

ELECTRODES FOR BRAIN SLICES

T.J. Teyler, L. Cauller, G. Vaknin and T. Perkins

Neurobiology Department
Northeast Ohio College of Medicine
Rootstown, Ohio 44272

Tim Teyler is Professor of Neurobiology. He received his PhD in 1969 from Oregon Health Sciences Center, Portland and held postdoctoral positions at the University of California, Irvine, and the University of Oslo, Norway, 1970-74. He was on the faculty at Harvard prior to his present position. Cauller, Vaknin and Perkins are graduate students. This is the second part of a two part article. The first part appeared in the previous issue of the Carrier, No. 17. The introduction of the article is repeated here.

As reviewed in numerous places (including the *CARRIER*, Oct. 1986), the brain slice is now established as a standard paradigm in neurobiology. This article will deal with only one aspect of brain slice neurobiology - the electrodes used for recording and stimulating. Whereas just about any recording and stimulating electrode can be used with brain slices, the unique aspects of the brain slice present the experimenter with recording and stimulating opportunities not present in intact systems. Thus this article will emphasize electrodes specialized for brain slices.

A RADICAL RECORDING ELECTRODE

The most radical recording electrode is one that is based on the physics underlying Computed Axial Tomography (CAT). For the reconstruction solution (Brooks & DiChiro, 1975) based upon poten-fields (in contrast to x-ray penetration) the potentials must be integrated across multiple parallel trajectories within the slice. Rather than using discrete electrodes, uninsulated wires running electrodes are made from either insulated wire

(through the slice are used to sum the potentials. Each wire has been shown to sum the potentials along its trajectory (Teyler et al, 1984). Three such arrays of parallel uninsulated conductors, termed a Wire Integrating Ray Electrode (WIRE) array (see Figure 1), each array 60 degrees from the other, are minimally needed to solve the CAT equations. While one can readily place two arrays of bare wire on a brain slice (one on the bottom of the slice, the other on the top), the third cannot be done simultaneously (because the wires will short-circuit). The best approach (which has not been tried) would be to make a WIRE electrode array using microelectronics techniques. Such an array, fully implemented, would allow the simultaneous recording of hundreds of channels and the measurement of the potential field across the brain slice, an invaluable aid to studies of microcircuitry and distributed networks.

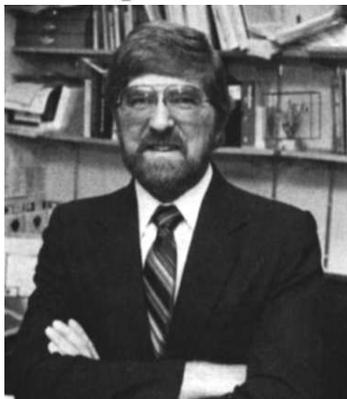
STIMULATING ELECTRODES

Conventional stimulating electrodes include the familiar metal monopolar and twisted-pair bipolar electrodes. Generally made of preinsulated wire in diameters ranging from 50 to 150 um, these electrodes are quite satisfactory for many purposes and are quite easy to construct. Major shortcomings of the monopolar electrode are the often significant stimulus artifacts associated with their use. In brain slice preparations the distance between stimulating and recording sites is often quite small, resulting in short-latency responses vulnerable to swamping by long-lasting stimulus artifacts.

Bipolar, twisted-pair electrodes are probably the most commonly used stimulating electrode. Stimulus artifacts are limited in this bipolar configuration and the electrodes are robust and easy to make (twist insulated wire together, cut end with scalpel or scissors). Limitations of this electrode are the difficulty in placing the two tips in the desired orientation on the slice for optimal tissue activation and in the relatively large size of the electrode tips.

Concentric bipolar electrodes are also used as they possess the lowest stimulus artifacts and are

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Editor's Column

This issue of the Carrier contains a special supplement which I hope you will look at and keep for your future reference. This supplement is a listing of most of the previous issues of the Carrier, all of which are

currently available to readers at your request. As you can see from the list, the Carrier has been in existence for almost 15 years and there have been a wide variety of interesting articles published.

