoption by nonrelatives, and no artificial insemination. Sex meant reproduction and vice versa. There was no food from domesticated plants or animals, so there was no baby formula; all children were breast-fed. There was also no paid day care, and no househustands; babies and toddlers hung around with their mothers and other women. These conditions persisted through ninety-nine percent of our evolutionary history and have shaped our sexuality. Our sexual thoughts and feelings are adapted to a world in which sex led to babies, whether or not we want to make babies now. And they are adapted to a world in which children were a mother's problem more than a father's. (468)

In evolutionary terms, a man who has a short-term liaison is betting that his illegitimate child will survive without his help or is counting on a cuckolded husband to bring it up as his own. For the man who can afford it, a surer way to maximize progeny is to seek several wives and invest in all their children. Men should want many wives, not just many sex partners. And in fact, men in power have allowed polygyny in more than eighty percent of human cultures. Jews practiced it until Christian times and outlawed it only in the tenth century. Mormons encouraged it until it was outlawed by the U.S. Government in the late nineteenth century, and even today there are thought to be tens of thousands of clandestine polygynous marriages in Utah andother western states. Whenever polygyny is allowed, men seek additional wives and the means to attract them. Wealthy and prestigious men have more than one wife; ne'er-do-wells have none. Typically a man who has been married for some time seeks a younger wife. The senior wife remains his confidante and partner and runs the household; the junior one becomes his sexual interest. [...] Polyandry, by comparison, is vanishingly rare. Men occasionally share a wife in environments so harsh that a man cannot survive without a woman, but the arrangements collapses when conditions improve. Eskimos have sporadically had polyandrous marriages, but the co-husbands are always jealous and one often murders the other. As always, kinship mitigates enmity, and among Tibetan farmers two or more brothers sometimes marry a woman simultaneously in the hope of putting together a family that can survive in the bleak territory. The junior brother, though, aspires to have a wife of his own. (476-477)

What could ancestral women have gained from liaisons that would have allowed the desire [promiscuity] to evolve? One reward is resources. If men want sex for its own sake, women can make them pay for it. In foraging societies, women openly demand gifts from their lovers, usually meat. You may be offended at the thought that our foremothers gave themselves away for a steak dinner, but to foraging peoples in lean times when high-quality protein is scarce, meat is an obsession. (In *Pygmalion*, when Doolittle tries to sell his daughter Eliza to Higgins, Pickering shouts, “Have you no morals, man? Doolittle replies, “Can't afford them, Governor. Neither could you if you was as poor as me.”) From a distance it sounds like a prostitution, but to the people involved it may feel more like ordinary etiquette, much as a woman in our own society might be offended if a wealthier lover never took her out to dinner or spent money on her, though both parties would deny there is a quid pro quo. In questionnaires, female college students report that an extravagant lifestyle and a willingness to give gifts are important qualities in picking a short-term lover, though not in picking a husband. (479)

Symons' summary of the sex difference is adultery is that a woman has an affair because she feels that the man is in some way superior or complementary to her husband, and a man has an affair because the woman is not his wife. (480)

What goes into sexiness? Both sexes want a spouse who has developed normally and is free of infection. Not only is a healthy spouse vigorous, non-contagious, and more fertile, but the spouse's hereditary resistance to the local parasites will be passed on to the children. We haven't evolved stethoscopes and tongue-depressors, but an eye for beauty does some of the same things. Symmetry, an absence of deformities, cleanliness, unblemished skin, clear eyes, and intact teeth are attractive in all cultures. Orthodontists have found that a good-looking face has teeth and jaws in the optimal alignment for chewing. Luxuriant hair is always pleasing, possibly because it shows not only current health but a record of health in the years before. Malnutrition and disease weaken the hair as it grown from the scalp, leaving a fragile spot in the shaft. Long hair implies a long history of good health. (483-484)

Both sexes can feel intense jealousy at the thought of a dallying mate, but their emotions are different in two ways. Women's jealousy appears to be under the control of more sophisticated software, and they can appraise their circumstances and determine whether the man's behavior poses a threat to their ultimate interests. Men's jealousy is cruder and more easily triggered. (Once triggered, though, women's jealousy appears to be as intensely felt as men's.) In most societies, some women readily share a husband, but in no society do men readily share a wife. A woman having sex with another man is *always* a threat to the man's genetic interest, because it might fool him into working for a competitor's genes, but a man having sex with another woman is not necessarily a threat to the woman's genetic interests, because his illegitimate child is another woman's problem. It is only a threat if the man diverts investment from her and her children to the other woman and her children, either temporarily or, in the case of desertion, permanently. (488)

