Comments and Communications

Depth of Field in Microscope Objectives

It would be unfortunate if microscopists encountering the need for increased depth of field in their work were to gain the impression that the procedure described by Roy J. Pence (*Science*, June 11, pp. 631–632) provided a method for circumventing one of the fundamental laws of optics.

"The necessity for *higher magnifications, with some corresponding degree of depth of focus without appreciable loss of definition and resolution*" simply cannot be met. It is not merely that ". . . when extreme depth of focus is attained, a certain amount of resolving power is necessarily sacrificed"; rather, the depth of field is strictly inversely proportional to the resolving power. The depth of field decreases as the aperture increases; the resolving power increases with the aperture.

It is disconcerting that submitting a paper for criticism to a faculty member in charge of Geometric Optics does not protect a biologist from falling into such an elementary error.

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Surface Electrodes for Recording Bioelectric Potentials

Several types of electrode have been tested in this laboratory for a number of desirable characteristics in recording bioelectric phenomena from the skin surface of the intact, normal human subject. Desirable characteristics of the ideal electrode are: (1) maintenance of low-resistance contact for long periods of time; (2) absence of artifacts from bodily movement, vibration, or deformation of the skin; (3) comfort in wearing for long periods; (4) ease of application and removal; and (5) durability and low cost.

Metal electrodes, such as flattened drops of solder or silver cups, plates of "hats," all require a liquid adhesive such as collodion to make and keep a firm contact with the skin. The collodion takes time to apply and to dry, and usually the contact with the skin must be obtained with a paste or jelly placed under the electrode. Satisfactory contact with the skin is maintained by such electrodes, but their nuisance value to both experimenter and subject is high. If collodion or some similar adhesive is not used and surgeon's tape or Scotch tape is substituted to hold the electrode in place, the resistance level will change with movements of the skin from underlying muscles, particularly if the electrode is placed on a skin area in which wrinkling occurs. The effect of skin movement is to raise the rigid metal electrode from the surface of the skin, thus suddenly changing the surface area in contact with the electrode. This sudden change in area results in an increased resistance and will block the usual push-pull preamplifier and introduce artifacts into the record.

Most of the requirements listed above have been met in electrodes developed in this laboratory in connection with continuous recording of muscle action potentials over long periods of time. These electrodes are simple in construction, lightweight, easily attached and removed, comfortable to the subject, and maintain a constant uniform contact with the skin for long periods of time regardless of subcutaneous muscle movement.

The contact part of the electrode is made from sponge rubber $\frac{1}{2}''$ in diameter and $\frac{3}{16}''$ thick. The rubber discs are punched out of a flat sponge-rubber mat $\frac{3}{8}''$ thick and sealed on both sides. Each punched-out disc is then cut in two pieces, producing two electrode discs, each with a rough side and a sealed side. The stripped end of a cotton-covered, standard, flexible wire is pulled by a large needle laterally through the side of the disc, back out near the point of entry, and clipped flush with the side. This process will firmly connect wire and disc.

In use, the sealed side of the electrode is pressed to a piece of surgeon's tape or Scotch tape, and the rough side is then applied to the subject's skin on the area desired. The sponge is thoroughly moistened with saline to produce a liquid contact. These electrodes may also be mounted in a head-band or in special holders for recording the corneoretinal potential.

Some 40 subjects have been tested for change in resistance for periods up to 5 hrs. If the electrode contains enough fluid to wet the skin completely, the resistance between two such electrodes, placed $2\frac{1}{4}''$ apart on the forehead just above the eyebrows, usually decreases slightly with time. Initial resistance varied from 4,000 to 41,000 ohms, and final resistance, from 2,000 to 38,000 ohms. Thirty-two subjects showed a decrease, four subjects no change, and four an increase in final resistance level. The electrodes do not dry out rapidly, possibly because the normal perspiration of the skin, soaked up by the sponge, serves to maintain the fluid connection. Blocking of amplifiers due to surface change of electrodes has disappeared completely from our records since adopting the sponge-fluid electrode.

Some observations have been made on the possible use of these electrodes in electroencephalography. Satisfactory recordings of alpha have been obtained, using a head-band and placing the electrodes near the occipital region on top of the hair. The hair was parted to expose the scalp, but no effort was made to remove all hair under the electrode. Further exploration might possibly yield a more convenient way of attaching these electrodes for EEG purposes.

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