Resuming the Enlightenment Quest

by Edward O. Wilson

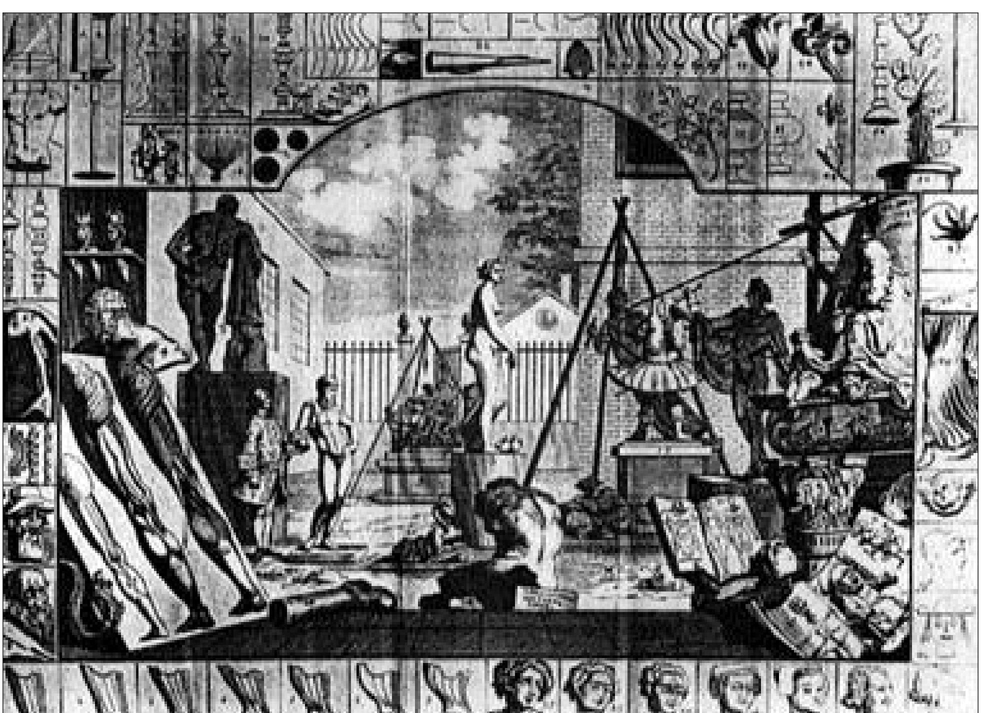
Consilience, a term introduced by the English theologian and polymath William Whewell in his 1840 masterwork *The Philosophy of the Inductive Sciences*, means the alignment (literally, the "jumping together") of knowledge from different disciplines. Exotic as its origins sound, the idea is neither an abstruse philosophical concept nor a mere plaything of intellectuals. It is the mother's milk of the natural sciences.

Since Whewell's time, physics, chemistry, and biology have been connected by a web of causal explanation organized by induction-based theories that telescope into one another. The entire known universe, from the smallest subatomic particles to the reach of the farthest known galaxies, together spanning more than 40 orders of magnitude (a magnification of one followed by more than 40 zeros), is encompassed by consilient explanation. Thus, quantum theory underlies atomic physics, which is the foundation of reagent chemistry and its specialized offshoot biochemistry, which interlock with molecular biology—essentially, the chemistry of organic macromolecules—and thence, through successively higher levels of organization, cellular, organismic, and evolutionary biology. This sequence of causal explanation proceeds step by step from more general phenomena to the increasingly complex and specific phenomena arising from them. Such is the unifying and highly productive understanding of the world that has evolved in the natural sciences. Its success testifies to a fortunate combination of three circumstances: the surprising orderliness of the universe, the possible intrinsic consilience of all knowledge concerning it, and the ingenuity of the human mind in comprehending both.

