lene blue, acid fuchsine, gentian violet, methylene green, etc., in 18 mm. test tubes observed in the daylight from the side, and finds the limit of color visibility in the ten millions, one thousand times above the limit for luciferin luminescence. There is one exception, which concerns not transmitted light, but fluorescence. A faint greenish fluorescence of fluoresceine is clearly visible in the light from a powerful carbon arc focussed in the solution, with one part of the dye in 10 billion parts of ordinary distilled water. Such water is not by any means optically empty and light scattering from dust particles interferes with the observation of fluorescence. Spring[6] has reported that with optically empty water, the fluorescence from 10^{-15} grams per c.c. of fluoresceine can be detected in the beam of an arc lamp.

Thus, luminescences from very small quantities of matter can be detected. We have an extreme case in the flash of light from impact of a single charged helium atom on fluorescent zinc sulphide. Biological reactions can not approach this in sensitivity, but I believe the value for *Cypridina* luciferin mentioned above sets a new record for chemiluminescence.

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MARCH 31, 1923

X-RAYS AND THE SEX CHROMOSOMES

IN two previous issues of this journal[1] the writer has reported what appeared to be the production of non-disjunction of the sex chromosomes of Drosophila by X-rays. When primary non-disjunction is found, as happens rarely, in ordinary cultures the two kinds of exceptional offspring do not occur in equal numbers. The exceptional sons which arise from the fermentation of eggs containing no X-chromosome by sperm containing an X-chromosome are considerably more numerous than the exceptional daughters which arise from the fertilization of eggs containing two X-chromosomes. Since the effect of X-rays is to increase proportionately the numbers of exceptional sons and daughters, the increased number of exceptional daughters obtained as a result of X-raying their mothers is considerably less than the increased number of exceptional sons. Up to the time of publication of the notes to which reference is made above, the data obtained showed clearly that X-rays caused an increased production of exceptional sons and probably also of exceptional daughters. Since that time the technique[2] has been improved and a large number of experiments have been performed. The data now accumulated make it reasonably certain that X-rays not only cause non-disjunction but that the exceptional daughters of X-rayed mothers are in most cases fertile and themselves produce exceptional offspring. Reference will here be confined to the third and fourth series of experiments which were performed with the improved technique. The results of the third series were stated at the Boston meeting of the American Association. The fourth series of experiments have only recently been completed.

The improvements in technique involved, among other things, using for the X-rayed mothers virgin heterozygous flies resulting from crossing white-eyed long-winged females with eosin-eyed, miniature-winged males. This made it possible to test for the presence of exceptional females among the flies to be X-rayed. After X-raying, the females were mated to wild-type males. The use for X-raying of females heterozygous for characters located in the sex chromosomes made it possible to follow individually by the characters of the offspring the sex chromosomes which had been submitted to X-rays. In the third series of experiments 76 females were X-rayed and 79 females were kept as controls. In each experiment the X-rayed and control females were sisters. The X-rayed mothers produced a total of 1557 regular sons, 42 exceptional sons, 1771 regular daughters and 8 exceptional daughters. Seven out of eight exceptional daughters were fertile

[6] Acad. Roy. de Belg. *Bull.* Class. sc., 1905, p. 201-211.

[1] "On the elimination of the X-chromosome from the egg of Drosophila melanogaster by X-rays," SCIENCE, Vol. LIV, pages 277-279, September 23, 1921; "The production of non-disjunction by X-rays," SCIENCE, Vol. LV, pages 295-297.

[2] The technique of these experiments is described in detail in a paper submitted to the editors of the *Journal for Experimental Zoology.*

and produced further exceptions. The control mothers, sisters of above, produced a total of 7,531 regular sons, 5 exceptional sons, 7,711 regular daughters and one exceptional daughter. The probability that the difference between the offspring produced by the X-rayed and control mothers was due to chance can best be calculated by a formula of K. Pearson[3] for the probable error of a difference, for reference to which the writer is indebted to Professor Pearl. Calculation shows that in the case of the exceptional daughters the difference between the number produced by the X-rayed mothers (8) and that which might be expected from the behavior of the control (mean = .46023) is 13.10 times the probable error of the difference, (.50751). The same quantity for the sons is 49.81 times the probable error of the difference. These numbers make it practically certain that the difference is not due to chance. Every cause for the difference except X-rays seems to have been eliminated from the experiments—the control and X-rayed females were sisters emerging at approximately the same time, were kept at the same temperature, etc.

In the fourth series of experiments all the mothers, both those which were X-rayed and those in the controls, were the daughters of one white-eyed female by two eosin-eyed, miniature-winged males. The 26 X-rayed females produced a total of 1,934 regular sons, 42 exceptional sons, 2,173 regular daughters and 8 exceptional daughters. Seven of the eight exceptional daughters were fertile and produced exceptional offspring. The 19 control females produced a total of 5,109 regular sons, three exceptional sons, 4,985 regular daughters and one exceptional daughter. The difference between the number of exceptional daughters produced by the X-rayed females and those produced by the control females is 9.425 times the probable error of the difference. The same quantity for the exceptional sons is 41.00 times the probable error of the difference. The fourth series of experiments therefore confirms the findings of the third series. The results of the two series of experiments may be added together. In this case we find that the difference between the number of exceptional daughters (16) produced by the X-rayed females and the expected mean (.9354) is 20.17 times the probable error of the difference.

3 On the influence of past experience on future expectation, *Phil. Mag.*, Sixth Series, Vol. XIII, page 365.

The exceptional daughters of the X-rayed females were of two kinds. Four of those in the third series were homozygous for both of the sex linked characters and were therefore formed by equational non-disjunction. Three of those in the third series and seven of those in the fourth series were heterozygous and therefore formed by reductional non-disjunction. Two of the exceptional daughters not included in the above two kinds were homozygous for one sex linked character and heterozygous for the other. Their constitution and the explanation of their occurrence will be discussed at a future date. It is clear from the results of the experiments described that X-rays may cause non-disjunction during either the first or the second of the maturation divisions and that the exceptional condition of the females produced by it, consisting in the possession of two X chromosomes and one Y chromosome, is transmitted to a proportion of their offspring. There is therefore in this effect of X-rays on the germ cells a very clear case of an external agent which modifies the mechanism of inheritance in such a way that a permanent effect is produced on the germ cells.

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THE eleventh annual meeting of the Oklahoma Academy of Science was held in Oklahoma City on February 9, and at the University of Oklahoma, Norman, on February 10. The following papers were read:

Responses of bruchus to modified environments: J. K. BREITENBECHER.

The Isleta Indians: ALBERT B. REAGAN.

Some birds of the Oklahoma Panhandle: R. C. TATE.

Additional evidence on the possibility of the redemption of the great plains from its semi-arid condition: J. B. THOBURN.

The possible contribution of the motion picture in the effective teaching of history: J. W. SHEPHERD.

Present-day objectives in physics: HOMER L. DODGE.

Present-day objectives in zoology: A. RICHARDS.