Healing spaces

THE SCIENCE OF PLACE AND WELL-BEING

ESTHER M. STERNBERG, M.D.

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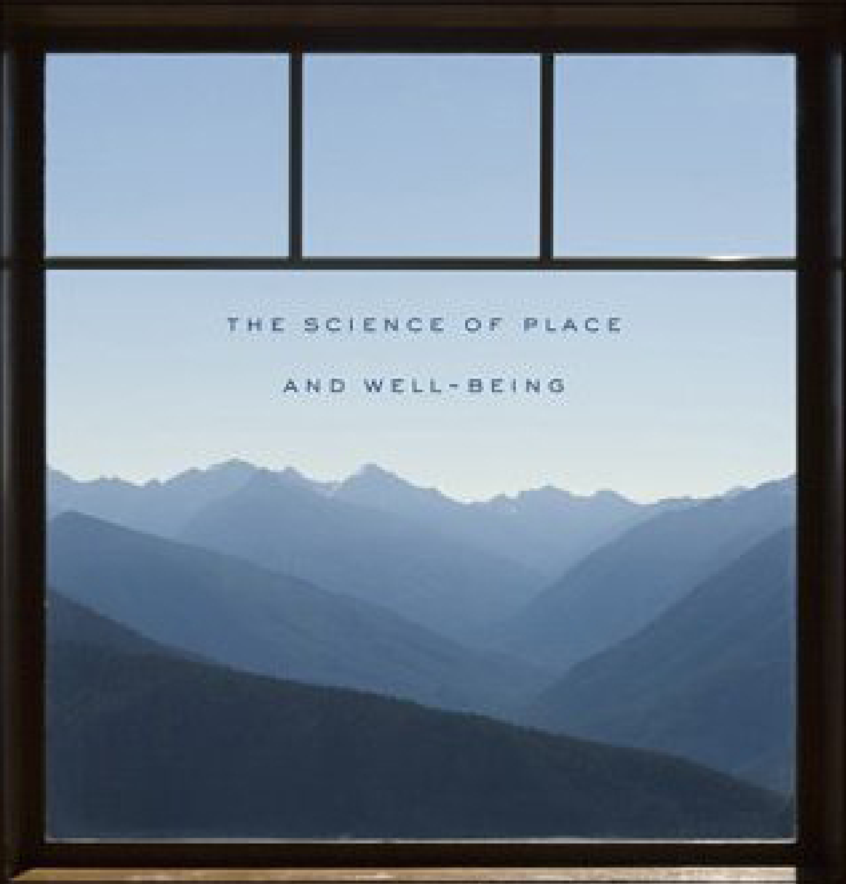

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HEALING PLACES

There is a turning point in the course of healing when you go from the dark side to the light, when your interest in the world revives and when despair gives way to hope. As you lie in bed, you suddenly notice the dappled sunlight on the blinds and no longer turn your head and shield your eyes. You become aware of birdsong outside the window and the soothing whir of the ventilation system down the hall. You no longer dread the effort needed to get up, but take your first cautious steps, like a child, to explore the newfound space around you. The smell of food does not bring on waves of nausea or revulsion, but triggers hunger and a desire to eat. The bed sheets feel cool and soothing—their touch no longer sends shivers through you, like chalk-squeak on a blackboard. Instead of shrinking from others, you welcome the chit-chat of the nurse who enters the room.

This is the point when the destructive forces of illness give way to healing. In every sense, it is a turning point—a turning of your mind's awareness from a focus on your inner self to a focus on the outer world. Physicians and nurses know that a patient's sudden interest in external things is the first sign that healing has begun. But do our surroundings, in turn, have an effect on us? Can the spaces around us help us to heal? Can we design places so as to enhance their healing properties? And if we ignore the qualities of physical context, could we inadvertently slow the healing process and make illness worse?

The idea that physical space might contribute to healing does, it turns out, have a scientific basis. The first study to tackle this question, published in *Science* magazine in 1984, showed that when hospital rooms have windows looking out on the natural world, patients heal more rapidly.

The sun was setting over Buzzard's Bay as the conference participants gathered for the evening. The sky glowed so brilliantly that even the white wine in their plastic cups seemed to catch fire.

