

ence, and science part of it. Interpretation will be the more powerful when braided together from history, biography, personal confession—and science.

The profane word now having been spoken on hallowed ground, a quick disclaimer is in order. While it is true that science advances by reducing phenomena to their working elements—by dissecting brains into neurons, for example, and neurons into molecules—it does not aim to diminish the integrity of the whole. On the contrary, synthesis of the elements to re-create their original assembly is the other half of scientific procedure. In fact, it is the ultimate goal of science.

Nor is there any reason to suppose that the arts will decline as science flourishes. They are not, as suggested recently by the distinguished literary critic George Steiner, in a twilight, past high noon in Western civilization, thus unlikely to witness the reappearance of a Dante, a Michelangelo, or a Mozart. I can conceive of no intrinsic limit to future originality and brilliance in the arts as the consequence of the reductionist understanding of the creative process in the arts and science. On the contrary, an alliance is overdue, and can be achieved through the medium of interpretation. Neither science nor the arts can be complete without combining their separate strengths. Science needs the intuition and metaphorical power of the arts, and the arts need the fresh blood of science.

Scholars in the humanities should lift the anathema placed on reductionism. Scientists are not conquistadors out to melt the Inca gold. Science is free and the arts are free, and as I argued in the earlier account of mind, the two domains, despite the similarities in their creative spirit, have radically different goals and methods. The key to the exchange between them is not hybridization, not some unpleasantly self-conscious form of scientific art or artistic science, but reinvigoration of interpretation with the knowledge of science and its proprietary sense of the future. Interpretation is the logical channel of consilient explanation between science and the arts.

FOR A PROMISING EXAMPLE out of many that might be chosen, consider the episode in *Paradise Lost*—Book IV, when, in a riveting narrative, Milton sends Satan to Eden. Upon arrival the arch-felon and grand thief leaps a barrier of impenetrable bramble and a high wall and settles “like a cormorant” in the branches of the Tree of Life. He waits for the fall of night, when he can enter the dreams of innocent Eve. Milton now unleashes his imaginative powers to tell us what humanity is about to lose. All around the roosting schemer is the environment designed by God to aesthetic perfec-

CHAPTER 10

THE ARTS AND THEIR INTERPRETATION

IN MANY RESPECTS, the most interesting challenge to consilient explanation is the transit from science to the arts. By the latter I mean the creative arts, the personal productions of literature, visual arts, drama, music, and dance marked by those qualities which for lack of better words (and better words may never be coined) we call the true and beautiful.

The arts are sometimes taken to mean all the humanities, which include not only the creative arts but also, following the recommendations of the 1979–80 Commission on the Humanities, the core subjects of history, philosophy, languages, and comparative literature, plus jurisprudence, the comparative study of religions, and “those aspects of the social sciences which have humanistic content and employ humanistic methods.” Nevertheless, the arts in the primary and intuitively creative sense, *ars gratia artis*, remain the definition most widely and usefully employed.

Reflection leads us to two questions about the arts: where they come from, in both history and personal experience, and how their essential qualities of truth and beauty are to be described through ordinary language. These matters are the central concern of interpretation, the scholarly analysis and criticism of the arts. Interpretation is itself partly an art, since it expresses not just the factual expertise of the critic but also his character and aesthetic judgment. When of high quality, criticism can be as inspired and idiosyncratic as the work it addresses. Further, as I now hope to show, it can also be part of sci-

tion: "Crisped brooks, rolling on orient pearl and sands of gold" descend to "a lake, that to the fringed bank with myrtle crowned her crystal mirror holds." All through the blessed oasis grow "flowers of all hue and without thorn the rose."

Milton, though now blind, has retained a fine sense of biophilia, the innate pleasure from living abundance and diversity, particularly as manifested by the human impulse to imitate Nature with gardens. But he is far from satisfied with the mere dream of natural harmony. In eight lines of astonishing symphonic power he tries to capture the mythic core of paradise:

Not that fair field

Of Enna, where Proserpin gathering flowers,

Herself a fairer flower, by gloomy Dis

Was gathered, which cost Ceres all that pain

To seek her through the world, nor that sweet grove

Of Daphne, by Orontes and the inspired

Castalian spring, might with this Paradise

Of Eden strive.

How can anyone hope to express Creation's heart at the dawn of time? Milton tries. He summons archetypes that have descended undiminished from ancient Greece and Rome to his own time, and thereafter to ours. They are of a kind, as I will suggest later, that are also innate to the human mental process. He shadows beauty with a hint of tragedy, giving us the untrammeled and fertile world awaiting corruption. He transforms the beauty of the garden into that of a young woman, Proserpine, about to be seized and taken away to the underworld by the god Dis. She, as Nature's beauty, will be concealed in darkness because of conflict between gods. Ceres, Proserpine's mother and goddess of agriculture, turns in grief from her duties and the world plunges into famine. The passion of Apollo for beautiful Daphne is unrequited; in order to escape she turns into a tree, a laurel, in a garden of her own.

Milton means to play on the emotions of readers of his own time, the seventeenth century, when Hellenic mythology was second nature to the educated mind. He counterposes emotions to magnify their force. Beauty clashes with darkness, freedom with fate, passion with denial. Building tension, he leads us through lesser paradises to arrive, suddenly, at the mystical prototype of Eden. In yet another well-grounded artifice, reliance on authority, Milton chooses allusions not to his own time, not for example to

Cromwell and Charles II and the Restoration, from which he himself has narrowly escaped death (he had championed revolution and the Commonwealth), but to ancient texts of another civilization, ancient Greece and Rome, robust enough to have survived in remembrance across centuries. He conveys by their use that what we are not told, we must know nevertheless to be true.

The defining quality of the arts is the expression of the human condition by mood and feeling, calling into play all the senses, evoking both order and disorder. From where then does the ability to create art arise? Not cold logic based on fact. Not God's guidance of Milton's thoughts, as the poet himself believed. Nor is there any evidence of a unique spark that ignites such genius as is evident in *Paradise Lost*. Experiments using brain imaging, for example, have failed to disclose singular neurobiological traits in musically gifted people. Instead, they show engagement of a broader area of the same parts of the brain used by those less able. History supports this incremental hypothesis. Behind Shakespeare, Leonardo, Mozart, and others in the foremost rank are a vast legion whose realized powers form a descending continuum to those who are merely competent. What the masters of the Western canon, and those of other high cultures, possessed in common was a combination of exceptional knowledge, technical skill, originality, sensitivity to detail, ambition, boldness, and drive.

They were obsessed; they burned within. But they also had an intuitive grasp of inborn human nature accurate enough to select commanding images from the mostly inferior thoughts that stream through the minds of all of us. The talent they wielded may have been only incrementally greater, but their creations appeared to others to be qualitatively new. They acquired enough influence and longevity to translate into lasting fame, not by magic, not by divine benefaction, but by a quantitative edge in powers shared in smaller degree with those less gifted. They gathered enough lifting speed to soar above the rest.