The word *adultery* is related to the word *adulterate* and refers to making a woman impure by introducing an improper substance. The infamous double standard, in which a married woman's philandering is punished more severely than a married man's is common in legal and moral codes in all kinds of societies. Its rationale was succinctly captured when James Boswell remarked, “There is a great difference between the offence of infidelity in a man and that of his wife,” and Samuel Johnson replied, “The difference is boundless. The man imposes no bastard on his wife.” both the married woman and her lover are commonly punishable (often by death), but the symmetry is illusory, because it is the woman's marital status, not the man's that makes it a crime, specifically, a crime against her husband. Until recently most of the world's legal systems treated adultery as a property violation or tort. The husband was entitled to damages, a refund of the bride-price, a divorce, or the right to violent revenge. Rape was an offense against the woman's husband, not against the woman. Elopement was considered an abduction of a daughter from her father. Until very recently, the rape of a woman by her husband was not a crime, or even a coherent concept:

husbands were entitled to sex with their wives. (491)

What evolutionary psychology challenges is not the goals of feminism, but parts of the modern orthodoxy about the mind that have been taken up by the intellectual establishment of feminism. One idea is that people are designed to carry out the interests of their class and sex, rather than to act out of their own beliefs and desires. A second is that the minds of children are formed by their parents, and the minds of adults are formed by language and by media images. A third is the romantic doctrine that our natural inclinations are good and that ignoble motives come from society. (492)

The archaeologist Lawrence Keely has documented that New Guineans, Australian aborigines, Pacific islanders, and Native Americans have been wracked by warfare, especially in the centuries before the pax Brittanica ended this nuisance to the colonial administrators in much of the world. In primitive warfare, mobilization was more complete, battles were more frequent, casualties higher, prisoners fewer, and weapons more damaging. War is, to put it mildly, a major selection pressure, and since it appears to have been a recurring event in our evolutionarily history, it must have shaped parts of the human psyche. [...] In foraging societies, men go to war to get or keep women – not necessarily as a conscious goal of the warriors (though often is is exactly that), but as the ultimate payoff that allowed a willingness to fight to evolve. Access to women is the limiting factor on males' reproductive success. Having two wives can double a man's children, having three wives can triple it, and so on. For a man who is not at death's door, no other resource has as much impact on evolutionary fitness. The most common spoils of tribal warfare are women. Raiders kill the men, abduct the nubile women, gang-rape them, and allocate them as wives. Chagnon discovered that Yanomamo men who had killed an enemy had three times as many wives and three times as many children as those who had not. Most young men who had killed were married; most young men who had never killed were not. The difference is not an accident of other differences between the killers and the non-killers, such as size, strength, or number of kin. Killers are held in esteem in Yanomamo villages; they attract and are ceded more wives. (510)

War, or aggression by a coalition of individuals, is rare in animal kingdom. You would think that the second-, third-, and fourth-strongest elephant seals would gang up, kill the strongest male, and divide his harem among them, but they never do. Aside from the social insects, whose unusual genetic system makes them a special case, only humans, chimpanzees, dolphins, and perhaps bonobos join up in groups of four or more to attack other males. These are some of the largest-brained species, hinting that war may require sophisticated mental machinery. (513)

The theory also predicts that men should be willing to fight collectively only if they are confident of victory and none of them knows in advance who will be injured or killed. If defeat is likely, it's pointless to fight on. And if you bear more than your share of the risk – say, if your platoonmates are eposing you to danger by looking out for their own hides – it's also pointless to fight on. These two principles shape the psychology of war. (515)

If the brain has not changed over the centuries, how can the human condition have improved? Part of the answer, I think, is that literacy, knowledge, and the exchange of ideas have undermined some kinds of exploitation. It's not that people have a well of goodness that moral exhortations can tap. It's that information can be framed in a way that makes exploiters look like hypocrites or fools. One of our baser instincts – claiming authority on a pretext of beneficence and competence – can be cunningly turned on the others. When everyone sees graphic representation of suffering, it is no longer possible to claim that no harm is being done. When a victim gives a first-person account in words the victimizer might use, it's harder to maintain that the victims are a lesser kind of being. When a speaker whose policies led to disaster, his authority can crumble. When peaceable neighbors are described, its' harder to insist that war is inevitable. When martin Luther King said, “I have a dream that one day this nation will rise up and live out the true meaning of its creed: 'We hold these truths to be self-evident, that all men are created equal,'” he made it impossible for segregationists to maintain they were patriots without looking like charlatans. (518)

The function of the arts is almost defiantly obscure, and I think there are several reasons why.

