A LONG LINE OF CELLS

Lewis Thomas has a theory that mankind is "going through the early stages of a species' adolescence. If we can . . . shake off the memory of this century . . . we may find ourselves off and running again." His optimism stems from the "high probability that we derived, originally, from some single cell." From "that first microorganism, parent of us all," man's development has mirrored the process that creates each of our bodies, with myriad cells replicating and splitting, sharing chromosomes "by random chance." Here, the noted writer-scientist assesses man's progress on the evolutionary path, pinning his hopes for the future on "better breeding, in both senses of the term."

by Lewis Thomas

An autobiography, I take it, is a linear account of one thing after another, leading—progressively, one hopes—to one's personal state of affairs at the moment of writing. In my case this would run to over 70 years, one after the other, discounting maybe 25 of the 70 spent sleeping, leaving around 45 to be dealt with. Even so, a lot of time to be covered if all the events were to be recalled and laid out.

But discount again the portion of those 16,500 days, 264,000 waking hours, spent doing not much of anything—reading the papers, staring at blank sheets of paper, walking from one room to the next, speaking a great deal of small talk and listening to still more, waiting around for the next thing to happen, whatever. Delete all this as irrelevant, then line up what's left in the proper linear order without fudging. There you are with an autobiography, now relieved of an easy three-fourths of the time lived, leaving only 11 years, or 4,000 days, or 64,000 hours. Not much to remember, but still too much to write down.

But now take out all the blurred memories, all the recollections you suspect may have been dressed up by your mind in your favor, leaving only the events you can't get out of your head, the notions

Lewis Thomas, in a 1986 photograph.

that keep leaping to the top of your mind, the ideas you're stuck with, the images that won't come unstuck, including the ones you'd just as soon do without. Edit these down sharply enough to reduce 64,000 hours to around 30 minutes, and there's your memoir.

In my case, going down this shortened list of items, I find that most of what I've got left are not real memories of my own experience, but mainly the remembrances of other people's thoughts, things I've read or been told, metamemories. A surprising number turn out to be wishes rather than recollections, hopes that something really did work the way everyone said it was supposed to work, hankerings that the one thing leading to another has a direction of some kind, and a hope for a pattern from the jumble—an epiphany out of entropy.

To begin on a confessional note, I was at one time, at my outset, a single cell. I have no memory of this stage of my life, but I know it to be true because everyone says so. There was of course a sort of half-life before that, literally half, when the two half-endowed, haploid gametes, each carrying half my chromosomes, were off on their own looking to bump into each other and did so, by random chance, sheer luck, for better or worse, richer or poorer, et cetera, et cetera, and I got under way.

I do not remember this, but I know that I began dividing. I have probably never worked so hard, and never again with such skill and certainty. At a certain stage, very young, a matter of hours of youth, I sorted myself out and became a system of cells, each labeled for what it was to become—brain cells, limbs, liver, the lot—all of them signaling to each other, calculating their territories, laying me out. At one stage I possessed an excellent kidney, good enough for any higher fish; then I thought better and destroyed it all at once, installing in its place a neater pair for living on land. I didn't plan on this when it was going on, but my cells, with a better memory, did.

Thinking back, I count myself lucky that I was not in charge at the time. If it had been left to me to do the mapping of my cells I would have got it wrong, dropped something, forgotten where to assemble my neural crest, confused it. Or I might have been stopped in my tracks, panicked by the massive deaths, billions of my embryonic cells being killed off systematically to make room for their more senior successors, death on a scale so vast that I can't think of it without wincing. By the time I was born, more of me had died than survived. It is no wonder I can't remember; during that time I went through brain after brain for nine months, finally contriving the one model that could be human, equipped for language.

It is because of language that I am able now to think farther back into my lineage. By myself, I can only remember two parents, one grandmother and the family stories of Welshmen, back into the shadows when all the Welsh were kings, but no farther. From there on I must rely on reading the texts.

