Three functions may be added instead of two, or two functions may be multiplied together. The latter mathematical process indicates that two separate and distinct sets of lines may occur on a single plate at one time. Several such curves will be found in the last two pages of the article referred to above.

A fairly complete discussion of the method may be of interest whereby the mathematical curve of Fig. 2(*c*) is obtained from the Chladni plate shown in Fig. 1(*c*). To begin with it is usually best to take $A=B=1$; by doing this one is often able to recognize related configurations which previously had escaped notice. In the Chladni plate Fig. 1(*c*), there are seen six diameters and at least one circle. This reduces the total possibilities to a limited number, and it is finally found by trial that the two modes of vibration which produce this Chladni pattern correspond to one circle and six diameters combined with one circle and two diameters. Now the correct values of the *k*'s for these circles are found in tables of Bessel functions. From these the equation

$$AJ_6\left(\frac{11.00r}{a}\right)\cos 6\theta + BJ_2\left(\frac{5.937r}{a}\right)\cos 2\theta = 0 \qquad (5)$$

is obtained.

When this equation is plotted the two predominant diameters are on the 45° and 135° lines. These can be related to the 0° and 90° lines by changing the cosine to sine. This changes Equation 5 to

$$AJ_6\left(\frac{11.00r}{a}\right)\sin 6\theta + BJ_2\left(\frac{5.937r}{a}\right)\sin 2\theta = 0 \qquad (6)$$

This is the first equation of the two shown in Equation 4, in which $A=10$ and $B=-1$.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A METHOD FOR MEASURING AND RECORDING CONTINUOUSLY THE pH OF THE CIRCULATING BLOOD[1]

WITHIN recent years the glass electrode has been found readily adaptable to the continuous measurement and recording of the pH of the circulating blood in experimental animals. Of the more recent descriptions of a method of this type is that presented by Nims, Marshall and Burr.[2] Our report briefly describes a method similar in principle, but differing in details.

The units of the assembly employed consist of a chamber containing the glass electrode, a Cameron detector and pH meter, a potentiometer, a Leeds and Northrup mirror type galvanometer, a light source and a kymographic camera.

The essential features of the glass electrode assembly are shown in Fig. 1; during its use the ends of the severed blood vessel are attached to side inlet and outlet tubes, directly in case the vessel is large enough or by means of glass cannulae and rubber tubes. From the bottom of the chamber there is a recurved tubular extension to which there is attached a stiff rubber tube connecting with the KCl chamber containing the reference electrode. The electrode stem is held firmly in a tapered glass stopper which is ground to fit accurately the mouth of the chamber. The stopper is secured against arterial pressure by stopcock grease or rubber bands stretched between glass ears on both the stopper and chamber. The chamber with the electrode in place has a volume of approximately 1 cc.

For measuring the pH of the circulating blood the method of operation of the Cameron detector and meter is the same as that employed in the determination of the pH of any other fluid. The pH may be read directly from the dial; however, provision has been made for recording the electrode potentials by

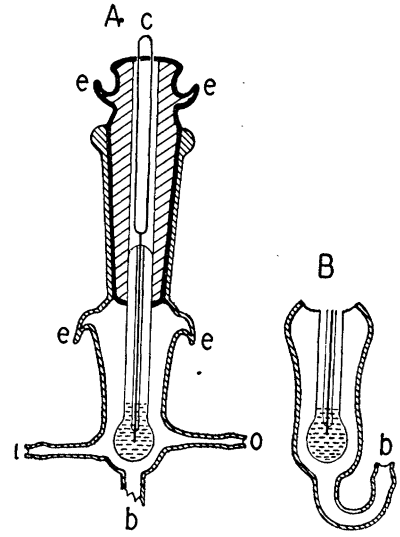

FIG. 1. A, cross section of the glass electrode and chamber, about two thirds natural size; b, position of salt bridge tube; c, wire contact; e–e, glass ears; i, inlet tube; o, outlet tube. B, cross section of the lower part of the chamber, showing the salt bridge tube more in detail. This tube lies in a plane at right angles to the planes of the inlet and outlet tubes.