One is that the arts engage not only the psychology of aesthetics but the psychology of status. The very uselessness of art that makes it so incomprehensible to evolutionary biology makes it all too comprehensible to economics and social psychology. What better proof that you have money to spare than your being able to spend it on doodads and stunts that don't fill the belly or keep the rain out but that require precious materials, years of practice, a command of obscure texts, or intimacy with the elite? Thorstein Veblen's and Quentin Bell's analyses of taste and fashion, in which an elite's conspicuous displays of consumption, leisure, and outrage are emulated by the rabble, sending the elite off in search of new inimitable displays, nicely explain the otherwise inexplicable oddities of the arts. The grand styles of one century become tacky in the next, as we see in words that are both periods labels and terms of abuse (*gothic, mannerist, baroque, rococo*). The steadfast patrons of the arts are the aristocracy and those who want to join them. Most people would lose their taste for a musical recording if they learned it was being sold at supermarket checkout counters or on late-night television, and even th work of relatively prestigious artists, such as Pierre Auguste Renoir, draws derisive reviews when it is shown in a popular “blockbuster” museum show. The value of art is largely unrelated to aesthetics: a priceless masterpiece becomes worthless if it is found to be a forgery; soup cans and comic strips become high art when the art would says they are, and then command conspicuously wasteful prices. Modern and postmodern works are intended not to give pleasure but to confirm or confound the theories of a guild of critics and analysts, to *épater la bourgeoisie*, or to baffle the rubes in Peoria. (552)

When a rat has access to a lever that sends electrical impulses to an electrode implanted in its medial forebrain bundle, it presses the lever furiously until it drops of exhaustion, forgoing opportunities to eat, drink, and have sex. People don't yet undergo elective neurosurgery to have electrodes implanted in their pleasure centers, but they have found ways to stimulate them by other means. An obvious example is recreational drugs, which seep into the chemical junctions of the pleasure circuits. (524)

There is another way that the design of the mind can throw off fascinating but biologically functionless activities. The intellect evolved to crack the defenses of things in the natural and social world. It is made up of modules for reasoning about how objects, artifacts, living things, animals, and other human minds work [...]. There are problems in the universe other than those: where the universe came from, how physical flesh can give rise to sentient minds, why bad things happen to good people, what happens to our thoughts and feelings when we die. The mind can pose such questions but may not be equipped to answer them, even if the questions have answers. Given that the mind is a product of natural selection, it should not have a miraculous ability to commune with all truths; it should have a mere ability to solve problems that are sufficiently similar to the mundane survival challenges of our ancestors. According to a saying, if you give a boy a hammer, the whole world becomes a nail. If you give a species an elementary grasp of mechanics, biology, and psychology, the whole world becomes a machine, a jungle, and a society. I will suggest that religion and philosophy are in part the application of mental tools to problems they were not designed to solve. (525)

All neurologically normal chldren spontaneously speak and understand complex language, and the complexity of spoken vernaculars varies little across cultures and periods. In contrast, while everyone enjoys listening to music, many people cannot carry a tune, fewer can play an instrument, and those who can play need explicit training and extensive practice. (529)

I suspect that music is auditory cheesecake, an exquisite confection crafted to tickle the sensitive spots of at least six of our mental faculties. A standard piece tickles them all at one, cut we can see the ingredients in various kinds of not-quite-music that leave one or more of them out: [language, auditory scene analysis, emotional calls, habitat selection, motor control, something else]. (534)

First, laughter is noisy not because it releases pent-up psychic energy but so that others may hear it; it is a form of communication. Second, laughter is involuntary for the same reason that other emotional displays are involuntary [...]. The brain broadcasts an honest, unfakable, expensive advertisement of a mental state by transferring control from the computational systems underlying voluntary action to the low-level drivers of the body's physical plant. As with display of anger, sympathy, shame, and fear, the brain is going to some effort to convince an audience that an internal state is heartfelt rather than sham.

