‘The poet laureate of medicine’
New York Times

The River of Consciousness

Oliver Sacks

Author of *The Man Who Mistook His Wife For a Hat*

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Foreword

Two weeks before his death in August 2015, Oliver Sacks outlined the contents of *The River of Consciousness,* the last book he would oversee, and charged the three of us with arranging its publication.

One of many catalysts for this book was an invitation Sacks received in 1991 from a Dutch filmmaker to participate in a documentary television series called *A Glorious Accident.* In the final episode, six scientists—the physicist Freeman Dyson, the biologist Rupert Sheldrake, the paleontologist Stephen Jay Gould, the historian of science Stephen Toulmin, the philosopher Daniel Dennett, and Dr. Sacks—gathered around a table to discuss some of the most important questions that scientists investigate: the origin of life, the meaning of evolution, the nature of consciousness. In a lively discussion, one thing was clear: Sacks could move fluidly among *all* of the disciplines. His grasp of science was not restricted to neuroscience or medicine; the issues, ideas, and questions of all the sciences enthused him. That wide-ranging expertise and passion informs the perspective of this book, in which he interrogates the nature not only of human experience but of all life (including botanical life).

In *The River of Consciousness,* he takes on evolution, botany, chemistry, medicine, neuroscience, and the arts, and calls upon his great scientific and creative heroes—above all, Darwin, Freud, and William James. For Sacks, these writers were constant companions from an early age, and much of his own work can be seen as an extended conversation with them. Like Darwin, he was an acute observer and delighted in collecting examples, many of which came from his massive correspondence with patients and colleagues. Like Freud, he was drawn to understand human behavior at its most enigmatic. And like James, even when Sacks's subject is theoretical, as in his investigations of time, memory, and creativity, his attention remains on the specificity of experience.

Dr. Sacks wished to dedicate this book to his editor, mentor, and friend of more than thirty years, Robert Silvers, who first published a number of the pieces gathered here in *The New York Review of Books.*

—Kate Edgar, Daniel Frank, and Bill Hayes

The River of Consciousness

Darwin and the Meaning of Flowers

We all know the canonical story of Charles Darwin: the twenty-two-year-old embarking on the *Beagle,* going to the ends of the earth; Darwin in Patagonia; Darwin on the Argentine pampas (managing to lasso the legs of his own horse); Darwin in South America, collecting the bones of giant extinct animals; Darwin in Australia—still a religious believer—startled at his first sight of a kangaroo ("surely two distinct Creators must have been at work"). And, of course, Darwin in the Galápagos, observing how the finches were different on each island, starting to experience the seismic shift in understanding how living things evolve that, a quarter of a century later, would result in the publication of *On the Origin of Species.*

The story climaxes here, with the publication of the *Origin* in November 1859, and has a sort of elegiac postscript: a vision of the older and ailing Darwin, in the twenty-odd years remaining to him, pottering around his gardens at Down House with no particular plan or purpose, perhaps throwing off a book or two, but with his major work long completed.

Nothing could be further from the truth. Darwin remained intensely sensitive both to criticisms and to evidence supporting his theory of natural selection, and this led him to bring out no fewer than five editions of the *Origin.* He might indeed have retreated (or returned) to his garden and his greenhouses after 1859 (there were extensive grounds around Down House, and five greenhouses), but for him these became engines of war, from which he would lob great missiles of evidence at the skeptics outside—descriptions of extraordinary structures and behaviors in plants very difficult to ascribe to special creation or design—a mass of evidence for evolution and natural selection even more overwhelming than that presented in the *Origin.*

Strangely, even Darwin scholars pay relatively little attention to this botanical work, even though it encompassed six books and seventy-odd papers. Thus Duane Isely, in his 1994 book, *One Hundred and One Botanists,* writes that while

> more has been written about Darwin than any other biologist who ever lived . . . [he] is rarely presented as a botanist. . . . The fact that he wrote several books about his research on plants is mentioned in much Darwinia, but it is casual, somewhat in the light of "Well, the great man needs to play now and then."