"Look at that. That's got to have a healing effect!" Roger Ulrich waved his hand over the scene—dozens of sailboats moored in a still and fiery sea. He was standing on a bluff overlooking the bay at the southern end of Cape Cod, in front of a rambling gray saltbox-style building: the retreat and conference center of the National Academy of Sciences. It was here in August 2002, near the old whaling village of Woods Hole, Massachusetts, that John Eberhard, director of research at the American Institute of Architects (AIA), was hosting a collaborative workshop for scientists and architects, to explore the interface between architecture and neuroscience. It was the first workshop of what would become the Academy of Neuroscience for Architecture.

Ulrich's relaxed demeanor and boyish face belied the fact that he was a noted authority on the subject. He wasn't making an offhand remark or a haphazard guess. It was he who had performed the landmark 1984 study showing that window views could affect healing. He was responding to a question about what had inspired him to conduct that study.

"It just seemed like common sense," he said. "And the patients were already there, already being monitored for all sorts of things—heart rate, EKG, blood pressure, temperature—everything you could imagine. So we used those numbers to measure whether or not the windows had an effect on healing. We did it. And it worked."

He had examined the hospital records of patients who had undergone gall bladder surgery in a suburban Pennsylvania hospital during the period 1972–1981. He'd chosen forty-six patients, thirty women and sixteen men, whose beds were near windows that overlooked either a grove of trees or a brick wall. Twenty-three beds had views of nature and twenty-three did not.

Ulrich had recorded each patient's vital signs and other indicators of health, including dosages and types of pain medication and length of hospital stays. He'd found that patients whose beds were located beside windows with views of a small stand of trees left the hospital almost a full day sooner than those with views of a brick wall. Not only that, but the patients with nature views required fewer doses of moderate and strong pain medication. The results were dramatic and statistically significant. Ulrich had selected only forty-six patients to study because he was controlling for variables that could affect recovery, such as age, sex, whether the patients were smokers, the nature of their previous hospitalizations, the year of their surgery, even the floor their room was on. Each pair of patients—view of nature, view of brick wall—had been cared for by the same nurses, so differences in nursing care could not account for the differences in speed of recovery. Even doubters had to sit up and take notice.

The notion that nature was important to healing had been around for thousands of years—going back to classical times, when temples to Asclepius, the Greek god of healing, were built far from towns, high up on hilltops overlooking the sea. But by the late twentieth century, state-of-the-art hospitals were generally designed to accommodate state-of-the-art equipment. The more scanners and X-ray devices a hospital had, the more electroencephalograms and electrocardiograms it conducted, and the more sophisticated its biochemical blood and urine tests, the more advanced its care was considered to be. Often, the hospital's physical space seemed meant to optimize care of the equipment rather than care of the patients. In the early 1970s, one could still find hospitals where the only department that was air-conditioned was the Radiology Department, because the delicate equipment could not tolerate the summer heat. As reliance on and awe of medical technology increased in the mid-twentieth century, the comfort of the patients was somehow pushed aside and their surroundings were often ignored. Hospital planners assumed that patients could adapt to the needs of technology, rather than the other way around. When did this happen? When did the focus change from the patients to the disease, from healing to diagnosing and treating?

In the nineteenth century, hospitals were built with large windows and even skylights. Although this was done for the sake of visibility, in the days before powerful electric-light sources had been perfected, it was also done to help patients heal. Clinics and hospitals were designed to take maximum advantage of available sunlight, with large windows facing south and a solarium at the end of each ward. Even the word "solarium," meaning a room where patients could sit and absorb the healthful rays of natural light, is derived from *sol,* the Latin word for "sun."

In the late nineteenth and early twentieth centuries, the notion that sunlight could heal was very much in vogue. The great scourges in those days, before the development of antibiotics, were infectious diseases, especially tuberculosis. Sunlight and open windows were thought to be among the most effective means of purifying the air. In 1860, Florence Nightingale wrote that darkened rooms were harmful and sunlit rooms healthful; large, airy, bright rooms were the hallmark of what came to be known as a "Florence Nightingale" hospital ward. In 1877, a paper was presented to the Royal Society in London showing that sunlight could kill bacteria. In 1903, Dr. Auguste Rollier opened a sunlight clinic in the Swiss Alps. This may have been an inspiration for Modernist architects of the 1920s and 1930s, who designed homes and hospitals to take advantage of the sun.

Roger Ulrich's 1984 study grew out of this tradition, but had an added twist. He wanted to test whether views of nature were calming, and whether, by reducing the stress of hospitalization, they could in turn improve health. His ideas were based on a long tradition in modern architecture that posited a connection between architecture, health, and nature. Prairie School architects like Frank Lloyd Wright and Modernists such as Richard Neutra and Alvar Aalto designed buildings that appeared to grow out of their natural settings. In Neutra's structures, the glass walls seemed to melt away, allowing the indoor space to merge, almost seamlessly, with the outdoors.

