Colombia (2640 m). The only significant change in the activity pattern during this period was the increase in W^{185} concentration in the mid-latitudes of the Northern Hemisphere.

Both the high W^{185} activity and the high gross β-activity found in South America during the period May–July document the fact that one or more transfers of air from the Eniwetok-Bikini area into the Southern Hemisphere occurred. This is the first time that any appreciable quantity of radioactive matter from a known source in the Northern Hemisphere has been identified south of the equator.

In Fig. 2, plots of W^{185} relative to the gross fission-product β-activity (assumed to have an average β-energy of 1 Mev) are shown. It may be noted that even though debris from Hardtack appeared at a number of sites in the Northern Hemisphere, at only a few places did it contribute significantly to the total radioactivity present. The tungsten-containing debris was relatively more important during May and June at sites where the fission-product background was low, as at Miraflores, Panama Canal Zone, and Bogota, Colombia, above the equator and at most sites in the Southern Hemisphere.

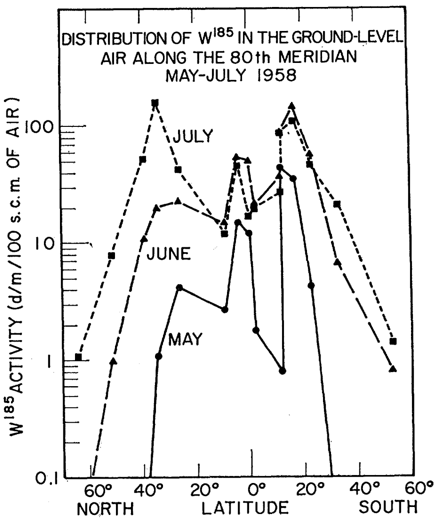

Fig. 1. Distribution of W^{185} in the ground-level air along the 80th meridian, May–July 1958.

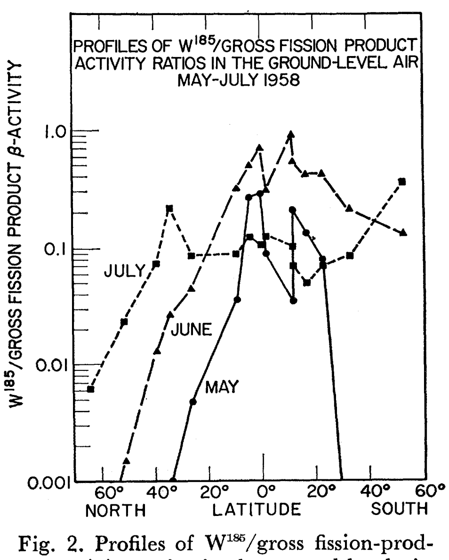

Fig. 2. Profiles of W^{185}/gross fission-product activity ratios in the ground-level air, May–July 1958.

At Lima, Peru, during June, the W^{185} activity was nearly as high as the gross fission-product activity. If a 1:1 ratio represents the relative values of these components of Hardtack debris during June, undiluted by fission products from other sources, the contribution of this debris to the activity in the air at other sites may be calculated. The fraction of the total activity due to the fresh debris at sites in the Northern Hemisphere decreases rather uniformly from 70 percent at the equator (Quito), to 30 percent at Miraflores, to 5 percent at Miami, Florida, and 1 to 2 percent at Washington, D.C. It is impractical to attempt a similar analysis for July because of the changes in this W^{185}/fission-product activity ratio through radioactivity decay and because of the influx of fresher debris having different amounts of tungsten activity. The different composition of the newer debris is evident in a comparison of the July data presented in Figs. 1 and 2. While at the sites between 10°N and 40°S latitude there was little change in the absolute quantity of W^{185} in the air, its activity relative to that of the gross fission products decreased markedly, indicating the presence of considerable radioactive material having a lower radiotungsten content. This was most evident at the sites which had previously had the highest W^{185} activity.

Results from the triad of stations at Subic Bay, Philippine Islands, and Pearl Harbor and Mauna Loa, Hawaii, are particularly interesting. Subic Bay, lying to the west of the test site, received a large amount of new debris in May, as is shown by increases both in the total β-count and in the W^{185} activity, but these decreased markedly during June. Pearl Harbor and Mauna Loa collected no tungsten-containing Hardtack debris during May. During June some of this material arrived at Pearl Harbor, but nearly 10 times as much appeared at the high altitude station of Mauna Loa (3394 m). This altitude difference was even more marked in July. Since no significant changes in Sr^{90} concentration occurred during this period, a rather stable background of old debris at these sites is indicated.

