3/1. This suggests that square root of conductance is the best measure to use where it is important to have the closest approximation to normality, especially over wide ranges of conductance. For most routine purposes, however, conductance would seem to be a perfectly adequate measure. It might be noted that a microammeter reads in units directly linear with mhos; such as ammeter, plus a suitable voltage divider is perfectly adequate for measuring conductance directly.

Our data furnished no evidence on the appropriate units for measuring rapid changes in skin conductance, but it may be noted that Lacey and Siegel (*6*) found conductance to be a satisfactory measure of GSR (or PGR). Hence, it would save much time and confusion if workers calibrated their instrument dials in micromhos instead of in ohms.

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A Simple and Practical Method for Measuring and Recording Blood Coagulation Time

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Since the work of Stewart (*1*) in 1899, many investigators have been interested in conductivity as a method of studying the physical properties of blood. Most of this work has been concerned with the relative proportions of blood ingredients (*1–5*). Numerous methods have been devised for these measurements as new instrumentation has developed (*1–8*). A few attempts have been made to correlate the electrical conductivity of blood with blood coagulation, with different conclusions resulting from these studies. In 1905 Frank (*9*) reported no appreciable change in conductivity during blood coagulation. However, Rosenthal and Tobias (*7*) in 1948 described a method more precise than that of Frank. By the use of a 1000 cps a-c voltage across a bridge they were able to measure resistance changes with blood clot formation. Later, in 1949, Henstell (*10*) reported that by the use of a similar method, with a 60 cps a-c voltage, resistance changes with clot formation could be measured. These methods, however, require a complex apparatus, and the results may be affected appreciably by the constituents of the blood. In fact, Hirsch and colleagues (*8*) used a similar apparatus to evaluate the hematocrit.

[1] Jack H. Hall assisted during these studies.

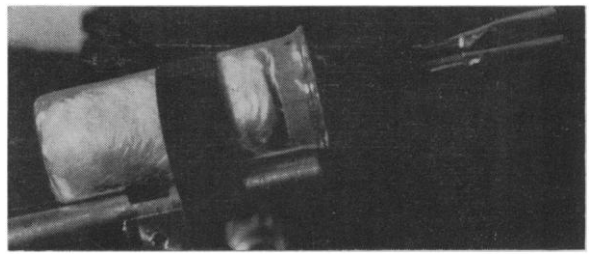

Fig. 1.

Lee and White (*11*) in 1913 devised a somewhat satisfactory mechanical technique for observing and measuring blood coagulation time. This method consisted of withdrawing venous blood, placing it in a small test tube, and rotating it every 30 sec until a clot was formed. This method is widely used today. In 1952 Macht and Hoffmaster (*12*) reported a mechanical method for modifying the Lee and White technique which demonstrated that blood coagulation did not occur as a discrete event. This finding is in agreement with the methods that used conductivity measurements, but progressive changes in coagulation would not be delineated by the original Lee and White method. It also has been shown by Sigman *et al.* (*13*) that motion of blood has an effect on electrical conductivity of the fluid. From this evidence one might conclude that any motion of the blood during a measurement of coagulation time should be uniform, if a maximum reliability of the measurements is to be achieved.

With all these factors in mind, we have developed a new method in this laboratory for the measurement of the coagulation time of blood. This is a modification of the method of Lee and White (*11*) and uses the conductivity of blood as a means of recording the onset and final clot formation. The method is exceedingly simple and practical for use clinically or in the research laboratory.

The apparatus used is composed of a 110-v a-c motor attached to a gear that oscillates back and forth through 90° in such a manner that an attached platform will swing 45° up and down from horizontal. A full oscillation occurs every 10 sec. On the platform attached to the shaft of the gear is placed a container for blood, and a mercury switch. This switch may be reversed so that it makes contact at either extreme of the vertical motion but is always open at the other extreme.

Three different modifications have been employed for blood containers: (1) a culture tube 75 mm × 10 mm; (2) an insulated container of two sealed chambers—an inner glass tube 55 mm × 12 mm and an intermediate chamber filled with glass wool (Fig. 1); and (3) a dual chamber similar to (2), but with a constant temperature fluid circulating through the intermediate chamber that surrounds the inner chamber (Fig. 2). In all cases the tube containing the blood is

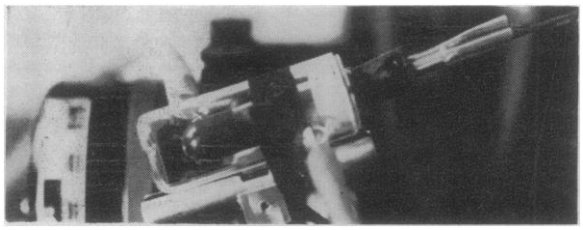

FIG. 2.

coated inside with parafin oil and allowed to drain preceding each measurement. Because of the possibility of temperature loss, the latter two containers are preferable, the perfused container being the most reliable.