On the horizon are the social sciences and the humanities. Ever since the decline of the Enlightenment in the late 18th century—and, with it, confidence in the unity of knowledge—it has been customary to speak of these second and third great branches of learning as intellectually independent. They are separated, conventional wisdom has it, by an epistemological discontinuity, in particular by possession of different categories of truth, autonomous ways of knowing, and languages largely untranslatable into those of the natural sciences.

Now, however, the expansion of consilient cause-and-effect explanation outward from the natural sciences toward the social sciences and humanities is calling the traditional division of knowledge into question. What most of the academy still takes to be a discontinuity is starting to look like something entirely different, a broad and largely unexplored terrain of phenomena bound up with the material origins and functioning of the human brain. The study of this terrain, rooted in biology, appears increasingly available as a new foundational discipline of the social sciences and humanities. The discontinuity, it now seems, is neither an intrinsic barrier between the great branches of learning nor a Hadrian's Wall protecting humanistic studies and high culture from reductionistic barbarians, but rather a subject of extraordinary potential awaiting cooperative exploration from both sides.

At the heart of this borderland is the shifting concept of culture and its hitherto puzzling relation to human nature—and thence to the general inherited properties of individual behavior. In the spirit of the natural sciences, the matter can be expressed, I believe, as a problem to be solved. It is as follows: Compelling evidence shows that all culture is learned. But its invention and transmission are biased by innate properties of the sensory system and the brain. These developmental biases,



The Analysis of Beauty *(1753), by William Hogarth*

The Tower of Philosophy, *from* Margarita Philosophica *(1508), by Gregor Reisch, depicts a premodern ideal of intellectual unity.*

which we collectively call human nature, are themselves prescribed by genes that evolved or were sustained over hundreds of thousands of years in primarily cultural settings. Hence, genes and culture have coevolved; they are linked. What then, is the nature of gene-culture coevolution, and how has it affected the human condition today? That, in my opinion, is the central intellectual question of the social sciences and humanities. It is also one of the most important remaining problems of the natural sciences.

Confidence in the unity of knowledge—universal consilience—rests ultimately on the hypothesis that all mental activity is material in nature and occurs in a manner consistent with the causal explanations of the natural sciences. During the past several decades, that hypothesis has gained considerable support from four disciplines that succeed partially in connecting the great branches of learning. The first is cognitive neuroscience, also known as the brain sciences—the once but no longer "quiet" revolution of neuroscience—which is physically mapping the mental process. The second is human behavioral genetics, now in the early stages of teasing apart the hereditary basis of the process, including the biasing influence of the genes on mental development. The third bridging discipline is evolutionary biology (including human sociobiology, often referred to as evolutionary psychology), which attempts to reconstruct the evolution of brain and mind. The last is environmental science, which describes the physical environment to which humanity is genetically and culturally adapted.

The natural sciences are best understood as humanity's way of correctly perceiving the real world, as opposed to the way the human brain

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perceives that same world unaided by instruments and verifiable fact and theory. The brain, it is becoming increasingly clear, evolved as an instrument of survival. It did not evolve as a device to understand itself, much less the underlying principles of physics, chemistry, and biology. Under the circumstances of physical environment and culture prevailing from one generation to the next during the long haul of prehistory, natural selection built a brain that conferred the highest rates of survival and reproduction. The jury-rigged quality of our perceptual and cognitive apparatus, the legacy of genetic evolution, is part of the reason social scientists have such a hard time grappling with human nature, why so much of the history of philosophy can be fairly said to consist of failed models of the brain, and why people generally understand automobiles better than their own minds.

