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For the purposes of this experiment, v flies may be regarded as completely lacking the v^+ hormone.

AN X-RAY INDUCED INTERCALARY DUPLICATION IN DROSOPHILA INVOLVING UNION OF SISTER CHROMATIDS

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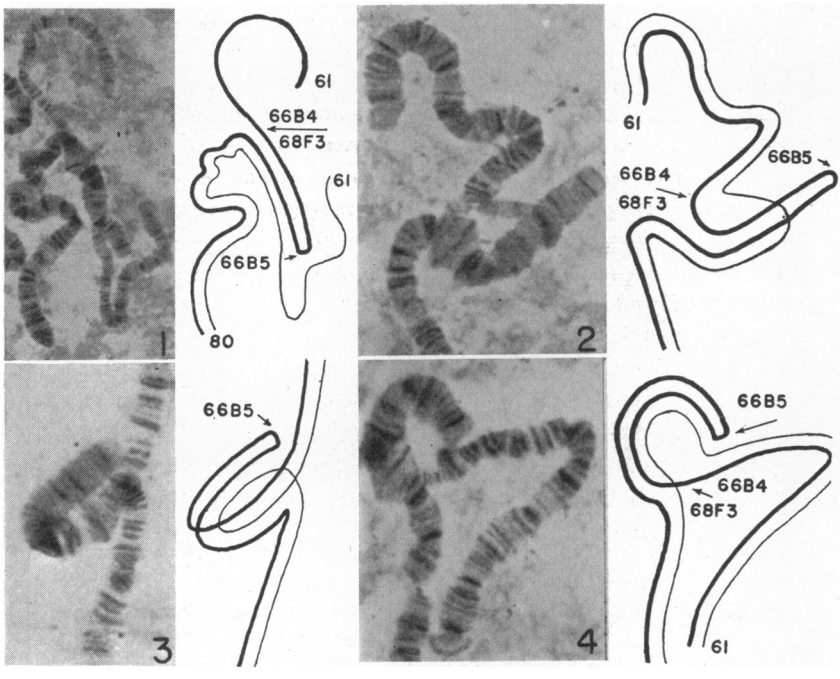
In a study recently completed in this laboratory, Carlson[1] has found striking evidence that sister chromatids of broken sections of irradiated neuroblast chromosomes of the Orthopteran, *Chortophaga*, may fuse *inter se* at the breakage points to produce either chromatid bridges, ring-shaped or V-shaped fragments, depending on whether they originally occupied proximal, intercalary or distal positions. Bauer, Demerec and Kaufmann[2] in appraising the evidence for and against the possible occurrence of single induced breaks have suggested that the rarity of unequivocal cases of terminal deficiencies and terminal inversions in Drosophila may be due to their elimination rather than to non-occurrence. Assuming that two chromatids of the same chromosome could unite at a breakage point, a bridge would be formed as the spindle attachment regions separate at anaphase. Rupture across the bridge with subsequent refusion of chromatids, and repetition of the process in successive mitoses would increase the genic unbalance in daughter nuclei so that non-viable combinations would result.

The present report is presented to show that two chromatids of a chromosome of *Drosophila melanogaster* with breaks at identical loci may unite with one another at these broken ends, and that under suitable conditions the resulting rearrangement may be perpetuated.

Salivary glands secured from an F_1 female larval descendant of a father irradiated at 3000 r-units showed a duplicated section of the left limb of the third chromosome extending from 66*B*5 to 68*F*3 of Bridges' 1935 map. The duplication is arranged in the pattern of a "reversed repeat," as may be represented by the sequence abcd*gfeef*ghijk. In several of the nuclei the two strands of paternal origin and the maternal chromosome had



FIGURES 1–4

Salivary gland chromosomes of intercalary duplication. In the diagrams shown to the right of each photograph the altered paternal strand is represented by the heavier line; the maternal, unaltered strand by the lighter line. The tip of 3*L* is marked by the figure 61; the spindle attachment end by the figure 80. Arrows indicate the inversion point and the limits of the duplicated section. Further description in the text.