The conducting electrodes are made by inserting two metal rods of 3 mm diameter through a cork stopper so that they touch the inner surface 3.5 mm apart, and protrude 0.2 mm through the stopper. These electrodes may be made of a noncorrosive metal, or they may be electroplated with a noncorrosive plate. The cork stopper is painted with a dissolved solution of plastic which is allowed to dry to a hard film, in order to present a nonwettable surface to the blood during measurement. With the cork stopper inserted in the inner glass tube so that the electrodes are horizontal to each other, leads are taken to the circuit as shown in Fig. 3.

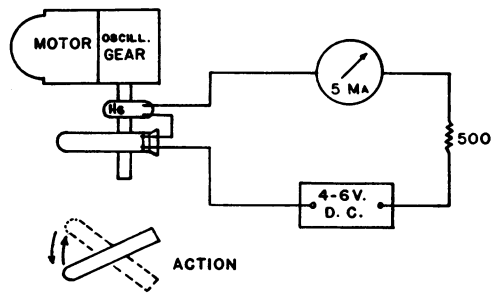

FIG. 3.

The simple circuit consists of a d-c source such as a battery, a 5 ma, 70 ohm Esterline-Angus ink-writing recorder, and a 500 ohm resistor in series with the instrument to protect its movement. This circuit is completed by the electrodes which intermittently contact the blood, and by the mercury switch in series. As shown in the diagram, the switch makes contact when the blood, coagulated or uncoagulated, is in contact with the electrodes. This arrangement is desirable only if the resistance changes of the blood are to be studied throughout the period of observation. With the mercury switch in juxtaposition with the electrodes, the record allows a measurement of resistance by the application of Ohm's law:

$$Ra + Rx = \frac{E}{I},$$

where E is the d-c voltage, I is the current in amperes, Ra is the total series resistance in the circuit excluding that of the blood, and Rx is the resistance of the blood. There is an additional factor in the measurement, however, because of the resistance Rx being a function of the geometric shape of the formed clot as well as of its presence.

A more desirable procedure for the measurement of blood coagulation time, with the elimination of intervening variables, is to reverse the mercury switch so that it closes when the uncoagulated blood is not in contact with the electrodes. Under these conditions, at the initiation of clotting a good contact is initially established at the electrodes and, not being fluid, it maintains its contact throughout the cycle of oscillation. Thus coagulation, and not intervening blood resistance changes, is the variable measured. It can be shown, however, that there is a progressive change in resistance during clot formation, and this is recorded by the instrument until a firm clot is established. With the mercury switch reversed, the conductivity changes closely follow clot formation and proceed to its ultimate completion. By following this procedure, the measurement of blood coagulation has been found quite adequate. Conductivity follows the progressive formation of the clot, which is the only means of altering the conductivity. Fig. 4 shows the complete apparatus.

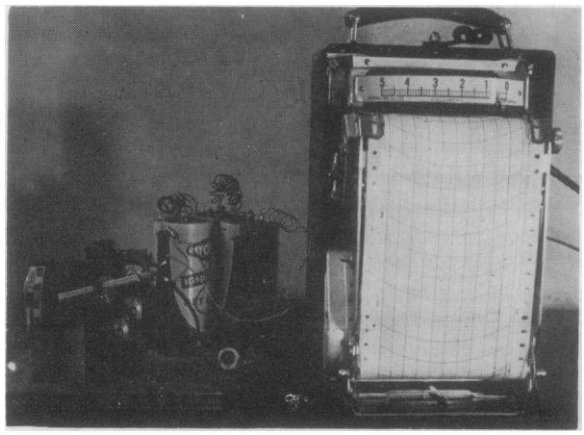

FIG. 4.

The procedure employed is to draw 1 ml of blood into a syringe and needle (size 22) previously coated with paraffin oil. With the needle removed, 0.5 ml of the blood is carefully discharged into the inner glass chamber of the instrument and oscillation is started. A time is marked on the moving chart at the instant of withdrawal.