Consider the matter of vision. What we intuitively believe to be the "real world" is what we see. But what we see is only an infinitesimal slice of the electromagnetic spectrum, comprising wavelengths of 400 to 700 billionths of a meter. With instrumentation, we are now able to observe the remainder of the spectrum that rains down on our bodies, from gamma waves trillions of times shorter than visible light to radio waves trillions of times longer. Many animals see a part of the spectrum outside our range. Insects, for example, depend heavily on ultraviolet light at wavelengths shorter than the human visible spectrum. Color in the visible spectrum also deceives us. We intuitively think that the rainbow is a natural phenomenon existing apart from the human mind, but it is not. Its palette is a product of the way the visual system and brain break the continuously varying wavelength of sunlight into the seemingly discrete segments we call colors. Such hereditary filtering and self-deception occur in all of the other senses. And some capabilities present in other organisms are totally absent from our uninstrumented minds. We have, for example, no organs to monitor the electric fields that some species of fish use to guide themselves through dark water, or the magnetic field by which migratory birds navigate across clouded night skies.

Why are human beings, supposedly the summum bonum of creation, so handicapped? The simplest and most thoroughly verifiable answer has been provided by the natural sciences, and most particularly the borderland disciplines of cognitive neuroscience and evolutionary biology. Outside our heads there is freestanding reality. Only lunatics and a sprinkling of constructivist philosophers doubt its existence. Inside our heads is a reconstruction of reality based on sensory input and the self-assembly of symbol-based concepts. Scenarios based on these concepts, rather than an independent executive entity in the brain—the "ghost in the machine," in philosopher Gilbert Ryle's famous derogation—appear to constitute the mind. The scenarios of conscious thought move constantly back and forth through time. As these configurations fly by, driven by stimuli and drawing upon memories of prior scenarios, they are weighted and guided by emotion, which is the modification of neural activity that animates and focuses mental activity.

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Emotion, as now understood, is not something separate and distinct from thinking, as the Romantics fancied. Rather, it is an active partner of ratiocination and a crucial component of human thought. Emotion operates through physiological processes that select certain streams of information over others, shifting the body and mind to higher or lower degrees of activity, agitating the neural circuits that create scenarios, and selecting for ones that end in certain ways. The winning scenarios, those that match goals preprogrammed by instinct and the reinforcing satisfactions of prior experience, determine focus and decision.

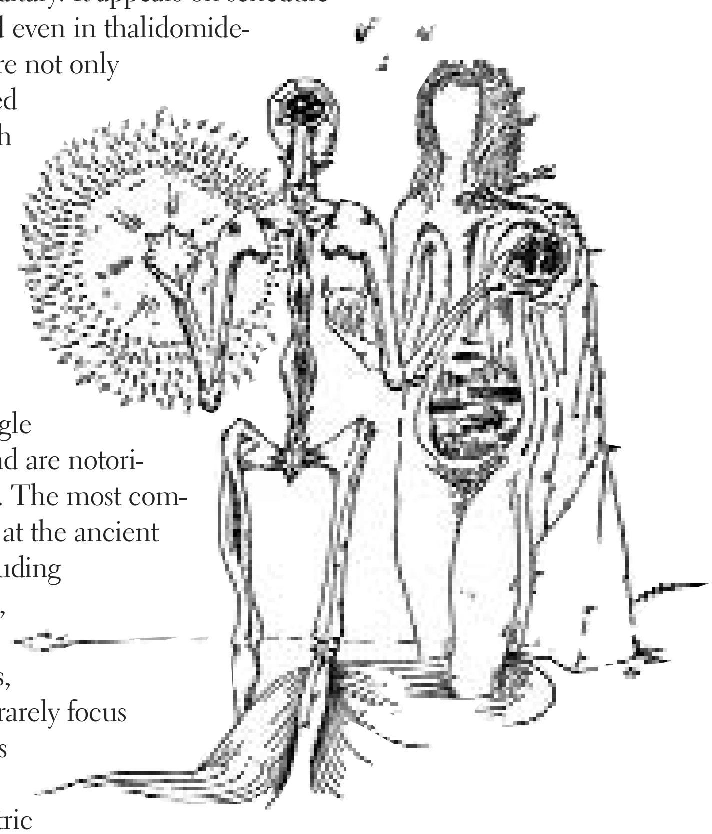
In this view, which represents a consensus of many investigators in cognitive neuroscience, what we call *meaning* is the linkage among the neural networks created by the spreading excitation that enlarges imagery and engages emotion. The competitive selection among scenarios is what we call *decision making*. The outcome, in terms of the match of the winning scenarios to instinctive or learned favorable states, sets the kind and intensity of subsequent emotion. The *self*, by virtue of the physical location of the brain in the body and the programs of emotional response, is the necessary central player in the scenarios. The persistent form and intensity of emotions is called *mood*. The ability of the brain to generate novel scenarios and settle upon the most effective among them is called *creativity*. The persistent production of scenarios lacking reality and survival value is called *insanity*.

