6. The committee is opposed to the addition of the question on ownership of radio sets.

7. The committee is opposed to the inclusion of the suggested group of questions on children born (number of children born to each married woman, number of these children living, age at first marriage [or duration of marriage], whether first, second or later marriage), and recommends that the executive committee give favorable consideration to the inclusion of these items in a special sample inquiry.

8. The conference desires to emphasize as a general principle that the population schedule should be used only for the purpose of completing enumeration and should be confined therefore to those items for which information on every individual is necessary and should not include items for which data can be collected in special surveys, or by canvassers of samples of the population.

In accordance with this principle the conference is of the opinion that the schedule should be restricted to the minimum item of the items but recommends that the director take into consideration a supplementary family schedule for a sample of the population to include several important items for which a special enumeration is not needed or practicable, the choice of which items to be left for consideration by the executive committee of this conference.

9. That a question be added to the schedule to determine the extent of migration between farms and cities during 1929. The schedule already contains a question as to farm residence on the census date. The additional question would read, "Did this person live on a farm 12 months ago?" and the migrants would be those persons who answered "Yes" to one question and "No" to the other.

10. The conference strongly approves the proposal of the Census Bureau to draw up a family card and recommends that the details of this card be left to the executive committee in consultation with the director.

11. The committee authorizes the chairman to appoint an executive committee to work in conjunction with the director.

At a recent meeting of the full advisory committee, made up of representatives from a wide range of business, governmental and other organizations, such as the American Federation of Labor; the Curtis Publishing Company; the Department of Labor; the National Electric Light Association; the Scripps Foundation for Research in Population Problems; the Institute for Government Research; Columbia University; the Metropolitan Life Insurance Company; the International Advertising Association, and similar interests, it was recommended that a small executive committee be named by the Secretary of Commerce to carry on the work of the full committee.

The nominations for the executive committee as recommended by the parent advisory committee have been approved by the Secretary of Commerce as follows:

Dr. Louis I. Dublin, statistician, Metropolitan Life Insurance Company, Madison Square, New York City.

Dr. Robert E. Chaddock, Columbia University, New York City.

Dr. Lewis Meriam, Institute for Government Research, 28 Jackson Place, Washington, D. C.

Edgar Sydenstricker, Milbank Memorial Fund, 49 Wall Street, New York City.

Dr. Warren S. Thompson, director, Scripps Foundation for Research in Population Problems, Miami University, Oxford, Ohio.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

CONSTRUCTION OF MICRO-THERMOCOUPLES

THE purpose of this paper is to describe a method of constructing micro-thermocouples which are small enough and at the same time strong enough to be inserted by means of a micro-manipulation instrument into small living cells or into tissues. They are small enough to be used in measuring light absorption of a single plastid or for any purpose requiring temperature measurements at minute points.

The method of drawing various metals in glass to wires or filaments of exceedingly small size was first employed by G. F. Taylor.[1,2] The same method was independently discovered a few months later by C. V. Taylor[3] in the construction of microelectrodes and micromagnets.

If a small wire of nearly any metal is inserted into a slightly tapered capillary of glass or quartz until it fits tightly and the region of tight fit is melted over a very small gas or oxygen-gas flame, a sudden pull will draw the glass and metal to microscopic dimensions. Glass-covered electrodes less than one micron in diameter can readily be made. Certain requirements must be met, however, in choosing the metal and the glass. The coefficient of expansion of the metal must be at least as great as that of the glass

[1] G. F. Taylor, "A Method of Drawing Metallic Filaments and a Discussion of their Properties and Uses," *Phys. Rev.*, xxiii, p. 655, 1924.

[2] Fine wires made by this process may be obtained from Baker and Co., Newark, New Jersey.

[3] C. V. Taylor, "Microelectrodes and Micromagnets," Proc. Soc. Exp. Biol. and Med., xxiii, p. 147, 1925. See also C. V. Taylor and D. M. Whitaker, "Potentiometric Determinations in the Protoplasm and Cell-sap of Nitella," *Protoplasma*, 1927, iii, no. 1.

or on cooling the glass will shrink onto the metal and shatter. The melting-point of the glass must be between the melting-point and the boiling-point of the metal. Thus for platinum, iron and other metals of high melting-point capillaries of clear fused quartz are used.[4] For silver, pyrex glass has a suitable melting-point. For bismuth, solder, lead, etc., very soft soda glass can be used.