It is the intent of the Editor and of the Kopf Company that the Carrier serve as a medium for disseminating information on techniques and methodology of particular interest to the Neuroscience community. The content of the articles could also include topics of current concern such as issues of animal rights and ethics of research which need general discussion. The Carrier is received by more than 10,000 readers, and has a worldwide distribution. As you scan the back issues list, you can see that the range of articles has been great. Some of the articles have been about Kopf equipment, but this is not true of the majority. I hope that seeing this list and realizing the variety of content which has been published will encourage you to think about submitting an article for publication in the Carrier, I would especially encourage our readers from overseas to think about submitting articles. Just write to me for information on the format and submission information for articles. There is also a reimbursement for each article published. I would also encourage you to send any questions which you may need to have answered about Kopf equipment to me at the address below and I will get the answer from the Kopf engineers in the next issue.

In addition, please remember that Kopf has an annotated list of stereotaxic atlases available which you may receive simply by requesting it from the company or from me. This is a fairly complete listing and is very useful for any lab doing stereotaxic work. On the back page of this issue, you will notice the announcement about the condition of returned

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easier to orient in the tissue (since they have no directionality). Concentric electrodes made from stainless-steel tubing and an insulated inner conductor are one possibility, but suffer from several shortcomings. The smallest concentric electrodes are made from 30 gauge tubing (if it can be found), as well as 28 gauge tubing. Unfortunately, the electrodes have a significant tissue "footprint." Additionally, these electrodes will deteriorate with use due to the development of salt-bridges inside the electrode (discussed in Teyler, 1987).

A better bipolar concentric electrode can be constructed by sputter-coating a thin layer of pure gold over small diameter (50-75 μ m) Teflon insulated, PtIr or stainless-steel wire (see Chiaia & Teyler, 1983, for details). These electrodes are quite small and surprisingly tough and their stimulation current is restricted, resulting in limited activation of the tissue. A disadvantage of these small electrodes is in manipulating them into position on the slice due to their surface tension which deflects them from their targets.

Several of the recording electrodes discussed above also make fine stimulating electrodes. The carbon-filled pipette, for instance, is an effective stimulating electrode aside from its use as a recording, marking and voltammetry electrode. The graphite fiber rake electrode is another recording electrode that serves as a stimulating electrode as well.

A couple of laboratories have reported using specially constructed recording/stimulating devices, some using microelectronics fabrication techniques, for brain slices (and dispersion culture systems). These techniques promise a very high density of electrodes/unit tissue. Unfortunately some of them compromise the life support requirements of the brain slice and most require access to microelectronic fabrication facilities. Nonetheless, these electrode arrays probably represent the future.

None of the specialized electrodes discussed here are available commercially. However, with some effort, a bit of ingenuity, and some imposing on electron microscopist friends, most of these electrodes can be readily constructed.

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Wire Integrating Ray Electrode