The alignment of outer existence with its inner representation has been distorted by the idiosyncrasies of human evolution, the hundred-millennium process directed primarily by the struggle to survive rather than the pursuit of self-understanding. The brain, although a magnificent instrument, is still rooted in the deep genetic history of the Paleolithic Age, when most or all of human evolution occurred. Introspection alone cannot disclose the sensory and psychophysiological distortions it creates, which are usually beneficent but sometimes catastrophic. To diagnose and correct the misalignment is the proper task of the natural sciences and—one can reasonably hope—the social sciences and humanities as well. To explore the borderland between the great branches of learning would seem to lead to a better understanding of the human condition than the various skeptical and relativistic accounts of "socially constructed" realities supplied by intellectuals who have lost faith in the original Enlightenment quest for unified knowledge.

Much of the new understanding will hinge on an inquiry into the exact manner by which genetic evolution and cultural evolution have been joined to create the mind. The key to the linkage can be found in the properties of human nature. This diagnostic core of Homo sapiens is not the genes, which prescribe it, nor culture, which is its product. Human nature is the ensemble of epigenetic rules of mental development, the hereditary regularities in the growth of individual minds and behavior. Following are some of the examples that researchers in the natural and social sciences have identified, proceeding from the relatively simple to the complex:

- The smile, which appears in infants from the ages of two to four months, invariably evokes affection from adults and reinforces bonding between caregiver and infant. In all cultures and throughout life, smiling is used to signal friendliness, approval, and a sense of pleasure. Each culture molds its meaning into nuances determined by form and the context in which it is displayed. There is no doubt that smiling is hereditary. It appears on schedule in deaf-blind children and even in thalidomide-deformed children who are not only deaf and blind but crippled so badly they cannot touch their own faces.

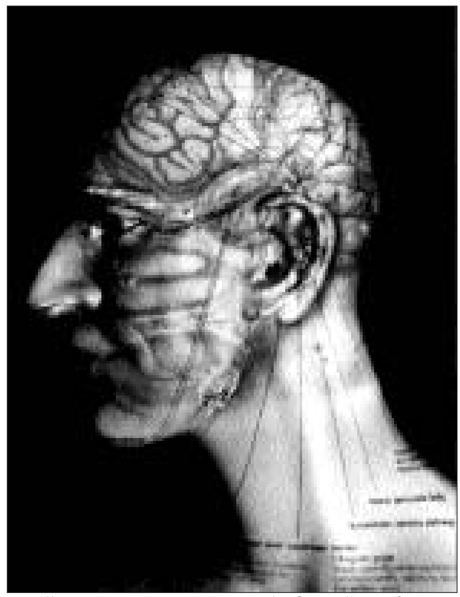
- Phobias are aversions powerful enough to engage the autonomic nervous system. They can evoke panic, cold sweat, and nausea; are easily acquired, often from a single frightening experience; and are notoriously difficult to eradicate. The most common phobias are directed at the ancient perils of humankind, including snakes, spiders, dogs (thus, wolves), heights, closed spaces, crowds of strangers, and running water. They rarely focus on the far more dangerous objects of modern life, such as automobiles, electric sockets, knives, and firearms. It is reasonable to suppose that such selective avoidance is an inherited predisposition that reflects the long history of natural selection during which the human brain formed. In other words, the ancient dangers are “remembered” in the epigenetic programs, while the modern ones have not existed long enough for aversions to them to be hereditarily installed in the same manner.



