determination of viable L. acidophilus in acidophilus milk and other cultures seems warranted at this time.

The medium recommended here is whey-peptone-galactose agar.

Whey is made by the method advocated by Rettger and Cheplin[8] (1921), which is essentially as follows: Skimmed milk is heated to 85–90° C. The amount of 10 per cent. HCl necessary to precipitate the casein in 10 cc amounts of the hot milk is determined. From this the volume of acid required to precipitate the casein in the entire volume of milk is calculated. The whey is removed from the precipitated casein by filtration through three or four thicknesses of cheesecloth. The filtrate is adjusted to a reaction of pH 6.8 with 10 per cent. NaOH and placed in flasks. The cotton-plugged flasks are autoclaved at fifteen pounds extra steam pressure for twenty minutes. The lact-albumen is completely coagulated and after this precipitate has settled to the bottom of the flask, the supernatant whey is decanted off and filtered. It is the custom in this laboratory to employ one and one half liter flasks and to fill them only two thirds full to avoid boiling over, on sudden cooling after autoclaving. Whey prepared in this manner can be used when needed.

The method for the preparation of agar is as follows. To 1000 cc of whey add 5 grams peptone. Adjust reaction to pH 6.5. Add 10 grams Difco granular agar and autoclave to dissolve the agar. Add 10 grams galactose and filter through absorbent cotton.

The milk sample and all dilutions are treated as stated in the first part of this paper.

Carbon dioxide gas amounting to from 5 to 10 per cent. of the container volume is added immediately before incubation.

A satisfactory and readily available container is the Kodak Developing Tank made by the Eastman Kodak Company and sold by their agents in all parts of the country. The tank should be about five inches in diameter and eight inches high, the one used in developing five by seven films. The accompanying cut[8] with appended note illustrates the set-up for L. acidophilus work.

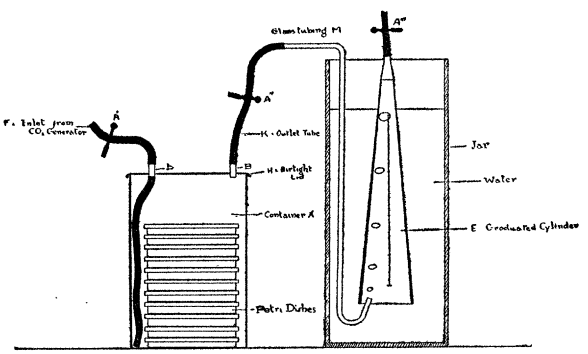

FIG. 1

EXPLANATION OF FIGURE 1

The agar plates are placed in the container X and the lid H screwed on tightly. The inlet tube F is connected with a CO_2 generator and the outlet tube K with the glass tubing M, the open end of which is placed in the mouth of the inverted graduated conical cylinder E. A Sedgwick-Rafter funnel is employed, but any large bruette or graduated cylinder will serve the purpose. The jar holding the inverted cylinder is filled with water.

The volume of the container X must be known. By subtracting from the total volume of the can 40 to 50 cc for each agar plate the approximate volume of the container is obtained. The clamps A′ and A″ are opened and CO_2 allowed to enter the container through F, forcing a corresponding amount of the contained air through K. The volume of displaced water in E is a direct measure of the expelled air. A volume of CO_2 equal to from 5 to 10 per cent. of the total atmospheric volume of X should be displaced. A′ and A″ are then tightly closed and the rubber tubing disconnected from the CO_2 generator and the gasometer jar. The apparatus is now ready for incubation.

Methods of incubation and counting have already been described briefly.

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SPECIAL ARTICLES

THEORIES OF A NEW SOLID JUNCTION RECTIFIER

AT the Physical Society meeting held at Washington on April 23 and 24, this year, the writer described a new type of electronic rectifier. The rectifier unit consists of a disc of copper having an oxide formed on its surface. It is found that, under suitable conditions, current flows more readily from the oxide to the copper than in the reverse direction, the phenomenon being very much like that observed in a high-vacuum electronic-discharge tube, in which electrons flow more readily from the hot cathode to the anode than from the anode to the cathode. The new rectifier acts as if a minute electronic cell existed at the junction between the copper and the oxide.