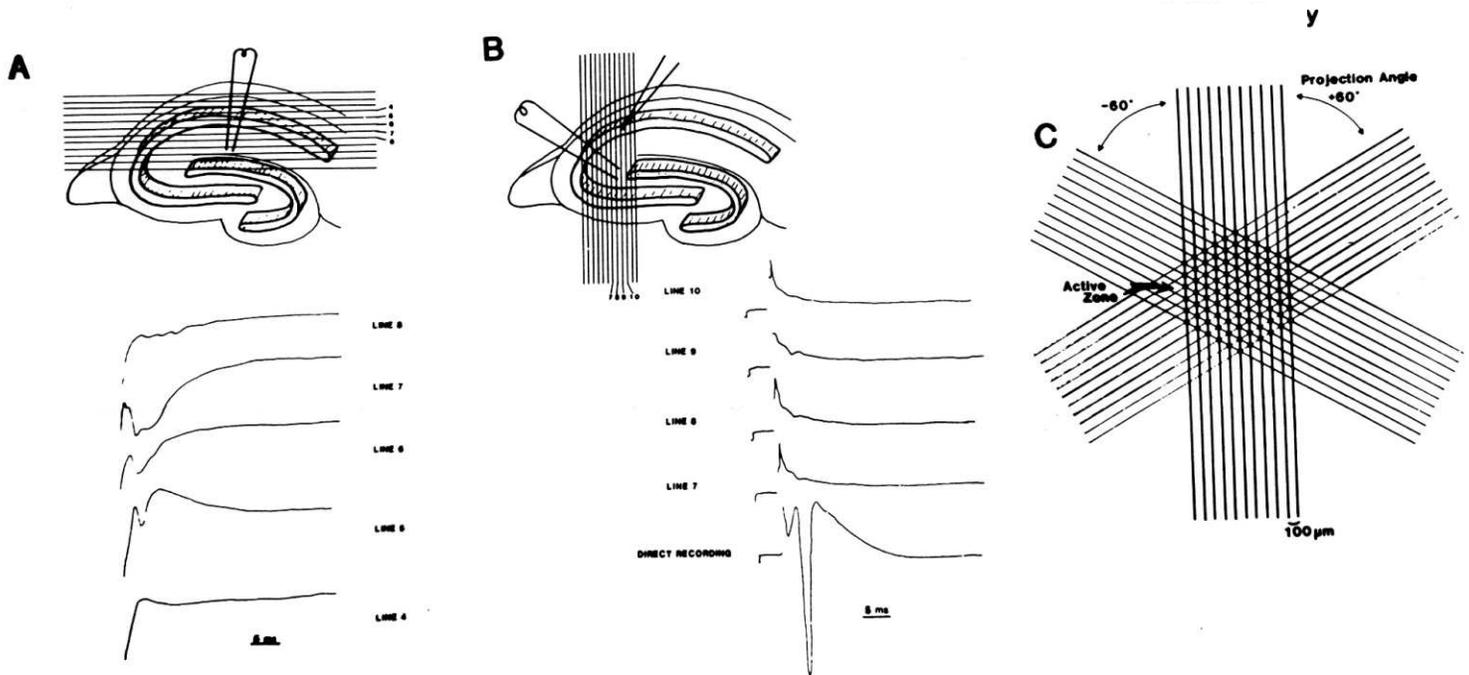


Figure 1. The WIRE electrode being used on a hippocampal slice. The WIRE electrode consists of 50 μ m diameter, uninsulated stainless steel wires strung in parallel (50-100 μ m spacing) across a glass form. The slice rests on the WIRE electrode, which is at the incubation media/atmosphere interface. The signal recorded by each electrode is the integral of all potentials encountered along its exposed path.

In (A) the WIRE was projected parallel to the CA1 cell body layer, whereas in (B) the WIRE was perpendicular to the CA1 layer. A characteristic CA1 depth profile was observed when the WIRE was parallel (A) to the CA1 layer, with stratum radiatum potentials reversed with respect to stratum oriens recordings. In the perpendicular orientation (B), null potentials were observed due to cancellation of the reversed portions of the depth profile, as independently confirmed by CSD analyses on these tissues (not shown). In (C) is depicted the minimum WIRE array configuration required to apply the CAT algebraic reconstruction algorithm which will result in a potential matrix for each sampling interval. Subsequent potential matrices may be rapidly displayed to animate the dynamics of activity in this tissue.

References

Brooks & DiChiro (1975) *Radiology*, 777, 561-572.

Chiaia & Teyler (1983) *Journal of Neuroscience Methods*, 7 269-273.

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Teyler, Cauller & Wilhite (1984) *Society for Neuroscience Abstracts*, A305.8.

instruments. Please observe this request when you send any instrument back to the factory for repairs or recalibration. If you put yourself in the place of the repair staff, I am sure you would see that you would be very uncomfortable receiving equipment which was very dirty and which you could not be sure was safe to handle.

Don't forget to stop by the Kopf booth at the FASEB Meetings in May.

Michael M. Patterson, Ph.D.
Scientific Editor
College of Osteopathic Medicine
Ohio University
Athens, OH 45701-2979 USA