Artistic inspiration common to everyone in varying degree rises from the artesian wells of human nature. Its creations are meant to be delivered directly to the sensibilities of the beholder without analytic explanation. Creativity is therefore humanistic in the fullest sense. Works of enduring value are those truest to these origins. It follows that even the greatest works of art might be understood fundamentally with knowledge of the biologically evolved epigenetic rules that guided them.

THIS IS NOT the prevailing view of the arts. Academic theorists have paid little attention to biology; consilience is not in their vocabulary. To varying degrees they have been more influenced by postmodernism, the competing hypothesis that denies the existence of a universal human nature. Applied to literary criticism, the extreme manifestation of postmodernism is the deconstructive philosophy formulated most provocatively by Jacques Derrida and Paul de Man. In this view, truth is relative and personal. Each person creates his own inner world by acceptance or rejection of endlessly shifting linguistic signs. There is no privileged point, no lodestar, to guide literary intelligence. And given that science is just another way of looking at the world, there is no scientifically constructible map of human nature from which the deep meaning of texts can be drawn. There is only unlimited opportunity for the reader to invent interpretations and commentaries out of the world he himself constructs. "The author is dead" is a favorite maxim of the deconstructionists.

Deconstructionist scholars search instead for contradictions and ambiguities. They conceive and analyze what is left out by the author. The missing elements allow for personalized commentary in the postmodernist style. Postmodernists who add political ideology to the mix also regard the traditional literary canon as little more than a collection confirming the world view of ruling groups, and in particular that of Western white males.

The postmodernist hypothesis does not conform well to the evidence. It is blissfully free of existing information on how the mind works. Yet there is surely *some* reason for the popularity of postmodernism other than a love of chaos. If the competing biological approach is correct, its widespread appeal must be rooted in human nature. Postmodernism in the arts is more than a School of Resentment—Harold Bloom's indictment in *The Western Canon*—and more than the eunuch's spite, to borrow a phrase from Alexander Pope, and it is sustained by more than the pathetic reverence commonly given Gallic obscurantism by American academics. There is also a surge of revolutionary spirit in postmodernism, generated by the real—not deconstructed—fact that large segments of the population, most notably women, have unique talents and emotional lives that have been relatively neglected for centuries, and are only now beginning to find full expression within the mainstream culture.

If we are to believe evidence from the biological and behavioral sciences gathered especially during the past quarter century, women differ genetically from men in ways other than reproductive anatomy. In aggregate, on average, with wide statistical overlap, and in many venues of social experience, they

speak with a different voice. Today it is being heard loud and clear. But I do not read the welcome triumph of feminism, social, economic, and creative, as a brief for postmodernism. The advance, while opening new avenues of expression and liberating deep pools of talent, has not exploded human nature into little pieces. Instead, it has set the stage for a fuller exploration of the universal traits that unite humanity.

Looked at with a different perspective, postmodernism can also be viewed as one extreme in an historical oscillation in literary world view. The great American critic Edmund Wilson noted, in 1926, that Western literature seems "obliged to vibrate" in emphasis between the two poles of neoclassicism and romanticism. Conceived very broadly, the cycle can first be picked up in the Enlightenment with Pope, Racine, and other poets who drew on the scientists' vision of an orderly world. They were replaced in public esteem by the rebellious romantic poets of the nineteenth century, who yielded in turn to Flaubert and others returning to rational order, who gave way to a flow in the opposite direction as embodied in the modernist writings of the French Symbolists, including Mallarmé and Valéry, and of their British peers Yeats, Joyce, and Eliot. Because each of the extremes proved ultimately "unbearable" as a reigning fashion, Wilson said, it guaranteed reversion toward the opposite pole.

The same mood swing can be seen in recent, post-Wilsonian literary criticism. Earlier in this century scholars stressed the personal experiences of the authors and the history of their times. In the 1950s the New Critics insisted on drawing out the full meaning of the text, without much concern for the personal history of the author. They agreed with Joseph Conrad's famous dictum that a work of art "should carry its justification in every line." In the 1980s the New Critics quite suddenly gave way to the postmodernists, who argued the opposite approach. Search, they said, for what the text does not control, and explain the entirety as a social construction on the part of the author. Their stance has been summarized in a pointed manner by the poet and critic Fredrick Turner, as follows: Artists and poets should dismiss the constraints of Nature even in a time of ecological crisis, ignore science, abandon the forms and disciplines of the arts and hence their own culture's shamanic tradition, turn away from the idea of a universal human nature, and, having freed themselves from such stifling confinement, favor snideness and rage over hope and other uplifting emotions. According to Turner, a reversal in fashion is already beginning. "The tradition of Homer, Dante, Leonardo, Shakespeare, Beethoven, and Goethe is not dead. It is growing up in the cracks of the postmodern concrete."

Edmund Wilson hoped for a damping of this perpetual cycle in the arts, which he considered a peculiar affliction of the modern mind. Favoring synthesis in principle, he wrote of his admiration for Bertrand Russell and Alfred North Whitehead, the two great culture unifiers of the first half of the twentieth century. We envy the classics, he said, for the equilibrium they appear to have achieved. "Regularity and logic in Sophocles do not exclude either tenderness or violence; and, in Virgil, the sort of thing that Flaubert can do, the exact objective reproduction of things does not exclude the sort of thing that Wordsworth and Shelley can do, the mysterious, the fluid, the pathetic, and the vague." I like to think that Edmund Wilson would have been favorable to the idea of consilience.

CAN THE OPPOSED Apollonian and Dionysian impulses, cool reason against passionate abandonment, which drive the mood swings of the arts and criticism, be reconciled? This is, I believe, an empirical question. Its answer depends on the existence or nonexistence of an inborn human nature. The evidence accumulated to date leaves little room for doubt. Human nature exists, and it is both deep and highly structured.

If that much is granted, the relation of science to interpretation of the arts can be made clearer, as follows. Interpretation has multiple dimensions, namely history, biography, linguistics, and aesthetic judgment. At the foundation of them all lie the material processes of the human mind. Theoretically inclined critics of the past have tried many avenues into that subterranean realm, including most prominently psychoanalysis and postmodernist solipsism. These approaches, which are guided largely by unaided intuition about the way the brain works, have fared badly. In the absence of a compass based on sound material knowledge, they make too many wrong turns into blind ends. If the brain is ever to be charted, and an enduring theory of the arts created as part of the enterprise, it will be by stepwise and consilient contributions from the brain sciences, psychology, and evolutionary biology. And if during this process the creative mind is to be understood, it will need collaboration between scientists and humanities scholars.

The collaboration, now in its early stages, is likely to conclude that innovation is a concrete biological process founded upon an intricacy of nerve circuitry and neurotransmitter release. It is not the outpouring of symbols by an all-purpose generator or any conjunction therein by ethereal agents. To fathom the origin of innovation in the arts will make a great deal of difference in the way we interpret its creations. The natural sciences have begun to form

a picture of the mind, including some of the elements of the creative process itself. Although they are still considerably far from the ultimate goal, they cannot help in the end but strengthen interpretation of the arts.