The rectifier operates with quite large current den-

[8] The writer is indebted to Mr. George Hunt for this drawing.

sities and ratios between high resistance and low resistance as great as 20,000 to 1 have been obtained.

The structure of this new rectifier is radically different from that of other similar rectifiers that have been developed in the past. The seat of rectification is apparently restricted to the layer near the junction between the copper and the compound formed on it, and the explanations of contact rectification that appear most prominently in the literature are untenable in regard to this rectifier. These explanations are based, most frequently, on either electrolysis or thermo-electricity.

The solids that rectify electrolytically require some time to come to their steady state and deteriorate rather rapidly. The rectified currents are unsteady and full of abrupt changes. The products of electrolysis soon appear at the boundary and even throughout the body of the compound. The present rectifier has none of these characteristics. It responds immediately and does not show any signs of either chemical or physical change even after long continuous operation at the proper operating temperatures. The current is steady and indicates a definite resistance at each value of the voltage. The action is, therefore, not electrolytic.

The layer of compound used in the new rectifier may be as low as 0.025 mm in thickness. This in itself makes it seem rather unlikely that the effect is thermoelectric, since it would be difficult to maintain any appreciable temperature difference between two surfaces that are so near one another. The fact that the thermo-electromotive force that may be assumed is in the wrong direction makes the theory entirely untenable.

Jolley in his book on "Alternating Current Rectification" mentions a theory which assumes a double layer, each half of which is made up of one constituent of the crystal. This condition may exist in the present instance at the surface where the two substances are joined to each other. It may be that below the last layer that contains oxygen atoms there is a layer of copper atoms all or most of which are in chemical combination with the oxygen. It is not easy to get a mental picture of the action of such a double layer, but the idea may have value when taken together with work function considerations.

Many observations indicate that the essential characteristic of this rectifier is the very intimate relationship that exists between the metal and the oxide and that the rectification takes place at the junction where the copper and the oxide may be thought of as being each within the sphere of influence of the other. Schottky[1] shows how it is possible to make some cases of unidirectional conductivity seem plausible on such considerations. In the present case, however, it seems likely that copper has a greater work function and also that its work function involves a steeper potential gradient than does that of copper oxide. It is difficult to see on this basis why it should be easier by means of an externally applied electromotive force to make electrons pass from the copper into the oxide than the reverse. It seems likely that Schottky's theory of contact rectification does not give the full explanation of the present phenomenon.

I wish to make a very tentative suggestion of another theory which goes one step farther than the suggestions made by Schottky. Schottky assumes that an electron has to move up through one potential gradient and down through the other. If the two substances form one continuous body, an electron in passing from one to the other may have to move through a potential difference corresponding to only the difference between the electron affinities of the two materials. If the electron affinities of copper and of copper oxide are nearly the same and the two materials are in such relationship as to really constitute a single body we may then have a condition in which only a small amount of energy is necessary to enable an electron to escape from one substance and into the other. If we think of copper as having a great number of free electrons this may result in an enormous emission of electrons from the copper into the oxide even at room temperatures. Under this condition the copper serves the same purpose as the hot wire filament in a vacuum tube and maintains an atmosphere of electrons in the oxide in excess of the normal amount.

The evaporation of electrons from the copper into the oxide proceeds until an equilibrium is established between what we might call either the vapor tension or the diffusion pressure of the electrons in the copper and the electrostatic forces that are set up by the excess electrons in the copper oxide, similar to the electron equilibrium that exists at the surface of a hot filament.

If an external potential difference is applied between the copper and the contact on the free surface of the oxide a current will flow, and if the potential difference is very small the current is approximately the same, independent of the direction of the applied e.m.f. This is to be expected because the equilibrium is only slightly disturbed and the electrons may move with equal facility in either direction. When the potential difference is increased, a new condition of equilibrium is set up, depending on the direction of the electromotive force. If the e.m.f.

