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Notes:

chromosome at treatment. Unless, therefore, there is an enormous amount of rehealing or failure of potential breaks to become actual breaks, it can only be concluded that the number of ionizations produced within the chromosome is greatly in excess of those effective in producing breaks.

Summary.—The hypothesis that the single chromosomal break is the result of a single event, namely, a single ionization or excitation, which occurs entirely at random, is supported by (1) the linear proportionality existing between dosage measured in r-units and number of chromosomal breaks, (2) the apparent absence of any threshold below which breaks do not occur, (3) the close correspondence between the observed and expected distribution of the breaks among different cells after each of the doses. The analysis of single breaks in terms of ion pairs per chromosome indicates that only a small proportion of the ionizations produced by x-rays is effective in the production of breaks.

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* Rockefeller Fellow in the Natural Sciences.

¹ Sax, K., *Genetics*, 25, 41–68 (1940).

² Carlson, J. G., *Ibid.*, 23, 596–609 (1938).

³ Carlson, J. G., *Proc. Nat. Acad. Sci.*, 24, 500–507 (1938).

⁴ Sax, K., *Ibid.*, 25, 225–233, 397–405 (1939).

DISCOVERY OF A PREDICTED GENE ARRANGEMENT IN *DROSOPHILA AZTECA*

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A method which under certain conditions permits prediction of as yet undiscovered gene arrangements was described a few years ago.^{1,2} Its essence is as follows. If an inversion transforms the gene arrangement *ABCDEFGH* into *AEDCBFGH*, a second inversion taking place in the altered chromosome may be of the overlapping type, that is one of the breaks of the second inversion may lie within and the second break outside the limits of the first inversion. Thus the arrangement *AEDCBFGH* becomes *AEDGFBCH*. If the first and the third of these arrangements are known, one can postulate the existence of *AEDCBFGH* as a necessary intermediate step. If a family of gene arrangements related as overlapping inversions is known, a phylogenetic scheme indicating the lines of descent within this family may be drawn. Occasionally such phylogenetic schemes

involve hypothetical links constructed with the aid of the method just outlined. The purpose of the present note is to record an instance of the discovery of such an hypothetical link, and certain related facts.

Six gene arrangements were found in the *A*-chromosome, an autosome, of *Drosophila azteca*.³ They are designated as Alpha, Beta, Gamma, Delta, Epsilon and Eta. Their relationships are as indicated in the scheme in the upper right corner of figure 1. Any two arrangements which are adjacent in this scheme produce, when present together in the salivary gland cells of a larva, a characteristic single inversion loop; any two arrangements removed in the scheme by two steps produce a double inversion loop, etc. The arrangements Epsilon and Eta were found to give a double loop, an analysis of which permitted devising an hypothetical arrangement, Zeta, which had not been detected in the material then available.

Drosophila azteca was known to occur from central Mexico (Durango) to Guatemala, and in two localities north of the San Francisco Bay, California.³ Recently it has been found at San Miguelito, Nuevo Leon, Mexico (Mr. Bob Camp), at Huachuca Mountains, Arizona (Professor Carl Epling), at Stony Creek, Sequoia National Park, California (Mr. W. Hovanitz) and at Deer Creek, south of the Lassen National Park, California (Professor Carl Epling, Mr. E. Berkoff and the writer). The distribution of this species in Mexico and Guatemala is probably continuous along the mountain ranges, but in Arizona and California the distribution is very spotty, since despite extensive collecting the species has not been found except in the few places indicated above. An examination of the salivary gland chromosomes showed that Zeta, the once hypothetical gene arrangement in the *A*-chromosome, is present in three strains from Stony Creek, two strains from Huachuca Mountains and one strain from Nuevo Leon (Fig. 1). Eta arrangement is found in two strains from Deer Creek (which are homozygous for this arrangement), in two strains from Stony Creek and in three strains from Huachuca. Epsilon arrangement is found in all three strains available from Nuevo Leon, and Alpha arrangement in one strain from the same locality.

Figure 1 shows that only phylogenetically closely related arrangements in the *A*-chromosome tend to occur in any one geographical region. Thus, Beta arrangement is confined to central and southern Mexico and to Guatemala. Alpha occurs with Beta, but extends northward as far as Durango and Nuevo Leon. Gamma and Delta are so far known only from Durango, in north-central Mexico. Epsilon and the formerly hypothetical but now actually encountered Zeta extend from Nuevo Leon to California, while the extreme member, Eta, is found only in Arizona and California. Geographical relationships as simple as these are by no means common in other species of *Drosophila* in which phylogenies of gene ar-