They instruct me that I go back to the first of my immediate line, the beginner, the earliest *Homo sapiens*, human all the way through, or not quite human if you measure humanness as I do by the property of language and its property, the consciousness of an indisputably singular, unique self. I'm not sure how far back that takes me, and no one has yet told me about this convincingly. When did my relations begin speaking?

Lewis Thomas, 74, is chancellor of Memorial Sloan-Kettering Cancer Center. Born in Flushing, New York, he received a B.S. from Princeton (1933), an M.D. from Harvard (1937), and an M.A. from Yale (1969). He received the National Book Award for Lives of a Cell *(1974), and the American Book Award for* Medusa and the Snail *(1979). His most recent books include a memoir,* The Youngest Science *(1983), and* Late Night Thoughts on Listening to Mahler's Ninth Symphony *(1983).*

Writing is easier to trace, having started not more than a few years back, maybe 10,000 years, not much more. Tracking speech requires guesswork. If we were slow learners, as slow as we seem to be in solving today's hard problems, my guess is that we didn't begin talking until sometime within the last 100,000 years, give or take 50,000. That is what's called a rough scientific guess. But no matter, it is an exceedingly short time ago, and I am embarrassed at the thought that so many of my ancestors, generations of them—all the way back to the very first ones a million-odd years ago—may have been speechless. I am modestly proud to have come from a family of tool makers, bone scratchers, grave diggers, cave painters. Humans all. But it hurts to think of them as so literally dumb, living out their lives without metaphors, deprived of conversation, even small talk. I would prefer to have had them arrive fully endowed, talking their heads off, the moment evolution provided them with braincases large enough to contain words, so to speak. But it was not so, I must guess, and language came late. I will come back to this matter.

What sticks in the top of my mind is another, unavoidable aspect of my genealogy, far beyond my memory, but remembered still, I suspect, by all my cells. It is a difficult and delicate fact to mention. To face it squarely, I come from a line that can be traced straight back, with some accuracy, into a near-infinity of years before my first humanoid ancestors turned up. I go back, and so do you, like it or not, to a single Ur-ancestor whose remains are on display in rocks dated approximately 3–5 thousand million years ago, born a billion or so years after the Earth itself took shape and began cooling down. That first of the line, our n-grand-uncle, was unmistakably a bacterial cell.

I cannot get this out of my head. It has become, for the moment, the most important thing I know, the obligatory beginning of any memoir, the long-buried source of language. We derive from a lineage of bacteria, and a very long line at that. Never mind our embarrassed indignation when we were first told, last century, that we came from a family of apes and had chimps as near-cousins. That was relatively easy to accommodate, having at least the distant look of a set of relatives. But this new connection, already fixed by recent science beyond any hope of disowning the percentage, is something else again. At first encounter the news must come as a kind of humiliation. Humble origins indeed.

But then, it is some comfort to acknowledge that we've had an etymological hunch about such an origin since the start of our language. Our word *human* comes from the Proto-Indo-European root *dhghem*, meaning simply "earth." The most telling cognate word is *humus*, the primary product of microbial industry. Also, for what it's

worth, *humble*. Also *humane*. It gives a new sort of English, in the sense of a strange spin, to the old cliché for an apology: "Sorry, I'm only human."

Where did that first microorganism, parent of us all, come from? Nobody knows, and in the circumstance it's anyone's guess, and the guesses abound. Francis Crick suggests that the improbability of its forming itself here on Earth is so high that we must suppose it drifted in from outer space, shifting the problem to scientists in some other part of the galaxy. Others assert that it happened here indeed, piecing itself together molecule by molecule, over a billion years of chance events under the influence of sunlight and lightning, finally achieving by pure luck the exactly right sequence of nucleotides, inside the exactly right sort of membrane, and we were on our way.

No doubt the first success occurred in water. And not much doubt that the first event, however it happened, was the only such event, the only success. It was the biological equivalent of the Big Bang of the cosmo-physicists, very likely a singular phenomenon, a piece of unprecedented good luck never to be repeated. If the sheer improbability of the thing taking place more than once, spontaneously and by chance, were not enough, consider the plain fact that all the cells that came later, right up to our modern brain cells, carry the same strings of DNA and work by essentially the same genetic code. It is the plainest evidence of direct inheritance from a single parent. We are all in the same family—grasses, seagulls, fish, fleas, and voting citizens of the republic.