Laughter appears to have homologues in other primate species. The human thologist Irenaus Eibl-Eibesfeldt hears that rhythmic noise of laughter in the mobbing call that monkeys give when they gang up to threaten or attack a common enemy. Chimpanzees make a different noise that primatologists describe as laughter. It is a breathy pant made both when exhaling and when inhaling, and it sounds more like sawing wood than like the exhaled ha-ha-ha of human laughter. (There may be other kinds of chimpanzee laughter as well.) Chimps “laugh” when they tickle each other, just as children do. Tickling consists of touching vulnerable parts of the body during a mock attack. [...]

Humor is often a kind of aggression. Being laughed at is aversive and feels like an attack. Comedy often runs a slapstick and insult, and in less refined settings, including the foraging societies in which we evolved, humor can be overtly sadistic. Children often laugh hysterically when other children hurt themselves or suffer misfortune. Many reports in the literature on humor among foragers are similar. When the anthropologist Raymond Hames was living with the Ye'Kwana in the amazon rainforest, he once smacked his head on the crossbar of the entrance to a hut and crumpled to the ground, bleeding profusely and writhing in pain. The onlookers were doubled over in laughter. Not that we are all that different. Executions in England used to be occasions for the whole family to turn out and laugh at the condemned man as he was led to the gallows and hanged. In *1984*, Orwell presents a satire of popular entertainment through Winston Smith's diary that comes uncomfortably close to a typical evening in today's cinemaplexes. (546-547)

In culture after culture, people believe that the soul lives on after death, that rituals can change the phsical world and divine the truth, and that illness and misforture are caused and alleviated by spirits, ghosts, saints, fairies, angels, demons, cherubim, djinns, devils, and gods. According to polls, more than a quarter of today's Americans believe in witches, almost half believe in ghosts, half believe in the devil, half believe that the book of Genesis is literally true, sixty-nine percent believe in angels, eighty-seven percent believe that Jesus was raised from the dead, and ninety-six percent believe in a God or universal spirit. (554)

The Bible contains instructions for genocide, rape, and the destruction of families, and even the Ten commandments, read in context, prohibit murder, lying and theft only within the tribe, not against outsiders. Religions have given us stonings, witch-burnings, crusades, inquisitions, jihads, fatwas, suicide bombers, abortion-clinic gunmen, and mothers who drown their sons so they can be happily reunited in heaven. As Blaise Pascal wrote, “Men never do evil so completely and cheerfully as when they do it from religious conviction.” (555)

If you can convince your children that your soul will live on and watch over their affairs, they are less embolden to defect while you are alive. (555)

Witches are often mothers-in-law and other inconvenient people. Shamans and priests are Wizards of Oz who use special effects, from sleight-of-hand and ventriloquism to sumptuous temples and cathedrals, to convince others that they are privy to forces of power and wonder. (555)

The anthropologist Ruth Benedict first pointed out the common thread of religious practice in all cultures: religion is a technique for success. Ambrose Bierce defined *to pray* as "to ask that the laws of the universe be annulled on behalf of a single petitioner confessedly unworthy." People everywhere beseech gods and spirits for recovery from illness, for success in love or on the battlefield, and for good weather. Religion is a desperate measure that people resort to when the stakes are high and they have exhausted the usual techniques for the causation of success – medicines, strategies, courthis, and, in the case of the weather, nothing. (556)

...nonliterate peoples are not psychotic hallucinators who are unable to distinguish fantasy from reality. They know there is a humdrum world of people and objects driven by the usual laws, and find the ghosts and spirits of their belief system to be terrifying and fascinating precisely *because* they violate their own ordinary intuitions about the world.

[...] the spirits, talismans, seers, and other sacred entities are never invented out of whole cloth. People take a construct from one of the cognitive modules of Chapter 5 – an object, person, animal, natural substance, or artifact – and cross out a property or write in a new one, letting the construct keep the rest of its standard-issue traits. A tool or weapon or substance will be granted some extra causal power but otherwise is expected to behave as it did before. It lives at one place at one time, is unable to pass though solid objects, and so on. A spirit is stipulated to be exempt from one or more of the laws of biology (growing, aging, dying), physics (solidity, visibility, causation by contact), or psychology (thoughts and desires are known only through behavior). But otherwise the spirit is recognizable as a kind of person or animal. Spirits see and hear, have a memory, have beliefs and desires, act on condition is that they believe will bring about a desired effect, make decisions, and issue threats and bargains. When the elders spread religious beliefs, they never bother to spell out these defaults. No one ever says, "If the spirits promise us good weather in exchange for sacrifice, and they know we want good weather in exchange for a sacrifice, and they know we want good weather, they predict that we will make the sacrifice." They don't have to, because they know that the minds of the pupils will automatically supply these beliefs from their tacit knowledge of psychology. Believers also avoid working out the strange logical consequences of these piecemeal revisions of ordinary things. They don't pause to wonder why a god who knows our intentions has to listen to our prayers, or how a god can both see into the future and care about how we choose to act. Compared to the mind-bending ideas of moder science, religious beliefs are notable for their lack of imagination (God is a jealous man;