Being and Nothingness *(1941), by André Masson*

- Color vision, one of the important sensory determinants of culture, has been relatively well tracked all the way from genes to neurons. The chemistry of the three protein cone pigments of the retina, both the amino acids of which they are composed and the shapes into which the molecular chains are folded, is fully known. So is the sequence of base pairs in the genes on the X-chromosome that prescribe them, as well as the sequence of the mutations that cause color blindness, the triggering of the cone neurons by light-induced changes in the pigments, the coding used by the optic nerve to distinguish wavelength, and the pathways leading from the optic nerve cells to the higher integrating centers of the visual cortex in the rear of the brain.

By inherited molecular processes, the human sensory and nervous systems break continuously varying wavelengths of light into colors. We perceive, in proceeding from the short-wavelength end to the long-wavelength end of the spectrum, first a broad band of blue, then green, then yellow, and finally red. The array is arbitrary in an ultimately biological sense. That is, it is only one of many arrays that might have evolved over the past millions of years. But it is not arbitrary in a cultural sense. Having evolved genetically, it cannot be altered by learning or by conscious internal construction of new color codes.



"Brain/Dummy" *(1995) from* "Inside/Outside" *series, by Katherine Du Tiel*

All of culture involving color is derived ultimately from these molecular and cellular processes. Color terms independently invented by societies around the world are faithfully clustered in the least ambiguous wavelength zones of the four elementary colors. Cultures tend to avoid the ambiguous intermediate zones. Each society uses from two to 11 basic linguistic terms drawn from within the favored zones. The maximum 11 are black, white, red, yellow, green, blue, brown, purple, pink, orange, and gray. At one extreme, the Dani of New Guinea, for example, use only two of the terms, and at the other extreme, English speakers use all 11. From societies with simple classifications to those with complex classifications, the combinations of basic color terms generally grow in a hierarchical fashion, as follows:

Languages with two basic color terms distinguish black and white.

Languages with three terms have words for black, white, and red.

Languages with four terms have words for black, white, red, and either green or yellow.

Languages with five terms have words for black, white, red, green, *and* yellow.

Languages with six terms have words for black, white, red, green, yellow, and blue.

Languages with seven terms have words for black, white, red, green, yellow, blue, and brown.

No such precedence occurs among the remaining four basic colors, purple, pink, orange, and gray, when these have been added to the first seven.

If basic patterns were invented and combined at random from the 11 basic colors, the vocabularies of different societies would be drawn helter-skelter from among 2,036 mathematically possible combinations. The evidence indicates that, on the contrary, they are drawn primarily from only 22. This constraint can be reasonably interpreted as an epigenetic rule in addition to that of color vision itself. Unlike those of basic color vision, however, its genetic and neurobiological bases remain unknown.

• Incest avoidance, the focus of so many cultural conventions, also springs from a hereditary epigenetic rule. The rule is called the Westermarck effect, after the Finnish anthropologist Edward A. Westermarck, who first reported it in 1891. Recent anthropological research has refined it as follows: when a boy and girl are brought together before one or the other is 30 months of age, and then the pair are raised in proximity (they use the same potty, so to speak), they are later devoid of sexual interest in each other; indeed, the very thought of it arouses aversion. This emotional incapacity, fortified in many societies by a rational understanding of the consequence of inbreeding, has led to the cultural incest taboos—whose origins Sigmund Freud explained differently, and erroneously, as barriers against strong innate urges to commit incest. The Darwinian advantage of the epigenetic rule is overwhelming. The mortality rate among children born of incest—mating of full siblings or parents and offspring—is about twice that of outbred children, and among those who survive, genetic defects such as dwarfism, heart deformities, deaf-mutism, and severe mental retardation are 10 times more common.

