

LEONARDO'S

BRAIN

UNDERSTANDING
DA VINCI'S
CREATIVE GENIUS

LEONARD SHLAIN

Best-selling author Leonard Shlain explores the potential for humankind through the life, art, and mind of the first true Renaissance Man, Leonardo da Vinci. The author hypothesizes that da Vinci's staggering range of achievements in such a wide range of fields demonstrates a harbinger of the future of our species. Da Vinci's innovations as an artist, scientist, and inventor are recast through a modern lens, with Shlain applying contemporary neuroscience to illuminate da Vinci's creative process. No other person in human history has excelled in so many areas of innovation: Shlain reveals the how and the why.

Shlain theorizes that Leonardo's extraordinary mind came from a uniquely developed and integrated right and left brain, which offers a model for how we too can evolve. Using past and current research, *Leonardo's Brain* presents da Vinci as the focal point for a fresh exploration of human creativity. With his lucid style and remarkable ability to discern connections among a wide range of fields, Shlain brings the reader into the world of history's greatest mind.

LEONARDO'S BRAIN

Understanding da Vinci's Creative Genius

LEONARD SHLAIN



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To my incredible wife, Ina Gyemant



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NOTE TO READER

On September 6, 2008, our father entered emergency surgery and was diagnosed with stage 4 brain cancer and given nine months to live. The prospect of losing our father, a simultaneously larger-than-life and loving and fully present figure, took our breath away. Up until that fateful day, he had been diligently finishing this book that he had worked on for seven years, *Leonardo's Brain*.

Our days were spent eating meals together, searching for silver brain-cancer bullets, shuttling between radiation and daily blood transfusions, and writing this book. So whether we were reading or talking about his book, or the tumor we were trying to shrink in his head, we were always talking about *Leonardo's Brain* in one form or another.

These days were especially high-definition. He reached out to people he hadn't seen in years, and they would pick him up at home, take him out for a fabulous lunch with a glass of wine, and reconnect. After this, he would sit in the blood transfusion chair at the hospital and then go home and get back to writing. He was trying to download all his ideas and knowledge before it was too late.

He finished the book on Monday, May 3, 2009. It was akin to watching a long-distance runner cross the finish line. On Thursday, May 6, we spent the evening selecting quotes from a large list of favorites he kept in a document, placing two or three atop every chapter, like putting dewdrops on the leaves of a Japanese tea ceremony orchid.

On Friday, May 7, Ina, his wife and our stepmother, called all three children and his two best friends to his bedside. She said he had something he wanted to tell all of us. We gathered around him, but this time he couldn't speak. Still, we could see the thoughts dancing in his eyes. He looked frustrated at not being able to find words, but then he started to look amazed. He kept saying "Wow." Then he started to slip away.

He died Monday, May 11, 2009, at 5:40 a.m.

NOTE TO READER

Leonardo's Brain is not only one of his grandest intellectual journeys, akin to his books *Art & Physics*, *The Alphabet Versus the Goddess*, and *Sex, Time, and Power*, but it also kept him alive.

He loved more than anything else to share. As his children, we are honored to share this book with you.

Kimberly (Shlain) Brooks, Jordan Shlain, and Tiffany Shlain

AUTHOR'S NOTE

Dear Reader,

In the months before September 6, 2008, I noticed that I was having trouble buttoning my sleeves with my right hand more than my left, even though I am right-handed. When I came down for breakfast that morning, I could barely speak. My alarmed wife, Ina, called my son, Jordan, a doctor, who scheduled an emergency MRI. I emerged to find my friend Brian Anderson, a neurosurgeon, at my bedside. He told me in a serious voice that I would need emergency brain surgery in two hours.

The brain tumor was large and malignant. Even though I knew that the tremendous difficulty I was having speaking and moving my right side was as a result of brain swelling secondary to the surgery, at the time I was not so sure I would recover. Thankfully, I did.

The reason I am telling you of this development, dear reader, is to let you know that I am determined to finish this book. Tiffany Shlain, my youngest daughter, who lives near me, has assured me that she will be there for any help I need. Most of it is written, and the last few chapters are in my head. I had planned to make this book as accurate as possible, and to meticulously go over every fact and date to ensure that there are no errors. Alas, there is not enough time left for me to guarantee that, so I ask for your tolerance if the book slips on a detail, or if an endnote is missing.