heaven and hell are places; souls are people who have sprouted wings). That is because religious concepts are human concepts with a few emendations that make them wondrous and a longer list of standard traits that make them sensible to our ordinary ways of knowing. (556-557)

... the demand for miracles creates a market that would-be priests compete in, and they can succeed by exploiting people's dependence on experts. (557)

The problem with religious solution was stated by Mencken when he wrote, "Theology is the effort to explain the unknowable in terms of the not worth knowing." For anyone with a persistent intellectual curiosity, religious explanations are not worth knowing because they pile equally baffling enigmas on top of the original ones. What gave *God* a mind, free will, knowledge, certainty about right and wrong? How does he infuse them into a universe that seems to run just fine according to physical laws? How does he get ghostly souls to interact with hard matter? And most perplexing of all, if the world unfolds according to a wise and merciful plan, why does it contain so much suffering? As the Yiddish expression says, If God lived on earth, people would break his windows.

Modern philosophers have tried three other solutions. One is to say that the mysterious entities are an irreducible part of the universe and to leave it at that. The universe, we would conclude, contains space, time, gravity, electromagnetism, nuclear forces, matter, energy *and consciousness* (or will, or selves, or ethics, or meaning, or all of them). "Get over it, it just does." We feel cheated because no insight has been offered, and because we know that the details of consciousness, will, and knowledge are minutely related to the physiology of the brain. The irreducibility theory leaves that coincidence.

A second approach is to deny that there is a problem. We have been misled by fuzzy thinking or by beguiling but empty idioms of language, such as the pronoun *I*. Statements about consciousness, will self, and ethics cannot be verified by mathematical proof or empirical test, so they are meaningless. But this answer leaves us incredulous, not enlightened. As Descartes observed, our own consciousness is the most indubitable thing there is. It is a datum to be explained; it cannot be defined out of existence by regulations about what we are allowed to call meaningful (to say nothing of ethical statements, such as the slavery and the Holocaust were wrong).

A third approach is to domesticate the problem by collapsing it with one we *can* solve. Consciousness is activity in layer 4 of the cortex, or the contents of short-term memory. Free will is in the anterior cingulate sulcus or the executive subroutine. Morality is kin selection and reciprocal altruism. Each suggestion of this kind, to the extent that it is correct, does solve *one* problem, but is just as surely leaves unsolved the main problem. *How* does activity in layer 4 or the cortex cause my private, pungent, tangy sensation of redness? I can imagine a creature whose layer 4 is active but who does not have the sensation of red or the sensation of anything; no law of biology rules the creature out. No account of the causal effect of the cingulate sulcus can explain how human choices are *not caused at all*, hence something we can be held responsible for. Theories of the evolution of the moral sense can explain why we condemn evil acts against ourselves and our kith and kin, but cannot explain the conviction, as unshakable as our grasp of geometry, that some acts are inherently wrong even if their net effects are neutral or beneficial to our overall well-being.

I am partial to a different solution, defended by McGinn and based on speculations by Noam Chomsky, the biologist Gunther Stent, and before them David Hume. Maybe philosophical problems are hard not because they are divine or irreducible or meaningless or workaday science, but because the mind of *Homo sapiens* lacks the cognitive equipment to solve them. We are organisms, not angels, and our minds are organs, not pipelines to the truth. Our minds evolved by natural selection to solve problems that were life-and-death matters to our ancestors, not to commune with correctness or to answer any question we are capable of asking. We cannot hold ten thousand words in short-term memory. We cannot see in ultraviolet light. We cannot mentally rotate an object in the fourth dimension. And perhaps we cannot solve conundrums like free will and sentience. (560-561)