One of the difficulties encountered is the occurrence of gaps in the metal core, especially at the base of the taper. It has been found that these gaps can best be avoided by starting with wires which are at least as small as thirty gauge (B and S) and preferably thirty-five gauge.

In order that the microelectrode shall be strong and rigid and of low electrical resistance, it is important to have a fairly steep final taper. This taper should not be more than one half or one centimeter long. With practice short tapers can be drawn, especially if attention is given to two things: Only a small section of capillary should be melted (*i.e.*, the diameter of the burner should be less than .5 mm); the glass should not be too fluid at the instant of drawing, or it will become a long fine thread instead of drawing to a point.

The micro-thermocouple which is being described is simply a double electrode in which two different metals are used. They are joined at the tip to make the sensitive junction. The double electrode is made by taking two capillaries of equal size and of the same kind of glass, each containing one of the metals, and fusing the two capillaries together at the region which is to be drawn. They round up by surface tension to give a rod which in cross-section is more or less elliptical and contains the two metal cores entirely surrounded and separated by glass. This is drawn to microscopic dimensions in the same way as the electrode just described. After drawing, the two capillaries must be held very carefully in the fingers until they are joined at several points with De Kotinsky cement so that they will not move with respect to each other and break the tip.

Choice of Metals

Pairs of metals must be chosen which have a suitable thermal E.M.F. and which have melting-points near enough together so that they may be drawn in the same kind of glass. Some metals have an exceptional tendency when melted to separate into little beads. Constantan is difficult to use for this reason. Iron and platinum are a combination much easier to draw than copper and constantan, and with almost as high an E.M.F. (19 microvolts per degree). Another good combination of higher sensitivity is iron against an alloy of gold and palladium (Au 60 per cent., Pd 40 per cent.). This combination is drawn in quartz and has a thermal E.M.F. of about 45 mv. per degree. Still higher E.M.F. (95–100 mv. per degree) is obtained by using bismuth against an alloy of bismuth and tin (Bi 95 per cent., Sn 5 per cent.). These metals, which are too brittle to be made into wire, may be obtained already drawn in glass or as granulated metal from Baker and Company. It is more practicable to use the granulated metals and draw capillaries, as in this way the thickness of the glass covering can be varied to suit needs. It has been found best to make the walls about as thick as the metal core since almost the entire strength is provided by the glass. Too thick a wall, however, is more difficult to remove with HFl (see below).

Cutting Off the Tip

The double electrode is cemented to a glass holder and is held in a micro-manipulation instrument. In the mechanical stage of the microscope a slide is held bearing a small piece of razor blade, with vertical edge, to be used as an anvil. A diamond splint[5] with a sharp point mounted on a glass rod is held in the other arm of the micro-manipulator.

Under the microscope (about 100 diameters magnification is usually sufficient) the electrode is placed across the razor blade. By means of the diamond the side of the electrode is scratched. The electrode should now be rotated through 180° and scratched on the opposite side. Then with the scratch on the razor blade, the diamond is used to push against the electrode further out toward the tip. The electrode will usually snap off squarely through the scratches, with the two metal cores now ending (abruptly) flush with the end of the glass (Fig. 1a).

Removing Glass from the Tip

In order to project the embedded wires beyond the glass or quartz so that they may be joined, a section of the glass is removed. The most satisfactory way to do this when the wires are of metals of some shearing strength is to scratch both sides of the glass a

[4] A very good grade of clear fused quartz tubing may be obtained from the Hanovia Chemical and Manufacturing Co., Newark, New Jersey. Heavy walled tubing (about 5 mm outside and 2 mm inside diameter) is best for drawing electrodes and thermocouples.