From the data presented here it is evident that fission products or other materials introduced into the atmosphere at a particular latitude do not necessarily remain in any restricted zone near that latitude but spread rapidly throughout the hemisphere. If such materials are introduced simultaneously on both sides of the equator, as happened in this case, rapid spread throughout both hemispheres occurs. The rapid spread of radioactive debris throughout the atmosphere of the Northern Hemisphere has been noted previously for a number of series of nuclear detonations in both Nevada and the U.S.S.R.

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Phenotypic Effects of Heterozygous, X-ray-Induced Mutations in Drosophila

Abstract. Heterozygous mutations produced by 3000 r delay pupation in about 9 percent of larvae of *Drosophila melanogaster* under nutritional stress and kill approximately 6 percent. The effects are less, though appreciable, when there is excess nutrient; no effects are detectable after oögonia are irradiated. Irradiated sperm and oöcytes cause detriment, partly via different types of mutations, in approximately equal amounts.

In large cross-fertilizing populations, germinal mutations are usually present in heterozygous condition. Because of this it is desirable to determine, in the first generation receiving mutated genes induced by a large radiation dose, the nature and amount of the heterozygous effect, its dependence upon environmental factors, and its basis in chromosomal rearrangements and point mutations.

The specific aims of the present work (*1*) with *Drosophila melanogaster* were to study in F_1 larvae, some of which had been subjected to nutritional stress and some not, some of the heterozygous effects of eucentric rearrangements and point mutations induced by administration of 3000 r of x-rays (*2*) to sperm or to oöcytes and oögonia. The phenotypic effects studied were delay in pupation and failure to pupate.

Virgin yellow (y) females were mated to gray (y^+) males from an apparently unrelated strain. Males, when irradiated, were discarded after one day of mating. Females were permitted to oviposit on protein-deficient (sugar, agar, water) medium for ½ to 1 day; then they were removed, and the eggs were allowed to develop for 1 day into larvae. In this cross the sex of newly hatched F_1 larvae is easily distinguished, males having yellow mouth parts and females gray. In cases where larvae were to be "fed," the medium was sown with live yeast. For each test, 100 newly hatched larvae (either males or females) were transferred to a bottle containing unyeasted protein-deficient medium (which included, in the second experiment, the mold inhibitor Tegosept-M).

In the first experiment, some P_1 males were irradiated and some were not. An excess of live yeast was added to the bottles either immediately after the larvae were transferred to them ("fed" series) or four days later ("semistarved" series). The number of larvae eventually able to pupate was determined.

The second experiment involved, besides unirradiated controls, males and 4-day-old, well-fed females which were irradiated and crossed to unirradiated flies. In addition to a "fed" series there was an "undernourished" series—one in which 6 mg of yeast was placed in each bottle prior to transfer of the larvae to the bottles, an excess of yeast being added 4 days later. The number of larvae that pupated by the 9th day after oviposition and the number that finally pupated were recorded.

Following irradiation of sperm, F_1 females have approximately a 20-percent greater chance to show heterozygous effects of point mutations than do F_1 males, since this is approximately the percentage by which X-bearing sperm exceed Y-bearing sperm in level of euchromatin. There may be, however, an equal or greater chance that Y-bearing as compared with X-bearing sperm will undergo rearrangement at fertilization or produce heterozygous position effects through rearrangement, or both. Differences in effect actually obtained in sons and daughters were not significant in six possible comparisons (of which four were independent of one another) and were equally frequent in both directions. The absence of a detectable sex difference is attributable to the fact that heterozygous effects of rearrangement are greater than those of point mutation of euchromatic genes.

In view of this, and of the fact that the number of tests in comparable unirradiated and irradiated series was almost exactly equal for a given sex, the results for sons and daughters of irradiated fathers have been combined in Table 1. As is shown there, irradiation of sperm caused 4 to 7 percent of the larvae to die prior to pupation. An additional effect—delay in pupation—is demonstrated by the larger number of larvae (approximately 9 percent) which had failed to pupate by the 9th day after oviposition.

When females are irradiated, mutations involving the X-chromosome are heterozygous in daughters but hemizygous in sons. Since hemizygous mutations produce more phenotypic effect than heterozygous ones, a difference in results between F_1 male and female larvae is expected. While the difference in effect obtained for F_1 males and females from irradiated mothers was not significant in 12 possible comparisons (of which six are independent), the values for sons were higher than those for daughters in every case (see Table 1); this demonstrates that there is a greater over-all effect in larval males than in larval females.

