Chromosome Structural Aberrations

Origin of Structurally Abnormal Chromosomes

Chromosome breaks sometimes occur spontaneously, or they may be induced by a mutagenic agent such as ionizing radiation or DNA-damaging chemicals. Unlike normal chromosome ends, broken ends tend to join together. Usually the broken ends rejoin; in other words, the break heals. However, a break may lead to a deletion or, if more than one break has occurred in a cell, to structural rearrangements of chromosomes.

Chromosomes may break at any stage of the cell cycle—G₁, S, G₂—during mitosis, or during meiosis. Various cell types and stages show very different responses to chromosome-breaking agents even in the same organism. Thus, in Vicia, a dose of x-rays that induces one aberration visible at metaphase per 10 cells when irradiation is given in G₁ will produce approximately one aberration per cell if given in G₂ (Evans, 1974). Even greater differences are found when different plant and animal species are compared. In different species of higher plants, the doses of radiation needed to inhibit growth or to cause death were found to vary more than 100-fold (Sparrow, 1965).

The study of chromosome breaks is intimately connected with research on gene mutations, because most mutagens induce both chromosome breaks and gene mutations. Often the same agents are also carcinogenic. We know that the radiations and drugs used in cancer therapy can also cause malignant disease. Various aspects of chromosome breakage are reviewed in numerous books and articles, of which the following reflect a somewhat arbitrary sample: Kihlman, 1966; Rieger and Michaelis, 1967; Gebhart, 1970; Evans, 1962, 1974, 1983; Auerbach, 1976, 1978; Mendelsohn and Albertini, 1990.
Figure 9.1. Results of G₁ breaks in one chromosome (a), and in two chromosomes (f); (b) broken chromosome; (c) centric ring and acentric fragment; (d) acentric ring and centric fragment; (e) chromosome with pericentric inversion; (g) dicentric chromosome and acentric fragment; (h) balanced reciprocal translocation.

Chromosome Breaks and Rearrangements

If a chromosome breaks during the G₁ stage, when it consists of only one chromatid, the break may be perpetuated in S and affect both chromatids in the following metaphase. If a single break does not rejoin, the result will be a deleted chromosome and an acentric fragment (Fig. 9.1b) that may be lost in a subsequent mitosis. Alternatively, the acentric fragment may be included in a daughter nucleus and replicate, so that there will be double fragments in the next metaphase.

Two breaks in the same chromosome may result in the formation of either a centric ring and an acentric fragment or an acentric ring and an interstitial deletion (Figs. 9.1c and d, and Fig. 9.2g). A segment that is