Darwin had always had a special, tender feeling for plants and a special admiration, too. ("It has always pleased me to exalt plants in the scale of organised beings," he wrote in his autobiography.) He grew up in a botanical family—his grandfather Erasmus Darwin had written a long, two-volume poem called *The Botanic Garden,* and Charles himself grew up in a house whose extensive gardens were filled not only with flowers but with a variety of apple trees crossbred for increased vigor. As a university student at Cambridge, the only lectures Darwin consistently attended were those of the botanist J. S. Henslow, and it was Henslow, recognizing the extraordinary qualities of his student, who recommended him for a position on the *Beagle.*

It was to Henslow that Darwin wrote very detailed letters full of observations about the fauna and flora and geology of the places he visited. (These letters, when printed and circulated, were to make Darwin famous in scientific circles even before the *Beagle* returned to England.) And it was for Henslow that Darwin, in the Galápagos, made a careful collection of all the plants in flower and noted how different islands in the archipelago could often have different species of the same genus. This was to become a crucial piece of evidence for him as he thought about the role of geographical divergence in the origin of new species.

Indeed, as David Kohn pointed out in a splendid 2008 essay, Darwin's Galápagos plant specimens, numbering well over two hundred, constituted "the single most influential natural history collection of live organisms in the entire history of science. . . . They also would turn out to be Darwin's best documented example of the evolution of species on the islands."

(The birds Darwin collected, by contrast, were not always correctly identified or labeled with their island of origin, and it was only on his return to England that these, supplemented by the specimens collected by his shipmates, were sorted out by the ornithologist John Gould.)

Darwin became close friends with two botanists, Joseph Dalton Hooker at Kew Gardens and Asa Gray at Harvard. Hooker had become his confidant in the 1840s—the only man to whom he showed the first draft of his work on evolution—and Asa Gray was to join the inner circle in the 1850s. Darwin would write to them both with increasing enthusiasm about "*our* theory."

Yet though Darwin was happy to call himself a geologist (he wrote three geological books based on his observations during the voyage of the *Beagle* and conceived a strikingly original theory on the origin of coral atolls, which was confirmed experimentally only in the second half of the twentieth century), he always insisted that he was not a botanist. One reason was that botany had (despite a precocious start in the early eighteenth century with Stephen Hales's *Vegetable Staticks,* a book full of fascinating experiments on plant physiology) remained almost entirely a descriptive and taxonomic discipline: plants were identified, classified, and named but not *investigated.* Darwin, by contrast, was preeminently an investigator, concerned with the "how" and "why" of plant structure and behavior, not just the "what."

Botany was not a mere avocation or hobby for Darwin, as it was for so many in the Victorian age; the study of plants was always infused for him with theoretical purpose, and the theoretical purpose had to do with evolution and natural selection. It was, as his son Francis wrote, "as though he were charged with theorising power ready to flow into any channel on the slightest disturbance, so that no fact, however small, could avoid releasing a stream of theory." And the flow went both ways; Darwin himself often said that "no one could be a good observer unless he was an active theoriser."

In the eighteenth century, the Swedish scientist Carl Linnaeus had shown that flowers had sexual organs (pistils and stamens), and indeed had based his classifications on these. But it was almost universally believed that flowers were self-fertilized—why else would each flower contain both male and female organs? Linnaeus himself made merry with the idea, portraying a flower with nine stamens and one pistil as a bedchamber in which a maiden was surrounded by nine lovers. A similar conceit appeared in the second volume of Darwin's grandfather's book *The Botanic Garden,* titled *The Loves of the Plants.* This was the atmosphere in which the younger Darwin grew up.