[1] This work was aided by a Fluid Research Fund from the Rockefeller Foundation.

[2] Nims, Marshall and Burr, SCIENCE, 87: 197, 1938.

inserting a double-pole-double-throw switch into the circuit of the galvanometer within the instrument. In one position of the switch the circuit within the meter is unaltered, in a second position the galvanometer in the meter is disconnected and an outside galvanometer is substituted without disturbing the adjustment of the meter.

A Leeds and Northrup galvanometer unit (2420-c) with a plane mirror and mounted on a heavy wood base is used for recording. A narrow beam of light reflected from the mirror moves across the slit of the camera placed at a distance of one meter. A potentiometer, inserted between the pH meter and the recording galvanometer, is used to control the excursion of the light beam for a given unit change in pH. The calibration on the record is obtained by moving the pH dial through a given interval, usually 0.1 pH, and photographing the resulting excursion of the light beam.

For rendering the blood incoagulable heparin has been used in some instances; but we have also found Pontamine Fast Pink BL or Chlorazol Fast Pink B, 200 to 250 mgm per kilogram, satisfactory.

This apparatus is quite rugged and stabile. Continuous records of the pH of the circulating blood can be made with an accuracy of at least 0.01 pH, and with good approximation to the third decimal place. The type of record obtainable is shown in Fig. 2. This

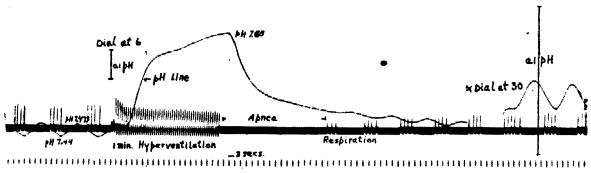

FIG. 2. A record of spontaneous breathing, hyperventilation, and the pH of the circulating arterial blood, obtained from a dog under barbital-sodium anesthesia. Dial readings refer to figures on the dial of the potentiometer between the meter and the recording galvanometer.

record was obtained from a dog under barbital-sodium anesthesia. The animal, as indicated, was hyperventilated for one minute. Prior to the hyperventilation, as well as after that procedure, the breathing was of the periodic type. The record shows, in addition to the marked rise in the pH of the arterial blood incident to the hyperventilation, a definite fluctuation in pH with each group of respirations. In a number of instances, in animals breathing slowly and deeply, we have observed and recorded measurable fluctuations in the pH of the circulating arterial blood coincident with each respiratory movement.

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A SIMPLE INEXPENSIVE DEVICE FOR ACCURATE DELIVERY OF SMALL AMOUNTS OF FLUID

To overcome the difficulties which are encountered when treating a large number of animals with small identical volumes of material, Dr. Robert T. Frank suggested that I devise an attachment for a tuberculin syringe which can be readily set and promptly made to deliver any desired amount of liquid. The device was not to interfere with quick assembly and cleaning.

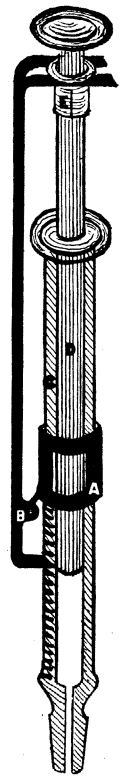

FIG. 1

The apparatus which has proved efficient consists of a spring clamp (A) encircling the barrel (C) with an arm (B) attached by a pivot. Both ends of this arm are bent at right angles. At the front end, facing the barrel, there is a sharp edge which engages the graduation lines etched into the barrel. The other end of the arm acts as a stop to the plunger (D) which carries a metal collar (E) with a flange to give a surface perpendicular to the stop. The amount delivered, when using this device, is as accurate as the graduation markings on the syringe. The device can be easily detached and applied to another syringe as required.

This device has been used with success by Dr. Robert T. Frank for injecting quantities as small as 0.02 cc.

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