I have poured myself into this book by reading and synthesizing an enormous amount of background information about Leonardo and the evolutionary development of the brain. In this book I aim to present original theories that weave together the different aspects of Leonardo's life (and brain) that have not yet been considered by previous scholars from the fields of psychology, art history, and science. In doing so, I hope to stimulate new thinking about Leonardo and humankind alike.

Leonard Shlain
Mill Valley, California
April 2009

Great art can communicate before it is understood.

—T. S. ELIOT

It seems to me that in the question of truth and beauty one finds what is really the deepest root of the relationship between science and art.

—DAVID BOHM, QUANTUM PHYSICIST

The artist is the antennae of the race.

—EZRA POUND

PREFACE

Another book about Leonardo da Vinci? Is there no end to authors, poets, historians, art critics, scientists, and psychiatrists rooting around in this cultural giant's extensively overexamined life? Can we not let this poor soul's psyche rest in peace? I would answer, "Well, not yet." Scholars have scrutinized both Leonardo's life and work with a perspective particular to each of their specialties and interests. I intend to scrutinize Leonardo utilizing the knowledge others have gained, but seen from a perspective none have previously employed—that of a general and vascular surgeon with an abiding interest in brain science, and, in particular, the division of functions between the two hemispheres of the brain. I am convinced that many of the mysteries of the human condition are a result of this split-brain duality. It forms a paradox best represented by the English first-person singular "I." This perpendicular straight line with no subsidiary parts seems the perfect icon for the self-contained human being "I." The vertical stroke creates a division between everything within the waterproof bag we call our skin, and everything on the other side of that bag.

But neuroscientists have learned that what we think of as the singular "I" can more accurately be construed as a sharp line cleaving the two, sometimes competing and sometimes cooperating, halves of a person's cerebral hemispheres. In truth, we are Siamese twins conjoined at the corpus callosum—the broad band of fibers that connects the right and left halves of the brain in all vertebrates. Each of the halves of a human brain can generate opinions, perceptions, likes, and dislikes different from those of its yoked twin across the way. There is a long history in literature and art of two personas existing within one body, epitomized by Robert Louis Stevenson's two characters operating within the confines of one body that sometimes manifested as Dr. Jekyll, and other times as Mr. Hyde. Only recently has it been possible to assign to each of them their own individual anatomical mailing addresses.

Despite the many different theories about how the brain processes information and generates the sublime mystery of human consciousness, no neuroscientist disputes the fact that the human brain differs from those of other animals in the unparalleled degree to which its two cortical hemispheres have specialized their functions.

Human creativity, I will argue, must be intimately bound up in this unique arrangement. But why are some individuals more creative than others? If, as many have conjectured, the brains of the truly creative are wired differently than those of the plodding masses, then it is a worthy exercise to compare the wiring diagram of an average person's brain with that of a creative genius.

But how would a researcher choose among the many creative people presently alive? Some would opt for the latest winner of the Nobel Prize in Physics. Others would propose the greatest contemporary composer. Still others would advocate that the head encircled by the magnetic doughnut should be the winner of a prestigious art prize, such as the Rome Prize.

Rather than attempt to contrast the average brain with a renowned contemporary creative genius, I have decided to choose the one individual whom the majority of inhabitants of the Western world would agree was the most creative person who ever lived—Leonardo da Vinci.

Ah, but someone is quick to point out that the exact site where Leonardo was buried in France is presently unknown. Besides, his brain decomposed along with the rest of him nearly five hundred years ago. These are not insurmountable obstacles. Twenty-first-century strides in neurocognitive research will allow me to investigate one of the mysteries about Leonardo that remains unexplored: How was Leonardo's brain organized? What extraordinary neuroconfiguration did he possess that allowed him to attain his singular place in history?

To solve this mystery, I must pursue two entirely different stories. One story will be about the life and works of Leonardo; the other will be about the evolution of brains. This two-strand braid will make up roughly the first two-thirds of the book, creating the foundation for the third part of the book, which will explore the effect of brain organization on creativity and suggest new directions toward which the human species is evolving.

An exposition of the environmental pressures that caused the human brain to evolve so differently from the brains of other mammals leads to a discussion of the unique human arrangement of a split brain, with each hemisphere assigned different functions. The ratio of right-hand/left-brain-dominant individuals compared to left-hand/right-brain dominance is 90 percent, a percentage that has remained stable throughout history and across differing cultures. If being right-handed was such an advantage for humans, why are not all humans right-handed? Or, alternatively, why not a fifty-fifty ratio? What was the evolutionary advantage of a dominant cerebral hemisphere in the first place? Why not the ambidextrous model used with great success by the majority of other animals?

The right brain (in right-handers) best processes information that is for the most part emotional and spatial. The left brain (in right-handers) processes information that is primarily rule-driven and temporal. Similar to the Chinese yin/yang symbol, each major side contains within its core a small essence of its opposite. When discussing the brain, distinctions are never black and white. There is considerable crossover in function. Not all language centers are in the left brain, and not all spatial judgments are processed in the right brain. Nevertheless, our present and past can be better understood if we examine human history using this dualistic model.

The right- and left-brain functions are commonly associated with the dualities of masculine/feminine, active/passive, particular/general, focused/holistic, and rational/intuitive. The arrangement of a masculine side of the brain and a feminine side promotes a psychic hermaphroditism in both men and women, making the human sexes unlike any other species. Every man has an *animus* and an *anima* just as every woman has an *anima* and an *animus*. I will apply this understanding of how human brains are organized to speculate on the design of Leonardo's brain.

The final section of the book will build upon the re-creation of Leonardo's brain to launch into a discussion of human consciousness (after all, I am a California author!). The question I will try to answer is whether Leonardo, because of the unique arrangement of his neural cabling, was able to access a qualitatively different state of consciousness than practically all other humans.

I am a synthesizer by nature in an age when the information explosion has resulted in compartmentalized education and highly specialized professions. In an attempt to reverse this process, my passion is to integrate unrelated disciplines. Mimicking Leonardo's diverse interests, *Leonardo's Brain* will draw from a disparate group of thinkers, as well as the principles and discoveries of a wide range of endeavors: Classical philosophers, art historians, modern physics, enlightenment thinkers, sociobiology, paranormal investigations, evolutionary theory, neuroscientific discoveries, and many more will become strands in the complex tapestry I plan to weave. I do not profess to be an expert in any of these fields, but I have spent a considerable amount of time and effort trying to make myself one.

I do profess a certain degree of expertise in matters concerning the brain. As a medical student, I had to learn the intricacies of neuroanatomy and neurophysiology. As an aspiring psychiatrist, I enjoyed studying the puzzle of consciousness and contemplating how the *mind* works. When I decided not to take a psychiatric residency and begin instead a surgery residency to become a vascular surgeon, I had to learn how the *brain* works.

A writer is always refining his ideas, and this book represents the trajectory and culmination of thought that I laid out in my three previous books. Because I am not sure whether or not the reader has read them, I need, on occasion, to repeat a few of their themes. For readers of one or all of my books, an occasional *déjà vu* may surface from time to time.

In *Art & Physics: Parallel Visions in Space, Time, and Light*, I proposed that the visionary artist is the first person in the culture to *see* the world in a new way. Later, or sometimes simultaneously, the revolutionary physicist has an insight of such import that it changes the way we *think* about the world. In that book, I had a chapter on Leonardo, which was the seed from which this book grew. The division between the right and left sides of the brain and its correspondence to the divisions between art and physics figured prominently in that book.

My next book had a similar right-/left-brain theme. *The Alphabet Versus the Goddess: The Conflict Between Word and Image* examined what happened to gender relations when cultures discovered writing,

particularly the alphabet. Every ancient culture worshipped goddesses. Then the three monotheistic religions came into being—Judaism, Christianity, and Islam—each founded on a sacred alphabetic book, and each denying the existence of goddesses. I wanted to understand what event in culture could have been so pervasive that it changed the sex of God. I concluded that learning how to read and write an alphabet reconfigured the brain, bolstering the dominance of the left hemisphere. Reading and writing, unlike speaking and listening, are primarily left hemispheric tasks. Whenever writing appears, women's rights suffer, image information becomes an "abomination," and goddesses disappear. Whenever images regain prominence in the culture over written words, as they did in the Dark Ages, the goddess (Mary) makes a comeback. The Protestant Reformation, coincident with the sharp rise in literacy in the Renaissance, devalued the divinity of Mary; consequently, women's rights suffered. Now, as our culture becomes more image-based, women are making incredible advances. Images are primarily processed by the right brain.