Human incest avoidance is obedient to the following general rule in animals and plants: almost all species vulnerable to moderate or severe inbreeding depression use some biologically programmed method to avoid incest. Homo sapiens not only conforms to this rule but does so in the same manner as our closest evolutionary relatives. Among the apes, monkeys, and other nonhuman primates, resistance to incest consists of two barriers. In the first, young individuals of all 19 social species whose mating patterns have been studied practice the equivalent of human exogamy: before reaching full adult size, they leave the group in which they were born and join another. The second barrier is the Westermarck effect. In all species whose sexual development has been carefully studied, including marmosets and tamarins of South America, Asian macaques, baboons, and chimpanzees, adults avoid mating with individuals who were intimately known to them in early life. In as many as a third of human societies there exists in addition a third, cultural barrier: incest is proscribed due to the direct recognition that children with congenital disabilities are a frequent product of incestuous unions. Thus, the incest taboos and myths that pervade cultures everywhere appear likely to have arisen from the Westermarck effect, but also, in a minority of societies, from a direct perception of the destructive effects of inbreeding.

Epigenetic rules, the true combinatorial elements of human nature, evidently shape the development of mind and social interaction through most, if not all, categories of behavior. While the full causal sequences into which the rules fit, which run from genes to cells to sensory organs to behavior to culture, are still poorly understood, they appear clearly to be the key link between the evolution of genes and the evolution of culture.

The process of gene-culture coevolution itself is also still in an early stage of research, but a broad outline of the process in theory is possible. I believe the following account represents a consensus of the small number of investigators working on the subject.

Culture is created by the communal mind, this view holds, and each mind in turn is the product of the genetically structured human sensory system and brain. Genes and culture are therefore inseparably linked. But the linkage is flexible, to a degree still mostly unmeasured. The linkage is also tortuous: genes prescribe epigenetic rules, which are the inherited neural pathways and regularities in cognitive development by which the mind assembles itself. The mind grows by learning those parts of the environment and surrounding culture available to it. Mental development is a selective absorption process, one that is unavoidably biased by the epigenetic rules.

As part of gene-culture coevolution, culture is reconstructed collectively in the minds of individuals each generation. When oral tradition is supplemented by writing and the arts, it can grow indefinitely large (example: five million patents to the present time in the United States alone), and it can even skip generations. But the biasing influence of the epigenetic rules, being genetic and ineradicable, remains the same across all societies and generations.

The epigenetic rules nevertheless vary genetically in degree among individuals within populations. Some individuals have always inherited epigenetic rules in different strengths from others, degrees of expression which, in past evolutionary time at least, enabled them to survive and reproduce better in the surrounding environment and culture. By this means, over many generations, the more successful epigenetic rules spread, along with the genes that prescribe them. As a consequence, the human species has evolved by natural selection in the developmental biases of mind and behavior, hence in human nature, just as it has in the anatomy and physiology of the body.

To outline the theory of the coevolution of genes and culture in this way is not to claim that particular forms of culture are genetically determined. Certain cultural norms can survive and reproduce better than others, even when guided by exactly the same epigenetic biases as competing norms, causing culture to evolve in a track parallel to and usually much faster than genetic evolution. The quicker the pace of cultural evolution, the weaker the connection between genes and culture, although the connection is never completely broken. Culture allows a rapid adjustment to changes in the environment by finely tuned adaptations invented and transmitted without correspondingly precise, matching genetic prescription. In this respect, human beings differ fundamentally from all other animal species. Particular cultures can also be maladaptive in the long term, causing the destruction of individuals and societies that contrived them. But the linkage between genes and culture is unbreakable; culture can never have a life entirely on its own. Nor, I believe, should we