Both Aalto and Neutra were explicit about the health benefits of well-planned architecture and about the importance of nature and natural views in health and healing. This concept may have had its roots in the tuberculosis sanatoriums of the nineteenth and early twentieth centuries, in the days before antibiotics. Patients with TB were sent to hospitals high in the mountains, in the hopes that the air at those altitudes would snuff out the infection. A perhaps unintended advantage was that these hospitals were all located in beautiful and isolated natural settings.

Indeed, the TB sanatorium designed by Alvar Aalto, built in 1929–1932 in the town of Paimio in his native Finland, became the standard for all later hospitals. It featured a patients' wing with light-filled rooms that faced south and overlooked a pine forest. The resting lounge was also bright, with a wall of tall windows looking out on forest views. Aalto was careful to stipulate that the surroundings be pleasant and tranquil. He even designed the furniture with the patients' comfort in mind, slanting the back of his sleek, laminated-wood "Paimio" chairs so as to ease the patients' breathing.

Although Richard Neutra admired and emulated the way

Frank Lloyd Wright embedded buildings in natural surroundings, he went beyond Wright, using steel and concrete and walls of glass to create structures that had a much lighter and airier feel and that blended indoors with outdoors. His Lovell "Health House" in Los Angeles—designed for the physician and *Los Angeles Times* health-column writer Philip Lovell and his wife, Lea—fit with the couple's convictions about health. It had views of nature on all sides.

These Modernist architects based their work on theories of the interface between design and health, but Roger Ulrich was the first to actually measure the effects of patients' surroundings on the healing process. The question at the Woods Hole Conference was not so much *whether* windows and nature views could heal, but *how* the healing mechanism operated. What brain pathways did windows and their views of nature activate? And how might these affect the immune system and its healing process?

John Eberhard, in his late seventies at the time of the conference, was a complicated man. He had held many important posts, including the chair of the Department of Architecture at Carnegie Mellon University. He had come up through the ranks in an era when architecture was almost exclusively the purview of white Protestant men. It had been a time when even the now world-famous architect Frank Gehry was persuaded by his wife to change his birth name, Goldberg, in order to get ahead. Perhaps because of his life experience, Eberhard wore his authority on his sleeve. He was a man used to wielding power and getting results, fast, and he sometimes pushed underlings almost to the point of tears to get things done. But under this tough exterior he had a softer side. He could come close to tears when talking about his legacy and his vision for his beloved field of architecture. He was also a talented artist who could execute quick, detailed sketches of buildings. And he read voraciously in pursuit of his interests, especially, at this juncture, in the field of neuroscience.

In 2002, Eberhard's title as director of research at the American Institute of Architects was a bit of an oxymoron, since the AIA was at times ambivalent about its role in research. Its primary mission is to set and maintain the highest standards in architecture, not to oversee or support research. But the AIA governance structure charged its CEO with setting programmatic priorities for its "knowledge communities," including architecture of hospitals, churches, schools, technology, and building science. Norman Koonce, a gracious, erudite gentleman from Lousiana, was then CEO and had long been interested in how architecture could enrich the human experience. In fact, he had recruited Eberhard in part with this goal in mind. The interface between architecture and neuroscience fit perfectly with these goals, and Koonce gladly supported exploring how the fields could inform one another. The workshop at Woods Hole brought together architects, neuroscientists, and psychologists whose expertise spanned the areas of stress research, visual perception, and environmental psychology.

If they could understand how physical surroundings affect emotions and how emotional responses to architecture affect health, then people's health could be taken into account in the design of buildings. Perhaps architects might even have some objective ammunition when trying to convince clients to spend a little more on larger windows and natural settings. Perhaps "green" design would turn out to be as beneficial to individuals' health as it is to the planet's health.

In his 1954 book *Survival through Design,* Richard Neutra said: "A workable understanding of how our psychosomatic organism ticks, information on sensory clues which wind its gorgeous clockwork or switch it this way or that, undoubtedly will someday belong in the designer's mental tool chest." In those days, the tools of neuroscience and immunology had not yet advanced to the point where they could be included in that tool chest. Today they have. And this is what the Woods Hole conference was all about: how to use those tools to inform the fields of neuroscience and architecture, and in turn promote healing.