[5] Good selected splints may be obtained from the L. M. Van Moppes Diamond Company, Newark, New Jersey. An easy way to mount the splints is to put a ball of De Kotinsky cement on the end of a glass rod. Then holding the diamond in a pair of forceps, heat the base, which is to be embedded, in a small flame, and press it against the cold cement so that it melts its own way in.

short distance back from the end and break off the glass as in cutting off the tip (Fig. 1b, c). With care this can be done without breaking the wires in the case of Pt, Fe, Cu, Ag, Au-Pd, etc. The wires are left bright and clean. But if a very small junction is being constructed, that is, with total diameter less than five or ten microns, it is difficult to avoid breaking off the wires. In this case the glass or quartz may be removed by dipping the tip in hydrofluoric acid[1] to the desired depth. A small drop of the acid is placed on a horizontal paraffined slide in the

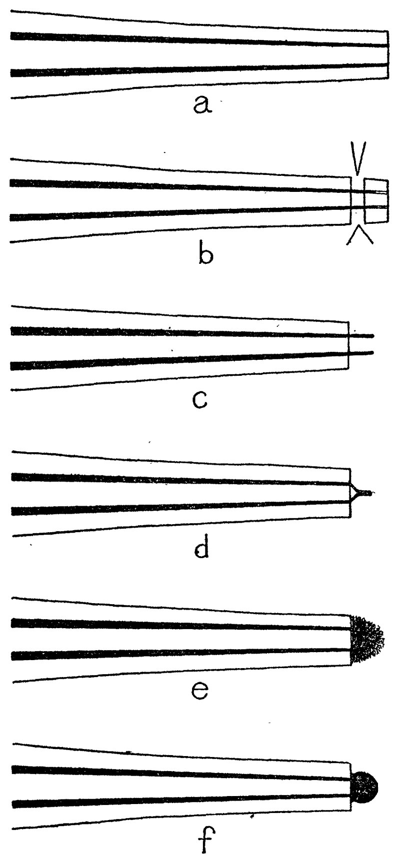

Fig. 1. Diagrams of successive stages in the construction of the micro-junction.

mechanical stage of a horizontally tipped microscope. The electrode is held in a manipulator and dipped in from above. A piece of glass slide held over the objective of the microscope with paraffin protects the lens from acid. In some cases the acid fumes destroy the glass of the electrode too far up the stem. This can be checked by first dipping the electrode in hot paraffin, which can be removed from the tip alone with xylol and 100 per cent. alcohol, or by cutting off the tip so that no paraffin covers the end. After the acid process the electrode should be washed in distilled water and then dipped in a strong base to stop the action of the HFl.

In removing glass from the tips of electrodes of Bi and Bi-Sn the acid method must be used even for larger sized electrodes, as it is practically impossible to cut off the glass without also shearing these soft metals. Strong acid will remove glass from small tips in a few seconds. Twenty minutes or more is required for larger tips. The disadvantage in the use of acid is that the glass of the stem is usually somewhat corroded so that it is less trustworthy as an insulator, and the wires of the tip are left with a thin film of corroded glass and salts which it is difficult to remove.

Joining the Tips

The tips may be joined by soldering, welding or electroplating. Electroplating is by far the most satisfactory method when practicable, because all methods involving much heating tend to oxidize most of the metals and prevent good contact. Wires may be joined by electroplating which are too small to be handled mechanically. The success of electroplating in making a stable junction depends on having the wires rigidly stationary with respect to each other. This condition is met in the process of double drawing.

The first step is to bend the two wires together so that they touch or almost touch (Fig. 1d). In the case of exceedingly fine wires which are already very close together this step may be omitted.

Silver is a good metal to deposit. It has high heat conductivity and is comparatively inactive. It may be deposited from any standard silver-plating solution and makes a good smooth coating which is quite strong.

The depositing can be done under the microscope by means of a hanging drop on the under side of a supported coverslip. One dry cell supplies a suitable potential. A delicate regulation of deposit rate can be made by placing a moistened finger across an open switch and varying the pressure of contact. The positive electrode is a silver wire held in one arm of the manipulator. First one of the microwires should be connected to the negative terminal by its lead and a thin coat deposited. Then the first lead should be disconnected and the lead of the other fine wire should be made negative. As the deposit builds up on this second wire contact will be established with the first wire which will now also receive deposit. All the current which deposits silver on the first wire now passes through the plating which joins the wires. This keeps the thin connection charged with respect to the solution and causes it to be continually thickened by deposition. When enough silver has been deposited (Fig. 1e) the junction should be washed in distilled water and thoroughly dried.