But within a year or two of his return from the *Beagle,* Darwin felt forced, on theoretical grounds, to question the idea of self-fertilization. In an 1837 notebook, he wrote, "Do not plants which have male and female organs together yet receive influence from other plants?" If plants were ever to evolve, he reasoned, cross-fertilization was crucial—otherwise, no modifications could ever occur, and the world would be stuck with a single, self-reproducing plant instead of the extraordinary range of species it actually had. In the early 1840s, Darwin started to test his theory, dissecting a variety of flowers (azaleas and rhododendrons among them) and demonstrating that many of these had structural devices for preventing or minimizing self-pollination.

But it was only after *On the Origin of Species* was published in 1859 that Darwin could turn his full attention to plants. And where his early work was primarily as an observer and a collector, experiments now became his chief way of obtaining new knowledge.

He had observed, as others had, that primrose flowers came in two different forms: a "pin" form with a long style—the female part of the flower—and a "thrum" form with a short style. These differences were thought to have no particular significance. But Darwin suspected otherwise, and examining bunches of primroses that his children brought him, he found that the ratio of pins to thrums was exactly one to one.

Darwin's imagination was instantly aroused: a one-to-one ratio was what one might expect of species with separate males and females—could it be that the long-styled flowers, though hermaphrodites, were in the process of becoming female flowers and the short-styled ones male flowers? Was he actually seeing intermediate forms, evolution in action? It was a lovely idea, but it did not hold up, for the short-styled flowers, the putative males, produced as much seed as the long-styled, "female" ones. Here (as his friend T. H. Huxley would have put it) was "the slaying of a beautiful hypothesis by an ugly fact."

What, then, was the meaning of these different styles and their one-to-one ratio? Giving up theorizing, Darwin turned to experiment. Painstakingly, he tried acting as a pollinator himself, lying facedown on the lawn and transferring pollen from flower to flower: long-styled to long-styled, short-styled to short-styled, long-styled to short-styled, and vice versa. When seeds were produced, he collected and weighed them and found that the richest crop of seeds came from the crossbred flowers. He concluded that heterostyly, in which plants have styles of different length, was a special device that had evolved to facilitate outbreeding and that crossing increased the number and vitality of seeds (he called this "hybrid vigour"). Darwin later wrote, "I do not think anything in my scientific life has given me so much satisfaction as making out the meaning of the structure of these plants."

Although this subject remained a special interest of

Darwin's (he published a book on it in 1877, *The Different Forms of Flowers on Plants of the Same Species*), his central concern was how flowering plants adapted themselves to using insects as agents for their own fertilization. It was well known that insects were attracted to certain flowers, visited them, and could emerge from blossoms covered with pollen. But no one had thought this was of much importance, since it was assumed that flowers were self-pollinated.

Darwin had already become suspicious of this by 1840, and in the 1850s he set five of his children to work plotting the flight routes of male humble bees. He especially admired the native orchids that grew in the meadows around Down, so he started with those. Then, with the help of friends and correspondents who sent him orchids to study, and especially Hooker, who was now director of Kew Gardens, he extended his studies to tropical orchids of all kinds.

The orchid work moved quickly and well, and in 1862 Darwin was able to send his manuscript to the printers. The book had a typically long and explicit Victorian title, *On the Various Contrivances by Which British and Foreign Orchids Are Fertilised by Insects.* His intentions, or hopes, were made clear in its opening pages:

> In my volume "On the Origin of Species" I gave only general reasons for the belief that it is an almost universal law of nature that the higher organic beings require an occasional cross with another individual. . . . I wish here to show that I have not spoken without having gone into details. . . . This treatise affords me also an opportunity of attempting to show that the study of organic beings may be as interesting to an observer who is fully convinced that the structure of each is due to secondary laws, as to one who views every trifling detail of structure as the result of the direct interposition of

the Creator.

Here, in no uncertain terms, Darwin is throwing down the gauntlet, saying, "Explain *that* better—if you can."