The decision to include environmental psychologists like Roger Ulrich represented something of a rapprochement among the fields represented at the workshop. For decades, psychologists had been studying the effects of physical space on various aspects of mood, problem solving, and productivity. But as often happened in the scientific community, their methods, based in large part on participants' responses to questionnaires, were viewed by more biologically oriented investigators as "soft science." For their part, the architects had long known about these findings and felt there was nothing new to be learned from this approach. Nonetheless, the workshop provided a forum for a rich exchange of ideas—a chance for each field to contribute to the exploration of how the brain responds to built space, and how physical context in turn could foster good health, productive energy, and creative thought.

At Woods Hole, after a series of introductory lectures, the conferees broke up into working groups, each co-chaired by a neuroscientist and an architect. Roger Ulrich chaired the "Windows" group. These smaller sessions were meant for brainstorming. The "Windows" group would use the time to speculate freely about how windows might promote healing, and also to come up with ideas about what each discipline could measure. Why and how could window views affect healing? Was it because they provided more natural light? More airflow? Access to the sounds and smells of nature? Awareness of the rhythms of day and night? Did they simply distract patients from the monotony of days trapped in bed?

The architects in the group went first. They could measure light intensity, wavelength, and color; temperature; airflow; and levels of activity in the scene being viewed. They went through the list of all the qualities that one could measure with sophisticated instruments in minute detail, to quantify every imaginable characteristic of physical space. This list would make it possible to design a study where researchers could measure and control these variables, in order to work out which factor or factors might explain the windows' effects.

The neuroscientists went next. They could monitor areas in the brain that became active when the patient was looking at a scene. They could measure physiological responses such as stress and relaxation. They could measure stress hormones in saliva, and changes in heart-rate variability and breathing. And they could measure general indicators of health such as immune responses, dosages of pain medications prescribed, and length of hospital stays.

The group concluded that by combining the most advanced tools of neuroscience, architecture, and engineering, one could dissect and measure each feature of a patient's physical environment, and the way each of those stimuli was received by the patient's brain and body. Researchers might then be able to identify elements in the physical environment that help people heal.

But could all this really be done? Would it be possible to isolate the single or several factors in the physical environment that contribute to healing? Or would it turn out to be something more—something intangible—that makes some places heal and others harm? Perhaps the most important thing a window does is provide a portal—an escape from the frightening, painful reality of disease, or a way of accessing memories of a better time and place. Maybe windows exert their effect by allowing a patient to step into a space of meditation—a reverie that brings not just distraction but relief. And relief could bring healing, through all those beneficial chemicals that flow from the brain through the body and change illness into wellness. Any or all of these hypotheses were possible, the workshop concluded. Research would confirm which ones were valid.

The conferees at Woods Hole were by no means the only ones advocating a collaboration between neuroscience and architecture to answer these questions. A new field does not emerge solely from the efforts of a few individuals, though it certainly needs individuals with vision, courage, perseverance, and drive to build and sustain it. A new field emerges after years, often decades, of accumulated knowledge, which at some point takes off exponentially. But even this often stems from thousands of years of implicit knowledge and questions that have been circulating in the general culture.

The idea that built space may affect health could not be investigated in scientific terms without the late twentieth-century advances which established that connections between the brain and the immune system are essential to maintaining health. Implicit in an understanding of the mind-body connection is an assumption that physical places that set the mind at ease can contribute to well-being, and those that trouble the emotions might foster illness. It would take significant advances—elucidating how the brain perceives physical space, how we remember and navigate the world around us, and how all this can affect emotions—to lay the groundwork for a new field linking those who design physical space with those who seek to understand the brain's responses to it. Collaborative intellectual endeavors between neuroscientists and architects are not new. From the days when scientists first began to study the brain, architects played a prominent role in attempts to map the brain and its mysterious structures.

Some four hundred stone steps lead up through the dome of St. Paul's Cathedral, built four centuries ago in London by the architect Sir Christopher Wren. Climb those steps and you will come to a narrow balcony ringing the dome's interior, halfway to the top. It is called the Whispering Gallery because two people can stand at opposite sides of the enormous space and carry on a conversation in whispers, every word clearly intelligible. Children who visit the dome delight in trying out the acoustics.

But Wren didn't build St. Paul's so that people could play games. He built it, and many other churches in the vicinity—a "flock of Wrens," Londoners call them—to replace structures destroyed in the Great Fire of 1666. If you wander into the cathedral when the choir is practicing, you might hear the crystalline voice of a countertenor wafting up past the Whispering Gallery to the very top of the dome—a voice so clear that no matter where you stand, it seems the singer is standing next to you, and this with no microphones or amplification. You feel a sense of awe and peace in that vast space, exactly as Wren had intended when he built the dome.

Walk west from St. Paul's, past the staid stone buildings that house the courts and legal offices of Temple Bar, and soon you come to Oxford Street's bustling shopping district. Your gaze is attracted by windows filled with goods from all over the world. Keep walking down Oxford Street past Oxford Circus, make a little jog to Cavendish Square, and you reach the Royal Society of Medicine, part of the Royal Society established around the same time that Wren built his cathedral. One of the society's founders was Sir Thomas Willis, the anatomist whose intricate drawings of the brain, published in 1664, first showed what that organ really looked like. Before Willis opened up cadavers' skulls and dissected the contents, physicians and scientists had little notion of what the brain looked like, much less of what it did. Today, medical students know his name because it remains associated with the ring of nutritive blood vessels at the base of the brain—the "Circle of Willis." This group of arteries looks unimportant, but the rupture of a single one will cause almost instant death, because the vessels are so close to the brain regions that support the vital organs.

It was anatomical knowledge such as this that helped to shape the modern era of medicine—the understanding that abnormalities of anatomy could lead to disease. To discover this principle, anatomists first had to map human anatomy accurately. They did so by dissecting corpses (often stolen from graveyards) and carefully drawing what they saw. The only tools they had for gaining entry into the skull were hacksaws, hammers, and chisels. And once inside, all they could use to dissect the delicate brain tissue were primitive knives, scissors, and tweezers. Yet Willis was able to produce drawings so detailed, so precise, so finely engraved, that they could still be used today as a guide to every nook and cranny of the brain.

Willis' treatise *Cerebri Anatome,* which so changed medicine, presents drawings of the brain from all angles: above and below, front and back and side, and slices all the way through. The illustrations—sharply engraved, and printed on fold-out leaves of thick rag paper—alternate with pages of Latin text. If you visit the library of the Royal Society of Medicine, you can request the volume and, wearing white cotton gloves, page through it at your leisure. Turn to the front of the book and you will make an amazing discovery. Willis dedicated it, in Latin, to one of its illustrators: Sir Christopher Wren.

Willis and Wren were friends and colleagues. In those days, scholars didn't stay within the confines of their disciplines, but often drifted into other areas of expertise. Wren had started off as an anatomist, fascinated by the structures of the human body. Only later did he find his calling as an architect. Indeed, there are many similarities between the practice of architecture and that of anatomy. Both require an ability to visualize a structure in three-dimensional space and to render it in two dimensions, on paper, so that those less skilled at visualization can see it as well. Both require an ability to rotate objects in one's imagination, to slice them and examine them in many planes. It must have been for this reason that Willis turned to Wren, an architect, when he needed help drawing what he saw.

Wren himself had unusual skill at dissection, as well as an inventive mind. He had helped to develop a technique of injecting ink into arteries, in order to trace blood flow. Together, Willis and Wren injected, cut, and teased apart vessels from brain tissue to clearly distinguish each tiny structure and allow Wren's artistic hand to render it on paper.

At the time these artist-scientists lived, it was impossible to say how the organ inside the skull could possibly affect thinking and feeling. Yet they had an inkling of the central role the brain played in these activities. About twenty years before the publication of *Cerebri Anatome,* the French philosopher René Descartes had drawn a rough sketch linking an object viewed to the viewer's eye and, through the brain, to movement of the arm. That sketch may have been the first to show explicitly that the brain receives sensory input from the environment and then, in some mysterious manner, makes us act.

Today, four centuries after Descartes made his rudimentary drawing and Christopher Wren designed his magnificent cathedral and illustrated Sir Thomas Willis' book, we can actually see, with the tools of modern science, how our sensory organs receive signals from the world around us, and how the cells and molecules of the brain work together to blend these signals into a perception, enabling us to sense and negotiate the spaces around us. We can discern how the nerve chemicals produced by the brain when we react to our environment may in turn influence the immune system that helps us heal. We can do all this without ever breaking through the skull.

With modern imaging tools we can slice the brain from every possible angle without touching it, using instruments that detect magnetic fields or radiation or light. We can see how different parts of the brain work together, how the centers that produce and control our emotions interact with those parts that create thought and memory. With the modern techniques of biochemistry, cell biology, and molecular biology, we can piece together how the elements of the world around us, which we perceive through our senses, can trigger different areas of the brain in order to generate feelings of awe or fear or peace and comfort. We can understand, too, how these different kinds of emotions, when blended together, can promote healing.

We can use these new technologies to prove that the spaces through which we move—the contexts of our world—play a very important part in cementing memories. And we can measure how molecules of the immune system that are released when we are sick change our ability to form memories of place and space. We can show how these molecules change our moods, especially when we are sick. And finally we can show how, when we reencounter a place that evokes a certain mood, an emotional memory can revive in full force and change the brain's hormones and nerve chemicals to help or hinder healing.

In order to understand how this happens, we need to know both what healing is and what place is. If illness and health are nouns, then healing is a verb. It is movement in a desired direction—a journey that takes you from illness to health. There are as many kinds of healing as there are cells and organs in the body and diseases that can affect them, but all involve restoring the body to a state of balance. In fact, healing is going on all the time—microscopic bits of healing, at every moment of the day. The very fact that we are living means that we are being buffeted about, injured with every action we take and every stimulus to which we are exposed. Failure to heal after each insult would eventually result in death. It's like walking up a down escalator.

You must keep taking a step up in order to remain in the same spot. Health is that spot, and healing is the perpetual march you must make to stay there.

Healing also takes place in different regions of the body. It is easy to imagine a diseased liver or heart or lungs—filled with scar tissue or fatty deposits or infectious pus—going from illness to health. Gradually the infection clears, the fat dissolves, the scar shrinks, and the organ is restored to full functioning. What about the brain? It too can be filled with tumor cells, or clots, or inflammation, and some of these likewise can resolve. There are also illnesses of the mind—of our thoughts and our emotions. These can heal as well. In this kind of healing, brain chemicals and the cells that make them must find their right balance.

How a thought or an emotion emerges from those cells and brain chemicals is a process we do not yet understand. What we do know is that the same nerve chemicals and cell processes that create mood and imbalances of mood are also involved in our perception of the world around us. We construct an image of a place based on the information we receive through our senses, and somehow, somewhere—actually in many places in the brain—it all gets put together to create our sense of place. Just as healing is a constant process, so is sense of place. Our perception of place changes not only with our location, the weather, and the time of day—the physical elements of space—but also with our moods and our health. Our sense of where we are is continually being created and re-created in our brain, depending on current conditions and on our memories of what went on there.

Think of a widow, long married and recently bereaved. She finds herself in a resort town where she used to come year after year with her husband when he was well. His declining health prevented them from visiting here in the waning years of his life, and months of grieving have prevented her from coming back until now, a year after his death. She longs to revisit a tiny restaurant, not more than a hole in the wall where only the locals dined, which she and her husband had made their own. Night after night they used to come to the place for a simple supper—large prawns broiled in special spices were his favorite. They had a favorite waiter, too, who always chose the freshest seafood and showed it to them, before asking the chef to prepare it exactly as they liked. The place is not close to where she is staying now, but she had to go there, drawn by the memories and the desire to relive those days. She can't remember exactly where the restaurant is, since they always went on foot from their hotel. Now, as the cab winds its way through the dark and narrow streets, she recognizes the neighborhood, and, with a mixture of excitement and anxiety, finally sees the restaurant's awning and the pool of light spilling into the street. There's no window, not even a door, just an open wall, and, separating the tiny room from the street, a refrigerated glass case filled with fish, crabs, prawns, and octopus freshly caught from the bay. With trepidation she gets out of the taxi and walks up to greet the waiter, *their* waiter, who immediately recognizes her. In the same instant, he notices that her husband is not with her. They embrace, shed a few tears, recall his booming presence and the sadness of their loss. The waiter seats her at the couple's favorite table. She looks around and is flooded with emotions—happy memories of their times there together, mingled with sad ones of the present. The light, the smells, the sounds are all the same. One moment, she travels back into memory and revels in it; the next moment, she becomes aware of her husband's absence, and weeps. But there is something comforting about visiting this place one more time. The welter of emotions inside her is helping to close the wound and bringing her back to the stream of life.

It is at this level—in the brain and in the mind—that healing and places intertwine. Healing has a rhythm and a flow. Some illnesses stop and start, some have a downward course, and some resolve. The pace toward recovery is often agonizingly slow and often jerky, as sudden improvements alternate with backward steps. Imagine what one of Roger Ulrich's gall bladder patients must have experienced before waking up in that hospital bed by the window.