I wrote my third book, *Sex, Time, and Power: How Women's Sexuality Shaped Human Evolution*, because after examining gender relations in the context of the arrival of the written word, I began to wonder why humans had wandered so far away from the mating systems used by the other three million sexually reproducing species. The human female abandoned estrus (the recurring but periodic state of sexual excitation in most mammals) but gained menses, the menstrual flow that in humans exceeds the hundred or so other mammals out of four thousand exhibiting this trait. How astonishing! Although primarily a discourse on the evolution of humans, in this book, once again the split brain plays a prominent role.

This book carries the question even further. Why do we have a split brain in the first place? Realizing that every virtue comes with a vice, I ask the question: Did divided hemispheres that served us well on the African Serengeti in the Pleistocene Epoch now possess a curse that could destroy us? How do we change as a species to extract ourselves from this dilemma? Thinking about the wiring in the brain of Leonardo provides a convenient jumping-off point. He had, from what we know, the most creative brain in history. And he was a vegetarian pacifist. He

overcame his initial aggressive stance toward designing weapons. How do the rest of us achieve greater creativity while becoming more peaceful?

As I have done in my earlier books, I will capitalize the terms Natural Selection and Mother Nature. Also, I should explain where I locate myself on the spectrum of opinion regarding the role of genetics in determining evolution. At one end of the spectrum stand Stephen Jay Gould and Richard Lewontin, who propose that many traits, both physical and behavioral, are the result of Natural Selection's random processes, and not too much should be read into them. They believe these genetic quirks neither help nor hinder the species.

On the other end is the school headed by Jerome H. Barkow, Leda Cosmides, and John Tooby, which maintains that most of what is in the human genome is there to assist humans in surviving the vicissitudes of the environment to reach reproductive age and find a willing mate. If a mutation is deleterious to the survival and reproductive success of the species, it will be culled out of the genome within a few generations. If it is beneficial, it spreads throughout the species. Its rate of disappearance or multiplication depends on how much it is a winner or a loser. On the sliding scale of opinion, I align myself with this camp.

I have poured myself into this book after reading an enormous amount of background information about Leonardo, the development of the brain, and the process of human evolution. I wanted to fulfill Franz Kafka's pronouncement that a book should "be wielded like a pickaxe to shatter the frozen sea within the reader's mind. If the book in our hands does not wake us, as with a fist that hammers on the skull, then it just isn't worth reading." I would prefer a similar, but less violent response. I want this book to stimulate thinking as I present a series of what I think are original theories. And I want it to be an enjoyable read. In writing this book I am attempting to live up to the two major ideals Leonardo set for the rest of us: to conjoin art and science, and to be bold when proposing hypotheses.

Leonard Shlain
Mill Valley, California
March 2008

CHAPTER 1

Art/Science

The good painter has to paint two principal things, that is to say, man and the intention of his mind. The first is easy and the second difficult, because the latter has to be represented through gestures and movements of the limbs—which can be learned from the dumb, who exhibit gestures better than any other kind of man.

—LEONARDO DA VINCI

The true mark of genius is not perfection, but originality, the opening of new frontiers; once this is done, the conquered territory becomes common property.

—ARTHUR KOESTLER

Both science and art form in the course of the centuries a human language by which we can speak about the more remote parts of reality; the coherent sets of concepts of physics and the styles of art are different visions that offset the language of words.

—WERNER HEISENBERG

IMAGINE THAT YOU ARE THE CHAIRPERSON OF A HYPOTHETICAL NOBEL Prize committee that awards only one medal annually. The medal is given to an individual who has created not only a most extraordinary work of art, but who has also made a spectacular contribution to science. The competition would be open to any contemporary or historical figure, as well as the large swatch of humanity that lived before accurate biographical records were available.

