Polytene Chromosomes in Mutagenesis

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1 Introduction

Since Muller introduced mutagenesis research in Drosophila in the early 1920s and reported the production of mutations by X-rays in 1927, Drosophila has become one of the so far genetically best-analyzed eukaryotes. This is based on nearly a century of work in generating and analyzing mutants. Not only the ease of handling Drosophila melanogaster, the high reproductivity, the short generation time, and the existence of only four chromosomes per haploid genome have made the fly so suitable for genetic investigation, but also the existence of the giant polytene chromosomes in salivary gland nuclei played a crucial role in analyzing mutations.

The chromosomal nature of the "Kernschleifen" was established in the 1930s (Heitz and Bauer 1933; Painter 1933, 1934; King and Beams 1934; Koltzoff 1934) and the polytene chromosomes were subsequently widely used for studies...

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of genome organization, chromosome structure, chromosome replication, and
gene activation-related chromosome puffing. When the era of chemical mutagens began in the 1940s, it was possible to map newly generated lethal mutations
cytologically by the method of overlapping deficiencies and duplications. The
linear organization of genes was corroborated by comparing cytological loci
and complementation units, showing their colinearity (Judd et al. 1972). De-
tailed chromosome maps were published (C. B. Bridges 1935, 1938; Bridges and
Bridges 1939; P. N. Bridges 1941a, b, 1942) and refined with the introduction of
electron-microscopical mapping (Sorsa and Sorsa 1967, 1968; Berendes 1970;
Sorsa 1988).

Methods of molecular genetics then made it possible to exactly localize any
gene or part of the chromosome from which DNA is available by the elegant
method of in situ hybridization to squashed polytene chromosomes. Further-
more, a new approach in Drosophila mutagenesis, the method of transposon
tagging, combined with in situ hybridization to polytene chromosomes, allows
the immediate localization of a mutant gene as soon as the mutant strain is
established, cloning of the mutant gene by plasmid rescue and control for having
cloned sequences from the desired locus.

More and more new approaches have been developed, based on the easy
access to genetic material in situ and on the existence of detailed maps, and
make polytene chromosomes an excellent tool in molecular genetics.

2 Characterization of Polytene Chromosomes

2.1 The Structure of Polytene Chromosomes

The most striking feature of polytene chromosome structure is their banding
pattern. It consists of chromomeres (bands) where the DNA is highly condensed
and of interchromomeres (interbands) which are light regions of low DNA
content. In Drosophila melanogaster larval salivary glands the giant chromo-
somes are formed by 1024 parallel DNA strands which arise, according to the
“polyteny hypothesis” (Heitz and Bauer 1933; Painter 1933; Koltzoff 1934) from
nine cycles of endoreplication of the chromatids. As the homologous chromo-
somes in Diptera remain in close contact by somatic pairing, a final level of $2^{10}$
DNA strands is reached. But not all chromosome segments polytenize to the
same extent. It has been shown by cytogenetic, cytophotometric and auto-
radiographic studies that heterochromatin remains at a 4C level or undergoes
only a few replication cycles (Rudkin and Schultz 1961; Keyl and Pelling 1963;
Berendes and Keyl 1967; Mulder et al. 1968; Rudkin 1969). In Drosophila
melanogaster salivary gland nuclei only euchromatic parts of the X chromosome
are polytenized, and the Y chromosome, which is totally heterochromatic, is
completely undetectable. It is hidden in the chromocenter which also contains