conjugated to form a looped aggregate resembling the pairing configuration of an inversion heterozygote (figure 3). A striking feature of conjugation is the close association maintained between the duplicated regions of the 3*L* strand of paternal origin even when the maternal strand remains wholly or partially unpaired. As a result of this intimate lateral association the two linearly abutting homologous bands (the 66*B*5 bands) most frequently present the aspect of free ends of homologous strands (see figures 1, 2). A similar type of pairing of the duplicated intercalary sec-

tions inserted in the fourth chromosome in eyeless-dominant was observed by Bridges.[3]

Failure to observe evidence of linear continuity of the 66*B*5 bands suggested that we might possibly be dealing with a rearrangement involving translocation between the 66*B*5 ends and some poorly defined portion of the chromocentral region, such as those proximal chromomeres representing the short arms of the *X* and fourth chromosomes (Kaufmann[4]). Since the glands were obtained from an F_1 larva, it was impossible to secure additional salivary gland nuclei for study. Fortunately we had preserved the larval ganglia and were able to determine, as Bridges did in the case of eyeless-dominant, that the altered chromosome existed as a separate and continuous unit. Analysis of several mitotic figures of neuroblast and ganglion cells disclosed no perceptible alteration in the second, fourth or *X* chromosomes, although there was some intimation of difference in length between the two third chromosomes. We feel certain, therefore, that the sequence of banding in the altered third chromosomes is as follows:
61,62....66*B*4/68*F*3....66*B*5/66*B*5....68*F*3,69*A*1....80 sp. a. 81..100

The apparent lack of linear continuity across the 66*B*5/66*B*5 union in the salivary chromosomes presumably represents a rupture at this point due to the force of lateral attraction between identical loci of the duplicated regions, causing the chromosome to fold through 180 degrees. Lack of such intimate pairing in most of the reversed repeats which are present in nature in the chromosomes of Drosophila may be the result of the establishment of mutational differences between the duplicated sections in the period intervening since their origin.

It seems also significant that the duplicated sections of paternal origin are paired in practically every nucleus, whereas these two conjugate with the maternal strand in only some of the cells. Such observations suggest that when pairing is initiated, the proximity of adjacent bands favors their synapsis and the consequent conjugation of the duplicated sections prior to their union with the strand of maternal origin.

Whether the duplication results from strands which were split at the time of irradiation, or whether division and reunion occurred subsequently cannot be determined from this rearrangement. Data bearing on these problems have been obtained from other duplications and will be discussed in another publication.[5] In the present case we may assume that breaks occurred in 66*B* and in 68*F*, that at the time of reunion of the fragments the region between these points was present as twin strands, that the 68*F* end of one of the strands joined with the 66*B*4 end of the distal section of 3*L* to give an inverted section, and that the sister chromatids then fused at the 66*B*5 broken ends. The 68*F*3, 69*A*1 continuity may represent an unaltered sequence resulting from the fact that at the time of irradiation the chromosome had divided at this level and that only one

strand was broken, or the 68*F*3, 69*A*1 sequence may represent a refusion which would be necessary if both strands had broken at this level. The general plan of the rearrangement may be expressed as follows:

abcd|efg|hijk·lmnopqrstu
abcd|efghijk·lmnopqrstu giving abcd*gfeef*ghijk·lmnopqrstu

with probably another strand of the constitution: abcdhijk·lmnopqrstu. The fate of the latter chromosome remains conjectural, although it may as a result of the deficiency form a non-viable nucleus at the end of the first cleavage mitosis.

The union of sister chromatids of a chromosome in the manner here described offers a possible explanation of the origin in nature of the reversed repeats described by Bridges[6,7] and shown especially clearly in the 35*F*–36*D* regions of the left limb of the second chromosome. The same type of rearrangement has been postulated by Offerman[8] as an explanation of his interpretation of the structure of the bulb in division 2 of the *X* chromosome as a reversed repeat. If in such rearrangements the region of mirror-imaging is not too extensive to affect viability, and if it has selection value in nature, it may be expected to be perpetuated in phylogeny.

Summary.—An intercalary mirror-imaged duplication in the left limb of the third chromosome of *D. melanogaster* was found in an F_1 larval descendant of an irradiated father. Origin of the duplication is attributed to fusion at identical loci of the broken ends of two chromatids of the paternal third chromosome.

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