over, complicated as a consequence of its general physical metastability;[11] further, through the adsorption of foreign substances, the occasional occurrence of embedded abrasives (rouge, etc.), and the presence of more or less disturbed boundaries of contact between the minute particles. The importance of the latter factor is, of course, more pronounced than in the case of relatively coarse-grained materials, where the intergranular surface of contact is only a relatively small one.[12]

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[1] NATURE, 129, 169; 1932.
[2] Naturwiss., 20, 416; 1932.
[3] L. Hamburger, De Ingenieur, 46, W, 91-98; 1931.
[4] L. Hamburger, Paper read before the Colloid Section of the Netherl. Chem. Ver. at the meeting of May 28, 1932; in print.
[5] See R. Zsigmondy, "Zur Erkenntnis der Kolloide", p. 87; 1905.
[6] L. Hamburger, Proc. Kon. Ak. v. Wet. Amsterdam, 21, 1066; 1918. T. Haigh, Report Brit. Sci. Instr. Res. Ass. 1921; J. W. French, NATURE, 110, 97; 1922.
[7] Z. phys. Chem., 132, 295; 1928.
[8] Proc. Kon. Ak. v. Wet. Amsterdam, 1916, 1917.
[9] See also Rec. d. Trav. chim. des Pays-Bas (4), 12, 351, 441, 475; 1931.
[10] In case of more severe forms of cold-working, complications occur. See W. G. Burgers, Z. Phys., 58, 11; 1929.
[11] Spring, 1903; E. Cohen, 1910.
[12] See L. Hamburger, Ann. d. Phys. (5), 10, 789, 905; 1931: 11, 40; 1931.

Mechanism of the Action of X-Rays on Living Tissues

CHEMICALLY, nothing definite has been known on the action of X-rays. This lack of knowledge has led to their use where the benefits of X-irradiation are problematic. X-ray dosages, too, must be set empirically owing to inability to measure in any way their immediate effect on the cells. Even after waiting a week or ten days, only the gross effects can be determined.

From certain theoretical physical considerations based upon cellular oxidations and reductions of the redox type, it occurred to me that, when tissue was irradiated with X- or γ-rays, a definite amount of hydrogen should be evolved. This hydrogen should be rapidly diffused through the tissue walls, and thus could be measured.

A detailed explanation of the hypothetical assumptions made previous to this experiment will follow as soon as certain quantitative data are available. Such data, I hope, will give a criterion for determining the advisability of using X-rays, as well as definite information on which to base the dosage.

In this experiment a micro-respirometer was constructed, having by far the greater volume of air space concentrated in the middle of a tube. On either side of this air space stop-cocks were placed so that the whole could be dismounted for analysis. The respirometer was used to make sure that the tissues employed were alive, and air was used throughout. In the first case, a small piece (about 0·25 c.c.) of normal human rectus abdominus muscle was placed in Ringer's solution, and irradiated in the respirometer for 45 minutes with X-rays. A tungsten target and a dosage of 90,000 r. units (20 ma. 75 kv.) were used. The gases in the respirometer were then analysed and found to contain 1·6 per cent hydrogen, by volume. In the second and third cases, primary carcinoma of the breast were used, and 1·03 and 1·27 per cent hydrogen were evolved respectively. In the fourth case, primary carcinoma of the rectum showed 0·83 per cent hydrogen. The experimental error in the determination of hydrogen was less than 0·05 per cent by volume. As the volume of gas contained in the micro-respirometer was approximately 150 c.c., 1 per cent hydrogen would be equivalent to 1·5 c.c.

The amount of tissue used in each case was of the same order of size, but was not weighed or measured, as the important preliminary consideration was to establish the fact that both normal and pathological tissues actually gave off hydrogen during X-irradiation. γ-Rays were not used, but should have a similar effect. Controls were then run as follows: (1) the empty respirometer was irradiated to determine whether any hydrogen was given off from the glass; (2) Ringer's solution was irradiated; (3) and (4) normal and pathological tissue were allowed to respire freely. The gases in each case were then analysed. All the controls were found to be negative for hydrogen. Of course sodium hydroxide was used to absorb the carbon dioxide produced. This was irradiated in (2) above.

The tissues were all killed after about 25,000 r. units. A control was run on muscle tissue that had been killed by asphyxiation, and no hydrogen was evolved after a dose of 90,000 r. units had been used. This, of course, is significant, inasmuch as the hydrogen comes only from the living tissues. Later quantitative measurement, using normal and pathological tissues from the same area, should prove especially enlightening in view of the relative rates of metabolism. The effect of smaller doses of X-rays, and ascertaining which wave-lengths give the maximum effects, should aid in determining exact X-ray dosages.

The fact that hydrogen is removed from the scene of action in tissue metabolism, I believe, is largely responsible for the killing, or at least reducing, the vitality of the cells. Just how this affects them can probably best be shown through oxidation relationships. This will be discussed in a later paper. Regardless of the precise method of evolution of hydrogen, the fact remains that it does come from somewhere within the tissues.

I wish to express my indebtedness to Dr. N. Rachevsky for his continued help throughout this work, to N. A. Ziegler for making the hydrogen analyses, and to George V. Le Roy for certain physiological data resulting in this experiment. (Preliminary Report.)

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Radiographs of Insects

FINDING no record that radiographs of insects were ever made, last summer we took several hundred radiographs of some forty different species of insects. The X-ray tube, constructed in the laboratory, was of lithium glass, and furnished with a very thin window allowing rays of sufficient softness to be used. 3500 volts was the lowest potential with which this tube could be run, and with this potential the venation of wings was shown very distinctly. During the whole work, potentials ranging from this lower limit to 15,000 volts have been used, according to the size of the insect. The insect was placed directly on the photographic film, which was of the type manufactured by the Eastman Kodak Company for dental work.

As an example of the type of radiographs obtained, a reproduction of one showing a *Hydropsyche* larva is given in Fig. 1.[1] The coiled structure is the Malpighian tubules, while the long, narrow, longitudinal