Charles Lumsden and I reached this conclusion in the early 1980s while developing the full theory of gene-culture coevolution, described earlier. A similar position has been reached from different directions by a small but growing circle of artists and theorists of the arts, among whom the more prominent have been Joseph Carroll, Brett Cooke, Ellen Dissanayake, Walter Koch, Robert Storey, and Frederick Turner. Some of these scholars refer to their approach as biopoetics or bioaesthetics. The analyses have been independently bolstered by Irenäus Eibl-Eibesfeldt, the German ethologist, in his global studies of human instinct; by the American anthropologists Robin Fox and Lionel Tiger in their accounts of ritual and folklore; and by numerous researchers in Artificial Intelligence, whose work on artistic innovation is summarized (to take one excellent exposition) by Margaret Boden in *The Creative Mind*.

The body of the research to date can be fitted together into the following narrative of coevolution of genes and culture:

- *During human evolution there was time enough for natural selection to shape the processes of innovation.* For thousands of generations, sufficient for genetic changes in the brain and sensory and endocrine systems, variation among people in thought and behavior caused personal differences in survival and reproductive success.

- *The variation was to some degree heritable.* Individuals differed then, as they do today, not just in what they learned from their culture but also in their hereditary propensity to learn certain things and to respond by statistical preponderance in particular ways.

- *Genetic evolution inevitably ensued.* Natural selection, favoring some of the gene ensembles over others, molded the epigenetic rules, which are the inherited regularities of mental development that compose human nature. Among the most ancient epigenetic rules I have described to this point are the Westermarck effect, which inhibits incest, and the natural aversion to snakes. Those of more recent origin, perhaps no more than a hundred thousand years ago, include the swift programmed steps by which children acquire language and, we may reasonably presume, some of the creative processes of the arts as well.

- *Universals or near-universals emerged in the evolution of culture.* Because of differences in strength among the underlying epigenetic rules, certain

thoughts and behavior are more effective than others in the emotional responses they cause and the frequency with which they intrude on reverie and creative thought. They bias cultural evolution toward the invention of archetypes, the widely recurring abstractions and core narratives that are dominant themes in the arts. Examples of archetypes I have already mentioned are Oedipian tragedy (violating the Westermarck effect) and the serpent images of myth and religion.

- *The arts are innately focused toward certain forms and themes but are otherwise freely constructed.* The archetypes spawn legions of metaphors that compose not only a large part of the arts but also of ordinary communication. Metaphors, the consequence of spreading activation of the brain during learning, are the building blocks of creative thought. They connect and synergistically strengthen different spheres of memory.

GENE-CULTURE COEVOLUTION IS, I believe, the underlying process by which the brain evolved and the arts originated. It is the conceivable means most consistent with the joint findings of the brain sciences, psychology, and evolutionary biology. Still, *direct* evidence with reference to the arts is slender. It is possible that new discoveries concerning the brain and evolution will yet change the picture fundamentally. Such is the nature of science. The uncertainty makes the search for the alignment of science and the humanities all the more interesting a prospect.

This much can be said with confidence, however: The growing evidence of an overall structured and powerful human nature, channeling development of the mind, favors a more traditionalist view of the arts. The arts are not solely shaped by errant genius out of historical circumstances and idiosyncratic personal experience. The roots of their inspiration date back in deep history to the genetic origins of the human brain, and are permanent.

While biology has an important part to play in scholarly interpretation, the creative arts themselves can never be locked in by this or any other discipline of science. The reason is that the exclusive role of the arts is the transmission of the intricate details of human experience by artifice to intensify aesthetic and emotional response. Works of art communicate feeling directly from mind to mind, with no intent to explain why the impact occurs. In this defining quality, the arts are the antithesis of science.

When addressing human behavior, science is coarse-grained and encompassing, as opposed to the arts, which are fine-grained and interstitial. That is,

science aims to create principles and use them in human biology to define the diagnostic qualities of the species; the arts use fine details to flesh out and make strikingly clear by implication those same qualities. Works of art that prove enduring are intensely humanistic. Born in the imagination of individuals, they nevertheless touch upon what was universally endowed by human evolution. Even when, as part of fantasy, they imagine worlds that cannot possibly exist, they stay anchored to their human origins. As Kurt Vonnegut, Jr., master fantasist, once pointed out, the arts place humanity in the center of the universe, whether we belong there or not.

Several special powers were granted the arts by the genetic evolution of the brain. First is the ability to generate metaphors with ease and move them fluidly from one context to another. Consider the technical language of the arts themselves. A plot first meant a physical site and building plan, then the stage director's plot or blocking plan, then the action or story blocked out. In the sixteenth century a frontispiece was a decorated front of a building, then the title page of a book ornamented with a figure, usually the allegorical representation of a building, and finally the illustrated page that precedes the title page. A stanza, which in Italian is a public room or resting place, has been appropriated in English to mean the roomlike set of four or more lines separated typographically from other similar sets.

In both the arts and sciences the programmed brain seeks elegance, which is the parsimonious and evocative description of pattern to make sense out of a confusion of detail. Edward Rothstein, a critic trained in both mathematics and music, compares their creative processes:

We begin with objects that look dissimilar. We compare, find patterns, analogies with what we already know. We distance ourselves and create abstractions, laws, systems, using transformations, mappings, and metaphors. This is how mathematics grows increasingly abstract and powerful; it is how music obtains much of its power, with grand structures growing out of small details. This form of comprehension underlies much of Western thought. We pursue knowledge that is universal in its perspective but its powers are grounded in the particular. We use principles that are shared but reveal details that are distinct.

Now compare that insight with the following independent account of creativity in the physical sciences. The writer is Hideki Yukawa, who spent his career working on the nuclear binding forces of the atom, making discoveries for which he became the first Japanese to receive the Nobel Prize in physics.

Suppose there is something which a person cannot understand. He happens to notice the similarity of this something to some other thing which he understands quite well. By comparing them he may come to understand the thing which he could not understand up to that moment. If his understanding turns out to be appropriate and nobody else has ever come to such an understanding, he can claim that his thinking was really creative.

The arts, like the sciences, start in the real world. They then reach out to all possible worlds, and finally to all conceivable worlds. Throughout they project the human presence on everything in the universe. Given the power of metaphor, perhaps the arts began with what may be called the "Picasso effect." The artist is reported by his photographer and chronicler Brassai to have said in 1943: "If it occurred to man to create his own images, it's because he discovered them all around him, almost formed, already within his grasp. He saw them in a bone, in the irregular surfaces of cavern walls, in a piece of wood. One form might suggest a woman, another a bison, and still another the head of a demon." They may have come that route by perception of what Gregory Bateson and Tyler Volk have called metapatterns, those circles, spheres, borders and centers, binaries, layers, cycles, breaks, and other geometric configurations that occur repeatedly in nature and provide easily recognized clues to the identity of more complicated objects.