I ought to be able to remember the family tie, since all my cells are alive with reminders. In almost everything they do to carry me along from one day to the next, they use the biochemical devices of their microbial forebears. Jesse Roth and his colleagues at the National Institutes of Health have shown that the kingdom of bacteria had already learned, long before nucleated cells like ours came on the scene, how to signal to each other by chemical messages, inventing for this purpose molecules like insulin and a brilliant array of the same peptides that I make use of today for instructing my brain cells in proper behavior.

More than this, I could not be here, blinking in the light, without the help of an immense population of specialized bacteria that swam into cells like mine around a billion years ago and stayed there, as indispensable lodgers, ever since, replicating on their own, generation after generation. These are my mitochondria, the direct descendants of the first bacteria that learned how to make use of oxygen for energy. They occupy all my cells, swarming from one part to another wherever there is work to do. I could not lift a finger without them,

nor think a thought, nor can they live without me. We are symbionts, my mitochondria and I, bound together for the advance of the biosphere, living together in harmony, maybe even affection. For sure, I am fond of my microbial engines, and I assume they are pleased by the work they do for me.

Or is it necessarily that way, or the other way round? It could be, I suppose, that all of me is a sort of ornamented carapace for colonies of bacteria that decided, long ago, to make a try at real evolutionary novelty. Either way, the accommodation will do.

The plants are in the same situation. They have the same swarms of mitochondria in all their cells, and other foreign populations as well. Their chloroplasts, which do the work of tapping solar energy to make all sugar, are the offspring of ancient pigmented microorganisms called cyanobacteria, once known as blue-green algae. These were the first creatures to learn—at least 2.5 billion years ago—to use carbon dioxide from the air and plain water, and sunlight, to manufacture food for the market.

I am obsessed by bacteria in general, not just my own and those of the horse chestnut tree in my backyard. We would not have nitrogen for the proteins of the biosphere without the nitrogen-fixing bacteria, most of them living like special tissues in the roots of legumes. We would never have decay; dead trees would simply lie there forever, and so would we, and nothing on Earth would be recycled. We couldn't keep cows, for cattle can't absorb their kind of food until their intestinal bacteria have worked it over, and for the same reason there would be no termites to cycle the wood; they are, literally, alive with bacteria. We would not have luminous fish for our aquariums, for the source of that spectacular light around their eyes is their private colonies of luminescent bacteria. And we would never have obtained oxygen to breathe, for all the oxygen in our air is exhaled for our use by the photosynthetic microbes in the upper waters of the seas and lakes and in the leaves of forests.

It was not that we invented a sophisticated new kind of cell with a modern nucleus and then invited in the more primitive and simpler forms of life as migrant workers. More likely, the whole assemblage came together by the joining up of different kinds of bacteria; the larger cell, the original "host," may have been one that had lost its rigid wall and swelled because of this defect. Lynn Margulis has proposed that the spirochetes were part of the original committee, becoming the progenitors of the cilia on modern cells, also the organizers of meiosis and mitosis, the lining up of chromosomes, the allocation of DNA to progeny—in effect, the reading of all wills. If she is right about this, the spirochetes were the inventors of biologi-

cal sex and all that, including conclusive death.

The modern cell is not the single entity we once thought it was. It is an organism in its own right, a condominium, run by trustees.

If all this is true, as I believe it to be, the life of the Earth is more intimately connected than I used to think. This is another thing on my mind, so much in my head these days that it crowds out other thoughts I used to have, making me sit up straight now, bringing me to my feet and then knocking me off them. The world works. The whole Earth is alive, all of a piece, one living thing, a creature.

