Exploring the Minded Brain

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LECTURE I. THE MINDED BRAIN

What Is a Minded Brain?

I would like to begin this lecture by explaining that the topic of my work is the minded brain, not just any brain but the minded brain. You may wonder if by minded brain I mean the human brain, but I do not. The human brain is a minded brain, for certain, but so are, I believe, the brains of many other species though not all. Yet qualifying the brain as minded is not a trivial matter, because many brains of many creatures do not generate a mind in the proper sense. By this I mean that they probably do not generate what I regard as necessary for a normal mind: a continuous logically related sequence and concurrence of mental images of varied sensory modality oriented toward the resolution of some problem. I am not diminishing the value of plain brains without proper minds. Unminded brains can do wonderful things for the organisms they inhabit. They can help those organisms maintain life by responding in predetermined manner to the surrounding environment; they can incorporate ingredients; they can eliminate waste; they can move away from a physically and chemically hostile place or thing; they can seek physically and chemically greener pastures; they can respond to certain stimuli with a reflex. I am just drawing a distinction between minded and unminded brains.

By no means are unminded brains the hallmark of the simplest living creatures. Really simple creatures have no brains at all, minded or otherwise. Their life regulation dispenses with a nervous system altogether. Those creatures — an example is the many unicellular organisms that both surround us and live within us — form the most numerous class of living creatures in the universe, in the past as well as now. There are more *Escherichia coli* inside each one of us than there are people in the cities where we live.

Working on the minded brain, then, means working on complex organisms that like all other organisms, are equipped with an urge to maintain life, but in which the means to implement such an urge include a special kind of brain, the kind that can make mind as described above.

The minded brain is very much a part of the organism in which it lives. Its mindedness is in fact rooted in the body structure that constitutes the organism in which the brain lives. I have suggested that the body-proper, as represented in the brain, may constitute the frame of reference for the neural activities that we experience as the mind; that the very core of our organism is the ground reference for the constructions we make of the world around us and for the construction of the sense of self that is an indispensable part of our experience. I have suggested that our most refined thoughts and actions, our greatest joys and deepest sorrows, use the body as a yardstick; that the mind was first about the body and was then about many other things, real and imaginary; that our minds would not be the way they are if it were not for the continuous interplay of body and brain during evolution, during individual development, and at the current moment.

A brief summary of this situation can be made in the follow-lowing statements: (1) the human brain and the rest of the body constitute an integrated organism, brought together by means of mutually interactive biochemical and neural regulatory circuits that include endocrine, immune, and autonomic neural components; (2) the organism interacts with the surrounding environment as an ensemble: the interaction is neither of the body alone nor of the brain alone; (3) the physiological operations that we call mind rely on the ensemble; (4) the full understanding of mental phenomena should be sought in the context of an organism that is interacting with an environment. The environment continuously modifies the organism, but that environment is, in part, a product of the organism's activity itself.

I realize that it is unusual, although not unprecedented, to refer to organisms, let alone bodies, in discussions about brain and mind. It is so obvious that mind arises from the activity of neurons that neurons become the focus of interest, as if operation of the rest of the organism would be irrelevant to their function. My view is quite the opposite. Mental phenomena are based on neural events within a brain, provided that brain has been and is now interacting with its body. Relative to the brain, I believe that the body proper provides the reference content. In a curious way, pleasure and pain, whether they start in the skin or in a mental image, happen in the flesh.

We thus work, as scientists, on strange organisms indeed, the result of a bizarre combination of something very openly physical, their bodies, and something not apparently physical, their minds. Friedrich Nietzsche described this marriage, in a phrase of rare felicity, as "hybrids of plants and of ghosts." I am sympathetic toward his wording because, notwithstanding the physicality of mind, mind and body are sensibly different and their different kinds of physicality may well be honored by different words. Moreover, the word "hybrid" captures the organismic blend that I regard as so essential to the understanding of the biology of mind,

The Relation Between Mind and Brain

Let me clarify a bit more my ideas on the relation between mind and brain and make three points that I regard as especially important.

The first is that the mind is private. You may guess what is in my mind, but you will not know for certain unless I tell you, and I will not know for certain what is in your mind until you tell me.

