TECHNICAL PAPERS

The Genetic Effects of Low Intensity Irradiation[1]

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It has been shown by Spencer and Stern (*3*) that irradiation by X-rays at high intensity induces mutations in sperm of *Drosophila melanogaster* at dosages as low as 50 r and 25 r, and that the proportionality between r dose and mutation frequency is maintained down to these low dosages. Earlier workers had established independence of induced mutation frequency from the intensity of irradiation at high and medium dosages. In contrast to these findings, Caspari and Stern (*1*) obtained no significant difference in mutation rates between controls and experimentals, which had been subjected to a dose of 52.5 r in gamma rays administered continuously for 21 days at a rate of 2.5 r per day.

This unexpected result required further tests. After consideration of various factors the following were regarded as possible causes for the apparent inactivity of irradiation in the experiment by Caspari and Stern: (1) low sensitivity to irradiation of aged sperm, (2) dependence of induced mutation frequency at low dosages on a time factor, and (3) errors of sampling which might have obscured a true difference between control and experimental rates. The first possibility was studied by administering 50 r in gamma rays continuously over 24 hr to sperm which had been aged previously for 20 days in the spermathecae of females (*4*). In this experiment the intensity of irradiation was raised several times over that used by Raychaudhuri (*2*) who had found typical intensity independence of mutation rates. Any deviation from the effect of irradiation expected for 50 r at medium intensity would thus be due to a specific sensitivity or insensitivity of the aged sperm. The second possibility, interference by a time factor, was tested by increasing the intensity of irradiation, and the total dosage, by a factor of 2, that is, by administering 100 r instead of about 50 r through continuous gamma irradiation over 21 days. The third possibility, chance, was checked by a repetition of the original experiment, that is, by giving once more 52.5 r in gamma rays over 21 days. Parallel with each experiment, the spontaneous mutation rate was determined in a set of controls.

TABLE 1

MUTATION RATES FOR SEX-LINKED LETHALS IN SPERM OF *Drosophila melanogaster*, AFTER DIFFERENT TYPES OF TREATMENT

Treatment	No. of controls	No. of experimentals	Mutation rate percent: Controls	Mutation rate percent: Experimentals	Mutation rate percent: Difference	Significance of difference: χ^2	Significance of difference: P
50 r, 2.3–5 min exposure, not aged (Spencer and Stern)	73,901	31,560	0.0974	0.2440	0.1466	33.67	<< 0.01
52.5 r,* 21 days' exposure, aged (Caspari and Stern†)	56,252	51,963	0.2489	0.2848	0.0359	1.31	0.26
50 r,* 24 hr exposure after 20 days' aging	44,601	46,232	0.1682	0.2834	0.1152	13.31	<<0.01
100 r, 21 days' exposure, aged	22,958	31,562	0.2352	0.4658	0.2306	19.23	<<0.01
52.5 r,* 21 days' exposure, aged	36,184	29,424	0.1765	0.2542	0.0777	4.67	0.03

* Geometric errors in the administration of the radiation are larger than the difference between the values of 52.5 and 50 r.

† The mutation rates obtained by Caspari and Stern have been adjusted to the slightly different scoring of lethals used in the investigations reported in this paper.

The data, together with the earlier findings by Spencer and Stern (*3*) and Caspari and Stern (*1*), are summarized in Table 1. It is seen that all three new tests gave an increased frequency of sex-linked mutations in the treated sperm as opposed to the controls. The experimental rate observed by Caspari and Stern is statistically in good agreement with later determinations. The control rate of 0.2489% found by Caspari and Stern is higher than any one of the later control rates. By itself a rate of 0.2489% for sperm aged over 21 days as compared to 0.0974% for sperm not aged (Table 1, line 1) seemed in line with the degree of increase expected, according to the experience of other workers, after such aging. The new data on the control mutation rate in aged sperm suggest considerable variation of age accumu-

[1] The work described in this report was performed under the auspices of the Atomic Energy Commission.

lation of mutations in the Canton Special stock on which all tests were carried out.

A comparison of the differences in mutation frequencies between experimentals and controls in the chronic experiments (lines 2–5) with the difference in the acute experiment (line 1) should take into account the fact that the difference in the latter experiment is somewhat larger than expected on the basis of all of Spencer and Stern's data. The maximum likelihood calculation yields about 0.002% induced sex-linked mutations per r, which corresponds to an expected difference for the acute 50-r experiment of only 0.1000%. Viewing all experiments together, it appears that irradiation at low dosages, administered at low intensity, induces mutations in *Drosophila* sperm. There is no threshhold below which radiation fails to induce mutations. A more detailed account of the work will be presented later.