In the operating room, the surgeon, under the glare of the surgical lamp, swiftly and carefully put scalpel to skin. With one firm stroke the blade cut through the top layer of skin, through the underlying layer of yellow-white fat, down to the abdominal muscle. With another stroke the blade cut through the muscle, exposing the abdominal cavity just above the liver. In the early 1980s, when Ulrich performed his study, the incision would have been several inches long, exposing the liver's glistening reddish-brown surface. Today, it would be less than an inch, just enough to insert an optical device—a magnifying camera—through which the surgeon can peer. Once the gall bladder, like a green balloon filled with pebbles, is snipped from its stalk and removed, the surgeon works back up through layers of muscle, fat, and skin to suture the incisions.

These few cuts immediately set in motion a series of events that turn the body's energies toward a single goal: healing the wounds. The repair process is messy at best, and messier still if complications like infection arise.

It is the immune system that provides the machinery of healing. Many different kinds of immune cells, each with its special task, arrive on the scene like well-choreographed actors who know their cues and their places onstage. When the surgeon's blade pierces the skin and the tissue underneath, it also cuts through blood vessels. Sharp and clean as those cuts are, they inevitably kill cells as they rend the connections that hold together the surface of the skin. When cells die they release their contents, including chemicals that call living cells to the site. The cells they summon—white blood cells shaped like irregular spheres, called *monocytes*—have been happily floating through the bloodstream. Now they begin to assume a different shape, and no longer float smoothly through the blood but collide with the inner surface of the vessels. As they roll and bump along, they produce proteins on their surface that make them stick to the blood vessel walls. And then, like some primordial fish taking its first tentative steps onto land, they change shape even more. Bits of their surface reach out, like feet, and they begin to crawl and ooze, first along the blood vessel and then through cracks between the cells that make up the vessel's lining. They use these foot-like extensions, called *pseudopods,* to crawl through the tissues beneath the blood vessel, toward the wound, drawn inexorably by the scent of the chemicals released by the dying cells.

The substances that draw these cells toward them are proteins called *chemokines*—from the Greek words meaning "chemical" and "kinetic," literally "chemicals that make cells move." These molecules have an amazing power to summon cells that are crucial to the body's defense, the *phagocytes* (meaning "cells that eat"). These cells do indeed consume all of the foreign material in their path. Once a monocyte is activated and begins to move through the tissues, it is called a *macrophage* and begins to gorge itself with the debris it encounters. The feet on which it crawls reach out and engulf any dead or foreign tissue in its path. You can watch this drama in real time under a microscope, and even feed these cells tiny latex beads. They will envelop each bead until they swell to bursting. When they ingest dead or foreign material, they absorb it into pools of enzymes inside tiny balloons in their cytoplasm—the liquid inside the cell. These balloons are called *lysozomes,* and if their contents were to spill, the chemicals would destroy the nearby tissue. In fact, this is what happens when the surgeon's knife cuts through the cells. But when the enzymes are held safely inside a skin within a skin—inside the lysozome inside the macrophage—they become the cell's garbage disposal units. They quickly separate the debris into its component proteins, dismantle the proteins into bits and pieces, and then fragment the bits into the molecular building blocks (amino acids) that constitute those proteins. In this way the dead and dying tissues are broken down, recycled, and removed, making way for the next phase of healing.

New cells now stream into the site—cells whose job it is to fill the hole, to glue the edges of the cut together. These cells, called *fibroblasts,* make a kind of protein glue called *collagen.* This is what holds cells together in a matrix, to create the tissues—skin, tendon, fat, and muscle. It is what makes your skin firm and supple and elastic. And it is what creates a scar.

In the midst of all this activity, other cells arrive to fend off infection. These are *lymphocytes,* and there are many different kinds. They make antibodies, attack viruses, fend off bacteria. Each cell, while doing its job, also grows and divides, so that many more cells of each type accumulate at the scene, facilitating the healing process. It is this activity that causes the redness, heat, swelling, and pain at sites where healing is beginning. Only later does a scar appear.

All this takes a predictable amount of time. Even if you have very minor surgery—say, to remove a mole on your nose—you will be sent home with an instruction sheet that tells you when you can take off the outer pressure bandage (in twenty-four to forty-eight hours); when you can first wet your face or wash your hair (not before five to seven days); and when you should return to have the sutures removed (in seven to ten days). The reason doctors can foresee each step with such accuracy is that the healing process follows a set timeline.