Second, as I indicated earlier, I believe that mind requires a goal-oriented, logically informed continuous concurrence and sequence of mental images of varied sensory modalities. At first glance those images describe entities and actions, properties and relationships, both concrete and abstract, all of which pertain to the world within our organisms and outside our brains. In effect, those images describe either the state of the body-proper or the mapping of interactions between our organism and something in the environment that surrounds it.

Third, images arise from sensory maps located in specific sectors of complex brains. There are numerous lines of evidence that I cannot possibly detail here that support my statement unequivocally. Let me just review one bit of evidence that is especially relevant. Consider an experimental situation in which I would ask you to view a pattern, for instance, a cross of black lines at right angles. As you focus on it, you will form an optical image of the cross in your retina and go on to perceive the pattern. Now consider that in the same room there is also an experimental animal, say a monkey, that will be trained to look at that same cross from the same viewing angle. Finally, imagine that we will be allowed to study the brain of that animal with the appropriate histological method after he does look at that cross. We will find that in some layers of the visual cortext of the animal's brain the distribution of neuronal activity will have a pattern that in every way resembles the external pattern at which you, and I, and the monkey looked. This was shown in an experiment performed by Roger Tootell.

Now let us consider what this finding can and cannot tell us. To begin with, it can tell us about a consistency of patterns. You and I can see a pattern external to us and we can also see the same pattern within a specific brain structure. It is, incidentally, one of the brain structures in which we *expected* to encounter such a pattern, given our current knowledge of neurophysiology. The finding can also tell us that under certain experimental circumstances and for certain levels of knowledge, we can get around the barrier that the privacy of mind offers to the curious scientist. To be sure, I cannot have your experience when you see this cross, but I can learn a whole lot under experimental conditions about some of the structures and some of the biological states related to that kind of mental experience.

One thing that the finding does *not* tell us at all is the sum total of the structures and operations necessary to generate an image in the mind of the monkey or in your mind or my mind. And here we must return to the statement that motivated this digression: images arise *from* sensory maps located in specific sectors of complex brains. Note that I did not say that mental images *are* sensory maps. To say that images *arise* in or from sensory maps is neither a cop-out nor a pedantic distinction. It is, rather, the critical distinction with which I can make clear my sense of something very unclear: the relation between mind and brain. I believe that the images that constitute the mind are biological states that are, in turn, constituted by chemical and physical states within the neural tissue of a brain placed within an organism that is placed in an environment. Moreover, I know that the generation of those images holds a principled relationship to certain sectors of the brain. (For instance, visual images arise from visual sensory maps and not other maps, and visual sensory maps cannot support the generation of auditory or tactile or visceral images. This has become even more clear recently with the study of sensory processing in congenitally blind individuals.) But by no means do I know the full biological specification of the processes that allow us to construct a visual mental image or an auditory mental image. In other words, I am saying that there is a sizable gap between our current description of the physics of a mental image, in the broad sense of physics, and the description we must have if we are to talk confidently about the physical constitution and generation of that image. It should be clear that the gap that I am identifying is not to be filled by some nonphysical spook but rather by a detailed description of physics, by which I mean physics proper, chemistry, and biology. I am identifying a gap of knowledge, or rather plain ignorance, to put it in more modest terms. I am not identifying a necessarily insoluble mystery, or at least I hope I am not.

DEFINING A MATERIALIST POSITION ; AVOIDING DUALISM ; WHAT KIND OF REDUCTIONISM ?

What I need to clarify further regarding the relation between mind and brain is whether the materialist position I have just articulated means that I am reducing the mind to the brain. My answer is a firm no for a number of reasons. Mental phenomena and thus mind *are* mental phenomena and thus mind. They are also explainable in biological terms because certain biological states of high complexity constitute the class of phenomena we call mental. There is no incompatibility between the reality and particularly of mental phenomena and the fact that they are biological. But mental phenomena are not reducible to brain circuits or nerve cells, let alone to molecules, because they are not any of those things in isolation, and they are not *just* the mere collection of all those things together. Mental phenomena are biological states that occur when many brain circuits operate together according to particular designs. The plausible identity is not between mind and brain, or between mind and neurons, or circuits, or molecules. The plausible identity is between mind and complex biological states.