It was a short step not just to see but to re-create images on rock walls with charcoal lines or by etchings on stone, bone, and wood. The first faltering steps were attempts to stimulate and thereby humanize external Nature. The art historian Vincent Scully has observed that in early historical times, people constructed sacred buildings to resemble mountains, rivers, and animals. By so doing they hoped to draw upon the powers of the environment. The greatest ceremonial site of pre-Columbian America, in Scully's opinion, is Teotihuacán in central Mexico. "There the Avenue of the Dead runs directly to the base of the Temple of the Moon, behind which rises the mountain that is called Tenan ('Our Lady of Stone'). That mountain, running with springs, is basically pyramidal and shaped and notched in the center. And the temple imitates the mountain's shape, intensifies it, clarifies it, geometrizes it, and therefore makes it more potent, as if to draw water down from the mountain to the fields below."

Imitate, make it geometrical, intensify: That is not a bad three-part formula for the driving pulse of the arts as a whole. Somehow innovators know how it all is to be done. They select images from nature that are emotionally

and aesthetically potent. In the course of history, as techniques grew more sophisticated, the artists projected feelings back out to nature. Those in architecture and the visual arts created designs based on the idealized features of the human body and what they imagined to be gods modeled from the human body. Supplication, reverence, love, grief, triumph, and majesty, all emotion-charged constructions of the human mind, were captured as abstract images and forced onto both living and inanimate landscapes.

Artists, while free-ranging in the details selected, generally remain faithful to the innate universals of aesthetics. In his 1905-08 variations of *The Farm Weltevreden at Duivendrecht*, the young Piet Mondrian depicted a row of spindly trees in front of a shadowy house. The spacing of the tree trunks seems intuitively right, the redundancy in the canopy lacework is close to what (as I will describe shortly) modern EEG monitoring suggests is most arousing to the brain. The arrangement of open space and water nearby are those that recent psychological studies have revealed to be innately among the most attractive out of all such possible arrangements. Unaware of these neurobiological correlates, probably uncaring even if he had been told, Mondrian repeated the tree-row theme many times over a ten-year period as he felt his way toward new forms of expression. With the influences of Vermeer and van Gogh put well behind him, he discovered and experimented with cubism. In *Study of Trees II* (1913) the canopies of several trees are brought forward, dominating fences and other skeletonized and unfocused structures, yet all still balanced in composition and close to optimally complex by measure of brain arousal. Other variations of the same period increasingly abstract the whole into a mazelike configuration of reticulate lines. The interspaces capture patterns of light and color that change from one compartment to the next. The overall effect is not unlike that of a mottled sky viewed upward through a woodland canopy. Other subjects, including buildings, dunes, piers, and the sea, are similarly transformed. In the end Mondrian attained the pure abstract designs for which he was to be celebrated: "nothing human, nothing specific," as he put it. In this sense he liberated his art. But it is not truly free, and I doubt that inwardly he ever wished it to be. It stays true to the ancient hereditary ground rules that define the human aesthetic.

We do not see in the evolution of Mondrian a localized production of Western culture. The same process was at work in the confluence of Asian art and writing. Chinese characters were invented three thousand years ago as crude pictographs resembling the objects they represent. The sun and moon, mountains and rivers, people and animals, dwellings and utensils are

all instantly recognizable today in the ancient Chinese script. They too approach the optimum level of complexity by EEG standards. Over centuries the characters evolved into the elegant *karayo* calligraphy of standard script. An early version of *karayo*, after its introduction to Japan, gave rise to new forms, including the flowing *wayo* script unique to that country. As in Western calligraphy and the ornamental initial letters of medieval hand scripts, art imposed on the written word its own aesthetic standards.

BY INTUITION ALONE, and a sensibility that does not submit easily to formulas, artists and writers know how to evoke emotional and aesthetic response. Adding one artifice to another, obedient to the dictum *ars est celare artem*, it is art to conceal art, they steer us away from explanations of their productions. As Louis Armstrong is reported to have said about jazz: If you have to ask, you'll never know. Scientists, in contrast, try to know. They are anxious to tell you everything, and to make it all clear. But they must respectfully wait until the curtain falls or the book covers close.

The arts are eternally discursive. They seek maximum effect with novel imagery. And imagery that burns itself into the memory, so that when recalled it retains some of its original impact. Among examples I especially appreciate is the perfect opening of Nabokov's pedophilic novel. *Lo-lee-ta: the tip of the tongue taking a trip of three steps down the palate to tap, at three, on the teeth. Lo. Lee. Ta.* Thus with anatomical accuracy, alliterative *t*-sounds, and poetic meter Nabokov drenches the name, the book title, and the plot in sensuality.

Surprise, wit, and originality characterize the memorable use of metaphor. In another genre, the poet Elizabeth Spire tells us about a theological lesson given by a nun at St. Joseph's Elementary School in Circleville, Ohio, on a snowy winter morning. The subject was eschatology for beginners.

How long will those lost souls pay for their sins? For all eternity. Eternity.

How can we, at eleven years old, she must be thinking, possibly be able to conceive of just how long eternity is? *Imagine the largest mountain in the world, made of solid rock. Once every hundred years, a bird flies past, the tip of its wing brushing lightly against the mountaintop. Eternity is as long as it would take for the bird's wing to wear the mountain down to nothing.*

Ever after, I connect hell and eternity not with fire and flames, but with something cold and unchanging, a snowy tundra overshadowed by a huge granite mountain that casts a pall over the landscape.

WHAT CAN WE truly know about the creative powers of the human mind? The explanation of their material basis will be found at the juncture of science and the humanities. The first premise of the scientific contribution is that *Homo sapiens* is a biological species born of natural selection in a biologically rich environment. Its corollary is that the epigenetic rules affecting the human brain were shaped during genetic evolution by the needs of Paleolithic people in this environment.

The premise and corollary have the following consequence. Culture, rising from the productions of many minds that interlace and reinforce one another over many generations, expands like a growing organism into a universe of seemingly infinite possibility. But not all directions are equally likely. Before the scientific revolution, every culture was sharply circumscribed by the primitive state of that culture's empirical knowledge. The culture evolved under the local influence of climate, water distribution, and food resources. Less obviously, its growth was profoundly affected by human nature.

Which brings us back to the arts. The epigenetic rules of human nature bias innovation, learning, and choice. They are gravitational centers that pull the development of mind in certain directions and away from others. Arriving at the centers, artists, composers, and writers over the centuries have built archetypes, the themes most predictably expressed in original works of art.

Although recognizable through their repeated occurrence, archetypes cannot be easily defined by a simple combination of generic traits. They are better understood with examples, collected into groups that share the same prominent features. This method—called definition by specification—works well in elementary biological classification, even when the essential nature of the species as a category remains disputed. In myth and fiction as few as two dozen such subjective groupings cover most of the archetypes usually identified as such. Some of the most frequently cited are the following.

In the beginning, the people are created by gods, or the mating of giants, or the clash of titans; in any case, they begin as special beings at the center of the world.

The tribe emigrates to a promised land (or Arcadia, or the Secret Valley, or the New World).