It breathes for us and for itself, and what's more it regulates the breathing with exquisite precision. The oxygen in the air is not placed there at random, any old way; it is maintained at precisely the optimal concentration for the place to be livable. A few percentage points more than the present level and the forests would burst into flames; a few less and most life would strangle. It is held there, constant, by feedback loops of information from the conjoined life of the planet. Carbon dioxide, inhaled by the plants, is held at precisely the low level that would be wildly improbable on any lifeless planet. And this happens to be the right concentration for keeping the Earth's temperature, including the heat of the oceans, exactly right. Methane, almost all of it the product of bacterial metabolism, contributes also to the greenhouse effect, and methane is held steady.

Statesmen must keep a close eye on the numbers these days—we are already pushing up the level of CO_2 by burning too much fuel and cutting too much forest, and the Earth may be in for a climatic catastrophe within the next century.

But there it is: Except for our meddling, the Earth is the most stable organism we can know about—a complex system, a vast intelligence, turning in the warmth of the sun, running its internal affairs with the near-infallibility of a huge computer. Not entirely infallible, however, on the paleontological record. Natural catastrophes occur, crashes, breakdowns in the system: ice ages, meteor collisions, volcanic eruptions, global clouding, extinctions of great masses of its living tissue. It goes *down*, as we say of computers, but never out, always up again with something new to display to itself.

The newest of all things, the latest novelty among its working parts, seems to be us—language-speaking, song-singing, tool-making, fire-warming, comfortable, warfaring mankind, and I am of that ilk.

I can't remember anything about learning language as a child. I do have a few memories of studying to read and write, age four or five, I think, but I have no earlier recollection at all of learning speech. This surprises me. You'd think that the first word, the first triumphant finished sentence, would have been such a stunning land-

mark to remain fixed in memory forever, the biggest moment in life. But I have forgotten. Or perhaps it never embedded itself in my mind. Being human, I may have known all along about language, from the time of my first glimpse of human faces, and speech just came, as natural a thing to do as breathing. The reason I can't remember the learning process, the early mistakes, may be that at that time they were not mistakes at all, just the normal speech of childhood, no more memorable than the first drawn breath.

All my adult life I have hoped to speak French one day like a Frenchman, but I am near to giving up, troubled. Why should any small French child, knee high, be able to do so quickly something that I will never learn to do? Or, for that matter, any English or Turkish child living for a few months in Paris? I know the answer, but I don't much like to hear it, implying as it does that there are other knacks that I have lost as well. Childhood is the time for language, no doubt about it. Young children, the younger the better, are good at it, it is child's play; it is a one-time gift to the species, withdrawn sometime in adolescence, switched off, never to be regained. I must have had it once and spent it all on ordinary English.

I possessed a splendid collection of neurons, nested in a center somewhere in my left hemisphere, probably similar to the center in a songbird's brain—also on his left side—used for learning the species' song while he was still a nestling. Like mine, the bird's center is only there for studying in childhood; if he hears the proper song at that stage he will have it in mind for life, ornamenting it later with brief arpeggios so that it becomes his own particular, self-specific song, slightly but perceptibly different from the song of all his relatives. But if he can't hear it as a young child, the center can't compose it on its own, and what comes out later when he is ready for singing and mating is an unmelodious buzzing noise. This is one of the saddest tales in experimental biology.

Children may do more than simply pick up the language, easily as breathing. Perhaps they make it in the first place, and then change it around as time goes by, so that today's speech will, as always, be needing scholars as translators centuries hence. Derek Bickerton, professor of linguistics at the University of Hawaii, has studied the emergence of a brand-new language called Hawaiian Creole, which spread across the islands sometime after 1880, when the plantations were opened up for sugar export and large numbers of polyglot workers came from abroad to work the fields. The languages brought in were Japanese, Chinese, Portuguese, Spanish, and Korean, all added to the native Hawaiian and the then-dominant English speech. For a while nobody could understand anyone else. Then, as always happens

in such language crises, a form of pidgin English developed (pidgin is the mispronunciation of "business" English), not really a language, more a crude system for naming objects and pointing at work to be done, lacking structure and syntactical rules.