The process is difficult to speed up, but it can be impeded—by drugs or infection or even stress. If your father has Alzheimer's disease and you are his main caregiver, you grieve every single day, over and over again. Here is the same man you've known throughout your life, but his body is now just a shell. As time goes on, relentlessly, you find less and less of his personality as you look into his face. You worry about his health, about his tendency to wander off, about his combative moments when he strikes out at those who try to help. You sleep poorly, in fits and starts, and you are tired every moment of the day. You are depressed and have lost your appetite. You are chronically stressed. All of this affects your immune system and its ability to heal.

Place, too, can have an effect on healing. If you are living in dark, cramped, crowded quarters where noise is constant, you will be stressed. If you are isolated, far from friends and family, you will be stressed. In such cases your immune system is burdened and the healing process slows. Wherever you are in the course of illness or healing, your physical surroundings can change the way you feel and, as a result, can change how quickly you heal. In all these contexts, communication between the brain and the immune system is vital. Besides bringing in new cells to help fight germs, molecules released by immune cells during infections also travel to the brain and change the way it functions. One of the things immune molecules do when we are sick is wipe out memory of our surroundings. The part of the brain that focuses on sensations from our inner organs becomes more active, and the part that focuses on the outer world shuts down. So we become exquisitely sensitive to internal signals from our throat or stomach or lungs, and acutely aware of every breath or twinge, and we lose interest in anything beyond the self.

The brain, in turn, sends its own signals to immune cells—hormones and nerve chemicals that can tune up or tune down the ability of immune cells to fight disease. There are many things that can influence the release of these chemical signals from the brain, and our surroundings play a very important part. How we perceive the world around us, its features of light and dark, sound and smell, temperature and touch, feed into the brain through all our senses and trigger the brain's emotional centers, which make us react. These emotional centers release nerve chemicals and hormones that can change how immune cells fight disease. In turn, through this communication, our awareness of space and place changes when we are ill, and changes yet again when we begin to heal.

We don't yet fully understand all the ways in which windows could affect healing. Their influence could stem from the light they provide, the colors one sees, the sounds one hears, the odors one smells. Or it might be due to a release from boredom, the escape they offer—or to some or all of these factors, depending on the individual's experience. But the remarkable thing is that the fields of neuroscience, immunology, psychology, architecture, and engineering have reached the point where scholars and practitioners are ready to talk to one another and learn from one another. In so doing, they will come closer to answering such questions about the effects of place on healing.

It was the immunologist and virologist Jonas Salk whose legacy brought together the experts at Woods Hole, through a request born of his own experience with the inspirational nature of a place. In the 1950s, while Salk was working to develop a polio vaccine in his basement laboratory in Pittsburgh, he came to an impasse. Frustrated and demoralized, he decided to take a sabbatical, and stayed for a time in the Italian town of Assisi. So inspired was he by the light and beauty and spiritual aura of the place, that he hit upon the solution to his problem. He rushed back to his lab and created his vaccine, which has since saved millions of lives.

Salk was never awarded the Nobel Prize, nor was he even admitted to the prestigious National Academy of Sciences. But he received a gift of land from the San Diego City Council, and enough money from the March of Dimes to build his own research center. Salk vowed that, in the spirit of Assisi, he would build the facility in a place suffused with light and surrounded by beautiful views—a place that would inspire the imagination of other scientists just as Assisi had inspired him. He chose La Jolla, near San Diego in Southern California, and worked with the architect Louis Kahn to build what many architects view as one of the greatest architectural achievements of the twentieth century: the Salk Institute.

Set atop the cliffs overlooking the Pacific Ocean, the institute comprises a pair of long, four-story buildings that stand perpendicular to the cliffs. They appear to be made of the same chalky stone as the cliffs, but in fact are made of concrete—a concrete that Kahn designed to resemble the native limestone. At Salk's request, every researcher is assigned not only lab space on the main floor, but also a private office on the second floor, overlooking the sea. The wood-paneled offices are quiet and peaceful—ideal spaces for contemplation. Between the two buildings is a travertine-paved promenade which blends in so well that the cliffs, the outdoor space, and the structures appear as a unified whole. The buildings are aligned so that the beams of the setting sun fall directly between them as it sinks beyond the sea. A narrow channel of water, running the length of the promenade and emptying into a reflecting pool, catches the sun's rays like fire. The institute is now a mecca for architects and scientists alike, and has become world famous for its research in basic science, molecular biology, and neuroscience.

When Salk came to Washington, D.C., in 1992 to accept the American Architectural Foundation's prestigious award for a building that has stood the test of time, he told the officers of the foundation about his experience in Assisi, which had led him to re-create with Kahn the same atmosphere on the La Jolla