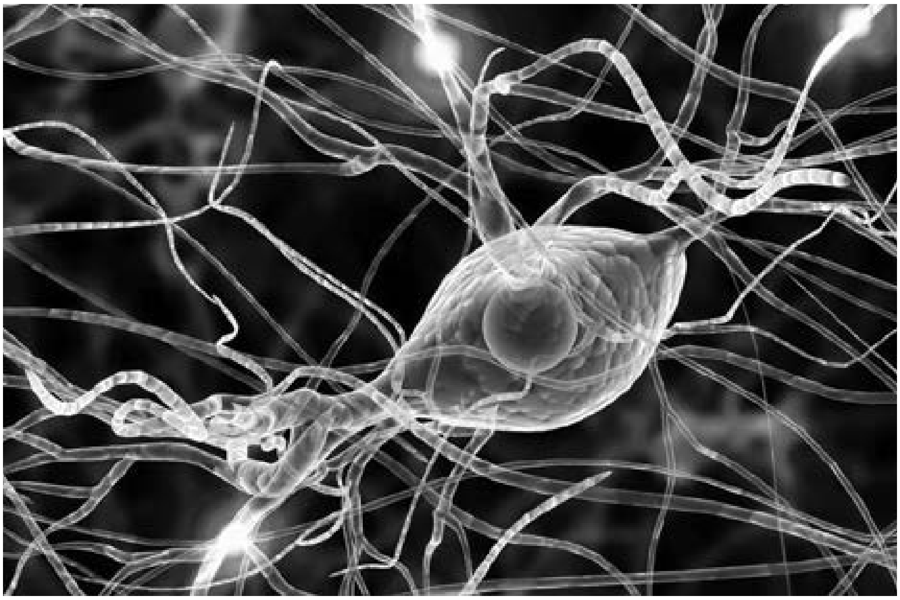

Fernanda Pérez Gay*

Changing Networks

The body is a machine with intricate universes: every cell, a microcosm; every molecule, a vehicle for life. How are all those random universes interlaced to constitute a unique living being with an unrepeatable combination of thoughts, feelings, and memories?

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The cell is the unit of life, a piece of matter separated from the rest of the world by a layer of fat. In the beginning, we were a cell. Even today, many, many microorganisms exist that are no more than that: one cell. Many of them live inside us. But, let's not go further than that yet. One cell, capable by itself of the most elementary functions, immersed in an environment that is no longer part of it, but that it needs to survive. What is there inside a cell? The same thing that is outside it actually, but organized in different ways: atoms, carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, sodium, chlorine. Some of these atoms wander about alone, entering and leaving the cell, swimming inside it. Others join together, attracted by inevitable electrical charges, and form molecules: water, sugars, proteins, fats. The space inside the cell that they swim in relatively freely is called cytoplasm, but the cell is not a ball of cytoplasm surrounded by fat —when I say fat, I mean an organized structure made up of different fat molecules or lipids, called the cell membrane. Inside each cell are other structures just as organized as the membrane itself. One of these is enormous, and although it is dispersed through the cytoplasm, it occupies the cell's operational center, like the Sun occupies the center of our system: the nucleus. The nucleus is considered important because inside it is that three-lettered thing that we talk about all the time without even knowing what the letters refer to: deoxyribonucleic acid, or DNA. A ladder made of molecules, of those same atoms mentioned above, but organized extremely intricately; so much so that they contain instructions to manufacture all the other components of that cell. Every piece of DNA has instructions for building a specific molecule, and those pieces are called genes: the famous code of life. The living cell is made of the same elements as many non-living things; the difference lies in their organ-

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ization. Life is the result of the organization of these molecules. From the simple to the complex; life is dynamism and complexity.

Four billion years ago, the information of all the future cells in the universe fit into a primitive version of what we now call cells. That first cell is called the Last Universal Common Ancestor (LUCA). The day I first imagined LUCA, the mother bacteria, floating in a sea of electrically charged atoms and molecules, about to bring forth the first of all the living organisms in the universe, I became passionate about the biological sciences forever. I wouldn't want to be lost inside LUCA because I would never get to what we're made of, what we have called "human beings," but we know that that cell existed and that it reproduced. To do that, it wandered through its environment looking for certain atoms or molecules that allowed it essentially to divide in two and that those two halves would later reconstitute themselves as complete cells: reproduction. For a cell, reproducing is dividing. LUCA divided over and over and over again, and its descendants adapted to the environment, becoming more efficient for certain tasks, mainly for moving around, and thus to be better able to interact with their surroundings. Moving around requires energy, so cells developed more and better mechanisms to transform their nutrients into energy, making them more complex.

The next step that takes us close to that ancestral bacteria is the moment when it met up with another ancestral bacteria floating in that ancient biochemical sea. The capacity of a cell to detect molecules that indicate the presence of another cell changes the course of the kingdom of the living. Two cells recognize each other and interact, and there begins the road to what we are: multicellular organisms: cells that cooperate to carry out a task. What for? Even on a microscopic level, cooperation facilitates survival. The cells that cooperate are preserved and eventually give rise to groups of cells with mechanisms that allow them to carry out different functions. We are, then, groups of cells that contain within themselves machinery that allows them to do different things: form a barrier, give support, carry nutritious molecules to other cells further away, store those molecules, eliminate those that are no longer useful, detect the characteristics of the world that surrounds us, facilitate the displacement of the collective of cells. The cells that are similar to each other and have the same function are called tissue; and those form organs; and the organs, systems. Are we the sum of all our systems? Yes. Are we "nothing more" than the sum of all our systems?

