Physiology. — *On some Properties of the Radiation-substances (with weak radiation).* By Prof. H. ZWAARDEMAKER.

(Communicated at the meeting of March 26, 1927).

In the November meeting of the Koninklijke Akademie van Wetenschappen the present writer demonstrated that radio-active radiation (radium rays of weak penetrating power, polonium rays) generates in the heart-muscle peculiar substances, which restore contractions of the heart that have ceased through deprivation of potassium [1]). Such an experiment succeeds best, when the organ is connected up in a small circulation of only 30 c.c. of liquid. This liquid (Ringer's potassium free solution) can be kept running by introducing air into a vertical portion of the course, along a small tube placed in a line with the direction of the stream. The air-bubbles carry the liquid upwards until it reaches the glass sphere open at the top, and can descend to the heart (eel-heart on glass canula in sinus or frog-heart on Kronecker canula. From the heart this liquid passes to an open receptacle, from which the liquid is again pumped up etc. [2]).

When such a heart has first come to a standstill through Ringer's solution without potassium (occasionally automatic), i. e. without washing out $^1/_3$ of the potassium, we proceed to radiation from three sides, e. g. with radiofères of enamel $1.6 + 1.8 + 1.9$ or plates covered with polonium of one square cm. [3]). After a latent period of from $^1/_2$ to 1 hour the heart begins to beat. Gradually the radiation substances in question, of which we are going to describe the properties, will then appear in the liquid.

In a second circulation such a liquid can also set another heart beating that has beforehand been treated in the same way, thanks to the presence of the radiation substance. The experiment may, however, also be carried out without resorting to a renewed circulation of the old liquid, by connecting a second heart, prepared in the same manner, in series with the first organ in the old circulation. Then the same liquid first perfuses the radiated heart, and subsequently a non-radiated one. The result is that after the radiated heart has begun to pulsate, the second non-radiated organ will also begin. The two hearts can be made to record the curve on one and the same smoked surface.

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1) H. ZWAARDEMAKER, Kon. Akad. v. Wet., Amsterdam, 27 Nov. 1926.

2) NOYONS et BELEHRADEK, C. R. Soc. de biol. T. **88**, p. 621, 1920.

3) H. ZWAARDEMAKER, Pflüger's Archiv Bd. **213**, p. 757, 1926; ibid. Bd. **215**, p. 460, 1927.

Such a graph is represented in our figure. The bottom curve registers the pulsation of the radiated heart (enamel radiofères), the top one that of the non-radiated organ. Initially the rhythm of the former heart, which commenced earlier, is quicker than that of the latter, but this changes as the experiment advances and the pulsations, not evoked by direct radiation, become better. Thus things go on for hours. All the while, besides radiation-substances some potassium-ions, also appear in the circulating fluid. These ions issue from the so-called fixed potassium of the muscles. Obviously their quantity is only small, so that they cannot of themselves evoke pulsations [1]). The latent period is of interest. It is essential to the effect of the radiation, but also to that of the radiation-substance. It stands to reason that when the hearts are equally sensitive, the effect of the radiation substance follows that of the radiation, since

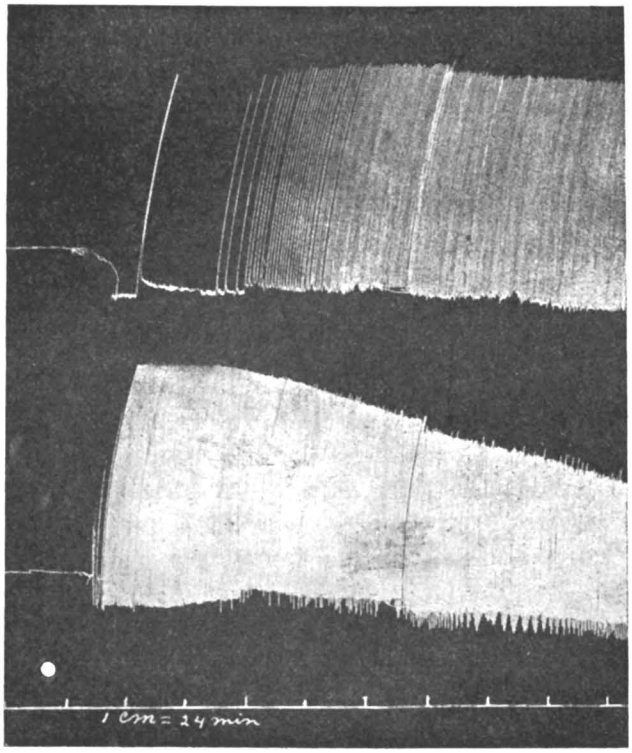

Fig. 1.

2 eel-hearts in one and the same circulation of 30 cc. of liquid.
Bottom-curve ; the organ under direct radiation.
Top-curve : the organ under indirect radiation. At the site of the speck radiation was started. (1 scale mark of the time-line represents 24 min.).

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[1]) These potassium-ions can emanate only from the muscles. Measured by the standard of the frog-tissue the two hearts contain 2 pro mille, or in 200 mgrs of muscle 0.4 mg K. Of this quantity only 0.12 mg can pass into the fluid.

this substance appears first in the heart subjected to direct radiation, subsequently in the liquid and finally in the second heart.

It is no trouble next morning to examine in every direction the liquid, which has been kept in circulation a whole night with the results illustrated above for both hearts.

Thanks to the valuable aid of Mr. Ph. ARONS, we were able in a few months to observe the properties of a large number of similar perfusion fluids. It appeared that the radiation-substance present in these fluids is

dialysable,
ultrafilterable,
thermostabile,
adsorbable to carbon and magnesium-silicate,
soluble in alcohol.

This is the case with the radiation-substance originating under the influence of polonium-radiation, as well as with the substance coming forth under the influence of radium-radiation.

Moreover the said radio-substances do not appreciably lower the surface-tension of water (dynamic measurement) [1]. Neither do they yield an adsorption-band in the ultraviolet, which other similar substances do.

With intenser and quicker radiation other radiation-substances will presumably develop, whose effect we suspected in the radiated heart.

Consequently this heart very often does not beat so well as the heart subjected to indirect radiation.

The long latency (48 minutes for direct radiation, 20 minutes after the addition of the radiation-substance in the perfusion-fluid) renders it probable that we have to do here with substances acting catalytically. They are probably identical with the „substances actives" previously described by J. DEMOOR [2], resp. the heart hormones of L. HABERLANDT [3] in normal life. As we have to differentiate two independent radiation-substances, the one produced by the α-rays, and the other by the β-rays, the catalytic substances, concerned here, have in this paper always been spoken of in the plural.

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[1] R. BRINKMAN, Abderhalden's Hdb. d. Biol. Arbeitsmethoden, Abt. IV, Teil **4**, Heft **6**, 1927.

[2] J. DEMOOR, Arch. int. de Physiol. t. **20**, p. 29, 446, 1922; t. **23**, p. 121, 1924; Bruxelles méd. 13 Sept. 1925.

[3] L. HABERLANDT, Klin. Wochenschr. 1924, N⁰. **36**, Das Hormon der Herzbewegung, Berlin—Wien 1927.