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Hubel D H. Tungsten microelectrode for recording from single units. *Science* 125:549-50, 1957.
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This brief paper describes a procedure for making a metallic electrode for extracellular recording from single cells in the central nervous system. [The *SCI*® indicates that this paper has been cited in over 490 publications.]

An Electrode for Recording Single Nerve Cells

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I was delighted to have been asked to write about this article for the *Citation Classics* section of *Current Contents*® because it is the second scientific paper on which my name appears and the first in which the work was done mainly by me. I was a beginner, at the Walter Reed Army Institute of Research, and had undertaken, with the blessing of Mike Fuortes and Bob Galambos, the ambitious project of recording from single cells in awake, attentive, virtually unrestrained cats. I soon became convinced that glass micropipettes were too fragile to penetrate through dura or even arachnoid and had too high an impedance, unless they were made so large that they leaked or plugged up.

Harry Grundfest[1] had succeeded in electropolishing steel wires to a fine tip and coating them, except for the tip, with a substance called Formvar; but steel was not stiff enough, and I never succeeded in making Formvar adhere to metal close to the tip. Luckily, a remarkable man, Irvin Levin, was head of instrumentation at the Walter Reed institute and had his office next door to my lab. He produced some tungsten wire from a drawer and said, "Why not try this?" I had no idea how to electropolish it to a point, but, again luckily, Levin, who had done his graduate thesis in electrochemistry, suggested using about 6 volts AC and a saturated solution of KNO_2. This was ideal, giving, after I had practiced a bit, a long taper to a diameter of 10 microns and then an abrupt, final pencil-point taper. Now the problem was to insulate the wire down to the shoulder, just proximal to the final taper. I groped for months. Finally, one day Guy Sheatz, a physiologist down the hall, brought in a can of a lacquer called Insulex and suggested I try that. Within a few days I was recording huge (several mV) spikes from the cochlear nucleus, and I knew that I had finally made something useful.

I subsequently switched to a vinyl lacquer made by Stoner Mudge, used otherwise to coat the inside of tin cans. It took about a year to work out the complete technique for chronic recording, and by that time the electrode was being used in many other laboratories. Torsten Wiesel and I are still using it after 28 years, as are many others. Others have modified it by using almost every conceivable metal, though I suspect almost any metal will do, perhaps excepting iron, which rusts, and sodium or potassium! I once tried using molybdenum, which is just as stiff, works as well, and is expensive. I considered sending a note to some journal, claiming the superiority of molybdenum, as some sort of gag. Platinum is often used, I suspect simply because people tend to feel that the costlier the material, the better. (This is the case with flutes.) Glass coating rather than vinyl lacquer has also become popular. I'm not sure if it is any better—in this field if something works you tend to stick with it. The position of the electrode tip in the brain, I subsequently found, can easily be marked by passing a few microamperes of current for several seconds. The electrode must be negative or you end up with an empty sleeve, like a wind sock.

The paper itself may have misled some people. I had hoped the electrode might be useful for intracellular work, but, if the insulation comes to within a few microns from the tip, the DC impedance becomes astronomic. For extracellular work the best electrodes have an uninsulated terminal cone about 10-20 microns in diameter and 10-25 microns from shoulder to tip. With care, a good electrode can last through many experiments. The hundreds of cells for our entire project on strabismus in 1965 were recorded with one electrode.

In common with other papers referred to with extremely high frequency—for example, the all-time winner by O.H. Lowry—this one is on a method. Methods certainly are important in science, but probably less so than the discoveries they make possible.[2-4]

1. Grundfest H, Sengstaken R W, Oettinger W H & Gurry R W. Stainless steel micro-needle electrodes made by electrolytic pointing. *Rev. Sci. Instr.* 21:360-1, 1950. (Cited 60 times.)
2. Hubel D H. Single unit activity in striate cortex of unrestrained cats. *J. Physiology* 147:226-38, 1959. (Cited 240 times.)
3. ————. Cortical unit responses to visual stimuli in nonanesthetized cats. *Amer. J. Ophthalmol.* 46:110-21, 1958. (Cited 35 times.)
4. Livingstone M S & Hubel D H. Anatomy and physiology of a color system in the primate visual cortex. *J. Neuroscience* 14:309-56, 1984. (Cited 160 times.)