THE EFFECTS OF RADIATIONS ON BIOLOGICAL SYSTEMS

III. THE EFFECT OF ULTRAVIOLET LIGHT ON THE RESPIRATION OF DROSOPHILA LARVAE AND THE DURATION OF THEIR PREPUPAL PERIOD

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In previous communications¹⁻³ a respirometer has been described which depends upon measurement (with adjustment for pressure and temperature) of change in refractivity and volume of the gas in a closed system in which the oxygen and carbon dioxide might vary independently but all other gases were present in either fixed amount or concentration, and the initial composition of the system known approximately. The system was provided with a means of circulation at a rate variable at will, and of regulation of temperature and humidity. The gaseous system was unaffected by the analysis except that circulation was temporarily stopped and a faint beam of light passed through a small portion in an attached interferometer while the bands were adjusted for readings—about 1 1/4 minutes were required for all adjustments and observations, five independent interferometer readings to the nearest tenth of a small scale division being made in quick succession. Chambers containing a respiring system could be attached and mercury-sealed to the apparatus or detached readily. The object was to investigate variations in CO₂ respiratory rate of Drosophila larvae following x-ray irradiation⁴ or similar phenomena where the mean effect on large numbers of individuals could be observed directly. By means of a careful preparation of a large batch of individuals of which random samples could be taken for various treatment, it

was hoped that precise mass phenomena might be observed. Thus a lower CO₂ respiratory rate, followed by a rise (but not enough to again approximate the rate of controls) was found immediately after x-ray irradiation of larvae.⁴

In earlier work⁵⁻⁷ the increase in duration of the larval stage after x-ray irradiation had been studied, but we were unable to produce similar effects with ultraviolet light. Striking resemblance has been found, however, in effects of these agents upon respiration. The purpose of the present communication is to report some of the results obtained with ultraviolet irradiation under various conditions.

**Technique**

The source of radiations for the present experiments was a mercury arc in quartz used in former work,⁸ operated at an angle of 30° from horizontal. Larvae were irradiated in tumblers (as in the x-ray experiments⁹) about 61 cm. below the lamp, and in a stream of air at approximately 22°C. They were prepared and maintained for respiratory studies on food of the same formula in the same manner in tapering glass tumblers as has been described previously, except in certain experiments already reported⁹ where variation of the sensitivity of the system to ultraviolet light was produced by increase in the acetic acid concentration in the food. About 200 to 500 larvae were used in each experimental lot, the lots within any given experiment being about equal in number.

As in previous work,⁴ the main interest was in estimation of relative respiratory rates of variously treated lots of larvae without unnecessary delay, and the same technique was employed with 20 minute observational intervals. Under the conditions of observation, the change in refractivity (Δr) of the inclosed gas was 2.00(10)⁻⁸ Δy by calibration,¹ where Δy was the difference in interferometer readings. The increment in CO₂, previously¹ denoted by ΔQ<sub>r</sub>, in a general formulation, may be estimated from a simple formula obtained from relation (16) of the first mentioned paper¹ by substitution of ΔQ<sub>r</sub>(1 - 1/F) for its equal, C·ΔQ<sub>r</sub>, where F is the respiratory quotient. Thus, dropping the primes, and introducing the values given by Edwards¹⁰ for the various constants involved,
where $V$ is the final volume of the gaseous system in liters. With $V$ approximately the same (0.81 liters in the present experiments), and $P$ assumed to vary only to a small extent; then, approximately, the CO$_2$ increment is proportional to $\Delta r$. Furthermore, the relation given in (1) is independent of temperature or pressure, and the humidity may be fixed arbitrarily.

The results to be reported at present will be given in graphic form; using the median age of larvae ($\alpha$) in days as abscissa, with $10^8 \Delta r$ per minute as ordinate—one-tenth the directly observed $\Delta y$ for a 20 minute interval—to indicate respiratory rate, and on a sub-graph as in the previous work an estimate of the fraction of the larvae having pupated.

**EXPERIMENTAL RESULTS**

The results of an experiment where lots of larvae were irradiated for 1/4, 1/2, and 1 hour, respectively, at a median age approximately 3.5 days are presented in contrast to a control lot in Text-fig. 1. Although there appears to be little or no effect on the duration of the larval stage, the initial effects upon respiration closely resemble those obtained with x-rays. No great difference is apparent as a result of the variation of the duration of irradiation, but it may be assumed that such differences would appear if shorter irradiations were made. That this is so and that the effect observed is due principally to the ultraviolet component of the radiations is indicated by another experiment where-in two lots of larvae were similarly irradiated for 1/2 hour, except that one lot was protected by an interposed pane of clear glass (cleared x-ray plate) which filtered out a considerable part of the ultraviolet radiation. The results, including observations on a control lot, are given in Text-fig. 2.

In a third experiment four lots of larvae were observed, three of which were given a single irradiation for 30 minutes as in the first experiment but at ages about 1 day apart. The results are given in Text-fig. 3, where there appears to be a greater deviation immediately after irradiation the older the larvae, but less total displacement of the respiratory curve. The initial depression of respiratory rate after
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Fig. 1

Fig. 2
Fig. 3

Fig. 4
irradiation appears to be roughly proportional to the respiratory rate just before. Again the median age at pupation is sensibly the same in all lots, and imagos appeared in each lot at about the same time.

Similarly with four lots, A, B, C, and D, an experiment was performed where D was the control, and all other lots were irradiated simultaneously on the 1st day, A and B again simultaneously on the 2nd day, and A once more on the 3rd day—all irradiations being of 10 minute duration, with the result represented in Text-fig. 4. Time of pupation and of emergence of imagos again appear little affected, and the same depressing effect on CO₂ respiration appears after each irradiation.

**DISCUSSION**

Over ranges wherein certain lots were still experimentally the same, the close comparability of the respective respiratory rates even to the extent of close agreement in response to a second irradiation in the last experiment is remarkable. The results given include all the observations made in four of the first seven experiments wherein respiration of larvae was used as an indicator of effects of ultraviolet irradiation. The first and third experiments presented are the better of duplicate experiments indicating roughly the same results. Success in developing precise mass phenomena depends obviously on the technique of preparation and random sampling of the material.

In further work where the acetic acid concentration of the food differed in pairs of lots of larvae after their random selection from a common batch—one of each kept as a control and the other irradiated with ultraviolet light—there appeared a marked concomitant variation in sensitivity. Interesting in connection with this is a consistent decrease noted in former work in sensitivity of larvae to x-ray irradiation (as evidenced by a halving of the extension of the prepupal period) when larvae sealed in paraffin-stearin wells were not provided with the usual ventilation during irradiation. Further study of the influence of pH and CO₂ tension upon sensitivity of biological systems to various forms of irradiation appears to offer prospects of interesting results. That such influence may be considerable, although of different significance in different situations, is indicated in the case of
mammals by the studies of Hussey,\textsuperscript{11, 12} Sprunt,\textsuperscript{13} and others on the influence of x-ray irradiation on the properties of the blood.

A considerable number of the observations in these studies were made by Mr. Emery F. Barringham.

**SUMMARY**

1. Although ultraviolet irradiation of larvae did not prolong the larval stage as is the case with x-rays, the immediate effects on respiratory rates are strikingly similar.

2. Effects of irradiation at different ages were observed and also effects of successive irradiations with remarkable agreement in comparable lots.

\textsuperscript{11} Hussey, R., *J. Gen. Physiol.*, 1921–22, 4, 511.