The tribe meets the forces of evil in a desperate battle for survival; it triumphs against heavy odds.

The hero descends to hell, or is exiled to wilderness, or experiences an

iliad in a distant land; he returns in an odyssey against all odds past fearsome obstacles along the way, to complete his destiny.

The world ends in apocalypse, by flood, fire, alien conquerors, or avenging gods; it is restored by a band of heroic survivors.

A source of great power is found in the tree of life, the river of life, philosopher's stone, sacred incantation, forbidden ritual, secret formula.

The nurturing woman is apotheosized as the Great Goddess, the Great Mother, Holy Woman, Divine Queen, Mother Earth, Gaia.

The seer has special knowledge and powers of mind, available to those worthy to receive it; he is the wise old man or woman, the holy man, the magician, the great shaman.

The Virgin has the power of purity, is the vessel of sacred strength, must be protected at all costs, and perhaps surrendered up to propitiate the gods or demonic forces.

Female sexual awakening is bestowed by the unicorn, the gentle beast, the powerful stranger, the magical kiss.

The Trickster disturbs established order and liberates passion as the god of wine, king of the carnival, eternal youth, clown, jester, clever fool.

A monster threatens humanity, appearing as the serpent demon (Satan) writhing at the bottom of hell), dragon, gorgon, golem, vampire.

IF THE ARTS are steered by inborn rules of mental development, they are end products not just of conventional history but also of genetic evolution. The question remains: Were the genetic guides mere byproducts—epiphenomena—of that evolution, or were they adaptations that directly improved survival and reproduction? And if adaptations, what exactly were the advantages conferred? The answers, some scholars believe, can be found in artifacts preserved from the dawn of art. They can be tested further with knowledge of the artifacts and customs of present-day hunter-gatherers.

This is the picture of the origin of the arts that appears to be emerging. The most distinctive qualities of the human species are extremely high intelligence, language, culture, and reliance on long-term social contracts. In combination they gave early *Homo sapiens* a decisive edge over all competing animal species, but they also exacted a price we continue to pay, composed of the shocking recognition of the self, of the finiteness of personal existence, and of the chaos of the environment.

These revelations, not disobedience to the gods, are what drove humankind from paradise. *Homo sapiens* is the only species to suffer psychological

exile. All animals, while capable of some degree of specialized learning, are instinct-driven, guided by simple cues from the environment that trigger complex behavior patterns. The great apes have the power of self-recognition, but there is no evidence that they can reflect on their own birth and eventual death. Or on the meaning of existence—the complexity of the universe means nothing to them. They and other animals are exquisitely adapted to just those parts of the environment on which their lives depend, and they pay little or no attention to the rest.

The dominating influence that spawned the arts was the need to impose order on the confusion caused by intelligence. In the era prior to mental expansion, the ancestral prehuman populations evolved like any other animal species. They lived by instinctive responses that sustained survival and reproductive success. When *Homo-level* intelligence was attained, it widened that advantage by processing information well beyond the releaser cues. It permitted flexibility of response and the creation of mental scenarios that reached to distant places and far into the future. The evolving brain, nevertheless, could not convert to general intelligence alone; it could not turn into an all-purpose computer. So in the course of evolution the animal instincts of survival and reproduction were transformed into the epigenetic algorithms of human nature. It was necessary to keep in place these inborn programs for the rapid acquisition of language, sexual conduct, and other processes of mental development. Had the algorithms been erased, the species would have faced extinction. The reason is that the lifetime of an individual human being is not long enough to sort out experiences by means of generalized, unchanneled learning. Yet the algorithms were jerry-built: They worked adequately but not superbly well. Because of the slowness of natural selection, which requires tens or hundreds of generations to substitute new genes for old, there was not enough time for human heredity to cope with the vastness of new contingent possibilities revealed by high intelligence. Algorithms could be built, but they weren't numerous and precise enough to respond automatically and optimally to every possible event.

The arts filled the gap. Early humans invented them in an attempt to express and control through magic the abundance of the environment, the power of solidarity, and other forces in their lives that mattered most to survival and reproduction. The arts were the means by which these forces could be ritualized and expressed in a new, simulated reality. They drew consistency from their faithfulness to human nature, to the emotion-guided epigenetic rules—the algorithms—of mental development. They achieved that fidelity by selecting the most evocative words, images, and rhythms,

conforming to the emotional guides of the epigenetic rules, making the right moves. The arts still perform this primal function, and in much the same ancient way. Their quality is measured by their humanness, by the precision of their adherence to human nature. To an overwhelming degree that is what we mean when we speak of the true and beautiful in the arts.

ABOUT THIRTY THOUSAND YEARS AGO *Homo sapiens* used the visual arts to bring the representation of large animals into shelters. Some of the oldest and most sophisticated of such works are the wall paintings, engravings, and sculptures found in caverns of the southern half of Ice Age Europe. More than two hundred such caverns, containing thousands of images have been found during the past century in Italy, Switzerland, France, and Spain. The most recently discovered, and oldest of all, is the spectacularly painted cave at Chauvet, in the valley of the Ardèche River, a tributary of the Rhône. Chemical tests have established the age of the art at $32,410 \pm 720$ years. The youngest cave galleries are Magdalenian paintings, etchings, and sculptures created as recently as ten thousand years before the present, near the dawn of the Neolithic era.

The best of the animal drawings are accurate and beautiful even by exacting modern standards. They are rendered with clean, sweeping lines, some of which are shaded to one side as though to convey three-dimensionality. They present a veritable field guide to the largest mammals of the region, from lion to mammoth, bear to horse, rhinoceros to bison, most of which are now extinct. The figures are more than abstract images. Some are clearly male or female, of different ages. A few of the females are swollen with young. Some wear recognizable winter or summer pelages. At Chauvet two rampant male rhinoceros lock horns in battle.

Given the antiquity of Chauvet and the scarcity of even older representational art, it is tempting to conclude that the skills of the cavern artists emerged quickly, perhaps within a few generations. But that would be premature. On the basis of genetic and fossil evidence, it appears that anatomically modern *Homo sapiens* evolved in Africa by about two hundred thousand years before the present, and entered Europe as recently as fifty thousand years ago. In the succeeding interval, up to the time of the Chauvet paintings, they slowly displaced the Neanderthal people, now considered by some anthropologists to be a distinct human species. It is reasonable to suppose that during this era, and before occupying the particular cave sites that today harbor the oldest known works, the artists improved their tech-

niques and style on surfaces now lost. Many of the early paintings might have been applied to outdoor rock walls, a practice still followed by hunter-gatherers in Australia and southern Africa, and as a result failed to survive the harsh climate of Ice Age Europe.