Even after a comprehensive materialist research program delivers all the details that I have indicated as currently missing from our accounts of the biology of mind, your experience of love or of listening to Mozart is not going to be *substituted by* the physical description of the antics of your neurons as you either love or listen. Love and listening will be *explained by* the antics of your neurons, but will remain as mental experiences, because mental experiences are the latest and greatest achievement of neuronal antics in the history of the universe.

It is important to note, then, that when we recognize mental phenomena as the highest level of biological phenomena, our position remains materialist, and that we are not endorsing dualism. The mind is the most complex aspect of biology, or to put it in slightly more precise terms, the images in the mind are constituted by the most complex biological states. Minds are part of biology, but their biological status in no way cancels out the mental properties we discover through our experience. The *res cogitum* is part of the *res extensa* rather than being something else. And the *res cogitum* remains as such rather than being eliminated.

The Appropriate Level of Study to Link Mind and Brain: The Large-scale Systems Level

For most of the history of civilization, which we can set as beginning 2,500 years ago around Plato's urbane dining table, some humans have maintained an interest in the working of their minds. On and off, especially for the last two centuries, they have even had an interest in both mind and brain. But interest, reflection, and description are one thing and exploration is another. By exploration I mean a real adventure of ideas that requires theories, hypotheses, and the scientific checking of those hypotheses by scientific experiments. In this particular sense, the explorations of the minded brain are of more recent vintage and have only begun in earnest over the past two decades, following the developments of a number of new scientific methods. They include the extension of our knowledge of biological systems to the molecular level and to genes antecedent to those molecules; the development of means to study cognitive processes rather than just behaviors; the ensuing strengthening of the available descriptions of mind; and the development of new probes for brain structure and brain function, in animals and in humans, capable of delivering measurement at the level of neurons and at the level of systems.

What we want to understand as we explore the minded brain depends largely on the operation of neurons and of the molecules that constitute them and make them fire away. We are beginning to know something about those neurons and about the genes that make those neurons develop and operate in a certain fashion. But the minded brain requires more than single neurons. It depends on overall patterns of the firing neurons, as assembled complicated networks that range from microscopic-scale circuits confined to a small brain area to macroscopic systems that span several centimeters. The complexity is immense. There are several billion neurons in the circuits of one human brain. The number of synapses formed among those neurons is at least 10 trillion. The length of the axon cables forming neuron circuits totals several hundred thousand miles. The product of activity in such circuits is a pattern of firing that is transmitted to another circuit. The time scale for the firing is extremely small, on the order of tens of milliseconds — which means that within one second in the life of our minds, the brain produces millions of firing patterns over a large variety of circuits distributed over various brain regions.

The secrets of the minded brain cannot be revealed by discovering all the mysteries of one typical single neuron or by discovering all the intricate patterns of local activity of one typical neuron circuit. The secrets of the minded brain are hiding in the interaction of firing patterns generated by many neuron circuits, locally and globally, moment by moment, within the brain of a living organism.

There is thus not one simple answer in the current explorations of the minded brain, but rather many answers, keyed to the myriad components of the nervous system at its many levels of structure. The approach to understanding those levels calls for various techniques and proceeds at various paces.

Some have asked why neuroscience has not yet achieved results as spectacular as those seen in molecular biology over the past four decades. Some have wondered what is the neuroscientific equivalent of the discovery of DNA structure, and whether or not a corresponding neuroscientific fact has been established. There is no such single correspondence, although some facts, at several levels of the nervous system, might be construed as comparable in practical value to knowing the structure of DNA — for instance, understanding the nature of an action potential. But the equivalent of DNA structure at the level of the minded brain is likely to be a large-scale outline of circuit and system designs and to involve descriptions at both microstructural and macrostructural levels.

The limits of our current neuroscientific knowledge have other justifications, to which I will return at the end of the talk. One is that only a part of our brain circuitry is specified by the genome. The human genome commands the construction of our bodies in great detail, including the overall design of the brain. But not all brain circuits end up wired and working as commanded by genes. A good part of the circuitry in each of our brains, perhaps most of it, reflects the particular history and circumstances of our organism and is thus relatively individual and unique. Each human organism operates in collectives of like beings. The mind of individuals operating in specific cultural and physical environments is not shaped merely by any kind of activity and even less is it shaped by genes alone. Social and cultural context are relevant to the shaping of the minded brain.

A successful exploration of the minded brain depends on choosing the right level of study. At the moment, the level of large-scale systems appears to be the right level to guide the study of the relation between neural processes and cognitive processes.