If the two leads of the junction are now connected through a spring switch to a single dry cell, one very quick tap of the switch will usually melt down the silver plating which rounds up by surface tension to form a neat solid ball in which the two wires are embedded (Fig. 1f). This makes a strong junction which can be readily inserted into tissues or cells with no change in electrical resistance. The comparatively low melting-point of silver is an advantage in this process of melting down. Its comparatively high coefficient of exapnsion causes it to contract tightly onto the wires when cooling.

Because of the low melting-points and lack of cohesion of Bi and Bi-Sn, it is practically impossible to melt down the plating on junctions of these metals without also melting and destroying the cores. This is so even when tin is used in plating (melting-point 232°) and even when heat is applied with a small filament. Junctions of these metals which are joined by unmelted silver plating maintain constant resistance if carefully handled and if only minute currents pass through them. With frequent calibration they may be satisfactory for use when mechanical strength is not required. The plating is not stable enough for inserting into cells. More rigid junctions of these metals may be made with somewhat more difficulty by bending the wires, which are much less brittle than large wires, into mechanical contact and melting them together under the microscope by means of a small filament held in the manipulator.

PROPERTIES

The resistance of the junctions varies greatly with size (inversely more or less as the square of the diameter), steepness of taper (or length), success of joining at the tip, and with the metals used. Iron and platinum junctions which are ten microns in diameter have a resistance of around ten or fifteen ohms (including two short leads of thirty-five gauge wire). Bismuth and bismuth-tin junctions have considerably greater resistance.

The temperature lag is negligible because of the minute mass of the junctions.

With a high sensitivity galvanometer such as the Leeds and Northrup all copper circuit type HS, with proper external critical damping and with a four-meter beam, the temperature of a Bi and Bi-Sn junction ten microns in diameter can be measured directly, without thermal relay, to less than 0.0005° C. (provided the rest of the system is constant within this limit).

OTHER APPLICATIONS

If both cores are platinum, the tips may be left unjoined (Fig. 1c) to form a minute bipolar electrode which may be lightly coated with platinum black. Such tips when joined with platinum form a filament which may be used as a minute source of light or heat. When the tip in air is white hot the cores within the quartz are red hot.

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SPECIAL ARTICLES

THE EARTHWORM FAUNA OF THE UNITED STATES

"THE fauna of this country is well known; only relatively insignificant questions of minor detail remain to be worked out." This is a dictum frequently expounded to-day by zoölogists. Perhaps certain classes have been exhaustively studied, but at least one group of common animals has been neglected. The particular group to which reference is made is the Oligochaeta and especially that section of the class which includes the forms commonly called earthworms.

Survey of zoological literature shows that Frank Smith is the single American to make an extended investigation (1895–1924) of these animals. He worked out, perhaps fairly completely, the earthworm fauna of a smallish region centering in Illinois. A Swede, Gustaf Eisen, published a series of papers (1874–1905) on North-American oligochaetes, but except for some half dozen forms from the state of California, practically all of the species described were Mexican or Central American. Papers by Garman, J. P. and H. F. Moore, Smith and three foreign oligochaetologists—Michaelsen, Perrier and Ude—containing descriptions of single species or reports on random collections from widely separated localities complete the bibliography on the earthworms of this country.

In a large portion of the glaciated area of North America we can not, of course, expect to find indigenous species of earthworms. This part of the continent is inhabited only by peregrine Lumbricids presumably introduced by man. It should not be without interest, however, to know what species have been so introduced, or more accurately, have been able to "occupy the land" after introduction, and how they have distributed themselves in the new regions. Comparatively little information of this sort is available. To illustrate: a student in the graduate school of Harvard University, while smoking an after-lunch pipe, on a pleasant May day a year ago, picked up seven species of earthworms from under leaves on the grounds of the Museum of Comparative Zoology. The worms in this small collection have been identified as follows: