The miniaturization of glass electrodes

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The miniaturization of cation sensitive glass electrodes (Eisenman, 1962) is part of a programme designed to monitor continuously the plasma cationic concentrations in human extracorporeal circulations and in the physiologically normal animal.

The investigation of diurnal and metabolic changes in plasma cationic parameters using flame photometry on samples from animals submitted to open operations leaves much to be desired. An implanted miniature glass electrode from which long-term readings could be obtained appeared to be the ideal for the investigation of such variations.

The model seen in Fig. 1 consists of a high density annealed nylon cannula which carries the 'stream' under investigation. Into this can be screwed the sensing head (Fig. 2) which can carry five sensing elements (Na⁺, K⁺, H⁺, another and a thermister) so that the elements lie directly in the 'stream'. This arrangement is necessary in order to keep the time constants of the assembly within reasonable bounds.

The second unit containing the reference electrodes screws into an isolating chamber filled with a saline conducting solution which is separated from the main 'stream' by an 18/32 cellulose membrane (Craig and King, 1962) held in place by an (No. 3) 'O' ring. This practice prevents cellular, proteinaceous and other similar materials present in the main stream from gaining access to the 'liquid junction' of the reference electrodes. This reference unit can similarly be a multi-unit carrying different or duplicated reference electrodes plus a thermister head. The main reference in use is a spectrographic silver/silver chloride electrode.

The three problems which this design overcomes are:

1. Difficulties of interference from extraneous bioelectrical potentials, which are overcome by positioning the reference electrode close to the sensing electrode or in the one unit.

2. The necessity of finding a suitable glass for fusion to the ion-sensitive glass in the construction of the sensing electrode: the 'potting' of the miniature sensing units in layers of different epoxy-resins within the small

FIG. 1. The miniature electrodes assembly.

1 A cation sensitive electrode unit.
2 A reference electrode unit.
3 A length of Vivosil silastic rubber tubing.
4 A short length of the special coaxial cable with the glass ring used as a bridge between the silastic rubber and the annealed nylon.
5 A complete nylon cannula unit.
6 An exploded view of 5.
7 A selection of miniature elements.
8 Two other cannulae of differing designs.
sensing head overcomes this difficulty and gives a very satisfactory electrical and fluid seal.

3 The instability (thermal or otherwise) and the practical difficulties of the liquid junction usually found with the standard reference electrodes are overcome by using a bridge of sodium or potassium chloride agar gel leading to an asbestos plug which in turn makes electrical contact with the 'stream' under investigation via the saline solution in the isolating chamber and the cellulose membrane.

The use of spectrographic silver, cold setting silver resin solders, specially designed non-microphonic coaxial cables, high quality plugs and sockets, silastic rubber (Vivosil) cable covers with associated room-temperature-vulcanizing medical rubber silastic solutions, and several adhesives, including the Araldite range, has made the project possible. The resultant electrode is satisfactorily stable over long periods, will read to a sensitivity of 1 to 2 mEq., and can be checked against temperature and instrumental variation.

These miniature glass assemblies, sterilized by gamma radiation (2.75 megard) or by ethylene oxide gas, have been implanted in a pig's aorta (Fig. 3) under general anaesthesia (Dawson, 1963) and have provided a continuous voltage from the fully recovered animal, recorded with an E.I.L. Vibron electrometer in conjunction with a Kipp and Zonen four-channel selector and micrograph recorder, which, it is believed, demonstrate changes in plasma ionic sodium concentrations. However, for various anatomical and calibration reasons this approach does not provide a satisfactory method for determining a physiological baseline of sodium ionic activity.

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