Darwin interrogated orchids, interrogated flowers, as no one had ever done before, and in his orchid book he provided enormous detail, far more than is to be found in the *Origin.* This was not because he was pedantic or obsessional but because he felt that every detail was potentially significant. It is sometimes said that God is in the details, but for Darwin it was not God but natural selection, acting over millions of years, which shone out from the details, details that were unintelligible, senseless, except in the light of history and evolution. His botanical researches, his son Francis wrote,

> supplied an argument against those critics who have so freely dogmatised as to the uselessness of particular structures, and as to the consequent impossibility of their having been developed by means of natural selection. His observations on Orchids enabled him to say: "I can show the meaning of some of the apparently meaningless ridges and horns; who will now venture to say that this or that structure is useless?"

In a 1793 book titled *The Secret of Nature in the Form and Fertilization of Flowers Discovered,* the German botanist Christian Konrad Sprengel, a most careful observer, had noted that bees laden with pollen would carry it from one flower to another. Darwin always called this a "wonderful" book. But Sprengel, though he drew close, missed the final secret, because he was still wedded to the Linnaean idea of flowers as self-fertilizing and thought of flowers of the same species as essentially identical. It was here that Darwin made a radical break and cracked the secret of flowers, by showing that their special features—the various patterns, colors, shapes, nectars, and scents by which they lured insects to flit from one plant to another, and the devices which ensured that the insects would pick up pollen before they left the flower—were all "contrivances," as he put it; they had all evolved in the service of cross-fertilization.

What had once been a pretty picture of insects buzzing about brightly colored flowers now became an essential drama in life, full of biological depth and meaning. The colors and smells of flowers were adapted to insects' senses. While bees are attracted to blue and yellow flowers, they ignore red ones, because they are red-blind. On the other hand, their ability to see beyond the violet is exploited by flowers which use ultraviolet markings—the honey guides that direct bees to their nectaries. Butterflies, with good red vision, fertilize red flowers but may ignore the blue and violet ones. Flowers pollinated by night-flying moths tend to lack color but to exude their scents at night. And flowers pollinated by flies, which live on decaying matter, may mimic the (to us) foul smells of putrid flesh.

It was not just the evolution of plants but the *coevolution* of plants and insects that Darwin illuminated for the first time. Thus natural selection would ensure that the mouth parts of insects matched the structure of their preferred flowers—and Darwin took special delight in making predictions here. Examining one Madagascan orchid with a nectary nearly a foot long, he predicted that a moth would be found with a proboscis long enough to probe its depths; decades after his death, such a moth was finally discovered.

The *Origin* was a frontal assault (delicately presented though it was) on creationism, and while Darwin had been careful to say little in the book about human evolution, the implications of his theory were perfectly clear. It was especially the idea that man could be regarded as a mere animal—an ape—descended from other animals that had provoked outrage and ridicule. But for most people, plants were a different matter—they neither moved nor felt; they inhabited a kingdom of their own, separated from the animal kingdom by a great gulf. The evolution of plants, Darwin sensed, might seem less relevant, or less threatening, than the evolution of animals, and so more accessible to calm and rational consideration. Indeed, he wrote to Asa Gray, "no one else has perceived that my chief interest in my orchid book, has been that it was a 'flank movement' on the enemy." Darwin was never belligerent, like his "bulldog" Huxley, but he knew that there was a battle to wage, and he was not averse to military metaphors.

It is, however, not militancy or polemic that shines out of the orchid book; it is sheer joy, delight in what he was seeing. This delight and exuberance burst out of his letters:

> You cannot conceive how the Orchids have delighted me. . . . What wonderful structures! . . . The beauty of the adaptation of parts seems to me unparalleled. . . . I was almost mad at the wealth of Orchids. . . . One splendid flower of *Catasetum,* the most wonderful Orchid I have seen. . . . Happy man, he [who] has actually seen crowds of bees flying round *Catasetum,* with the pollinia sticking to their backs! . . . I never was more interested in any subject in all my life than in this of Orchids.

