This Week's Citation Classic

Gesteland R C, Howland B, Lettvin J Y & Pitts W H. Comments on microelectrodes. *Proc. IRE* 47:1856-62, 1959.
[Research Lab. Electronics and Dept. Biology, Mass. Inst. Technology, Cambridge, and Lincoln Lab., MIT, Lexington, MA]

Metal-filled, platinum-coated microelectrodes are best for recording fast extracellular field potentials. Fluid-filled pipettes record DC values and slowly changing voltages. This paper reports the limitations and advantages of each and provides recipes for fabrication and use of both types. [The *SCI*® indicates that this paper has been cited in over 170 publications since 1961.]

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"I was one year into graduate studies in a laboratory which was rare in the world of science. Jerome Weisner, then head of the Research Laboratory of Electronics, encouraged crossing of disciplinary boundaries. The electrical engineering department was willing to take a chance on a candidate with a less than spectacular undergraduate record, a couple of years in industry, and an interest in the nervous system. I was fortunate to be adopted by the cybernetics research group consisting of Warren McCulloch, Jerome Lettvin, Walter Pitts, Patrick Wall, and Bradford Howland. This group, more than any other at the time, concerned itself with the connections between cellular biophysics and the processes of thought and memory. The sign on the door read 'Experimental Epistemology.'

"When I joined the laboratory, one of the many projects was concerned with the development of electrodes for exploration of the activity of single cells and of low noise amplifiers which optimally retrieved signals from these electrodes. While beginning the process of learning about comparative neuroanatomy, cellular biophysics, and physical chemistry, I spent my laboratory time using what I knew about electronics to aid in the investigation of the properties of microelectrodes.

"Dowben and Rose[1] pioneered the platinized metal tip for extracellular single unit studies. Lettvin built on this work, using new alloys and fabrication methods to optimize signal-to-noise ratios for nervous potentials. Howland devised unique measurement methods to determine real and imaginary components of the tip impedance. He also established the relation between noise voltage and the real component of tip impedance. Pitts investigated the theory of electrolyte-metal interfaces and applications to measuring systems. I devised some instrumental methods for making the measurements on the difficult-to-fabricate electrodes.[2]

"We found that rather simple functions described the frequency dependence of impedance for reversible and noble surfaces in different electrolytes. Platinum black in an electrolyte rich in adsorbable substances (such as cerebrospinal fluid) has a resistance and reactance which varies as $1/f$. This means that such an electrode will have very low thermal noise in the band of frequencies characteristic of nerve action potentials. Activity in the smallest nerve cells, obscured by the noise of conventional electrodes, is easily monitored with a platinum black surface a few μm in diameter.[3,4]

"Few could be so fortunate as was I. I was welcomed into an ongoing project which proved to be important to the new field of cellular neurophysiology. Even though I was a novice, my mentors insisted on alphabetical listing of authors on the manuscript. As a result, I am senior author on a widely quoted paper to which my contributions were small. This intellectual generosity was very helpful in my transition from the world of engineering to that of physiology. It is a pleasure to recall those stimulating years in the company of some of the truly bright minds of our time."

1. **Dowben R M & Rose J E.** A metal-filled microelectrode. *Science* **118**:22, 1953.
2. **Gesteland R C & Howland B.** Bridge for measuring the impedance of metal microelectrodes. *Rev. Sci. Instrum.* **30**:262-4, 1959.
3. **Lettvin J Y, Maturana H R, McCulloch W S & Pitts W H.** What the frog's eye tells the frog's brain. *Proc. IRE* **47**:1940-51, 1959. (Cited 330 times.)
4. **Gesteland R C, Lettvin J Y & Pitts W H.** Chemical transmission in the nose of the frog. *J. Physiol.—London* **181**:525-59, 1965.