References

1. Caspari, E. and Stern, C. *Genetics*, 1948, **33**, 75.
2. Raychaudhuri, S. P. *Proc. roy. Soc. Edinb.*, 1944, **62**, 66.
3 Spencer, W. P. and Stern, C. *Genetics*, 1948, **33**, 43.
4. Uphoff, D. E. and Stern, C. Atomic Energy Project Report M-2000.

An Electrical Logic Machine

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At the first annual open house meeting at Lewis Institute in 1936, the writer demonstrated an electrical Logic Machine useful for detection and demonstration of fallacies in deductive reasoning. The machine is equipped to test all syllogisms (categorical, hypothetical, and disjunctive), and both conversion and obversion. To facilitate portability, the machine is mounted inside the top half of a sturdy suitcase, with the classified blocks (representing propositions) resting in thin plywood compartments in the bottom half of the case. Total weight of the case, including machine and blocks, is 25 lb.

In order to test a syllogism, it is only necessary to select the blocks representing the major premise, minor premise, and conclusion, and place the blocks onto the three spaces provided on the panel of the machine. If the syllogism contains one or more fallacies, one or more light bulbs will light up. Each light bulb is identified by a printed name of a fallacy, as follows:

1. Undistributed middle.
2. Illicit major.
3. Illicit minor.
4. Two negative premises.
5. Two particular premises.
6. Affirmative conclusion from negative premise.
7. Universal conclusion from particular premise.

For the hypothetical syllogism, there are light bulbs for "Denying the antecedent," "Affirming the consequent," and "Hypothetical *non sequitur.*" For the disjunctive syllogism, there is a light bulb for "Disjunctive *non sequitur.*" There is one bulb for "False conversion," one for "False obversion," and a colored light bulb indicating that electrical current (battery or line) is established.

The principle of operation is that of establishing metal contact areas on the backs of flat wooden blocks, to convey information concerning the proposition printed on the front of the block. For example, the block representing the proposition "Some M is not S" (minor premise) has separate contact areas at selected positions on the back of the block, to represent the following items of information:

1. The middle term (M) is undistributed (that is, it refers to a limited number of its class).
2. The proposition is negative.
3. The proposition is particular (refers to "some").

Since, by definition, the conclusion of a syllogism represents the minor term by the letter S (subject), and the major term by the letter P (predicate), there are four blocks representing possible conclusions: All S is P, No S is P, Some S is P, Some S is not P. Using M for the middle term, there are eight blocks for all the possible combinations with P in the major premise, and eight blocks for the possible combinations with S in the minor premise. Additional blocks provide for testing hypothetical syllogisms, disjunctive syllogisms, conversion, and obversion.

Pairs of banana plugs in the panel receive items of information from the contact areas when the blocks are set onto the panel. Certain combinations of propositions will close one or more electrical circuits wired from the panel to pilot light bulbs. There is a separate circuit for each possible fallacy.

The panel is black hard rubber, 7 in. × 10½ in. × 3/16 in. To insure correspondence, a template was used to drill identically separated holes on both the panel and the wooden blocks, separated 5/16 in. horizontally, ¼ in. vertically. The banana plugs were inserted in the panel holes and secured with nuts behind the panel. The wiring is soldered to the back end of the plugs (behind the panel) and it leads to the pilot light sockets mounted on a vertical strip of black hard rubber. A white card next to the bulbs has a printed title for each kind of fallacy, indicated by the appropriate bulb. A knife switch permits use of either battery or line current; a transformer for line current is attached and wired behind the panel, out of sight. Panel, light sockets, and knife switch are mounted on a pressed cardboard backing, 17 in. × 14½ in. × ½ in. The backing is mounted inside the top of a suitcase.

The blocks are of hard wood, 5½ in. × 2½ in. × ¾ in. The contact areas consist of a pair of adjacent jacks soldered at their point of adjacency. The holes were drilled in the wood through the same template used for the panel, and were then widened to 3/16 in.; depth was ½ in. Then the blocks were sandpapered until they were smooth and easy to handle. The jacks were made from brass tubing, ¼ in. OD, 5/32 in. ID, cut into ⅜ in. lengths. One end of the jacks was trimmed down, to facilitate entry into the blocks. After each pair of jacks was hammered in, flush with surface, a narrow hole was drilled between the two