tributable to the route of administration rather than to the size of the dose employed. As regards the possibilities of intrarectal immunization, with or without previous sensitization with bile, our results clearly indicate the inefficacy of such a procedure. The small number of experimental animals, in part due to intercurrent deaths, precludes the drawing of more definite conclusions at this time.

We wish to state in passing, that 6 monkeys, not enumerated above, which carried collodion sacs with virus in the peritoneal cavity, died with symptoms of progressive toxic cachexia in the course of 2 to 4 weeks. All of these monkeys were awkward in climbing, showing not only marked weakness of the legs and arms but lack of coordination of movements, and in 4 we observed a faint head tremor. The autopsy findings demonstrated the absence of lung infections (tuberculosis, pneumonia) and enteric infection (parasites). In some cases we found a slight congestion of the cord; histological examination however was essentially negative, as was transfer of the cord to a new monkey. The significance of these observations at present is obscure; they are especially perplexing inasmuch as our previous experience indicates that the virus in collodion sacs in the peritoneal cavity of the monkey is not viable beyond a period of 48 hours, contrasted with a survival for 10 days in the rabbit under similar experimental conditions. Work is under way to determine more accurately the actual length of survival and the occurrence of any possible changes in the nature of the virus in such sacs.

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A Critique of Einthoven's Law in Electrocardiography.*

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It is stated in authoritative books on electrocardiography that Einthoven's Law is mathematically exactly true. I wish to discuss this statement and to show that it is not correct. It is true that Einthoven's Law is approximately correct,[1] and that its practical use-

* Aided by the Emil and Fanny Wedeles Fund of the Michael Reese Hospital for the Study of Diseases of the Heart and Circulation.

[1] Pardee, H. E. B., Clinical Aspects of the Electrocardiogram, (Hoeber) 1928, 166.

fulness is unimpaired; the authoritative misstatement quoted above should nevertheless be refuted for the sake of scientific accuracy. I shall first define Einthoven's triangle and develop Einthoven's Law, and shall then show its inaccuracies.

It is considered that an electrocardiographic lead records the projection on a single line, called *the line of the lead,* of the cardiac potential vector; this vector is the sum of all the individual vectors of the heart muscle fibers. The 3 lines of the 3 ordinary leads of clinical electrocardiography are considered as lying all in one plane, so that they determine a triangle $A_1A_2A_3$ (Fig. 1); this is Eintho-

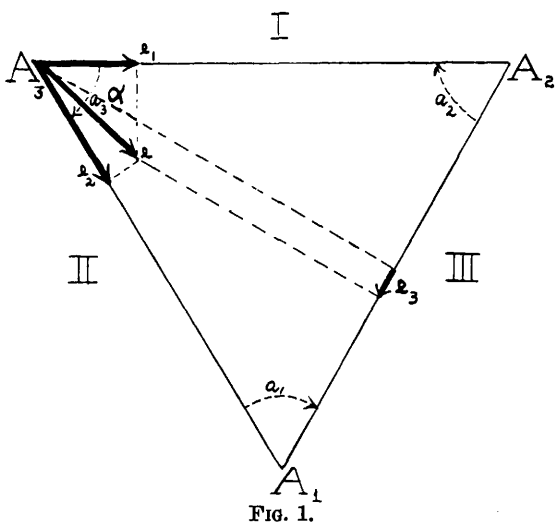

FIG. 1.

ven's triangle. In developing Einthoven's Law, it has been assumed that this triangle is equilateral; we gain something, however, by not making this assumption. Let the angles of the triangle be a_1, a_2, a_3. Let the projection of the cardiac potential on this plane be E; for convenience we represent E as directed from the point A_3, which may be done by shifting E parallel to itself, an operation which leaves unaltered its 2 properties, namely length and direction. Let e represent the length of E, and let α be the angle in a clockwise direction between A_3A_2 and E. It may be mentioned that whereas ordinarily E is spoken of as the electrical axis and α as the angle of this axis, this is not correct, since E is only the projection of the true electrical axis on this plane. The leads I, II, III record the projections e_1, e_2, e_3 of E on the lines A_3A_2, A_3A_1, A_2A_1. The vector E is constantly changing, and the corresponding changes of e_1, e_2, e_3 yield the electrocardiographic curves.