Examples of Advances in Cognitive Neuroscience

Virtually all of the cognitive macrofunctions, such as memory, language, and emotion, are now better understood in terms of their underlying neural systems. Numerous types of memory have been identified relative to their temporal dimension, their learning curve profile, their dependence on consciousness, their mode of access, and the form of output they require for a response. We have a sense now of the neural systems needed to learn a fact and of the learning systems needed to learn a skill. We know about systems needed for conditioning and we even know that they are independent of those required to hold on to a fact or to a skill.

Progress in the understanding of the neural basis of language has been just as remarkable and has proceeded along the same lines. Different components of language function — for instance, retrieval from the lexicon or organization of syntactic structure — depend on separable neural systems. In the most remarkable recent development in this area of study, it has become clear that even the systems that support lexical retrieval are segregated, at least in part. To invoke just one of the most dramatic examples, we rely on concerted activation of different brain regions as we search for the word with which we can denote a unique person or a manipulable tool.

Emotion is perhaps the subject about which there has been the most notable progress, though not necessarily the most abundant. The idea of understanding the neural underpinnings of emotion was neglected for a good part of the twentieth century and neuroscience has only recently approached it in earnest. But in just about a decade of new work we are gathering a rich view of the varied systems that support different kinds of emotion and feeling. Most importantly, the view of the role that emotion plays in human cognition has been changing radically. Rather than being a luxury, emotion is gradually being recognized as a fundamental function of the nervous system indispensable for biological regulation. Rather than being a hindrance to proper reasoning, emotion is now being seen as an obligate component of the mechanisms that permit efficient logical reasoning and advantageous decision-making. It is perhaps true that as research on emotion reveals a multiplicity of systems controlling mental and behavioral outputs, it is contributing powerfully to a reformulation of our views on human nature. Of necessity, our views on rationality, free will, and responsibility, though not necessarily shaken by research results, may be reconsidered and perhaps even adjusted, from the perspective afforded by new findings from the mind and brain sciences.

LECTURE II. MODERN NEUROBIOLOGY AND HUMAN VALUES

What do the facts of modern neurobiology mean for the managing of human affairs? Does it matter at all, to any but the curious, to know how varied aspects of the mind have evolved, have developed, and are currently constructed by the brain? I would say that it does.

First, I would not minimize the value of satisfying human curiosity, least of all curiosity about humanity itself. Second, I would say that modern neurobiological facts have an immediate practical value in medicine: the diagnosis and treatment of neurological and psychiatric diseases improve remarkably whenever we gather more knowledge about how the brain operates. Needless to say, the alleviation of suffering in those affected by brain disorders, directly or indirectly, is of immense value. Consider, for instance, the modern rehabilitation of patients who suffer from impairments of language or memory; the treatment of parkinsonism or of depression ; or the prospect of preventing catastrophic diseases caused by specific gene defects. Third, and no less importantly, I would say that knowing human nature more deeply and from a neurobiological perspective may be of considerable value in the understanding and management of human suffering in a wider context. I am not referring to disease in the narrow sense of the term. I am referring, rather, to the kind of personal suffering that results from the struggle for life in a complicated social and cultural environment — although I might as well refer to the pathologies of society and culture. My hope is that neurobiology can contribute to reduce suffering at that level too, and to achieve a greater realization of human potential.

Intriguingly, understanding human nature in ways that can be helpful to the resolution of human conflict — and, to put it bluntly, to the increase of human well-being — depends not just on how much we know about the ways in which the organism and its brain operate *now.* It also depends on our views of how organisms and brains came to be the way they are *now.* In short, it depends on their history in the perspective of evolution and individual development. Ideally, the evolutionary perspective should not make any difference, but in practice it does. Periodically, scientists, philosophers, and the general public revisit the issue of nature versus nurture, and the value of our knowledge of biology is indexed to the relative position one holds in the nature versus nurture debate. Worse than that, the degree to which practical interventions on the matter of human suffering and happiness are either promoted or withheld depends almost entirely on the nature/nurture position one holds. I would like to explain how I interpret the evidence currently available on this issue, and the position I hold as a result.