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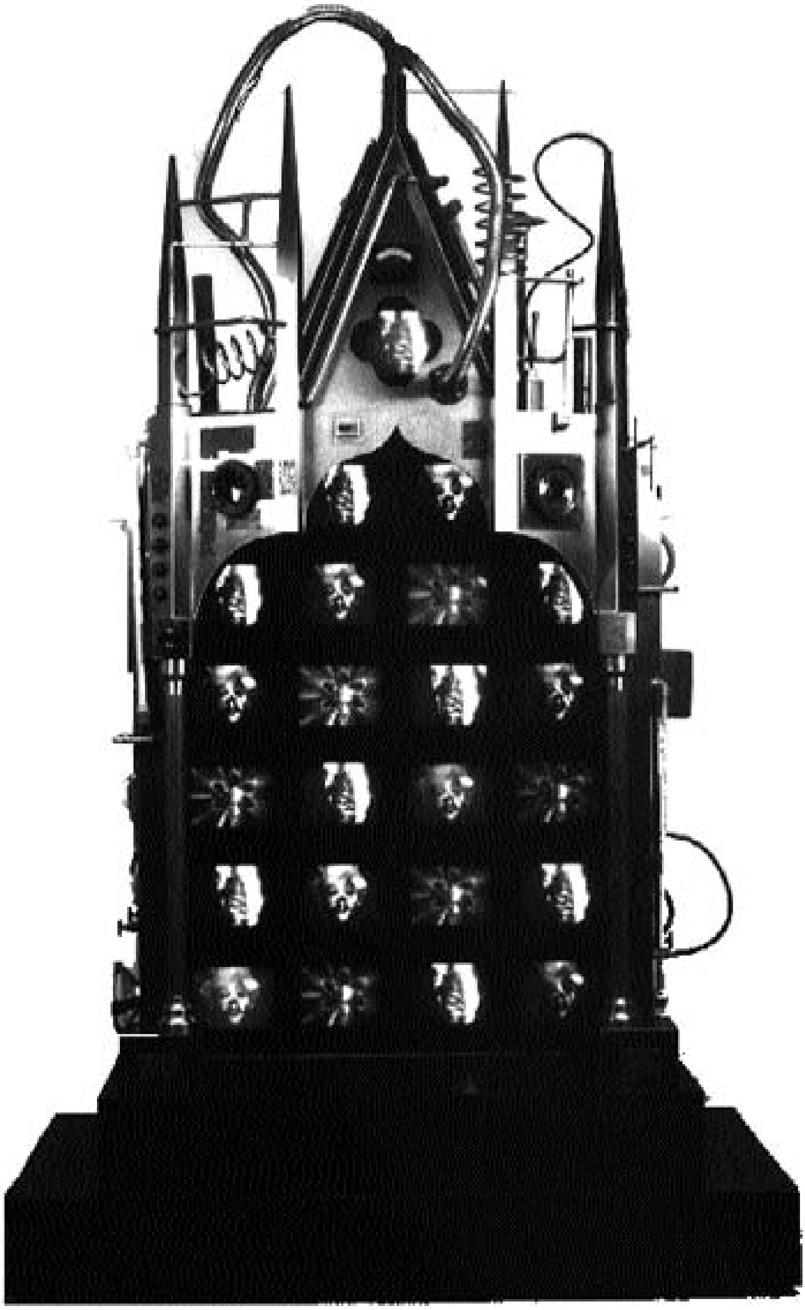
wish it otherwise. Human nature is what defines our species and binds it together.

The consilient view of the human condition that I have outlined only briefly here, and which I elaborate in *Consilience: The Unity of Knowledge*, is predicated on the well-supported assumption that Homo sapiens is a biological species, having evolved for the most part in the same manner as the remainder of life, and conservatively enough that the humanity-defining traits of language and culture retain a residue of their deeper, genetic history. While still very sketchy in detail, the emerging factual picture of the epigenetic rules lends support to consilience and, for the time being at least, to the theory of gene-culture coevolution. It also suggests in broad outline an important part of the terrain between the great branches of learning that can be fruitfully explored.