From Fig. 1 it follows by elementary trigonometry that

$$(1)\quad \begin{cases} e_1 = e\cos\alpha, \\ e_2 = e\cos(a_3 - \alpha), \\ e_3 = e\cos(180° - a_2 - \alpha) = e\cos(a_2 + \alpha). \end{cases}$$

From (1) it is readily proved that

$$(2)\quad e_2 \sin a_2 = e, \sin a_1 + e_3 \sin a_3;$$

this relation between e_1, e_2, e_3 is valid at every instant of the cardiac cycle.

If we assume, with Einthoven, that the triangle is equilateral, *i. e.*, that $a_1 = a_2 = a_3 = 60°$, then it follows at once from (2) that

$$(3)\quad e_2 = e_1 + e_3,$$

which is *Einthoven's Law*. This is well known, and has been demonstrated before, but the converse has apparently been overlooked, namely, that if (3) is true then the triangle is equilateral. The proof of the converse is as follows: If (3) is true then it follows from (1) that

$$(4)\quad \cos\alpha(\cos a_2 + \cos a_3 - 1) = \sin\alpha(\sin a_2 - \sin a_3);$$

since this holds throughout the cardiac cycle, it must be true for all α of the cycle, so that

$$\begin{cases} \cos a_2 + \cos a_3 - 1 = 0, \\ \sin a_2 - \sin a_3 = 0, \end{cases}$$

whence $a_2 = a_3 = 60°$, so that the triangle is equilateral. Consequently *Theorem: A necessary and sufficient condition for Einthoven's Law is that Einthoven's triangle be equilateral.*

We shall now discuss Einthoven's Law and the statements made concerning it. It has been stated that Einthoven's Law is necessarily true *a priori*;[2, 3] this statement is obviously based (erroneously) on the law of addition of forces, with which it has nothing to do; for e_1, e_2, e_3 are not independent forces but the projections of a single force. It is also stated that by observation Einthoven's Law is found to hold *exactly*;[4] this is simply based on insufficiently accurate measurements.

If Einthoven's Law held exactly, it would follow from our theorem that Einthoven's triangle is *exactly* equilateral. It would be an astounding biophysical fact if the arbitrary triangle obtained in every individual by using the arms and the left leg were exactly equilateral; indeed in this light it is clear *a priori* that Einthoven's Law can *not* hold exactly. There are further reasons for this view:

[2] Fahr, G., *Arch. Int. Med.*, 1921, **27**, 126.

[3] Lewis, T., The Mechanism and Graphic Registration of the Heart Beat. (Shaw & Sons, London), 3rd Ed., 1924, 107.

[4] Wenckebach und Winterberg, *Die Unregelmässige Herztätigkeit.* (Englemann, Leipzig), 1927, 90.

1. An electrocardiographic lead does not record accurately the projection on a single line of the cardiac potential, because (a) much of the potential from the heart never reaches the electrodes but goes to distant parts of the body; (b) the electrical resistance of the tissues between the heart and the electrodes is not to be neglected and is a variable quantity. The error thus introduced is not necessarily the same or proportional in the 3 leads, so that it may alter the relations between e_1, e_2, e_3. 2. The line of a lead may not be in the same plane as the line joining the 2 electrodes of the lead. For example, the lead AB (Fig. 2) records the current whose path

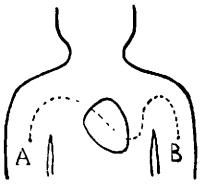

FIG. 2.

is represented by the dotted line, and this path may be largely in a direction not in the same plane as AB. Thus the 3 lines of leads I, II, III may not all be in one plane, so that there may actually not be any Einthoven triangle. 3. Even if there were an Einthoven triangle, it probably would be a changing one because the line of a lead may change slightly as the electrical axis moves; so that if the triangle were equilateral it would not remain so.

These points must make it clear that Einthoven's Law cannot hold exactly. It is enough that it holds approximately, and we should be satisfied with this and with its practical usefulness without claiming for it that which it can not possibly possess.

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Effects of Gonad Stimulating Extracts on Basal Gaseous Metabolism in Rats.

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Reiss and Winter,[1] using extracts containing the sex maturity stimulating principle from the urine of pregnant women, found no

[1] Reiss, M., and Winter, K. A., *Endokrinologie*, 1929, **3**, 174.