The fertilization of flowers engaged Darwin to the end of his life, and the orchid book was followed, nearly fifteen years later, by a more general book, *The Effects of Cross and Self Fertilisation in the Vegetable Kingdom.*

But plants also have to survive, flourish, and find (or create) niches in the world, if they are ever to reach the point of reproduction. Darwin was equally interested in the devices and adaptations by which plants survived and in their varied and sometimes astonishing lifestyles, which included sense organs and motor powers akin to those of animals.

In 1860, during a summer holiday, Darwin first encountered and became enamored of insect-eating plants, and this started a series of investigations that culminated fifteen years later in the publication of *Insectivorous Plants.* This volume has an easy, companionable style and starts, like most of his books, with a personal recollection:

> I was surprised by finding how large a number of insects were caught by the leaves of the common sun-dew (*Drosera rotundifolia*) on a heath in Sussex. . . . On one plant all six leaves had caught their prey. . . . Many plants cause the death of insects . . . without thereby receiving, as far as we can perceive, any advantage; but it was soon evident that *Drosera* was excellently adapted for the special purpose of catching insects.

The idea of adaptation was always in Darwin's mind, and one look at the sundew showed him that these were adaptations of an entirely novel kind, for *Drosera*'s leaves not only had a sticky surface but were covered with delicate filaments (Darwin called them "tentacles") with glands at their tips. What were these for? he wondered.

"If a small organic or inorganic object be placed on the glands in the centre of a leaf," he observed,

> they transmit a motor impulse to the marginal tentacles. . . . The nearer ones are first affected and slowly bend towards the centre, and then those farther off, until at last all become closely inflected over the object.

But if the object was not nourishing, it was speedily released.

Darwin went on to demonstrate this by putting blobs of egg white on some leaves and similar blobs of inorganic matter on others. The inorganic matter was quickly released, but the egg white was retained and stimulated the formation of a ferment and an acid that soon digested and absorbed it. It was similar with insects, especially live ones. Here, without a mouth, or a gut, or nerves, *Drosera* efficiently captured its prey and absorbed it, using special digestive enzymes.

Darwin addressed not only how *Drosera* functioned but why it had adopted so extraordinary a lifestyle: he observed that the plant grew in bogs, in acidic soil that was relatively barren of organic material and assimilable nitrogen. Few plants could survive in such conditions, but *Drosera* had found a way to claim this niche by absorbing its nitrogen directly from insects rather than from the soil. Amazed by the animal-like coordination of *Drosera*'s tentacles, which closed on its prey like those of a sea anemone, and by the plant's animal-like ability to digest, Darwin wrote to Asa Gray, "You are unjust on the merits of my beloved *Drosera;* it is a wonderful plant, or rather a most sagacious animal. I will stick up for *Drosera* to the day of my death."

And he became still more enthusiastic about *Drosera* when he found that making a small nick in half of a leaf would paralyze just that half, as if a nerve had been cut. The appearance of such a leaf, he wrote, resembled "a man with his backbone broken and lower extremities paralysed." Darwin later received specimens of the Venus flytrap—a member of the sundew family—which, the moment its trigger-like hairs were touched, would clap its leaves together on an insect and imprison it. The flytrap's reactions were so fast that Darwin wondered whether electricity could be involved, something analogous to a nerve impulse. He discussed this with his physiologist colleague Burdon Sanderson and was delighted when Sanderson was able to show that electric current was indeed generated by the leaves and could also stimulate them to close. "When the leaves are irritated," Darwin recounted in *Insectivorous Plants,* "the current is disturbed in the same manner as takes place during the contraction of the muscle of an animal."