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What we conceive of as our "self" depends —just like the words I'm writing now— on the appropriate functioning of each of our organs and systems, made according to our DNA. But one of those systems seems to have greater influence than the others: a network of star-shaped cells extending to the difficult-to-reach corners: neurons, cells that can open and close their membranes to let electrically-charged atoms through, thus generating electricity, and later letting it run through its extensions, organized into the multiple highways of the network, and, upon reaching its destination, free up a molecule faced with another neuron, and pass on a message. Thus, just as the future of LUCA changed forever the day its mechanisms detected the presence of another cell, when the ancestor of one of those star-shaped cells capable of sending electrical messages carried out its function for the first time, a new form of communication was born: synapsis. And that form of communication determined a new organization inside living beings: the nervous system.

When we are embryos, masses of cells beginning to take on their future role in the organism, the neuronal star is one of the cell destinations. After a series of steps, once that organism's mother cells turn into neurons, the task of designing the first connecting route remains to be finished; that is, the first point of what Bruno Estañol called "the enchanted loom."[1] For that to happen, during the development of our nervous system, the neurons, initially stars all of whose points are the same, will allow one of their points to grow. That long point will be called the axon (from the Greek "ἄξων," meaning axis), the axis of the star-cell. These embryonic axons find their way thanks to the different chemical signals that attract or reject them. The instruction to send these chemical signals is found in DNA. Following the steps, the axons first sketch out a nervous route, a future information highway. They stop when they get to their star, that is, when they find the target neuron. The largest group of star-neurons is the center of the spider's web, designed following the DNA's genetic instructions: the cerebrum (from the Latin *cerebrum*, "what leads to the head").

The cerebrum of a newborn is not a clean slate. Thanks to that precise axon journey that occurs during the embryonic/fetal period, our nervous system already contains certain nervous highways, determined genetically, at the moment of birth. It is a cerebrum whose neurons from different areas are already connected in a certain order, a spinal cord that allows the neurons to travel down the body and back. And nerves: groups of axons that travel together to the tips of the fingers, from a foot, an eye, or to a remote area of the intestine and back; a back-and-forth of information coded in electrical discharges that allow us to receive information from both the exterior and the interior world and respond with a few basic forms of behavior. We can see, hear, breathe, suck, cry. This pattern of connections established by axons that grow and travel to different destinations in the brain-in-formation are the first physical layer of future thoughts, movements, and feelings of the person that the newborn will become, although most of the functions of that starry network have not yet developed.

Compared to other animals, we human beings take much longer to mature our perceptive capabilities (the reception and interpretation of information received from the senses), as well as the motor and cognitive skills (for transforming information and making decisions). Feeling, doing, thinking. That is because, when we are born, we have only a schema of the future nervous model that will rule our adult life. But the genetic design of these star-cells and their nervous routes also has a trick up its sleeve: it can reinvent itself. Nervous tissue is born prepared to continue moving toward complexity.

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Starting from birth, these primitive nervous highways begin to be refined by sensorial stimulation and the movements with which we respond to it. Connections: synaptic unions that are formed, strengthened, weakened, or disappear until we can begin to navigate our surroundings and we begin to store information, using the same system of forming and strengthening connections; electrochemical links among groups of neurons that will help us, for example, respond better the next time we encounter a similar situation. Like in the solitary bacteria, in the star-shaped cell of an organism with more than 30 trillion other cells, cooperation also leads to success. So, our experiences in life are inscribed in our cerebral circuits, in the pattern of connections of our billions of neurons: the connectome. The day that I first imagined it coordinating our thoughts and behavior at the same time that it transformed, my motivation to continue studying the brain solidified. Each one of us has a unique genetic code and personal, unrepeatable life experiences, so no two connectomes are the same. Even if we had an identical twin, our connectome would change differently throughout our lives.

We come from LUCA. We are made of cells formed by the same atoms and molecules that have made up life since its beginnings, billions of years ago. Constituted by the same elements, in us lives a constantly changing network, a network permeated by our immediate physical, social, and cultural surroundings. Star-shaped cells with thousands of ramifications lose their branches or have them shortened, and thus make room for new informational highways. Our context is thus continually inscribed in this versatile nervous labyrinth; with time it tattoos itself onto the neuronal microcosmos of one of the body's most intricate universes. Star-shaped cells branch out thousands of times, losing or shortening branches, and thus allow for the creation of new informational highways. A forest of neuronal trees in continual metamorphosis. An electrical cellular malleable web: the warp and weft that holds our dreams, fears, desires, and emotions. UM

Notes

1 Eduardo Cesarman and Bruno Estañol, *El telar encantado. El enigma de la relación mente-cerebro* (Mexico City: Porrúa, 1994). [Editor's Note.]