Patricia Goldman-Rakic 1937–2003

Joaquín M. Fuster

On July 31, Patricia Goldman-Rakic died in New Haven, Connecticut from injuries suffered in a traffic accident. Pat was undoubtedly the most accomplished of the small group of pioneers who ventured into the frontal lobe at mid-century, then characterized by a prominent scientist as a "big chunk of the brain, the size of a fist, which nobody knows anything about." This was not quite accurate, as we knew that frontal cortex lesions, in man and monkey, often abolished memory for recent events, but the connectivity, biochemistry and physiology of the frontal lobe were not yet known, and would be the subjects of Pat's brilliant career. She was best known for advocating the idea that the prefrontal cortex holds working memory—a temporary internal representation for the attainment of a short-term objective—for different types of information in different locations.

Patricia Goldman-Rakic was born in Salem, Massachusetts. After getting her B.A., cum laude, at Vassar, she earned a Ph.D. in Developmental Psychology at UCLA with Wendell Jeffrey. She did postdoctoral work in psychophysiology, statistics, animal behavior, and clinical psychology, at UCLA and then in New York. In 1965, she entered the Laboratory of Neuropsychology of the National Institute of Mental Health, where she began to study the primate's frontal lobe, specifically the development of behavioral functions of different sectors of the frontal cortex. An interlude as a visiting scientist at M.I.T. with Walle Nauta, a master of axon tracing methods, initiated a long series of projects on the connectivity of the prefrontal cortex with other brain regions. These studies, notably with Selemon and with Cavada, hinted at the network-like architecture of cortical cognition. She complemented that view with the discovery that certain axon terminals in prefrontal cortex terminate modularly, like those in sensory areas. That finding led to the idea of modularity in the distribution of memory in the prefrontal cortex, which she would explore later with physiological methods at Yale. For her scientific contributions, Pat obtained an impressive array of awards and positions of distinction: Member of the National Academy of Sciences, President of the Society for Neuroscience, the Karl Lashley Award, the Fyssen Prize, the Ralph Gerard Prize and others.

From early in her career, Pat was a consummate integrator of neuroscience, using techniques from anatomy to physiology to functional imaging. Thus, her early studies on cortical connectivity led to the exploration of neurotransmitter systems in the frontal lobe, and then to studies of their development. By electron microscopy and double labeling, she and her colleagues demonstrated the action of dopamine directly on spines of pyramidal neurons. A more complete picture of the prefrontal circuitry grew out of the exploration of interactions between GABA, serotonin and dopamine receptors (with Williams, Rao and others). Pat's most important contribution to translational research was undoubtedly her work on dopamine, which points to the prefrontal cortex as deeply involved in the pathogenesis—if not etiology—of schizophrenia. For this work, the NIMH endowed Yale with the Center for the Study of Schizophrenia and put her in charge of it. The Center will continue under the direction of her husband Pasko Rakic, the world-renowned neurobiologist who collaborated with Pat on many projects, especially on the synaptogenesis of primate cortex.

In the early 1980s, Pat moved to Yale and turned her attention to prefrontal cortex physiology. She began with the activation of prefrontal neurons in short-term memory, which Alexander and I had discovered in 1971. During a delayed-response task, the activity of some cells is greater while the monkey is retaining an item in short-term memory than when it is not. Using an oculomotor delayed-response task, Pat, with Funahashi and Bruce, enriched the original description with a cortical topography that no one suspected. They found "mnemonic maps" in the prefrontal cortex—groups of neurons attuned to the memory of discrete directions of eye movement. Pat and her colleagues also identified prefrontal fields for object memory, and for face memory. Together, those findings supported the idea of a prefrontal quilt of domain-specific areas for memory. Then, in the late 1980s, Baddeley's concept of "working memory" entered her vocabulary to describe these neurons.

Because of her keen intelligence and boundless enthusiasm, Pat was a formidable scientific debater. She enjoyed every moment of any debate, especially, of course, if it went her way. I will never forget the twinkle in her eye when she saw me losing the argument. Or that hearty laughter when we both lost it, which happened often! She knew that I did not like the term "working memory" because it seems to characterize some special kind of memory, instead of a temporary state of long-term memory. However, the term is so widely used that any other now seems stodgy.

I chose a balmy California afternoon this January, strolling through the Getty Museum, to finally make my semantic concession to her: For me, it would be "working memory" from now on. She gave me that charming smile of hers in which I could read right away, "Now you tell me!" Seven months later, as I write these words, ordering on paper my memories of Pat, I find myself activating, one after the other, the memories of her scientific feats, of her ground-breaking data, of her sharp and engaging humor, of her fine ideas, of the joy of being with her. These memories will be working in all of us as we remember her in our conversations and in our writings, and as we try to do science as well as she did. ■

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