Plants are often regarded as insensate and immobile—but the insect-eating plants provided a spectacular rebuttal of this notion, and now, eager to examine other aspects of plant motion, Darwin turned to an exploration of climbing plants. (This would culminate in the publication of *On the Movements and Habits of Climbing Plants.*) Climbing was an efficient adaptation, allowing plants to disburden themselves of rigid supporting tissue by using other plants to support and elevate them. And there was not just one way of climbing but many. There were twining plants, leaf-climbers, and plants that climbed with the use of tendrils. These especially fascinated Darwin—it was almost, he felt, as if they had "eyes" and could "survey" their surroundings for suitable supports. "I believe, Sir, the tendrils can see," he wrote to J. D. Hooker. How did such complex adaptations arise?

Darwin saw twining plants as ancestral to other climbing plants, and he thought that tendril-bearing plants had evolved from these, and leaf-climbers, in turn, from tendril-bearers, each development opening up more and more possible niches—roles for the organism in its environment. Thus climbing plants had evolved over time—they had not all been created in an instant, by divine fiat. But how did twining itself start? Darwin had observed twisting movements in the stems, leaves, and roots of every plant he had examined, and such twisting movements (which he called circumnutation) could also be observed in the earliest evolved plants: cycads, ferns, seaweeds, too. When plants grow towards the light, they do not just thrust upwards; they twist, they corkscrew, towards the light. Circumnutation, Darwin came to think, was a universal disposition of plants and the antecedent of all other twisting movements in plants.

These thoughts, along with dozens of beautiful experiments, were set out in his last botanical book, *The Power of Movement in Plants,* published in 1880. Among the many charming and ingenious experiments he recounted was one in which he planted oat seedlings, shone light on them from different directions, and found that they always bent or twisted towards the light, even when it was too dim to be seen by human eyes. Was there (as he imagined of the tips of tendrils) a photosensitive region, a sort of "eye" at the tips of the seedling leaves? He devised little caps, darkened with India ink, to cover these and found that they no longer responded to light. It was clear, he concluded, that when light fell on the leaf tip, it stimulated the tip to release some sort of messenger which, reaching the "motor" parts of the seedling, caused it to twist towards the light. Similarly, the primary roots (or radicles) of seedlings, which have to negotiate all sorts of obstacles, Darwin found to be extremely sensitive to contact, gravity, pressure, moisture, chemical gradients, etc. He wrote,

> There is no structure in plants more wonderful, as far as its functions are concerned, than the tip of the radicle. . . . It is hardly an exaggeration to say that the tip of the radicle . . . acts like the brain of one of the lower animals . . . receiving impressions from the sense-organs, and directing the several movements.

But as Janet Browne remarks in her biography of Darwin, *The Power of Movement in Plants* was “an unexpectedly controversial book.” Darwin’s idea of circumnutation was roundly criticized. He had always acknowledged it as a speculative leap, but a more cutting criticism came from the German botanist Julius Sachs, who, in Browne’s words, “sneered at Darwin’s suggestion that the tip of the root might be compared to the brain of a simple organism and declared that Darwin’s home-based experimental techniques were laughably defective.”

However homely Darwin’s techniques, though, his observations were precise and correct. His ideas of a chemical messenger being transmitted downwards from the sensitive tip of the seedling to its “motor” tissue were to lead the way, fifty years later, to the discovery of plant hormones like auxins, which, in plants, play many of the roles that nervous systems do in animals.

Darwin had been an invalid for forty years, with an enigmatic illness that had assailed him since his return from the Galápagos. He would sometimes spend entire days vomiting or confined to his sofa, and as he grew older, he developed heart problems, too. But his intellectual energy and creativity never wavered. He wrote ten books after the *Origin,* many of which went through major revisions themselves—to say nothing of dozens of articles and innumerable letters. He continued to pursue his varied interests throughout his life. In 1877 he published a second edition, greatly enlarged and revised, of his orchid book (originally published fifteen years earlier). My friend Eric Korn, an antiquarian and Darwin specialist, told me that he once had a copy of this in which there was slipped the counterfoil of an 1882 postal order for two shillings and nine pence, signed by Darwin himself, in payment for a new orchid specimen. Darwin was to die in April of that year, but he was still in love with orchids and collecting them for study within weeks of his death.