It may never be known whether European cavern art sprang full-blown or was perfected in small steps across millennia, but at least we have strong hints as to why it was created. A number of the examples, as many as 28 percent at Cosques near Marseilles, for example, are depicted with arrows or spears flying about the bodies of the animals. A bison at Lascaux has been eviscerated by a spear that enters its anus and emerges through its genitals. The simplest and most persuasive explanation for the embellishment is the one proposed in the early 1900s by Abbé Breuil, the pioneer explorer and interpreter of European Paleolithic art. It is hunting magic, he said, the belief that by re-creating animals and killing their images, the hunters will more readily overcome real prey when the chase begins outdoors.

Art is magic. That has a modern ring, for as we often hear, the purpose of the arts is enchantment. Breuil's hypothesis is supported by an intriguing piece of additional evidence, the repeated depiction of the same animal species on the same rock-surface panels. In one case, chemical tests indicate that the portraits were drawn centuries apart. Duplicates are also commonly drawn—or in some cases etched on bone fragments—on top of the original. Rhinoceros horns are replicated, mammoths bear multiple head domes, lions have two or three complete heads. Although we will never be able to read the minds of the artists, it is a fair guess that they meant the images to be reborn with each duplication in order to serve the purpose of new rituals. Those rituals might have been part of full-blown ceremonies, accompanied by early forms of music and dancing. Flutes made of bone have been discovered in the caves, in good enough condition to be cleaned and played, and the paintings themselves are consistently located in places where the acoustics are excellent.

Hunting sorcery of one form or another has survived in hunter-gatherer societies to the present time. It is a form of sympathetic magic, an expression of the near-universal belief among prescientific peoples that the manipulation of symbols and images can influence the objects they represent. Sticking pins in dolls and other practices of malign voodoo are among the most familiar examples from popular culture. Most religious rituals contain elements of sympathetic magic. Children selected for sacrifice to Tlaloc, the Aztec god of rain and lightning, were first forced to shed tears, in order to bring raindrops to the Valley of Mexico. Christian baptism takes away the sins of the world.

To be cleansed, to be born again, you must be washed in the blood of the Lamb.

Belief in astrology and extrasensory perception, particularly psychokinesis, is built from similar elements in the sorcerer's toolkit. The near-universal faith in sympathetic magic of one form or another is easily explained. In a bewildering and threatening world, people reach out for power by any means they can find. Combining art with sympathetic magic is a quite natural way to make that attempt.

In opposition to the hunting magic hypothesis it can be argued that the cave art images served the much simpler purpose of instructing the young. Perhaps it was indeed only a prehistoric *Peterson's Field Guide to the Large Mammals of Pleistocene Europe*. But with no more than a dozen species to learn, it remains unclear why the portraits were drawn repetitively on the same panels. Or why the skills of hunting could not have been better learned by adolescent apprentices when they accompanied their elders in the field—the method used by hunter-gatherer people today.

The magic hypothesis of animal art is reinforced by other forms of behavior displayed by extant stone-age people. Their hunters are intensely preoccupied with the lives of the big animals around them, especially mammals that can be killed only by tracking or ambush. They are less concerned with smaller species, such as hares and porcupines, that can be snared or dug from burrows. They often impute to their large prey the possession of minds and special powers that project their own fierce human desires. The animals they kill they sometimes propitiate with ceremony. Hunters of many cultures collect skulls, claws, and skins as trophies to memorialize their own prowess. The totemic animals, invested with supernatural qualities and honored with reverential art, are then used as symbols to bind members of the clan together. Their spirits preside over celebrations of victory, and see the people through the dark hours of defeat. They remind each individual of the existence of something greater than himself, something immortal of which he is a part. The totems enforce moderation in dispute, and they soften dissension within the tribe. They are sources of real power. It is not surprising to find that among the few well-rendered human beings in Ice Age art are shamans wearing headgear of stag antlers or the head of a bird or lion. It seems logical that gods in the form of animals ruled the ancient civilizations of the Fertile Crescent and Mesoamerica. Such effects of sympathetic magic radiate out. Not just hunter-gatherer bands but also groups and nations at the level of high civilization are prone to adopt animal species as totems to reflect the qualities

they most value in themselves. American football fans, having at last found a way to form their own Paleolithic tribes, cheer for the Detroit Lions, Miami Dolphins, and Chicago Bears.

THE BIOLOGICAL ORIGIN of the arts is a working hypothesis, dependent on the reality of the epigenetic rules and the archetypes they generate. It has been constructed in the spirit of the natural sciences, and as such is meant to be testable, vulnerable, and consilient with the rest of biology.

So how then is the hypothesis to be tested? One way is to predict from evolutionary theory the themes and underlying epigenetic rules most likely to be encountered in the arts. We know that such near-universal themes do exist, and in fact form the scaffolding of most works of fiction and the visual arts. Their generality is the reason Hollywood plays well in Singapore, and why Nobel Prizes in Literature are given to Africans and Asians as well as to Europeans. What we do not understand very well is why this is so, why processes of mental development direct attention so consistently toward certain images and narratives. Evolutionary theory is a potentially powerful means of predicting the underlying epigenetic rules and understanding their origins in genetic history.

Earlier I described one important example of the evolutionary approach, in studies that address incest avoidance and taboos. The inborn inhibitory responses causing these phenomena have reverberated in myth and the arts throughout recorded history. Other responses that can connect biological theory to the arts are parent-infant bonding, family cooperation and conflict, and territorial aggression and defense.

A second, wholly different means of discovering epigenetic rules affecting the arts is simply to scan directly for them with methods from the neurosciences and cognitive psychology. In a pioneering study of "bioaesthetics" published in 1973, the Belgian psychologist Gerda Smets asked subjects to view abstract designs of varying degrees of complexity while she recorded changes in their brain wave patterns. To register arousal she used the desynchronization of alpha waves, a standard neurobiological measure. In general, the more the alpha waves are desynchronized, the greater the psychological arousal subjectively reported by subjects. Smets made a surprising discovery. She found a sharp peak of brain response when the redundancy—repetitiveness of elements—in the designs was about 20 percent. This is the equivalent amount of order found variously in a simple

maze, in two complete turns of a logarithmic spiral, or in a cross with asymmetrical arms. The 20 percent redundancy effect appears to be innate. Newborn infants gaze longest at drawings with about the same amount of order.

What does this epigenetic rule have to do with aesthetics and art? The connection is closer than may be immediately apparent. Smets' high-arousal figures, even though generated by a computer, have an intriguing resemblance to abstract designs used worldwide in friezes, grillwork, logos, colophons, and flag designs. They are also close in order and complexity to the pictographs of written Chinese, Japanese, Thai, Tamil, Bengali, and other Asian languages of diverse origin, as well as the glyphs of the ancient Egyptians and Mayans. Finally, it seems likely that some of the most esteemed products of modern abstract art fall near the same optimal level of order, as illustrated in Mondrian's *oeuvre*. Although this connection of neurobiology to the arts is tenuous, it offers a promising cue to the aesthetic instinct, one that has not to my knowledge been explored systematically by either scientists or interpreters of the arts.

Analyzing the beauty of a young woman's face is another way to scan directly for epigenetic rules relevant to aesthetics. For more than a century it has been known that photographic composites of many faces blended together are considered more attractive than most of the individual faces viewed separately. The phenomenon has led to the belief that ideal facial beauty is simply the average condition for the population as a whole. That entirely reasonable conclusion turns out to be only half true. In 1994 new studies revealed that a blend of individual faces considered attractive at the outset is rated higher than a blend of all the faces without prior selection. In other words, an average face is attractive but not optimally attractive. Certain dimensions of the face are evidently given more weight in evaluation than others. The analyses then produced a real surprise. When the critical dimensions were identified and exaggerated in artificially modified composites, attractiveness rose still more. Both Caucasian and Japanese female faces had this effect on young British and Japanese subjects of both sexes. The features thought most attractive are relatively high cheek bones, a thin jaw, large eyes relative to the size of the face, and a slightly shorter rather than longer distance between mouth and chin and between nose and chin.

Only a small percentage of young women fall at or close to the average. That is to be expected in a genetically diverse species whose precise combinations of features are created anew within and between families of every generation. What is more puzzling is the divergence of the optimum from the average. Few women—extremely few in fact—approach it. If the percep-

tion of facial beauty resulted in the higher survival and reproductive success of the most beautiful conceivable, then the most beautiful should be at or close to the average within the population. Such is the expected result of stabilizing natural selection. Deviations from the optimum dimensions in any direction are disfavored, and the optimum is sustained as the norm through evolutionary time.

The explanation for the rarity of great beauty may be (and I continue to speculate) the behavioral phenomenon known as the supernormal stimulus. Widespread among animal species, it is the preference during communication for signals that exaggerate the norms even if they rarely if ever occur in nature. An instructive example is female attractiveness in the silver-washed fritillary, a silver-dappled orange butterfly found in woodland clearings from western Europe to Japan. During the breeding season males instinctively recognize females of their own species by their unique color and flight movements. They chase them, but they are not what the males really prefer. Researchers found that they could attract male fritillaries with plastic replicas whose wings are flapped mechanically. To their surprise, they also learned that males turn from real females and fly toward the models that have the biggest, brightest, and most rapidly moving wings. No such fritillary super-female exists in the species' natural environment.

Males of the silver-washed fritillary appear to have evolved to prefer the strongest expression of certain stimuli they encounter, with no upper limit. The phenomenon is widespread in the animal kingdom. While experimenting with anole lizards of the West Indies a few years ago, I found that males display enthusiastically to photographs of other members of the same species, even though the images are the size of a small automobile. Other researchers have learned that herring gulls ignore their own eggs when presented with appropriately painted wooden models so large they cannot even climb on top of them.

In the real world the supernormal response works because the monstrous forms created by experimenters do not exist, and the animals can safely follow an epigenetic rule expressible as follows: "Take the largest (or brightest or most conspicuously moving) individual you find." Female fritillaries cannot be gigantic insects with brilliant whirling wings. Such creatures could not locate enough food to get through the caterpillar stage and survive in the Eurasian woodlands. In parallel manner, women with large eyes and delicate features may have less robust health, especially during the rigors of childbearing, than those closer to the population average. But at the same time—and this could be the adaptive significance—they present physical cues of youth, virginity, and the prospect of a long reproductive period.

The off-center optimum of female attractiveness is no more peculiar than most of the rest of human social behavior. The entire beauty industry can be interpreted as the manufacture of supernormal stimuli. Eyelid shadow and mascara enlarge the eyes, lipstick fills out and brightens the lips, rouge brings a permanent blush to the cheeks, pancake makeup smoothes and reshapes the face toward the innate ideal, fingernail paint adds blood circulation to the hands, and teasing and tinting render the hair full-bodied and youthful. All these touches do more than imitate the natural physiological signs of youth and fecundity. They go beyond the average normal.

The same principle is true for body adornment of all kinds in men and women. Clothing and emblems project vigor and advertise status. Thousands of years before artists painted animals and costumed shamans on the cave walls of Europe, people were fastening beads onto clothing and piercing belts and headbands with carnivore teeth. Such evidence indicates that the original canvas of the visual arts was the human body itself.

Ellen Dissanayake, an American historian of aesthetics, suggests that the primal role of the arts is and always has been to "make special" particular features of humans, animals, and the inanimate environment. Such features, as illustrated by feminine beauty, are the ones toward which human attention is already biologically predisposed. They are among the best places to search for the epigenetic rules of mental development.

THE ARTS, while creating order and meaning from the seeming chaos of daily existence, also nourish our craving for the mystical. We are drawn to the shadowy forms that drift in and out of the subconscious. We dream of the insoluble, of unattainably distant places and times. Why should we so love the unknown? The reason may be the Paleolithic environment in which the brain evolved. In our emotions, I believe, we are still there. As a naturalist, I use an explicit geographic imagery in reveries of this formative world.

At the center of our world is home ground. In the center of the center are shelters backed against a rock wall. From the shelters radiate well-traveled paths where every tree and rock is familiar. Beyond lies opportunity for expansion and riches. Down a river, through a wooded corridor lining the opposite shore, are campsites in grassy places where game and food plants are seasonally abundant. Such opportunities are balanced by risk. We might lose our way on a too-distant foray. A storm can catch us. Neighboring people—poisoners, cannibals, not fully human—will either trade or attack; we can only guess their intentions. In any case they are an impassable barrier. On the other side is the

rim of the world, perhaps glimpsed as a mountain front, or a drop toward the sea. Anything could be out there: dragons, demons, gods, paradise, eternal life. Our ancestors came from there. Spirits we know live closer by, and at fall of night are on the move. So much is intangible and strange! We know a little, enough to survive, but all the rest of the world is a mystery.

What is this mystery we find so attractive? It is not a mere puzzle waiting to be solved. It is far more than that, something still too amorphous, too poorly understood to be broken down into puzzles. Our minds travel easily—eagerly!—from the familiar and tangible to the mystic realm. Today the entire planet has become home ground. Global information networks are its radiating trails. But the mystic realm has not vanished; it has just retreated, first from the foreground and then from the distant mountains. Now we look for it in the stars, in the unknowable future, in the still teasing possibility of the supernatural. Both the known and the unknown, the two worlds of our ancestors, nourish the human spirit. Their muses, science and the arts, whisper: *Follow us, explore, find out.*

IN TRYING to comprehend this aura of the ancestral mind, we are not entirely dependent on introspection and fantasy. Anthropologists have carefully studied bands of contemporary hunter-gatherers whose lifeways appear to resemble those of our common Paleolithic forebears. In recording languages, daily activities, and conversations, the researchers have drawn reasonable inferences concerning the thought processes of their subjects.

One such account has been provided by Louis Liebenberg on the San-speaking "Bushman" hunter-gatherers of the central Kalahari, more particularly the Ju/wasi (or !Kung), /Gwi, and !Xo of Botswana and Namibia. He has drawn on his own researches and those of other anthropologists, most prominently Richard B. Lee and George B. Silberbauer, to record the vanishing culture of these remarkable people.

The Kalahari bands, in order to live on the sparse resources of the desert, must plan and act very carefully. Knowledge of the local terrain and of seasonal ecology is particularly important. The bands understand that the distribution of water resources within their territory is most important of all. In Liebenberg's words:

During the rainy season they live at temporary pools in the midst of nut forests. Only the most palatable and abundant foods that are the least distance from water are collected. As time goes on they have to travel further

and further to collect food. They usually occupy a camp for a period of weeks or months and eat their way out of it. During the dry season, groups are based at permanent waterholes. They eat out an increasing radius of desirable foods, and as the water-food distances increase the subsistence effort increases.

The Kalahari bands are experts on local geography and the many plants and animals on which their lives depend. Plant gatherers, usually women but also men on their way home from unsuccessful hunts, use knowledge of the botanical communities to pinpoint edible species. They are conservationists by way of necessity. Liebenberg continues:

They avoid stripping an area of a species, leaving a residue so that regeneration is not imperiled. Locally scarce specimens are not exploited even when these are found while gathering other species.

The hunters are also equally expert on the details of animal life. Their skills at tracking large animals depend on this knowledge.

When fresh spoor is found, hunters will estimate its age and how fast the animal was moving to decide whether it is worth following up. In thick bush, where there may be no clear footprints, or on hard ground, where only scuff marks may be evident, trackers may not be able to identify the animal. When this happens they will have to follow the trail, looking for signs such as disturbed vegetation and scuff marks, until clear footprints are found. They will reconstruct what the animal was doing and predict where it was going.

In the Kalahari, as throughout all of the hunter-gatherer world for countless millennia, the hunt holds a central place in the social life of the band.

In storytelling around the campfire at night men give graphic descriptions of hunts of the recent and distant past. To find animals requires all the information on their movements that can be gained from others' observations and the hunter's own interpretation of signs. Hunters will spend many hours discussing the habits and movements of animals.

The life of the Kalahari band, optimally comprising fifty to seventy members, is intensely communal and cooperative. Because the group must move

several times a year with all their possessions on their backs, individuals accumulate few material goods not essential to survival.

Ownership is limited to an individual's clothing, a man's weapons and implements and a woman's household goods. The band's territory and all its assets are not owned individually but communally, by the whole band.

To hold the group together, decorum and reciprocity are strictly observed.

While hunting is an important activity in hunter-gatherer subsistence, successful hunters, who may naturally be pleased with themselves, are expected to show humility and gentleness. To the Ju/wasi, for example, announcing a kill is a sign of arrogance and is strongly discouraged. Many good hunters do no hunting for weeks or months at a time. After a run of successful hunts a hunter will stop hunting in order to give other men the chance to reciprocate.

While the Kalahari hunters are close students of animal behavior, they are thoroughly anthropomorphic in their interpretation. They strain to enter the minds of the animals they track. They imagine, they project thoughts directly to the world around them, and they analogize.

Animal behaviour is perceived as rational and directed by motives based on values (or the negation of those values) that are either held by the hunter-gatherers themselves or by people known to them. The behaviour of animals is seen by the /Gwi as bound by the natural order of *Nladima* (God). Each species is perceived to have characteristic behaviour, which is governed by its *kwodzi* (customs), and each has its particular *kwisa* (speech, language). Animals are believed to have acquired special capabilities by means of rational thought.

Knowing the belief of preliterate people in the equivalency of the material and immaterial worlds, and of rational and irrational explanation, it is easy to see how they invent narrative forms loaded with myths and totems. The acceptance of mystery is central to their lives.

The /Gwi believe that some species possess knowledge that transcends that of humans. The bateleur eagle is believed to know when a hunter will be successful and will hover over him, thereby acting as an omen of

sure success. Some steenbok are thought to have a magical means of protecting themselves from a hunter's arrows, while the duiker is believed to practice sorcery against its animal enemies and even against conspecific rivals. Baboons, because of their legendary love of trickery and teasing, are believed to eavesdrop on hunters and to pass on their plans to the intended prey animals.

The world that preliterate humans factually perceive is only a small fragment of the full natural world. Thus by necessity the primitive mind is continuously tuned to mystery. For the Kalahari and other contemporary hunter-gatherers the experience of daily life grades imperceptibly into their magical surroundings. Spirits dwell in trees and rocks, animals think, and human thought projects outward from the body with a physical force.

We are all still primitives compared to what we might become. Hunter-gatherers and college-educated urbanites alike are aware of fewer than one in a thousand of the kinds of organisms—plants, animals, and microorganisms—that sustain the ecosystems around them. They know very little about the real biological and physical forces that create air, water, and soil. Even the most able naturalist can trace no more than a faint outline of an ecosystem to which he has devoted a lifetime of study.

Yet the great gaps in knowledge are beginning to be filled. That is the strength of cumulative science in a literate world. People learn and forget, they die, and even the strongest institutions they erect deteriorate, but knowledge continues to expand globally while passing from one generation to the next. Any trained person can retrieve and augment any part of it. By this means all the species of organisms in ecosystems such as the Kalahari Desert will eventually come to be known. They will be given scientific names. Their place in the food web will be discovered, their anatomy and physiology penetrated to the level of cell and molecule, the instinctive behavior of the animals reduced to neuron circuitry, then to neurotransmitters and ion exchange. If the history of biology is a guide, all the facts will prove consilient. The explanations can be joined in space from molecule to ecosystem, and in time from microsecond to millennium.

With consilient explanation, the units at different levels of biological organization can be reassembled. Among them will be whole plants and animals as we normally see them—not as collections of molecules in biochemical time, too small and fast-changing to be visible to the unaided eye, not as whole populations living in the slow motion of ecological time, but as

individual plants and animals confined to the sliver of organismic time where human consciousness, being organismic itself, is forced to exist.

Returning to that narrow sliver after the science-led grand tour of space-time, we arrive home in the world for which the evolution of the brain prepared us. Now, with science and the arts combined, we have it all.

Poet in my heart, walk with me across the mysterious land. We can still be hunters in the million-year dreamtime. Our minds are filled with calculation and emotion. We are aesthetes tense with anxiety. Once again the bateleur eagle wheels above our heads, trying to tell us something we overlooked, something we forgot. How can we be sure that eagles never speak, that everything can be known about this land? Nearby is spoor of the elusive duiker leading into the scrub: Shall we follow? Magic enters the mind seductively, like a drug in the veins. Accepting its emotive power, we know something important about human nature. And something important intellectually—that in expanded space-time the fiery circle of science and the arts can be closed.

Within the larger scale, the archaic world of myth and passion is perceived as it truly is, across the full range of cause and effect. Every contour of the terrain, every plant and animal living in it, and the human intellect that masters them all, can be understood more completely as a physical entity. Yet in so doing we have not abandoned the instinctual world of our ancestors. By focusing on the peculiarly human niche in the continuum, we can if we wish (and we so desperately wish) inhabit the productions of art with the same sense of beauty and mystery that seized us at the beginning. No barrier stands between the material world of science and the sensibilities of the hunter and the poet.