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Charles Gordon Gross (1936–2019)

We guarantee that you've never met anyone quite like Charlie Gross, an iconoclast and pioneer who blazed a trail through the uncharted territories of the cerebral cortex. Charles Gordon Gross was unconventional from the moment he was born on a leap day, February 29, 1936, to Communist parents (a "red-diaper baby"). Charlie was, by his own account, a mediocre young student, but he turned it around. He became a Westinghouse Science Finalist, the youngest Eagle Scout in Brooklyn, a Harvard graduate, and a Fulbright Scholar.

Charlie earned his doctorate with Larry Weiskrantz at Cambridge University studying a range of topics from vision to taste to frontal lobe function (the latter spawned his first *Science* paper). In 1961, Charlie became a postdoc under Hans-Lucas Teuber at the founding of our department at MIT, often claimed to be the first neuroscience department in the world. It was there, with his colleagues George Gerstein and Peter Schiller, that Charlie began his pioneering work on the visual cortex.

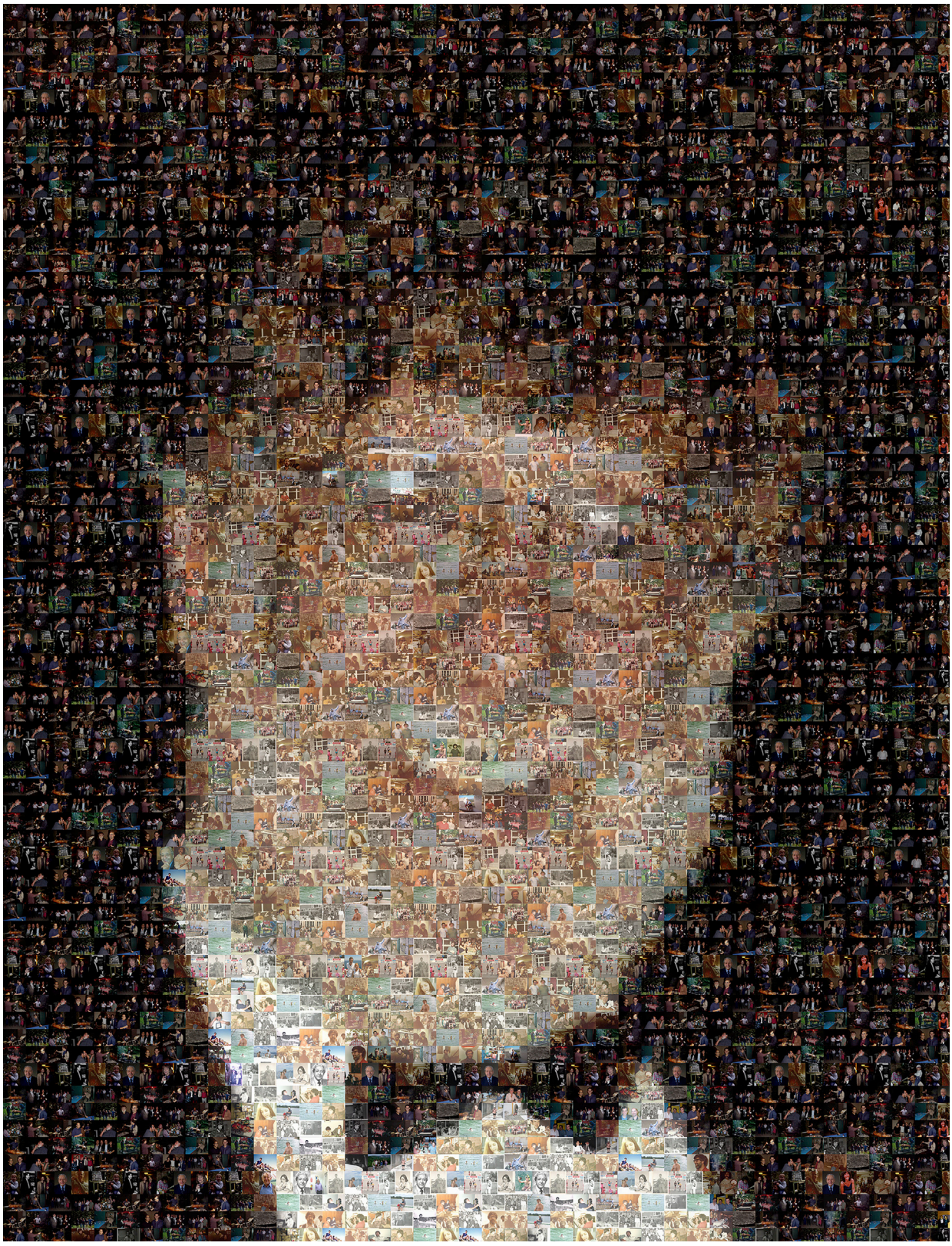
Understanding how bold and pioneering this work was requires some context. In the 1960s, Hubel and Wiesel were using single-unit electrodes to study cells in the visual cortex of the anesthetized cat for essentially the first time. In the occipital cortex, they reported the astonishing finding that cells responded selectively to simple, local features such as lines, edges, and corners. It was not clear what else, besides memory, was needed for the brain to recognize objects. Teuber encouraged Charlie and his colleagues to use the same, single-unit electrode approach to study the inferior temporal cortex (ITC) in the monkey, which was virtually uncharted territory but was thought to possibly be a repository of memories. Charlie knew of early work in the temporal lobe, some from the previous century and not widely known, that hinted at visual functions. Charlie's grasp of the historical sweep of our science was part of his genius, a point we will return to later.