For most of the twentieth century, cognitive science, neuroscience, and the related philosophy of mind have not made use of an evolutionary perspective. In many respects, the instance of emotion being perhaps the most blatant, the sciences of mind and brain proceeded as if Charles Darwin never existed, as if nothing in the theory of evolution or in the grand synthesis might constrain the hypotheses, the approaches, and the explanations devised to cope with mental and neural phenomena. Recently, however, under the growing volume of evidence amassed by general biology, the tide has turned and the evolutionary perspective seems to be everywhere at once. Better late than never, one might have said just a few years ago, but now I am beginning to wonder if one should not complain about too much of a good thing, or perhaps just complain about the misuse of a good thing. My complaint would take the form of calling attention to a number of issues that emphasize the importance and value of an evolutionary perspective while suggesting where evolutionary explanations are not sufficient to account for the operations of the human brain and mind in a significant way.

THE ISSUE OF NEURAL DEVELOPMENT

The brain's circuits and the operations they perform depend on the pattern of connections among neurons and on the strength of the synapses that constitute those connections. But it is not entirely clear how the connection patterns and the synaptic strengths are set, or when they are, and for which systems, and for how long. This much seems likely: the human genome, which is the sum total of the genes in our chromosomes, does not specify the entire structure of the brain. There simply are not enough genes available to determine the precise structure and place of everything in our organisms, least of all in the brain, where billions of neurons form their synaptic contacts. The disproportion is not subtle: we come to life and carry around about 100,000 genes, but we have more than 10 trillion synapses in our brains. Moreover, the genetically induced formation of tissues is assisted by interactions among cells, within a specific environment, in which cell adhesion molecules and substrate adhesion molecules also play an important role. What happens among cells as development unfolds depends on the cells' behavior and on the environment of which they are a part, and what happens in those interactions actually controls, in part, the expression of the genes that regulate development in the first place. As far as one can tell, then, many structural specifics are determined by genes, but the genes' actions themselves are controlled by environments, large and small, and are influenced by the activity of the living organism itself, as it develops. This remains true as the organism changes continuously throughout the life span.

The practical meaning of this situation is as follows. The genome puts in place the nearly precise structure of important systems and circuits in the evolutionarily old sectors of the human brain. Those sectors include the brain stem, hypothalamus, basal forebrain, amygdaloid nuclei, and cingulate region, and we share their essence with individuals in many other species. The role of the neural devices in these brain sectors is to regulate the life process *without* the help of a minded brain. The innate patterns of activity in these circuits regulate the physiological mechanisms without which there is no survival. They do not generate mental images, although the consequences of their activity can be represented in mental images. Without these innately set circuits we would not be able to breathe, regulate our heart and lungs, balance metabolism, seek food and shelter, avoid predators, or reproduce. But there is another role for these innate circuits, a role that is usually forgotten in the discussion of models of brain and mind. The innate circuits also intervene in the development and adult activity of the evolutionary modern structures of the brain, structures such as the neocortex.

In all likelihood, as far as the evolutionarily modern brain sectors are concerned, the genome only sets the general rather than the precise arrangement of the circuits in the evolutionary modern sectors of the brain. The specifics of circuitry equivalent to the specifics that genes help set in the circuitry of older sectors such as brain stem or hypothalamus only come long after birth, as individuals develop through infancy, childhood, and adolescence and interact with the physical environment and with other individuals. The specifics come about under the influence of environmental circumstances constrained by the influence of the innately and precisely set circuits that are concerned with basic life regulation.

In short, we have evolutionarily old and genetically preset circuits that regulate body function and ensure the organism's survival, by controlling the endocrine system, immune system, viscera, and enacting drives and instincts. But those circuits also interfere with the shaping of the evolutionarily more modern and only partially preset circuits that are concerned with representing our acquired experiences, and they are far more plastic. Why should this be so?