Natural beauty, for Darwin, was not just aesthetic; it always reflected function and adaptation at work. Orchids were not just ornamental, to be displayed in a garden or a bouquet; they were wonderful contrivances, examples of nature's imagination, natural selection, at work. Flowers required no Creator, but were wholly intelligible as products of accident and selection, of tiny incremental changes extending over hundreds of millions of years. This, for Darwin, was the meaning of flowers, the meaning of all adaptations, plant and animal, the meaning of natural selection.

It is often felt that Darwin, more than anyone, banished "meaning" from the world—in the sense of any overall divine meaning or purpose. There is indeed no design, no plan, no blueprint in Darwin's world; natural selection has no direction or aim, nor any goal to which it strives. Darwinism, it is often said, spelled the end of teleological thinking. And which one could see the whole history of life. The idea that it could have worked out differently, that dinosaurs might still be roaming the earth or that human beings might never have evolved, was a dizzying one. It made life seem all the more precious and a wonderful, ongoing adventure ("a glorious accident," as Stephen Jay Gould called it)—not fixed or predetermined, but always susceptible to change and new experience.

Life on our planet is several billion years old, and we literally embody this deep history in our structures, our behaviors, our instincts, our genes. We humans retain, for example, the remnants of gill arches, much modified, from our fishy ancestors and even the neural systems that once controlled gill movement. As Darwin wrote in *The Descent of Man,* "Man still bears in his bodily frame the indelible stamp of his lowly origin." We bear, too, an even older past; we are made of cells, and cells go back to the very origin of life.

In 1837, in the first of many notebooks he was to keep on "the species problem," Darwin sketched a tree of life. Its brachiating shape, so archetypal and potent, reflected the balance of evolution and extinction. Darwin always stressed the continuity of life, how all living things are descended from a common ancestor, and how we are in this sense all related to each other. So humans are related not only to apes and other animals but to plants too. (Plants and animals, we know now, share 70 percent of their DNA.) And yet, because of that great engine of natural selection—variation—every species is unique and each individual is unique, too.

The tree of life shows at a glance the antiquity and the kinship of all living organisms and how there is "descent with modification" (as Darwin originally called evolution) at every juncture. It shows too that evolution never stops, never repeats itself, never goes backwards. It shows the irrevocability of extinction—if a branch is cut off, a particular evolutionary path is lost forever.

I rejoice in the knowledge of my biological uniqueness and my biological antiquity and my biological kinship with all other forms of life. This knowledge roots me, allows me to feel at home in the natural world, to feel that I have my own sense of biological meaning, whatever my role in the cultural, human world. And although animal life is far more complex than vegetable life, and human life far more complex than the life of other animals, I trace back this sense of biological meaning to Darwin's epiphany on the meaning of flowers, and to my own intimations of this in a London garden, nearly a lifetime ago.

Speed

As a boy, I was fascinated by speed, the wild range of speeds in the world around me. People moved at different speeds; animals much more so. The wings of insects moved too fast to see, though one could judge their frequency by the tone they emitted—a hateful noise, a high E, with mosquitoes, or a lovely bass hum with the fat bumblebees that flew around the hollyhocks each summer. Our pet tortoise, which could take an entire day to cross the lawn, seemed to live in a different time frame altogether. But what then of the movement of plants? I would come down to the garden in the morning and find the hollyhocks a little higher, the roses more entwined around their trellis, but, however patient I was, I could never catch them moving.

Experiences like this played a part in turning me to photography, which allowed me to alter the rate of motion, speed it up, slow it down, so I could see, adjusted to a human perceptual rate, details of movement or change otherwise beyond the power of the eye to register. Being fond of microscopes and telescopes (my older brothers, medical students and bird-watchers, kept theirs in the house), I thought of the slowing down or the speeding up of motion as a sort of temporal equivalent: slow motion as an enlargement, a microscopy of time, and speeded-up motion as a foreshortening, a telescopy of time.