[1] W. Schottky, *Zeits. für Physik*, 14, p. 63, March, 1923.

is in such a direction as to force the electrons from the copper into the copper oxide, some of the electrons in the copper oxide are removed and the diffusion pressure of the electrons in the copper is then in such direction as to help the flow of the current. The electron current, therefore, flows freely from the copper to the oxide. The minute spacing between the electrodes, the comparatively large areas and possibly the dielectric constant of the copper oxide all contribute to make the impedance in this direction low.

When the applied potential difference is reversed so that the electrons are driven back into the copper, another condition of equilibrium is established in which the diffusion of the highest speed electrons against the applied potential difference maintains a smaller number of excess electrons in the copper oxide. These electrons occupy a thin layer very close to the junction between the copper and the copper oxide so that in the high resistance direction the whole potential gradient is concentrated in this thin layer. This agrees with the experimental fact that in the high resistance direction the potential drop is all at or very near the junction between the two materials. It is probably also in agreement with the fact that the high resistance decreases rapidly with rise in temperature, since at higher temperatures the conductivity of the oxide increases and this may correspond to a greater number of free electrons and a smaller difference between the free electron concentrations in the oxide and the copper.

The above is admittedly only the skeleton of a theory, but it seems to be consistent with the voltage and the temperature characteristics of the junction rectifier.

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EXPERIMENTAL MODIFICATION OF POLARITY IN MARINE OVA

IN their experimental studies on ova of the sea urchin *Lytechinus variegatus,* Taylor and Tennent (1924)[1] found that each half of an unfertilized ovum which had been bisected by the micromanipulation method either through the poles or through the equator would, upon subsequent fertilization, divide in both first and second cleavages at right angles to the plane of section.

These results suggested to us a similar problem on ova of the starfish *Patiria miniata* which abounds along the shore of Monterey Bay near the Hopkins Marine Station of Stanford University. This species is actively spawning during the months of April and May, when our experiments were performed. Several animals were brought into the laboratory each morning and placed upon clean glass plates. Usually within an hour or so sperm or eggs (fully matured) were freely extruding through the gonopores. These were carefully pipetted into thoroughly clean finger bowls containing fresh sea water. The eggs were well washed with one or two changes of sea water before the experiments were begun.

The polarity of the beautifully clear, matured ova of *Patiria miniata* can readily be recognized by the position of the conspicuous polar bodies. The first and second cleavage planes normally intersect at right angles near the polar bodies. In about sixteen hours after cleavage begins, that side of the blastula diametrically opposite the polar bodies shows a distinct thickening. This thickening represents the vegetal pole where invagination occurs some twenty-eight hours after fertilization.

The merotomy experiments were performed with the aid of quartz micro-needles which were operated in a moist chamber by means of a Taylor micromanipulator. Upon placing from one to several ova on a coverslip which had been scrupulously cleaned by the aqua regia-alcohol method (Taylor, 1920),[2] a suitable amount of the water was drawn off just sufficient to slightly compress the ova and thus hold them nicely in position for cutting.

More than eight hundred ova of this species *P. miniata* have thus been operated upon. These were bisected through various planes—some through the poles, others through the equator and still others (the majority) through planes making practically all angles with the polar axis.

The two fragments thus resulting were thereupon transferred by means of a mouth pipette to fresh sea water contained in inch size watch glasses, to which a drop of light sperm suspension was, a few minutes later, added. Fertilization membranes appeared usually, within three to five minutes after insemination. After three or four hours the fragments were transferred to fresh sea water. Careful observations were made on each fertilized fragment. Full notes were recorded on 653 fragments.

The results of our experiments appear to be conclusive in demonstrating that without exception the first and second cleavage planes passed through the fragment at right angles to the plane of section.

Immediately upon transection, the two fragments tend to be elongated parallel to the plane of cutting—

[1] Taylor, C. V., and Tennent, D. H., "Development of Egg Fragments," Carnegie Institution Year Book, No. 23, pp. 201–206, 1924.

[2] Taylor, C. V., "An Accurately Controllable Micropipette," SCIENCE, n. s., 51, 617–618.