The divergent flow of art and science in the historical record provides evidence of a distinct compartmentalization of genius. The river of art rarely intersected with the meander of science. Despite the abundance of fantastic artists and brilliant scientists in human history, the stark monolithic fact is the dearth of candidates who could be considered for their contributions to *both* fields. Who, upon reflection, would you nominate to win the award in the field of both art *and* science?

A disproportionate number of the short list of nominees would most likely emerge from the Italian Renaissance, a period when imaginative theories combined with experimental observation to form a solid basis for modern science, a development drastically reshaping society that intersected with equally innovative approaches to art. However, the historical record might be askew. For example, the twelfth-century Persian poet Omar Khayyam was the author of the acclaimed *Rubaiyat*. Lesser known is his towering reputation as a mathematician who advanced our knowledge of algebra.

Because the concept of the individual is a relatively recent innovation, little is known of specific inventors and artists in many of the world's cultures. We may never know if the Chinese scientific genius who invented the formula to glaze the delicate Sung Dynasty porcelain was also the same person who painted exquisite silk screens or composed deathless poetry. Poor record keeping and a pervasive cultural taboo against individuals taking credit for their personal contributions may have deprived many potential candidates from ever being recognized for their achievements in both art and science. The judges, however, must also entertain the very real possibility that no candidates exist during the majority of these relatively silent centuries.

Those whom we could confidently propose would include the Renaissance architect, sculptor, and mathematician Leon Battista Alberti. His 1435 treatise on geometry and science that explained to painters how to place their figures in proper perspective would make him eligible as a scientist, and one can argue that his beautiful buildings are great works of art. Brunelleschi would surely appear on both lists. His skill in sculpture and his engineering brilliance in raising the dome of the cathedral *Santa Maria del Fiore* in Florence make him an attractive nominee. There would

be no argument on granting the art prize to Michelangelo for his *David*, *Pieta*, and the Sistine Chapel. His solutions for many vexing architectural and engineering problems would ensure his scientific credentials as well. Architect Donato d'Agnolo, more commonly known as Bramante, would have a fair chance because of his buildings' exceptional grace and the ingenious solutions he instituted in the field of math, geometry, and engineering.

Galileo Galilei's many towering scientific contributions would secure for him the science aspect of the medal. Less well known are Galileo's masterful literary enterprises. He explained the intricacies of the scientific debates of his time in lucid prose that made accessible to the educated layperson the excitement of the Copernican ferment bubbling in seventeenth-century Europe.

After Renaissance Italy, the pickings, however, get progressively slimmer. Art and science begin to diverge. There are those who would posit that this was the result of the hyperinflation of knowledge in all fields of human endeavor. Johann Wolfgang von Goethe, the seventeenth-century German writer and poet, was one of the few who tried to breach both rapidly growing walls that increasingly separated art and science. He would surely get the nod for his contributions to literature, and his many investigative experiments advanced the progress of science.

Sigmund Freud made many scientific discoveries, as well as the one for which he is the most famous: the founding of psychoanalysis. His attempt to discern the structure of the undercarriage of human consciousness would earn him his place as one of the titans of science. His voluminous writings, clear in tone and rich in imagery, could stand on their own for literary value, making Freud an attractive candidate for the award.

Alas, upon closer scrutiny, the two committees conferring among each other would most likely arrive at a consensus for each of the above-named straddlers. The quality of their contributions in one or the other of the two fields did not meet the rigorous standards of a Nobel Prize. If they were known primarily as an artist, their contribution to the field of science would not quite attain the level of others who were first and foremost scientists. Similarly, if a candidate's main field of endeavor was science, his or her artistic creations were not of the same order of quality

as those of the artist contenders. Alexander Pope summed up this strange quandary when he wrote:

*One science only will one genius fit
So vast is art, so narrow human wit.*

There is only one person who could handily win the prize in both categories: in art, for his innovative paintings, and in science, for the large number of principles he discovered and the plethora of technological inventions he envisioned. This *sui generis* individual was Leonardo da Vinci.

Evolution rarely produces only one of anything. There is no skill, trait, deformity, or clairvoyance that has not been observed in more than one individual. Child prodigy violinists, high school genius mathematicians, and preternaturally athletic sportsmen sporadically attract the public's attention because of the rarity of their traits. But in every case, his or her talent, while extraordinary, was not so singular that there had never been anyone else who expressed the same talent with a similar degree of distinction.

How, then, are we to explain the fact that in all of history Leonardo occupies a solitary niche? His uniqueness has continued to enthrall commentators throughout the nearly five centuries that have followed his death in 1519.

As the 500th anniversary of his death approaches, the pace of interest in Leonardo is actually accelerating. A veritable army of PhD specialists has pored over Leonardo's chaotically organized manuscript pages, translating, collating, and trying to discern what this restless mind has to say to the rest of us. Art critics continue to tease out of his oeuvre so many new and unexpected details; it hardly seems possible the mind of one man could have considered so many factors in planning and making his art, while at the same time immersing himself in myriad scientific pursuits.

Although both art and science require a high degree of creativity, the difference between them is stark. For visionaries to change the domain of art, they must make a breakthrough that can only be judged through the lens of posterity. Great science, on the other hand, must be able to predict the future. If a scientist's hypotheses cannot be turned into a law that can

be verified by future investigators, it is not scientifically sound. Another contrast: Art and science represent the difference between “being” and “doing.” Art’s *raison d’être* is to evoke an emotion. Science seeks to solve problems by advancing knowledge. Candace Pert reminds us that in spite of our curiosity about science, we call ourselves, “human *beings*, not human *doings*.”

In the realm of science, pure mathematics comes the closest to art in that it often does not have any practical application in the real world. Artists and mathematicians extol the virtues of beauty and elegance. In his classic, *A Mathematician’s Apology*, G. H. Hardy wrote, “Beauty is the first test; there is no permanent place in the world for ugly mathematics.”

Leonardo’s story continues to compel because he represents the highest excellence all of us lesser mortals strive to achieve—to be intellectually, creatively, and emotionally well-rounded. No other individual in the known history of the human species attained such distinction both in science and art as the hyper-curious, undereducated, illegitimate country boy from Vinci.

With so much already written about this singular man, it seems presumptuous to fell another tree in the vainglorious attempt to understand his genius. Yet, I propose to undertake this project from a somewhat unorthodox point of view. I venture into the Leonardo thicket with the intent to reemerge having reconstructed the physical configuration of Leonardo’s brain by performing, what will be, in essence, a posthumous brain scan.

Hidden in the historical record is a veritable gold mine of unusual clues regarding Leonardo’s brain function. Leonardo was a left-handed, ambidextrous male. He is the only historical figure whom we know wrote backward. Some biographers believe that Leonardo was a gay male who did not indulge his sexual passions. He was both a composer and musician, and spoke and wrote several different languages.

We also have a report that he suffered a stroke in his last years that paralyzed his right hand. The reliable observer who recorded this most telling piece of the Leonardo brain puzzle also informs us that because of this infirmity, the master gave up painting and instead devoted his last years to his scientific investigations. This brief catalog of Leonardo’s neurological

features provides a wealth of information from which to begin a speculative analysis concerning the structure of his brain and its unique wiring diagram (his neurocircuitry) that fueled so much of his creativity.

Other tantalizing enigmas concerning the organization of Leonardo's nervous system abound. His neurological peculiarities emerge from the comprehensive historical record detailing his life. (And what a historical record!) Leonardo was a recognized genius during his lifetime, prompting many contemporaries to record their impressions of him. Also, we have a treasure trove from his own hand, with over five thousand pages of his manuscripts remaining. Despite his prodigious urge to scribble, he never managed to publish.

The same maddening pattern to leave projects unfinished also bedeviled his art. He left posterity with some fifteen paintings that we are sure came from all (or part) of his hand. None of his many sculptures and nothing of his musical compositions survive. Fortunately, much is known of many of these works because contemporaries who did see (or hear) them felt compelled to describe them in considerable detail. Also, his notebooks contain hundreds of preparatory sketches for later major works. Moreover, Leonardo's lost masterpieces so impressed many excellent artists—who had the opportunity to view them before they were destroyed, misplaced, or altered—that they reproduced faithful copies of Leonardo's originals.

Besides his paintings, thousands of Leonardo's drawings remain extant. Many of these were preparatory sketches for his later paintings, and thus provide valuable insights into his creative process. His numerous notes and drawings concerning his vast interest in science contain similar insights into how his mind worked, even if the many actual inventions and devices he made have not survived.

Though his notebooks don't reveal many—if any—close female relationships, one shouldn't assume Leonardo had no knowledge or appreciation of the female. In fact, if one contemplates Leonardo's paintings and drawings, an entirely different impression emerges. Has there ever been a male artist who more deftly depicted the enigma of a woman's smile, the love of a mother for her child, or the self-confidence of a beautiful woman posing for a famous painter? How is it possible that one man could have

coaxed out of mere paint the most subtle secrets of the feminine and yet not bother to allude to any of those revelations in ink, much less mention that he even *knew* any women? Quite to the contrary, a number of misogynist remarks mar his writings.

Leonardo was a vegetarian in a culture that thought nothing of killing animals for food. His explanation for his unwillingness to participate in carnivory was that he did not want to contribute to any animal's discomfort or death. He extended the courtesy of staying alive to all living creatures, and demonstrated a feeling of connectedness to all life, which was in short supply during a time that glorified hunting.

Another paradox: No other artist in history expended as much time and energy working out the geometrical details of the science of perspective. Page after page of his various codices contain intricate drawings that recursively return to the problems perspective posed to the artist. He gives precise instructions to painters on how they should depict the penumbra of shadows and how to position objects relative to each other in a composition so that the laws of perspective are rigorously followed. How, then, do we explain the unsettling discovery—when carefully examining Leonardo's paintings—that he cleverly violates the laws of perspective in all of them? These anomalies will be detailed in a later chapter. Leonardo is both an extraordinary left-brained academician obsessed with portraying perspective correctly and an impish right-brained trickster who takes delight in fooling the viewer with perspectivist sleights of hand.

An observer glancing back and forth between Leonardo's art and his notes would begin to suspect that the hand directing his pen did not seem to know what the hand holding his brush was doing, and vice versa. After poring over his voluminous notes and then studying his paintings, a neuroscientist most likely would conclude that only the paltriest of fiber bundles connected the two hemispheres of his brain. Yet, this neurological assessment regarding the status of Leonardo's corpus callosum—the broad band of fibers that connects the brain's two halves—would fly in the face of what we know about his left-handedness, which in turn is a fairly accurate predictor of hemispheric dominance. Leonardo was the rare writer who routinely engaged in reverse writing, or mirror writing. Someone wishing to read Leonardo's manuscripts must first hold the

pages before a mirror. Instead of writing from left to right, which is the standard among all European languages, he chose to write from right to left—what the rest of us would consider backward writing. And he used his left hand to write.

Thoroughly confusing the issue was the fact that sometimes he would switch in mid-sentence, writing some words in one direction followed by other words heading in the opposite direction. Another intriguing neurological datum: Careful examination of two samples of his handwriting show the one written backward moving from right to left across the page is indistinguishable from the handwriting that is not reversed.

Leonardo's quirks of penmanship strongly suggest that his two hemispheres were intimately connected in an extraordinary way. The traditional dominance pattern of one hemisphere lording it over the other does not seem to have been operational in Leonardo's brain. Based on what we can extrapolate from the brains of people who share Leonardo's ability to mirror-write, the evidence points to the presence of a large corpus callosum that kept each hemisphere well informed as to what the other was doing.

Another suggestive piece of evidence that Leonardo's corpus callosum was fairly bursting with an overabundance of connecting neurons was his seamless annealing of art and science. Numerous neurological studies have, in general, located the modules primarily concerned with art, music, imagery, metaphor, emotion, harmony, beauty, and the aesthetic sense of proportion in the right hemisphere of a right-handed person. Housed in the left hemisphere of a right-handed person are the skills required to carry out the logical, linear, sequential analysis necessary for grammar, syntax, reason, and mathematics. A neuroscientist, examining a subject who had harmonized the very different functions of art and science, would expect that an individual so endowed would possess an exceptionally robust corpus callosum. How, then, do we square these latter facts of hemispheric integration with the earlier observations of the seemingly apparent disconnect between the content of Leonardo's written words and the iconic imagery of his art? These neurological puzzles are just a few that I will try to decipher in my attempt to crack Leonardo's brain code.

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