fitness groups from 33 per cent., in the absence of treatment, to 86 per cent., when given sulfanilamide. The contribution of the adjunctive supporting treatment was apparent in the increase in percentage survival in the lower fitness groups from 25 per cent., with sulfanilamide alone, to 71–100 per cent. with sulfanilamide plus vitamin C, vitamin B_1 or liver extract.

The rabbits which survived were, almost altogether, those able to hold a negative blood culture, in spite of lesions at site of injection, as large, at twenty-four hours, as were observed in the controls. The percentage coming through to recovery without persisting fever or substantial weight loss was, for the higher fitness group receiving no treatment, sulfanilamide alone, and sulfanilamide plus adjuvant, respectively: 0, 57 and 60; for the corresponding lower fitness groups: 0, 25 and 64.

Treatment with sulfanilamide and especially with sulfanilamide plus fitness-promoting adjuvant tends to keep the blood stream clear enough of pneumococci invading from infected foci, in the rabbit, to permit the natural defensive forces to get an upper hand.

Detailed report will be deferred until completion of studies under way on optimum dosage and timing, limitations imposed by fitness-impairing potentialities of sulfanilamide itself; and considerations necessary because of differences in rate of conjugation of sulfanilamide to a less active derivative, in rabbits of divergent fitness rating.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN ELECTRIC CARDIOMETER

THE recording of the heart beat by the commonly used pneumatic method is not fully satisfactory because the adjustment of the apparatus is critical, and comparatively slight bodily movements on the part of the subject are sufficient to interfere with the registering. This latter defect becomes particularly serious during studies in the physiology of exercise, and in psychological experiments involving the determination of the cardiac rate immediately following strong stimuli, when movement is apt to occur.

Boas[1] seems to have been the first investigator to employ the action potential of the heart for recording purposes during exercise. He made use of a battery-operated vacuum tube amplifier controlling a sensitive relay, which actuated a second relay carrying contacts for operating an electric counter and pen recorder. This apparatus was found to operate perfectly when the various contacts, relays and amplification controls were properly adjusted, provided that the subject remained well insulated from the ground, did not touch other persons and did not engage in certain types of generalized muscular activity. Benedict, Lee and Striech[2] used the Boas apparatus successfully in connection with the bicycle ergometer.

Recent improvements in vacuum tube design have made it possible to develop a similar apparatus which operates from the 60-cycle lighting circuit, is rugged and non-critical in adjustment and apparently is free from the defects of the Boas instrument. The new apparatus is $9 \times 11 \times 17$ inches in size, weighs approximately 30 pounds when mounted in a steel cabinet and is self-contained.

The electrode system is similar to the one used by Boas, with the exception that the indifferent contact consists of a wire placed in the mouth instead of a cup electrode on the right side of the chest. It is bent in such a manner that it is self-retaining and does not interfere with breathing. This contact is connected to the grounded shield of a rubber-covered microphone cable, and the active electrode is connected through the center wire of this cable to the amplifier shown in the figure. The active electrode, which may be a metal plate covered with moistened cotton or kaolin paste, is placed over the apex of the heart.

The amplifier is of the four-stage resistance-coupled type, designed by the writer for studying nerve action potentials. Its over-all voltage gain is well over one million, with a noise level of about four microvolts. A double pole switch (S) is provided for inserting a band-pass filter into the input and output of one of the stages. Experimentally, the filter seems most effective for cardiometric work when both sections are resonated at 20 cycles. This may be accomplished by using 500 H. inductors shunted with 0.1 Mfd. capacitors. The output of the amplifier actuates a small copper oxide milliammeter having a light weight pointer, and also excites the grid of a gas-triode tube. When the grid of this tube becomes relatively positive (this occurs at each heart beat) anode current continuously flows through the coil of the electric counter until the anode potential is reduced below the ionization point. The amplified cardiac potential, therefore, simply acts as a trigger to start the anode current in this tube. Once started, the current flow maintains

[1] E. P. Boas, *Arch. Int. Med.*, 41: 403, 1928.
[2] F. G. Benedict, R. C. Lee and F. Striech, *Arbeitsphysiologie*, 8: 266, 1934.

itself. When the counter has completed its stroke a short-circuiting contact is made which momentarily reduces the anode potential to a value low enough to stop the current flow, whereupon the contact opens as the counter armature returns and awaits the next heart beat. It will be noted that this contact operates *after* the stroke has been completed, and therefore imperfections in the contact cause no inaccuracy in the count, provided only that the potential is reduced for an instant below the ionization value before the next beat.

A telephone message counter in which the original armature has been replaced with one made from 1/32 inch steel has been found to work perfectly as a counter up to 235 strokes per minute (this high rate was secured by artificial means). It is not necessary to use other contacts if a graphic record of the beat is desired, as a thread connected to a recording pen can be attached to a flat spring which is placed so that it is hit by the counter armature near the end of its stroke. The counter and other parts of the output circuit must be well shielded, as must the circuits associated with the first amplifier stage. Also, the first 6F5 tube must be carefully selected, as about 30 per cent. of the tubes commercially available seem to have a very high hum level or are defective in other ways.

This apparatus seems to be very dependable in operation. It is only necessary to attach the electrodes, turn the amplifier on and adjust the amplification so that the meter needle swings well above the point at which the trigger action occurs. The setting is not at all critical. If the amplification is more than about 15 fold above this value, multiple counts may occur due to electric feed-back between the counter and amplifier, but, in practical use, such high amplification is not necessary. When the electrodes are properly placed, the uninsulated subject can engage in any sort of violent activity without affecting the count.

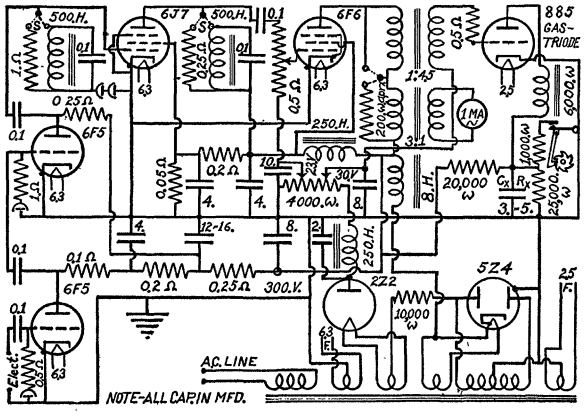

FIG. 1. The electric cardiometer.

The device seems particularly well adapted to the graphic recording of rate in connection with magnetic-clutch operated interval recorders as described by Fleisch[3] and by Gesell.[4] Additional contacts are not necessary; the magnet coil of the Fleisch apparatus, for example, is simply placed in series with the resistance R_x (see Fig. 1), which is reduced to compensate for the resistance of the coil. Experiments in progress indicate that a differentially wound magnet coil for the clutch is even better, as the anode current of the gas-triode can then release the clutch while at the same time the counter is being actuated. The clutch is "off" for the duration of the counter stroke, which seems to be reasonably constant and which may be varied within limits by changing capacitor C_x and associated resistors.

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[3] A. Fleisch, *Am. Jour. Psychol.*, 45: 335, 1933.
[4] R. Gesell, SCIENCE, 79: 275, 1934.

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