INTRODUCTION

Interest in the modification of responses of organisms to ionizing radiation has been motivated by several factors, not least being the belief that by studying post-irradiation modulation of damage some insight can be gained into the mechanisms whereby these radiations affect living systems (Bacq, 1965). Kimball, Gaither, & Wilson (1959) concluded that the then available data on post-irradiation responses were not ready to be organized into a comprehensive picture. Now, however, patterns are beginning to emerge. This review will attempt to collate the extensive information on the modulation of damage by post-irradiation treatments into a form where it may have conceptual and heuristic value. More research has been done with animal systems than with plants, but the con-

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cept appear to be the same, the results are the same, and the plant literature is not so large that it cannot be handled. Not all of the reports are reviewed here; selection has been exercised.

Arranging material and information in a review reflects not only natural groupings of reports on similar phenomena, but also the author’s concept of the area of study. Indeed, the ordering of sections and subsections provides a framework for developing concepts about the phenomena. In this review, the reports can be placed in three fairly well delimited sections representing operational if not mechanistic classes of post-irradiation modulation of biological response.

There is little consensus on the terminology used to discuss post-irradiation responses. Repair, restitution, recovery, restoration, and other terms have been used, in many cases interchangeably (Bacq & Alexander, 1961). These terms may have operational and conceptual connotations that are unjustified, but this semantic problem is insoluble simply because there is no comprehensive general theory. We will use the term “modulation” to permit discussion of positive and negative effects of post-irradiation treatments without implications as to mechanisms. It should be recognized that modulations caused by post-irradiation treatments alter the sequence or direction of events perceived as a radio-lesion, while pre-irradiation treatments can be considered protective if they prevent or ameliorate consequences of the radiation (cf. Laterjet, 1954; Laterjet & Gray, 1954). Pre-irradiation treatments resulting in radioprotection will not be covered in this review, although the mechanisms of action of some pre-treatments may be analogous or even homologous to those of post-treatments.

Underlying much of this research is the usually unstated assumption that the sensitive loci are the nucleic acids, particularly the DNA (Howard-Flanders, 1965; Setlow, 1966; Moseley, 1968). There is little uniformity in biological test systems used, in methods of handling, or in techniques of scoring for modulations caused by post-irradiation manipulations. Germination and growth, chromosome and chromatid aberrations (Wolff, 1961, 1963), and mutation have usually been used. All of the test systems used have advantages in terms of manipulative simplicity, and all have disadvantages; there does not appear to be a perfect test system. We believe, however, that mutational studies on microorganisms offer a precise system, and for this reason, we have included data on bacteria.

A Brief Consideration of Radiation Theory

This review cannot discuss and evaluate the many theories on the mode of action of ionizing radiation (cf. Harris, 1961; Setlow & Pollard, 1962), and radiation theory will be considered only with reference to the topic of this review.

Ionizing radiations include those electromagnetic frequencies that can cause the ionization of water, i.e., wavelengths below 100 nm. Primarily gamma and X-rays have been used. Although these wavelengths