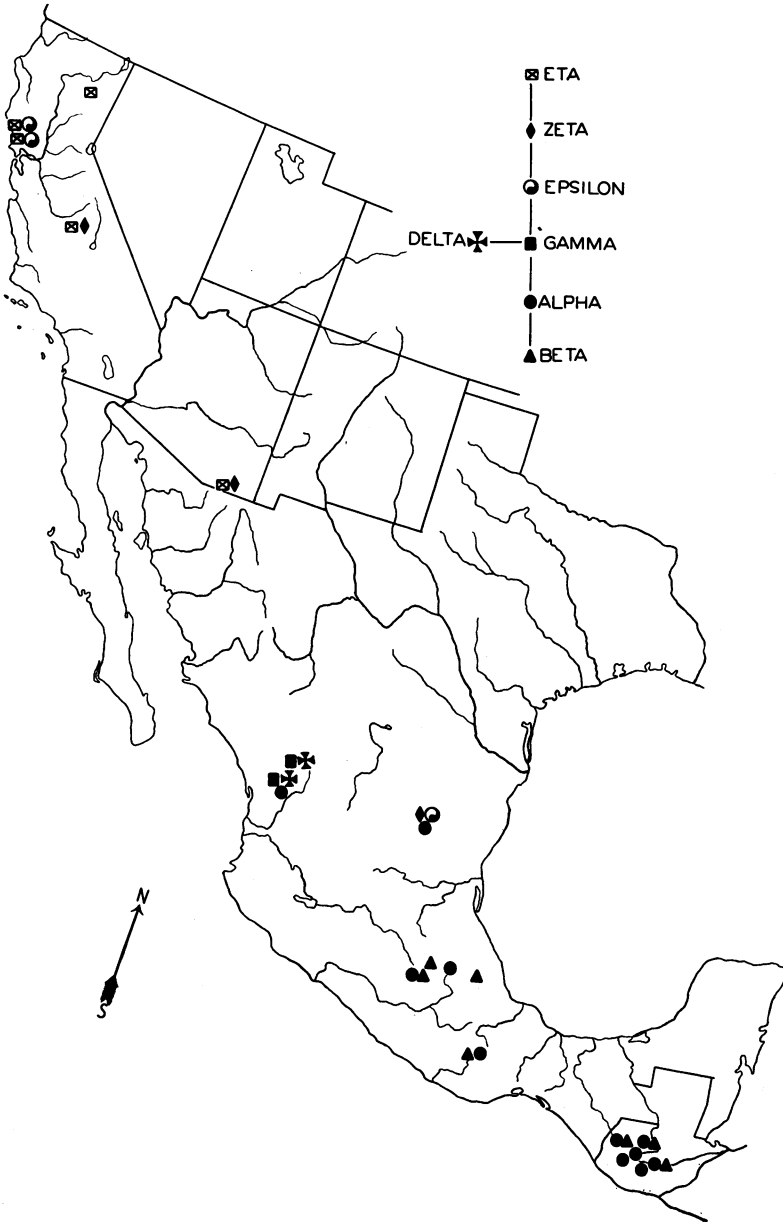
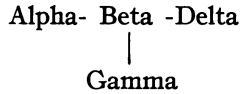


FIGURE 1

Geographical distribution of the gene arrangements in the A-chromosome of *Drosophila azteca*. The phylogenetic relationships of the known gene arrangements are represented in the upper right corner of the figure.

rangements have been studied; for example, in *Drosophila pseudoöbscura* phylogenetically remote arrangements frequently occur together in the same populations.

In the long limb of the *X*-chromosome of *Drosophila azteca*, two gene arrangements, Alpha and Beta, have been recorded.³ All the strains from Mexico and Guatemala were Alpha, those from California were Beta, while in Durango both Alpha and Beta were found. All the new strains from California and Arizona are also Beta, while those from Nuevo Leon are Alpha. In the proximal part of the *B*-chromosome two arrangements, Alpha and Beta, were known, both of which were recorded from Mexico and Guatemala, and only Beta from California. The new strains from California and Arizona are pure Beta, and those from Nuevo Leon pure Alpha. In the distal part of the *B*-chromosome a family of four gene arrangements, Alpha, Beta, Gamma and Delta, was recorded. The phylogeny is:



The old data³ showed Gamma to be the commonest in Guatemala, although occurring also in central Mexico; Alpha and Beta are common from Durango, Mexico, to Guatemala, inclusive; Delta was recorded only from Durango (one strain) and from California. The new strains from California and Arizona are homozygous for Delta, while in Nuevo Leon Alpha and Beta are found. All the available data on the geographical distribution of the gene arrangements in *Drosophila azteca* seem to make a simple and consistent story: a gradual spread from North to South, or vice versa, has taken place in the history of the species; the gene arrangements in the chromosomes have differentiated hand in hand with the distribution of the species itself.

¹ Sturtevant, A. H., and Dobzhansky, Th., "Inversions in the Third Chromosome of Wild Races of *Drosophila pseudoöbscura*, and Their Use in the Study of the History of the Species," *Proc. Nat. Acad. Sci.*, **22**, 448-450 (1936).

² Dobzhansky, Th., and Sturtevant, A. H., "Inversions in the Chromosomes of *Drosophila pseudoöbscura*," *Genetics*, **23**, 28-64 (1938).

³ Dobzhansky, Th., and Socolov, D., "Structure and Variation of the Chromosomes in *Drosophila azteca*," *Jour. Heredity*, **30**, 3-19 (1939).