Fig. 5 shows a sample record of coagulation time with the mercury switch reversed as suggested. This blood sample was taken from the femoral vein of a mongrel dog while under sodium phenobarbital anesthesia of 1-hr duration. It can be seen that only the conductivity of blood film between the electrodes is recorded at 10-sec intervals until coagulation begins. If not wanted, this initial recording of the film can be abolished by paraffin coating between the electrodes, but its presence makes a record of time and shows the incidence of initial oscillation during the measurement.

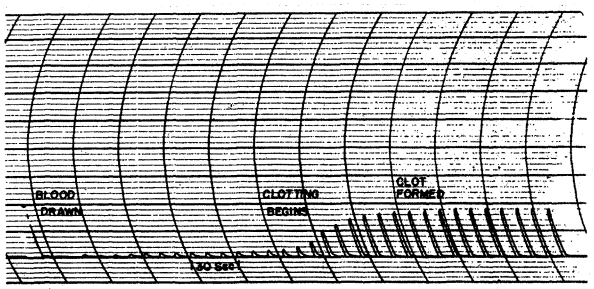

FIG. 5.

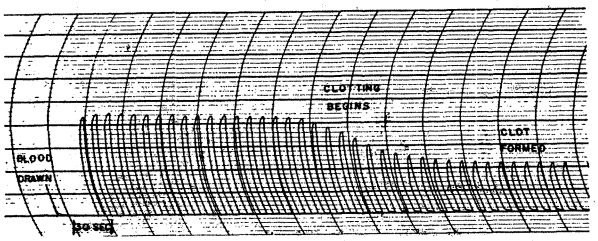

FIG. 6.

Fig. 6 gives a record of coagulation time with the mercury switch in juxtaposition with the electrodes, demonstrating continuously resistance changes in the blood leading to complete coagulation, this altered resistance being somewhat affected by the geometric changes as previously described.

Studies carried out in this laboratory have demonstrated this device to be exceedingly practical and reliable in determining the effect of anticoagulants and other variables upon coagulation time. Comparative studies of coagulation time, however, entail a decision as to the position on the curve of decreasing resistance to be used as a critical end point. Using the mercury switch reversed, we have used as an end point the position on the asymptote where the first oscillation is followed by no further change in resistance. Likewise the first significant rise from the baseline has been accepted arbitrarily as the beginning of a viscous gel formation.

The problems encountered in the past in the comparison of coagulation time determined by one method with that of another are not altered by the addition of a new method. These differences between various procedures usually can be ascribed, not to the properties of blood, but rather to differences of the surface to which blood is exposed, the method of blood withdrawal, the precision of measurement with respect to time, and the degree of agitation to which the blood is exposed. With most methods the subjective error in technical procedure creates a wide variation. It is believed that the method reported here represents a minimum of subjective error, presents a procedure for controlled agitation, utilizes the widely accepted Lee and White technique, and offers the advantage of reproducible permanent recordings, not offered previously by other methods. In view of these factors it is thought that the adoption of this method by various groups that may be engaged in studies of coagulation time may result in a closer agreement than studies using other prevalent, more variable methods.

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Fox Hills and Hell Creek Strata in the Bearpaw Mountains, Montana[1]

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New evidence concerning the identity and sequence of strata in the Bearpaw Mountains and surrounding region is appearing, as detailed geologic mapping by U. S. Geological Survey parties continues. Thus the fact that rocks of Wasatch age (early Eocene) overlie the coal-bearing Fort Union formation (Paleocene) in the Bearpaws was reported in 1949 by Brown and Pecora (*1*), who also suggested that a coal-barren section of sandstones and shales, about 600′ thick, between the Bearpaw shale (Upper Cretaceous) and the Fort Union formation, might be equivalent to the Fox Hills sandstone and the Lance formation (Hell Creek).

In previous publications these indefinitely identified sandstones and shales were called Lance (Tertiary?) and were regarded by Reeves (*2*) as classifiable with the overlying lignitic strata now known to be in the Fort Union formation. No fossils or other evidence, except stratigraphic position, have hitherto been adduced as indications of their age. In 1950 and 1951 Lindvall measured a composite section of these rocks, totaling 400′, in Sec 35, T28 N, R13 E, 5 mi east of Big Sandy; but this section, without good exposures above its top, does not represent the complete sequence to the base of the Fort Union, for it lacks about 200′ of sandstones and shales, which, however, are present in a similar conformable sequence in a ravine on the Nielsen ranch in Sec 24, T26 N, R17 E, 40 mi east of Big Sandy. At the latter locality the sequence just above the Bearpaw shale is incomplete because of faulting.

In carbonaceous shales about 335′ above the base

[1] Publication authorized by the director, U. S. Geological Survey.