My answer to the above question is as follows: both the records of experiences and the responses to them, if they are to be adaptive, must be evaluated and shaped by a fundamental set of organism preferences aimed at survival. Because this evaluation and shaping are vital for the continuation of the organism, genes seem to specify that the innate circuits must exert a powerful influence on virtually the entire set of circuits that can be modified by experience. In part, that influence is carried out by "modulator" neurons acting on the remainder of the circuitry. The modulator neurons are located in the brain stem and in the basal forebrain, and they are influenced by the interactions of the organism at any given moment. Modulator neurons distribute neurotransmitters such as dopamine, norepinephrine, serotonin, and acetylcholine to widespread regions of the cerebral cortex and subcortical nuclei. This arrangement can be summarized in the following statements: (1) the innate, regulatory circuits are involved in organism survival and are privy to activity in the modern sectors of the brain; (2) the value (goodness and badness) of situations is signaled to them continuously, following a process of evaluation (the evaluation can be exceedingly rapid, automatic, and nonconscious or be deliberately controlled) ; (3) the regulatory circuits express their automatic reaction to value (goodness and badness) by influencing how the rest of the brain operates. This influence begins to be exerted during development and continues in adulthood, in day-to-day operations. The influence ends up assisting the brain in achieving survival in the most efficacious way.

As we develop, the design of brain circuitries that represent our evolving body and its interaction with the world depends *both* on the activities the organism engages and on the responses of innate bioregulatory circuitries, caught in the process of reacting to such activities.

The above account underscores the inadequacy of conceiving brain, behavior, and mind in terms of nature versus nurture or genes versus experience. Our brains and our minds are not a tabula rasa when we are born. Yet neither are they fully determined. The genetic shadow is large but not complete. Genes provide for *precise* structure in one brain component and influence indirectly the determination of precise structure in another component. But the micro- and macro-environments surrounding the networks play a critical role in that determination. Thus, the to-be-determined structure is the result of three types of influence: (1) the precise structure of the regulatory sector; (2) the individual activity and circumstances related to the human and physical environment; and (3) the self-organizing pressures that arise from the sheer complexity of the system.

Since the profile of experiences of each individual is not predictable, that unpredictability has a say in circuit design, directly and indirectly, because of the varied reactions it engenders in the innate circuitries and because of the ensuing consequences of such reactions in the process of circuit shaping. Last but not least, the process never ends. Synaptic strengths can change throughout the life span, to reflect different organism experiences, and accordingly the design of brain circuits continues to change. The evolutionary modern brain circuits not only are receptive to the results of first experience, but are repeatedly pliable. They can learn from new experience.

The Limits of the Innate Bioregulatory Machinery

How much the innate bioregulatory machinery alone can ensure an organism's survival depends on the complexity of the environment and of the organism in question. From insects to mammals, there are unequivocal examples of successful coping with particular forms of environment on the basis of innate strategies, and those strategies include complex aspects of social cognition and behavior. When we consider humans, however, and the novel physical and social environments in which humans have thrived, it appears that we rely both on genetically based biological mechanisms and on suprainstinctual survival strategies that have developed in society and that are transmitted by culture. Those strategies require a minded brain, one with consciousness, reason, and willpower. Those strategies explain why human hunger, desire, and anger do not usually result in feeding frenzy, rape, and murder. Those strategies require both a healthy human organism and a long period of development in a society in which those survival strategies are actively transmitted and respected.

One task that faces neuroscientists today is to study and understand the brain structures required to learn and implement suprainstinctual regulations. This may give pause to those who see suprainstinctual regulation as purely cultural phenomena, but it should not cause any concern. I am not reducing social phenomena to biological phenomena, but rather calling attention to their powerful mutual interactions. Culture and civilization obviously arise from the behavior of biological creatures, but that behavior was generated in collectives of individuals interacting in specific environments. Culture and civilization could not have arisen from single individuals and cannot be reduced to biological mechanisms or to genetic messages. The comprehensive understanding of culture and civilization requires biology *and* the social sciences.

Human societies have produced social conventions and ethical rules over and above those that biology already provides. Those additional layers of control shape instinctual behavior so that it can be adapted flexibly to a complex and rapidly changing environment, modify it, and ensure survival in circumstances in which a "natural" response would be counterproductive, immediately or eventually. Social conventions and ethical rules preclude immediate physical or mental harm, or future losses of every kind. Such conventions and rules are transmitted by education and socialization, from generation to generation, not by genes. Yet I suspect that the neural representations of the wisdom they embody and of the means to implement that wisdom are connected indelibly to the neural representations of the innate, regulatory life processes I alluded to above. Elsewhere I have written that I see a "trail" connecting the brain that represents acquired social conventions and rules to the brain that represents innate life regulation, a trail that is made up of neuron connections, of course. For most ethical rules and social conventions, regardless of how elevated their goal, I believe that one can envision a meaningful link to simpler goals and to drives and instincts. There is a good reason why this should be so: the consequences of achieving or not achieving a rarefied social goal contribute, directly or indirectly, to survival and to the quality of that survival. More about quality of survival further on.

This is not the same thing as saying that we possess brain modules for the production of certain behavior — say, for males seeking social status or females marrying rich husbands — and even less claiming that those modules are set in place by genes. In fact, I see no need whatsoever to invoke genetic modules to carry out nature's survival intentions. I expect that such modules would actually compromise the flexibility the organism requires for future adaptations. Incidentally, the existence of free will hinges partially on the availability of a certain degree of freedom and indeterminacy in the learning, adoption, and utilization of such suprainstinctual strategies.

Human organisms come to life designed with automatic survival mechanisms. Culture then adds a set of socially permissible and desirable decision-making strategies that enhance survival and improve the quality of that survival. The human brain comes to development endowed with physiological devices to regulate metabolism, drives and instincts, and basic devices to cope with social cognition and behavior. It emerges from child development with additional layers of survival strategy, which are interwoven with those that support and implement the instinctual repertoire and both modify their use and extend their reach.

The neural mechanisms that support the suprainstinctual repertoire are similar in formal design to those governing biological drives and are constrained by them. But they require the intervention of society to develop and become whatever they become. They are related to general neurobiology and to a given culture. Out of that dual constraint, suprainstinctual survival strategies generate something unique to humans: a moral point of view that may transcend the interests of the immediate group and even the species.

BEYOND SURVIVAL

True enough, natural selection plays the lead part in evolution, and true enough, survival and reproduction are the agents of selection. But these simple facts hide other simple facts that are not unrelated and that require our consideration. For instance, side by side with the biological evolution whose information is transmitted by the genome, there is a cultural evolution, whose artifacts are transmitted by technologies as old as the printed word and as modern as the electronic media. Their influence on survival and reproduction is anything but modest.

Another fact: our biological makeup, brains and minds included, is presumed to be the result of successful adaptations to the environment obtained in the lengthy purifying process of evolution. But it is also a fact that many of the evolving organisms that led to humans, and humans in particular, are engaged in an active modification of the environment to suit their purposes. At this junction, in this room, we are indeed living on the capital of many successful adaptations to the environment, of many successful modifications of the environment, and of many mutual interactions of the former with the latter.

And yet another, perhaps most important fact: the mention of survival ignores the fact that for quite some time now — the quite some time being in the order of more than two millennia — humans have been engaged not just in surviving but in surviving well, not just in surviving well but in surviving better than before. To paraphrase Alfred North Whitehead, humans have been interested not just in maintaining life but in cultivating the art of life.

For several centuries now, humans have entered what I like to describe as the thoughtful phase of evolution. Human minds and brains can be both servants and masters of the organisms they inhabit and of the societies to which they contribute. Human brains and minds came from nature no doubt, but they can be apprentices to the sorcerer and influence nature itself. To be sure, sorcerer's apprentice is a risky role to play, but all is risky in the game of life, and not playing any role — doing just what comes naturally— is the most risky of all strategies. Besides, doing just what comes naturally can satisfy only those who are unable to imagine better worlds and better ways, those who believe they already live in the best of all possible worlds.

Needless to say, the decision to respond to the challenge of nature, the deliberate attempt to construct better worlds — worlds with less suffering, worlds with measurable increases of well-being for sentient creatures, worlds in which self-interest and the pursuit of happiness become tempered with a concern for the other — is not a direct consequence of our knowledge of neurobiology, but it can be influenced by it, positively or negatively. A view of mind as overdetermined by evolution and genes can discourage successful attempts to improve the human lot, especially when resources are scarce. On the contrary, a view of mind devoid of the constraints of evolution and genetics may foster unrealistic hopes for what cultures can achieve. The decision as to which shade of view will eventually prevail should not be a political matter. It should rest on the evidence. It is a matter of scientific and philosophic interpretation. Whatever you do with the decision is another issue, and it does involve politics. It should be clear that, at the moment, we do not have enough evidence for a definitive view, although I have indicated which view I see as likely to be correct. In spite of the uncertainty, I suspect that knowing more about the minded brain will help us find better ways for the management of human affairs.