Such an extension of consilient explanation from the natural sciences to the social sciences and humanities may be faulted as reductionistic, and for that reason unsuited to the hypercomplex realities of human social life. But reductionism is the driving wedge of the natural sciences, by which they have already broken apart many hypercomplex systems. Reductionistic analysis typically proceeds from more complex and specific phenomena and the disciplines addressing them to underlying phenomena that are less complex and specific. For example, the living cell has been opened to clear view by biochemistry and molecular biology, and mental processes are beginning to yield to cellular biology and neurophysiology. Both are among the hypercomplex phenomena that have so far proved congenial to consilient explanation, and both are directly relevant to human social behavior. There is no obvious reason why the social sciences and humanities, except by degree of their specificity and complexity (and, granted, these are important distinctions), should prove resistant to the same approach.

Moreover, the scientific method is equally concerned with synthesis, and thereby holism. The most successful research has always been cyclical. It begins with the description of a complex entity or process. It proceeds by reduction to the main components, then reassembly of the components in vitro or by abstract modeling to the original whole, followed by correction through testing, further reduction, and reassembly. And so on around, until understanding is considered satisfactory by even the most demanding critics.

It may be further argued that attempts at such an extension are merely a return to the failed program of logical positivism, a variation on general positivism that attempted to define the essence of scientific statements by means of rigorous logic and the analysis of language. But logical



Technology *(1991), by Nam June Paik*

positivism, whose influence peaked among philosophers from the 1920s to the early 1940s, lacked cognitive neuroscience, human genetics, evolutionary biology, and environmental science. None of these bridging disciplines were mature enough to shed light on the linkage between biology and culture. Logical positivism was also argued from the top down in a largely abstract framework. That is, its proponents set out to identify freestanding criteria against which scientific knowledge can be judged. Every symbol, they argued, should denote something real. It should be consistent with the total structure of established facts and theories, with no revelations or free-flight generalizing allowed. Theory must follow in lockstep with facts, during which process the informational content of language is carefully distinguished from its emotional content. Finally, verification, the logical positivists argued, is all-important; scientific statements should clearly imply the methods and reasoning used to verify the conclusions drawn. If these guidelines are progressively refined and followed, they concluded, we can hope to close in on objective truth.

The fatal flaw in logical positivism was in the semantic linchpin of the system: its creators and followers could not agree on the basic distinctions between fact and concept, between generalization and mathematical truth, or between theory and speculation. Stalled by the combination of these fog-shrouded dichotomies, they were unable to arrive at an invariant and fundamental difference between scientific and nonscientific statements.

The shortcoming of logical positivism was ignorance of how the brain works, and why. That, in my opinion, is the whole story. Neither philosophers nor scientists who attacked the problem could explain the physical acts of observation and reasoning in other than highly subjective terms. None could track material phenomena of the outer world through the labyrinth of causal processes in the inner mental world, and thus precisely map outer material phenomena onto the inner material phenomena of conscious activity. But there is every reason to suppose that such a feat can be accomplished. Such is the means by which symbols and concepts might in time be exactly defined, and objective truth more precisely triangulated.

In short, the canonical criterion of objective truth so ardently sought by the logical positivists is not a philosophical problem, and it cannot be attained, as many had expected, by logical and semantical analysis. It is an empirical problem solvable only by a continuing investigation of the physical basis of the mind itself. In time, like so many philosophical searches of the past, it will be transformed into the description of a material process.

Meanwhile, the search for universal consilience begun in the Enlightenment is gaining in factual substance. The borderland domain between the great branches of learning appears at last to be coming into focus. If successful, its exploration offers the prospect of a full disciplinary foundation of the social sciences, by extending analysis to the deeper levels of biological organization that underlie human behavior and the origins of culture. By this means, I believe, can the social sciences expect to create a true and more powerful body of theory. Through similar explanatory connections to the natural sciences, the exploration of aesthetics and the creative process offers a comparable foundation for interpretation of the arts. And not least, consilient explanation will shed much-needed new light on the material origins of ethical precepts and religious belief.