THE DECREASE IN SUGAR METABOLISM AND DESTRUCTION OF INSULIN BY ULTRA-VIOLET RADIATION.

By W. E. BURGE AND GEORGE C. WICKWIRE.

(From the Department of Physiology, University of Illinois, Urbana.)

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A great deal of interest has been aroused of late in ultra-violet radiation in connection with rickets (1). There are two things, at least, that strike one on reading the literature on the subject. One is the indifference as to the source of the radiation, so far as wave-lengths and intensity are concerned, and the other the complete ignorance of the wave-lengths absorbed. The only thing that is observed is the effect. This, of course, is the most important thing; but for an intelligent study of the subject it seems to us a knowledge of the wave-lengths used and their intensity, as well as their absorption, must be taken into consideration, for it is only the radiant energy that is absorbed that can be effective.

The present investigation was begun to determine what effect, if any, ultra-violet radiation has on sugar metabolism. For this purpose fairly transparent animal cells (Paramecia caudata) were used. These organisms were grown in large quantities on an infusion made of lake water, pond-lily leaves, and horse manure. The most difficult part of this investigation was the growing of these organisms in sufficiently large quantities and in fairly pure cultures. The organisms were collected and washed free of debris with the use of a small centrifugalizing machine. The centrifugalizing tubes were calibrated in cc., so the organisms were measured as they were collected. 5 cc. of the organisms in 100 cc. of liquid were used in each of the experiments. Air was kept bubbling slowly through the liquid containing the organisms to insure an adequate supply of oxygen. The sugars used were dextrose, levulose, and galactose. Sugar determinations were made according to the method of Benedict. The source of the ultra-violet radiation was a Cooper Hewitt quartz mercury arc, operated
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at 220 volts and 3.5 amperes. The following is the description of a typical experiment.

45 cc. of paramecia were collected as described above and introduced into 900 cc. of aerated lake water. While being thoroughly mixed by pouring from one vessel to another, the 900 cc. of liquid containing the organisms were divided into three batches of 300 cc. each. Into one batch 300 mg. of dextrose were introduced, and to the remaining two batches 300 mg. of levulose and galactose respectively were added. When the sugars were dissolved, each of the 300 cc. of paramecia-sugar preparations was divided into batches of 100 cc. each. One batch of 100 cc. of the dextrose, as well as the levulose and galactose preparations, was set aside for the controls. The remaining six batches were poured into glass dishes 35 cm. in diameter, and half of this number was placed 400 cm. from the light, and the other half 150 cm. away. Sugar determinations were made immediately and subsequently at intervals, as shown in Fig. 1, Columns 1, 2, and 3. It will be seen that the paramecia utilized all three sugars, and that dextrose and levulose were used more rapidly than galactose. In this respect, these organisms resemble the higher animals, for it is known that mammals use dextrose and levulose more rapidly than galactose (2). It will also be seen that ultra-violet radiation decreased the utilization of all three sugars, the greatest decrease being produced in the organisms closest to the light. We have carried out, during the past year, a great number of experiments similar to the preceding, and at different distances from the light, with essentially the same results as those given in Fig. 1. It should be mentioned that whatever water was lost by evaporation during the exposure was taken care of by the addition of an equal volume of water, and that the organisms were not killed at the end of 12 hours of exposure, either at the 150 cm. distance or at the 400 cm. The movements of the organisms at 150 cm. distance were slowed down considerably, but the organisms were still alive and active. Those at 400 cm. distance appeared as active as the controls, and in fact, so far as appearance under the microscope is concerned, they could not be distinguished from the controls. It should also be mentioned that air was kept bubbling slowly through the sugar solutions containing the organisms at all times to insure an adequate supply of oxygen. Control experiments
Fig. 1. In Columns 1, 2, and 3 are curves showing that animal cells (paramecia), utilize dextrose, levulose, and galactose and that ultra-violet radiation decreases this utilization. Column 4 shows that insulin prevents this decrease in sugar utilization by ultra-violet radiation. The photograph at the right of the chart shows the spectrum of the quartz mercury arc used in this investigation.
were carried out by bubbling air through sugar solutions not containing the organisms, to show that the bubbling of the air itself had little effect on the sugar content.

In Fig. 1 is also shown the photograph of the spectrum of the quartz mercury burner used. In another connection one of us had already made photographs of the spectrum of a burner very similar to the one used in this investigation, showing the absorption of ultra-violet rays by clear water, with and without paramecia. It was found, as has been known for a long time, that clear water absorbs a very small amount of the short wave-lengths. It was also found that when the paramecia were added to the water, none of the wave-lengths was completely absorbed, but the bands, particularly in the region of the short wave-lengths, were dimmed, thus showing that the organisms absorbed some of the radiation. In this connection the absorption by the cornea and the humors of the eye, as well as the short wave-lengths effective in coagulating protein and killing paramecia, was determined (3).

The next thing we were interested in was how does ultra-violet radiation decrease sugar metabolism. In connection with another piece of investigation we had already found that ultra-violet radiation destroys insulin. This suggested that the decrease in sugar utilization observed might be due to the destruction of insulin in the paramecia by the ultra-violet rays. To test out this idea, paramecia-sugar preparations were made similar to those already described. Insulin was introduced into some of the preparations exposed to the radiation and not into others. It was found that the organisms to which the insulin was added and exposed to the light utilized the sugar almost as rapidly as the controls, while the sugar utilization by the organisms to which insulin was not added and exposed to the ultra-violet radiation was much less than by the controls. The results of a typical experiment are given in Fig. 1, Column 4. The manner of adding the insulin was as follows: at the beginning of the experiment 2 cc. were added to the 100 cc. of liquid containing the organisms, after 4 hours 1 cc. was added, and at the end of 8 hours another 1 cc. added. By the addition of insulin we considered that the organisms would be kept supplied with this material, in spite of the destructive effect of the radiation on insulin. Since ultra-violet radiation destroys insulin and the addition of insulin in the manner described above keeps the sugar
utilization almost up to normal in the paramecia exposed to ultra-violet rays, it would seem a fair conclusion to draw that the decrease in the utilization of the sugar by the organisms exposed to the radiation was due to the destruction of the insulin in the cells by the radiation.

The following is proof that ultra-violet radiation destroys insulin. 5 units each of insulin were injected subcutaneously into medium sized rabbits, and convulsions were produced in 1½ to 2 hours. Dextrose was administered by a stomach tube, and the animals were relieved of the convulsions. Insulin was exposed to the radiation at a distance of 100 cm. for 9 hours. The injection of as much as 50 units of this irradiated insulin produced no convulsions in the rabbits, in which 5 units had previously produced convulsions.

SUMMARY.

1. *Paramecium caudatum* utilizes all the simple sugars: dextrose, levulose, and galactose. Dextrose and levulose are used more rapidly than galactose, just as is the case with the higher animals.

2. Ultra-violet radiation decreases the utilization of the sugars by these animal cells, without, at the same time, killing or injuring the cells.


4. The addition of insulin to the liquid containing the organisms prevents the decrease in sugar metabolism by the ultra-violet rays.

5. The decrease in sugar utilization brought about by ultra-violet radiation is attributed to the destruction of the insulin in the cells by the radiation.

BIBLIOGRAPHY.


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