I experimented with photographing plants. Ferns, in particular, had many attractions for me, not least in their tightly wound crosiers or fiddleheads, tense with contained time, like watch springs, with the future all rolled up in them. So I would set my camera on a tripod in the garden and take photographs of fiddleheads at hourly intervals; I would develop the negatives, print them up, and bind a dozen or so prints together in a little flickbook. And then, as if by magic, I could see the fiddleheads unfurl like the curled-up paper trumpets one blew into at parties, taking a second or two for what, in real time, took a couple of days.

Slowing down motion was not so easy as speeding it up, and here I depended on my cousin, a photographer, who had a cine camera capable of taking more than a hundred frames per second. With this, I was able to catch the bumblebees at work as they hovered in the hollyhocks and to slow down their time-blurred wing beats so that I could see each up-and-down movement distinctly.

My interest in speed and movement and time, and in possible ways to make them appear faster or slower, made me take a special pleasure in two of H. G. Wells's stories, "The Time Machine" and "The New Accelerator," with their vividly imagined, almost cinematic descriptions of altered time.

"As I put on pace, night followed day like the flapping of a black wing," Wells's Time Traveller relates:

> I saw the sun hopping swiftly across the sky, leaping it every minute, and every minute marking a day. . . . The slowest snail that ever crawled dashed by too fast for me. . . . Presently, as I went on, still

> gaining velocity, the palpitation of night and day merged into one continuous greyness . . . the jerking sun became a streak of fire . . . the moon a fainter fluctuating band. . . . I saw trees growing and changing like puffs of vapour . . . huge buildings rise up faint and fair, and pass like dreams. The whole surface of the earth seemed changed—melting and flowing under my eyes.

The opposite of this occurs in "The New Accelerator," the story of a drug that accelerates one's perceptions, thoughts, and metabolism several thousand times or so. Its inventor and the narrator, who have taken the drug together, wander out into a glaciated world, watching

> people like ourselves and yet not like ourselves, frozen in careless attitudes, caught in mid-gesture. . . . And sliding down the air with wings flapping slowly and at the speed of an exceptionally languid snail—was a bee.

"The Time Machine" was published in 1895, when there was intense interest in the new powers of photography and cinematography to reveal details of movements inaccessible to the unaided eye. Étienne-Jules Marey, a French physiologist, had been the first to show that a galloping horse at one point had all four hooves off the ground. His work, as the historian Marta Braun brings out, was instrumental in stimulating Eadweard Muybridge's famous photographic studies of motion. Marey, in turn stimulated by Muybridge, went on to develop high-speed cameras that could slow and almost arrest the movements of birds and insects in flight and, at the opposite extreme, to use time-lapse photography to accelerate the otherwise almost imperceptible movements of sea urchins, starfish, and other marine animals.

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It is often said that time seems to go more quickly, the years rush by, as one grows older—either because when one is young one's days are packed with novel, exciting impressions or because as one grows older a year becomes a smaller and smaller fraction of one's life. But if the years appear to pass more quickly, the hours and minutes do not; they are the same as they always were.

At least they seem so to me (in my seventies), although experiments have shown that while young people are remarkably accurate at estimating a span of three minutes by counting internally, elderly subjects apparently count more slowly, so that their perceived three minutes is closer to three and a half or four minutes. But it is not clear that this phenomenon has anything to do with the existential or psychological feeling of time passing more quickly as one ages.

The hours and minutes still seem excruciatingly long when I am bored and all too short when I am engaged. As a boy, I hated school, being forced to listen passively to droning teachers. When I looked at my watch surreptitiously, counting the minutes to my liberation, the minute hand, and even the second hand, seemed to move with infinite slowness. There is an exaggerated consciousness of time in such situations; indeed, when one is bored, there may be no consciousness of anything *but* time.

In contrast were the delights of experimenting and thinking in the little chemical lab I set up at home, and here,

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