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The linear dose-dependence of radiation-induced translocation frequency in *Drosophila melanogaster* at relatively low X-radiation doses

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The dose-dependence of the frequency of radiation-induced chromosome aberrations has recently aroused new interest (Wolff 1963). Regardless of how one explains the experimentally-obtained dosage-relationship, whether by Muller's 3/2 power rule or by Wolff's site-concept, a linear increase of translocation frequency with x-radiation dose is to be expected after exposure to relatively low doses (see Muller 1954 a). The reason is that at low doses only a negligible part of the whole aberration frequency is produced by two (or more) independent hits, the major portion being caused by the passage of only one electron track, that is, by one hit. Though there is some experimental evidence for this from *Tradescantia* (see Muller 1954 a, Neary, Savage, Evans and Whittle 1963), experimental proof is lacking in *Drosophila*.

We therefore irradiated sperm stored in females of *Drosophila melanogaster*, which can be considered as the most homogeneous germ-cell stage available in this organism. The genotype of the P-females was *y sc*^{S1} *In*49 *sc*^{s} ; *bw* ; *st*, that of the P-males *B*. Translocations between the second and third autosome were scored according to the usual genetical technique. The flies were irradiated with 150 kv x-rays at an exposure-rate of 500 r min. The h.v.l. was 6 mm Al. Although under the same experimental conditions we obtained with higher doses (between 0·5 and 5 kr) the typical increase of translocation frequency with a dose-exponent > 1, the expected linear increase at low doses (between 0·0 and 0·5 kr) is evident (see table). The statistical test, based on weighted regression analysis (Armitage 1955), shows no indication for departure from linearity for the dose-range from 0–0·5 kr ($P = 0{\cdot}70$), while there is a high degree of significance for the linear term ($P = 10^{-10}$). The experimental points can be fitted by the equation $y = 0{\cdot}071 + 1{\cdot}16x$ (y = translocation frequency in percentage, x = exposure in kr).

Exposure (kr)	Translocation frequency (per cent)	Exposure (kr)	Translocation frequency (per cent)
0	0·04 (2/5446)	1	2·1 (54/2526)
0·1	0·17 (15/8668)	1·5	3·5 (140/4008)
0·2	0·30 (11/3638)	2	4·8 (492/10288)
0·3	0·49 (51/10363)	3	9·7 (107/1102)
0·4	0·52 (49/9363)	4	13·0 (122/941)
0·5	0·59 (35/5905)	5	15·4 (358/2321)

This result has some practical bearing : radiation-induced human impairments and diseases, such as reduction of life-span, may be based on chromosome aberrations and therefore—partly at least—on those caused by multiple breaks (see Ostertag and Muller 1959). However, the relationship between dose and the incidence of such somatic damage is not well known (United Nations Report 1962). Our results support the hypothesis that this relationship is linear at low doses, which would mean that this risk of somatic damage, as well as that caused by single breaks, is connected with the absorption of even small amounts of ionizing radiation.

Further, an interesting comparison can be made between the translocation results reported here and previous neutron experiments (Muller 1954 b). Since the dose-response curves for x-ray and neutron-induced translocations at medium and higher doses have different dose-exponents (1 for neutrons, > 1 for x-rays), the RBE in this dose range is dependent on the dose. However, for the relatively low x-ray dose-range (0–0·5 kr), where we have found a linear dependence of translocation frequency on dose, the RBE is a *constant* value. In addition, it represents a *maximal* value, since the RBE increases with decreasing dose. Comparing our data (ranging from 0–0·6 per cent translocations) with those obtained by Muller (1954 b) for fast neutrons, we find an RBE of either 5·9 or 4·5, depending on which dosimetric criteria the neutron irradiations are based on. This value is, as expected, greater than for higher doses, e.g. for those leading to a translocation frequency of 10 per cent, where the RBE is 2·5 or 1·9. Our x-ray results are based on sperm treated in females ; but in Muller's neutron experiments, males were irradiated. Since higher mutation frequencies are associated with sperm x-rayed in females rather than with sperm released during the first three days after the irradiation of males, our RBE estimate of 5·9 or 4·5 may be somewhat too low. So far, the evidence that such a difference exists also for neutrons is contradictory. Oster (1961) found no difference between the frequencies of neutron-induced autosomal translocations from sperm whether treated in females or males. Alexander (1962), on the other hand, reported an approximately 30 per cent higher translocation frequency from sperm treated in females. Both authors compared sperm from the first and second day after the irradiation of males with sperm treated in females.

In a similar study on two-break chromosome aberrations in *Tradescantia* (Neary *et al.* 1963), in which the efficiency of fast neutrons was compared with that of γ-rays for the linear low dose-range, RBE-values up to 100 were approached ; these values are much greater than those reported for higher doses.

The results from *Drosophila* and from *Tradescantia* demonstrate that in the low dose-range, neutrons are much more efficient in the production of two-break chromosome aberrations than x- and γ-rays. Therefore, densely-ionizing radiations are especially dangerous to human populations as regards the induction of chromosomal damage in either reproductive or somatic cells.

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