temp. 104.2° F., marked tonic and clonic muscular contractions.

Experiment II. Dog ♀. Weight 15.9 Kilos. Age 12 Months.

1st set of obs. (average of 10 readings)—Coag. time 3½ min., normal.
2d " " " " " " " — " " 4 " "
3d " " " " " 8 " — " " 3 " during slight tetany.

No symptoms appeared until nine days after operation and then only slight muscular tremors were observed with no rise of temperature (100.6° F.).

Experiment III. Dog ♀. Weight 14.0 Kilos. Age 12 Months.

1st set of obs. (average of 10 readings)—Coag. time 5 min., normal.
2d " " " " " " " — " " 5 " "
3d " " " " " " " — " " 4½ " after operation.

This dog showed slight symptoms three days after operation. These passed off and did not return and fifteen days later the third set of observations was made after which the animal was killed.

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The relative efficiency of the biological action of the Roentgen rays emitted by the Coolidge and the old type tubes.

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In accordance with the modern conception in physics the Roentgen rays present pulsations in the ether analogous to the rays of light. The waves of ether forming the Roentgen rays are considerably shorter than the shortest ultra-violet waves of light. The waves of the so-called soft Roentgen rays are about 1,000 times shorter than those of ultra-violet light, and the waves of the hard Roentgen rays are still shorter.

Any substance, solid, liquid, or gaseous, absorbs a part of the Roentgen rays which pass through it. The fraction of the rays thus absorbed depends upon the density and thickness of the substance. The remaining rays penetrate beyond the interposed substance. The relation between the quantity absorbed by the substance and that penetrating beyond it is of fundamental importance for the proper understanding of the biological action of the Roentgen rays.

When the rays enter a plant or an animal body they injure the cells of the organism through the biochemical action of the rays on the protoplasm and mainly on the nuclei. This biological action differs quantitatively in accordance with the amount of rays absorbed by the cells and the susceptibility of the latter to the action of the rays. When slightly injured a cell may completely recover, while if the injury is severe the cell dies. Every cell of the organism may be killed by a sufficiently large quantity of rays. Nevertheless the biological action of the Roentgen rays must be considered selective in as much as quantities of the rays sufficient to kill a certain kind of tissue may leave adjacent tissues intact or only slightly injured. In order to obtain this selective action the rays must be distributed as evenly as possible through the organism. Such a distribution is possible only with the so-called hard rays, whose penetration is much greater than absorption.

At present there does not exist a direct method for measuring the quantity and the penetration of the rays necessary to kill or injure a given cell. All the measurements are indirect and are based on the fact that the various chemical actions of the rays are also in direct ratio to their quantity. A solution of barium-platincyanide which has normally a green color becomes brown under the influence of the rays, and the shade depends upon the quantity used. A photographic paper in black covering will not be influenced by rays of light, but will become blackened under the influence of the Roentgen rays. The shade of black deepens in proportion to the quantity of rays used. On the basis of these color reactions various apparatus are devised for measuring the quantities of the Roentgen rays emitted by a tube in a unit of time.

Before reporting the results of the present investigation a brief outline should be made of the differences in the physical characteristics of the two types of tubes used in the experiments.

Roentgen rays originate on the surface of a metal which is bombarded by the negative electrons of the kathode rays. The greater the velocity of the kathode rays the harder, the more penetrating are the Roentgen rays. The tubes of the old type have an incomplete vacuum. A high potential current passes in the tube from the anode to the kathode, frees the electrons of the latter and propels them towards the antikathode or target. The bombarding of the electrons induces the formation of the Roentgen rays on the surface of the target. The target is built of platinum and becomes overheated under the action of the kathode rays. The heat frees the gases in the platinum, and these in turn diminish the vacuum of the tube. As a consequence the velocity of the kathode rays also diminishes and the Roentgen rays become softer. Various regulating devices are added to the tube in order to keep the character of the Roentgen rays uniformly hard for a sufficiently long time to produce a biological action. Still the penetration of the rays emitted by the tube constantly changes. The fundamental advantage of the Coolidge tube consists in the fact that it has a nearly complete vacuum so that the small amount of gas escaping from a heated target can not influence it. Moreover the target is built of tungsten which is freed of gas with greater ease before the tube is built. In such a tube with a very complete vacuum high potential current can not pass from the anode to the kathode and free the negative electrons of the latter. The freeing of the kathode rays is accomplished in the Coolidge tube through the heating of the kathode to a very high temperature by the aid of a special storage battery. The kathode consists of a spiral tungsten filament supported by a molybdenum sleeve. The high potential current propels the electrons to the anode, which acts at the same time as a target. The number of the electrons depends upon the temperature of the filament of the kathode and the velocity on the voltage of the primary current.

A priori it could be expected that the Coolidge tube would not only produce a greater output of Roentgen rays, but also generate rays of greater penetrating power. Comparative experiments were done with the best model of tubes of the old type and with the Coolidge tube. Both tubes were placed approximately under similar conditions *i. e.*, the same voltage of primary electric current was sent through the coil, the same number of milliampers of high potential current were sent through the tube, and the resulting Roentgen rays showed the same penetrating power.

To study the distribution of the rays pieces of beef were radiated and also living animals (pigeons). Test strips of photographic paper (Kienboeck strips) were placed on the surface of the radiated piece and at various depth of tissue. Pieces of meat were used 1, $1\frac{1}{2}$, 2, 3 and 4 inches in thickness. The very soft rays, which usually act only on the surface of the skin of the animal and are not selective but caustic in their action were absorbed by a plate of aluminum 3 mm. thick placed between the tube and the tissue. The pigeons were placed in a box 4 inches deep. One Kienboeck strip was placed over the box and the other under the box. The results of numerous experiments may be summarized as follows:

It takes about $\frac{1}{3}$ of the time to obtain the same quantity of rays on the surface with a Coolidge tube as compared with the old type tubes. At the depth of 2 inches of meat the strip shows about $\frac{1}{3}$ of the quantity of the rays shown by the surface strip during the same experiment with an old type tube and about $\frac{1}{2}$ by the Coolidge tube. At a depth of 4 inches there is usually about $\frac{1}{7}$ of the quantity shown on the surface obtained from a tube of the old type, while from a Coolidge tube one obtains at the same depth usually about $\frac{1}{5}$ of the quantity shown on the surface. There is no complete regularity in the results of the experiments with either tube, but the Coolidge tube shows a far greater uniformity. The reason for this difference in the results is probably due to the following: the Roentgen rays emitted by a tube are never uniform in their character and represent all grades of hardness. The methods of measuring the penetration of the tube reveal only the hardest rays. Apparently the rays are more uniform in the Coolidge tube and therefore a greater fraction of those entering the surface reach a certain depth. This feature makes the tube more advantageous than those of the old types. On the other hand it must not be presumed that the rays of the Coolidge tube are greatly superior in their absolute capacity of penetration. As stated above the velocity of the kathode rays and the consequent penetration of the Roentgen rays is in direct proportion to the intensity of the high potential current. The latter can not be increased beyond a certain limit in the Coolidge tube as it is constructed today.