Charlie and crew used Hubel-and-Wiesel-style electrodes to record from ITC of awake monkeys, one of the first awake monkey recordings. They tried simple stimuli, but the ITC neurons were unimpressed. They realized that, unlike neurons in occipital cortex, ITC neurons were selectively activated by complex objects and were often activated most strongly when animals stared intently at objects, including Charlie's own eye peering at the monkey through a hole. However, Charlie worried that ITC neurons were only responding to objects because they attracted the monkey's attention, so he put the data aside. He switched to anesthetized monkeys where he didn't have to worry about attention. He realized that, unlike in occipital cortex, ITC neurons were selectively activated by complex stimuli, not simple edges. They did not respond to sounds, laying to rest the idea that ITC was a multimodal memory repository. As we now know, the ITC is the highest level of cortical processing for recognizing objects. And it is not a suburb of visual function outside the occipital cortex. It is at the highest level of a hierarchical network of many cortical areas that underlie perception. This began with Charlie.

This also led to one of Charlie's best-known discoveries: "face cells." Face cells are neurons selectively activated by the sight of faces. As Charlie took pains to point out, they were not "grandmother cells," an idea—widely scorned at the time—that we had individual neurons specialized to recognize even our grandmother. They were not selective for the face of a particular individual. Indeed, you don't have a neuron dedicated to each object in the world. Instead, face cells seem to be part of a widely distributed network of areas for face perception in ITC that developed because facial recognition is so important for us primates. This discovery spawned a new subgenre of neuroscience. Today, labs all over the world study face processing directly or use the selectivity of these neurons to leverage other questions about cortical processing.

Although the face cells are now in many textbooks, the neuroscience community did not immediately embrace the idea of face cells or any of the other complex feature selectivity that Charlie reported in ITC. These ITC properties were too big a leap from the lines and edges of Hubel and Wiesel. In fact, David Hubel visited Charlie's lab when one of us (Desimone) was a graduate student studying the face cells with Charlie. David seemed skeptical. We asked him for his confidential opinion about what ITC cells were "really" selective for. He whispered, "really long bars." David later became a strong believer in face cells, but it took many years for the field to come around. Charlie was unfazed. In fact, he seemed to relish being the iconoclast and delighted in posing questions about object recognition that were ahead of their time. For example, he used lesion and recording studies in monkeys to advance the idea that a major purpose of ITC was to achieve "invariance" in object recognition over common identity-preserving transformations (e.g., size, viewing angle). This idea is now one of the central ideas in the field. When everyone else was intrigued by neuronal selectivity for moving bars, Charlie wanted to understand cells in an area near ITC that seemed selective for biological motion. When he was joined by Ricardo Gattass from Brazil, his lab became one of the three or four leaders in mapping the properties and visual organization of the extrastriate cortex in monkeys, which was mostly terra incognita. Over the years, as he was joined by new students and colleagues, he pursued or championed other research directions that were often out of the mainstream or controversial, including the production of integrated movements by motor cortex stimulation, neurogenesis in primates, blindsight, and the development of visual functions.

Beyond his seminal discoveries, Charlie trained many students and postdocs who went on to become senior investigators (like us two authors). In fact, one of us (Miller) is simultaneously Charlie's scientific son and grandson due to his postdoc with the other (Desimone). Charlie did far more than give us opportunity. He taught us how to think (and we've paid that



Charles Gordon Gross. Photomosaic of Charles G. Gross composed of pictures of his students, colleagues, and friends. (Photo provided by Earl Miller.)

forward). Beyond his raw intellectual horsepower, Charlie's command of the history of neuroscience gave him a big picture view like no other. His books, *Brain, Vision, Memory: Tales in the History of Neuroscience* and *A Hole in the Head: More Tales in the History of Neuroscience*, are filled with stories of people whose scientific contributions were ignored or underappreciated in their time. Charlie made us realize that the things we think we know now are just stepping stones (sometimes recycled) to a greater truth that will be revealed in the future. This helps you avoid getting blinded by the current paradigm and fosters a willingness to bend or break it. Of course, most, if not all, scientists would agree with this sentiment. But in Charlie's lab, you talked about work through this scope, lived with it, internalized it until it was your scientific default mode. Added to this was Charlie's clarity of thought. He taught us that you don't truly understand something until you can state it plainly, clearly, and concisely, without jargon. He taught us that writing is thinking. And, we are sure everyone will agree, Charlie was a gifted writer.

We would be remiss if we did not also celebrate Charlie as a person. Charlie was generous and was compassionate for people who were less fortunate. For example, he taught at San Quentin prison for several years. He was proud of his children and grandchildren. He and his wife, Joyce, were inseparable. Charlie had a charisma and charm that was endearing and disarming. Part of that was a persona of "absent-minded professor" who would, on occasion, walk into walls (literally). But behind that well-worn stereotype was extraordinary brilliance. He was warm and loving with a quick, easy wit. As was true of his science, he loved to explore places that were off the beaten path, including the backroads and villages of India, China, Cuba, and Brazil. He scorned the luxuries of more typical travelers, except for his treasured camera. He traveled on buses like the locals—his bus was even hijacked once and he was robbed along with everyone else. An apocryphal story was that a group of western scientists took a bus from Beijing to see the countryside. When the bus stopped to allow the visitors to photograph workers in a field, they discovered Charlie working under a straw hat. Told about the story, Charlie laughed that it was not true but "it easily *could* have happened." We do not doubt that. As we both can attest, Charlie was up for any adventure. There was no such thing as a bad conversation or time with Charlie.

Charlie, you will be missed.

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