Within the next generation, between 1880 and the turn of the century, Hawaiian Creole appeared. This was a proper language, flexible and fluent, capable of saying anything that popped into the head, filled with subtle metaphors and governed by its own tight grammatical rules for sentence structure. It was a new language, borrowing its vocabulary from the original words in the various tongues but arranging them in novel strings and sentences. According to Bickerton, the new grammar resembles that of Creoles in other places—the Seychelles, for instance, and places in New Guinea—formed by other multilanguage communities. It also resembles, he asserts, the kind of sentence structure used by all children as they grow up in the acquisition of their native speech.

Hawaiian Creole was entirely new to the islands, in the important sense that it could not be understood or spoken by the adults of the community. Bickerton's conclusion, logically enough, is that it had to be a language invented *de novo* by the young children of Hawaii. He uses this observation for the deduction that children must possess in their brains what he calls a "bioprogram" for language, a neural mechanism for generating grammar (and a confirmation, on the facts, of Noam Chomsky's insight three decades ago).

If Bickerton is right, the way is open for a new kind of speculation about one of humanity's deepest secrets: How did language first develop? Who started all the talking, and under what circumstances? The story, I believe, tells itself.

I imagine a time, thousands of years ago, when there were only a million or so humans on the Earth, mostly scattered and out of touch, traveling in families from place to place in search of food—hunters and gatherers. Nobody spoke, but there were human sounds everywhere: grunts, outcries imitating animals and birds, expletives with explanatory gestures. Very likely, our ancestors were an impatient, frantic lot, always indignant with each other for lacking understanding. Only recently down from the trees, admiring their apposing thumbs, astonished by intelligence, already studying fire, they must have been wondering what was missing and what was coming next. Probably they had learned to make the sounds needed for naming things—trees, plants, animals, fish—but nothing like language.

Then they began settling down in places for longer stays, having invented the beginnings of agriculture. More families gathered together, settled in communities. More children were born, and ways

had to be found to keep the youngest ones safe from predators and out of the way of the adults. Corrals were constructed, fenced in, filled with children at play.

I imagine one special early evening, the elders sitting around the fire, grunting monosyllables, pointing at the direction of the next day's hunt or the next field to be slashed, thinking as hard as human beings can think when they are at a permanent loss for words. Then more noise than usual from the children's quarters, interrupting the thought. A rising surf of voices, excited, high-pitched, then louder and louder, exultant, totally incomprehensible to all the adults. Language.

It must have been resisted at first, regarded as nonsense. Perhaps resented, even feared, seeing it work so beautifully for communication but only among the children. Magic. Then, later on, accepted as useful magic, parts of it learned by some of the adults from their own children, broken Creole. Words became magical, sentences were miraculous, grammar was sacred. (The thought hangs on: The Scottish cognate for grammar is *glamour*, with the under-meaning of magic with words.)

"Kwei," said a Proto-Indo-European child, meaning "make something," and the word became, centuries later, our word *poem*.

But how did the children get it? I imagine they had it all the time, and have it still, latent in their brains, ready to make the words and join them together—to articulate, as we say. What was needed at the outset was a sufficient concentration of young children, a critical mass, at each other day after day, trying words out for sense.

Whatever happened in the human brain to make this talent a possibility remains a mystery. It might have been a mutation, a new set of instructions in our DNA for the construction of a new kind of center, absent in all earlier primates. Or it could have been a more general list of specifications: i.e. don't stop now, keep making more columnar modules of neurons, build a bigger brain. Perhaps any brain with a rich enough cortex can become a speaking brain, with a self-conscious mind.

It is a satisfying notion. I come from ancestors whose brains evolved so far beyond those of all their relatives that speech was the result, and with this in hand they became the masters of the Earth, God's image, self-aware, able to remember generations back and to think generations ahead, able to write things like "In the beginning was the word." Nothing lies any longer beyond reach, not even the local solar system or out into the galaxy and even, given time, beyond that for colonizing the Universe. In charge of everything.

But this kind of talk is embarrassing; it is the way children talk before they've looked around. I must mend the ways of my mind.