This sex difference cannot be attributed to the fact that sons are yellow and daughters are gray, since in the first experiment this difference was shown to have no effect. It is also not related to gross intrachromosomal and reciprocal interchromosomal rearrangements, which are so rare in the female germ line that the frequency of X-chromosome involvement is negligible. However, point mutations and half-translocations could, separately or together, account for the sex difference. The former produce hemizygous and heterozygous effects in sons and daughters, respectively; the latter produce hyperploidy (through cappings of X) and hypoploidy (through capturings).

Following irradiation of females, there was significant detriment in both son and daughter larvae from eggs laid during the first 6 days after mating. However, the final results for eggs laid on days 7 through 13 are not significantly different from those for the unirradiated controls and are significantly lower than those for comparable eggs laid on days 2 through 5. The 9th-day pupation rates for eggs laid on days 7 through 13, though they do not differ from those of the controls in the case of the daughters, show some effect of irradiation in the case of the sons, and the effects in both sons and daughters were significantly less than those for comparable eggs laid on days 2 through 5. These results correlate with those from other experiments, where similar females were irradiated. In these, half-translocation and recessive lethal mutation rates were significantly reduced among eggs laid more than 6 days after irradiation (usually oögonia when irradiated) as compared with eggs laid earlier (mostly oöcytes when irradiated).

One comparison between well-fed and nutritionally limited larvae gave statistical support for a difference in effect (experiment 1, well-fed versus semistarved larvae gave P approximately .05). Six other comparisons are possible (of which three are independent); of these, one furnished no test and five gave results in the expected direction. This demonstrates that nutritional stress enhances the detrimental effects of heterozygous mutations.

It can be calculated, on the basis of data for irradiated females for days 2 through 6, that point mutations in heterozygous condition could cause a maximum of about 2 percent mortality of larvae in these experiments. Since the x-ray-induced point mutation rates for sperm and for oöcytes are approximately equal, it is evident that nearly half or more of the detrimental effect found following irradiation of sperm results from reciprocal interchromosomal or gross intrachromosomal rearrangements.

It should be noted, finally, that at this dosage level the detriment to larvae is approximately equal following irradiation of sperm or oöcytes.

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Table 1. Results of tests on unirradiated and on x-irradiated (3000 r) male and female *Drosophila*.

Expt. No.	Nutrition*	F_1	No. of tests: Unirradiated	No. of tests: Irradiated	Day No. 9: Unirradiated†	Day No. 9: Irradiated‡	Final day: Unirradiated	Final day: Irradiated
			P_1 males					
1	Fed	♀ + ♂	24	24			98.0 ± 0.4	− 4.4 ± 0.7
1	Semistarved	♀ + ♂	23	24			94.6 ± 0.8	− 7.2 ± 1.3
2	Fed	♀ + ♂	10	10	97.7 ± 0.5	− 8.9 ± 1.1	97.7 ± 0.5	− 5.8 ± 1.0
2	Undernourished	♀ + ♂	25	44§	92.9 ± 0.8	− 9.3 ± 1.1	95.2 ± 0.7	− 5.8 ± 0.9
			P_1 females					
2	Fed (4 + 6)	♂	5	8	97.4 ± 0.9	− 6.7 ± 1.9	97.4 ± 0.9	− 6.1 ± 1.2
		♀	5	7	98.0 ± 0.2	− 4.7 ± 1.2	98.0 ± 0.2	− 3.5 ± 1.1
2	Undernourished (2 + 3 + 5)	♂	10	12	92.7 ± 1.5	− 8.7 ± 2.2	96.0 ± 1.3	− 7.0 ± 1.8
		♀	8	14	93.1 ± 1.6	− 8.3 ± 2.1	95.5 ± 0.7	− 6.2 ± 1.5
2	Undernourished (7 − 13)	♂	15	15	92.1 ± 1.2	− 4.1 ± 1.7	93.6 ± 1.0	0 ± 1.3
		♀	13	15	94.2 ± 0.7	− 1.7 ± 1.2	95.6 ± 0.3	+ 1.0 ± 0.7

* Values in parentheses show the number of days after irradiation on which eggs were laid. † Mean percentage pupated, plus or minus mean standard error. ‡ Mean induced (irradiated-unirradiated/unirradiated) percentage lowered, plus or minus mean standard error. § Only 39 scored on day 9.

References and Notes

1. This study was supported by a grant from the U.S. Atomic Energy Commission [contract AT(11-1) 633]. See also similar, independent, results of V. B. Crowell, *Drosophila Inform. Serv.* 32, 119 (1958).
2. Irradiation facilities were kindly provided by Firmin Desloge Hospital, St. Louis.

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