This is a very big place, and I don't know how it works, nor how I fit in. I am a member of a fragile species, still new to the Earth, the youngest creatures of any scale, here only a few moments as evolutionary time is measured, a juvenile species, a child of a species. We are only tentatively set in place, error-prone, at risk of fumbling, in real danger at the moment of leaving behind only a thin layer of our fossils, radioactive at that.

With so much more to learn, looking around, we should be more embarrassed than we are. We are different, to be sure, but not so much because of our brains as because of our discomfiture, mostly with each other. All the other parts of the Earth's life seem to get along, to fit in with each other, to accommodate, even to concede when the stakes are high. They live off each other, devour each other, scramble for ecological niches, but always within set limits, with something like restraint. It is a rough world, by some of our standards, but not the winner-take-all game that it seemed to us a while back. If we look over our shoulders as far as we can see, all the way past trillions of other species to those fossil stromatolites built by enormous communities of collaborating microorganisms, we can see no evidences of meanness or vandalism in nature. It is, on balance, an equable, generally amiable place—good-natured, as we say.

We are the anomalies, the self-conscious children at the edge of the crowd, unsure of our place, unwilling to join up, tending to grabbiness. We have much more to learn than language.

But we are not as bad a lot as some of us say. I don't agree with this century's fashion of running down the human species as a failed try, a doomed sport. At our worst, we may be going through the early stages of a species' adolescence, and everyone remembers what that is like. Growing up is hard times for an individual but sustained torment for a whole species, especially one as brainy and nervous as ours. If we can last it out, get through the phase, shake off the memory of this century, wait for a break, we may find ourselves off and running again.

This is an optimistic view, and I'm quick to say that I could be all wrong. Perhaps we have indeed come our full evolutionary distance, stuck forever with our present behavior, as mature as we ever will be for as long as we last. I doubt it. We are not out of options.

I am just enough persuaded by the sociobiologists to believe that our attitudes toward each other are influenced by genes, and by more than just the genes for making grammar. If these alone were our only wired-in guides to behavior, we would be limited to metaphor and ambiguity for our most important messages to each other. I think we do some other things, by nature.

From earliest infancy on, we can smile and laugh without taking lessons, we recognize faces and facial expressions, and we hanker for friends and company. It goes too far to say that we have genes for liking each other, but we tend in that direction because of being a biologically social species. I am sure of that point: We are more compulsively social, more interdependent, and more inextricably attached to each other than any of the celebrated social insects. We are not, I fear, even marginally so committed to altruism as a way of life as the bees or ants, but at least we are able to sense, instinctively, certain obligations to one another.

One human trait, urging us on by our nature, is the drive to be useful, perhaps the most fundamental of all our biological necessities. We make mistakes with it, get it wrong, confuse it with self-regard, even try to fake it, but it is there in our genes, needing only a better set of definitions for usefulness than we have yet agreed on.

So we are not entirely set in our ways. Some of us may have more dominant genes for getting along than others. I suspect, glancing around my life, that we are also endowed with other, inhibitory alleles, widely spread for the enhancement of anomie. Most of us are a mixture. If we like, we can sit tight, trusting nature for the best of possible worlds to come. Or we can hope for better breeding, in both senses of the term, as our evolution proceeds.

Our microbial ancestors made use of quicker ways for bypassing long stretches of evolutionary time, and I envy them. They have always had an abundance of viruses, darting from one cell to another across species lines, doing no damage most of the time ("temperate" viruses, as they are called), but always picking up odds and ends of DNA from their hosts and then passing these around, as though at a great party. The bits are then used by the recipients for their betterment—new tricks for coping with new contingencies.

I hope our species has a mechanism like this. Come to think of it, maybe we do. After all, we live in a sea of our own viruses, most of which seem to be there for no purpose, not even to make us sick. We can hope that some of them might be taking hold of useful items of genetic news from time to time, then passing these along for the future of the species.

It makes a cheerful footnote, anyway: Next time you feel a cold coming on, reflect on the possibility that you may be giving a small boost to evolution.