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The Abiotic Environment

1. Introduction

The development and reproduction of insects are greatly influenced by a variety of abiotic factors. These factors may exert their effects on insects either directly or indirectly (through their effects on other organisms) and in the short- or long-term. Light, for example, may exert an immediate effect on the orientation of an insect as it searches for food, and may induce changes in an insect's physiology in anticipation of adverse conditions some months in the future. Another abiotic factor to which insects are now routinely subjected (deliberately or otherwise) are pesticides. Apart from the obvious effect of lethal doses of such chemicals, pesticides may have more subtle, indirect effects on the distribution and abundance of species, for example, alteration of predator-prey ratios and, in sublethal doses, changes in fecundity or rates of development.

Under natural conditions organisms are subject to a combination of environmental factors, both biotic and abiotic, and it is this combination that ultimately determines the distribution and abundance of a species. Frequently, the effect of one factor modifies the normal response of an organism to another factor. For example, light, by inducing diapause (Section 3.2.3), may make an insect unresponsive to (unaffected by) temperature fluctuations. As a result, an insect is not harmed by abnormally low temperatures, but nor does it become active in temporary periods of warmer weather that may occur in the middle of winter.

2. Temperature

2.1. Effect on Development Rate

The body temperature of insects, as poikilothermic animals, normally follows closely the temperature of the surroundings. Within limits, therefore, metabolic rate is proportional to ambient temperature. Consequently, the rate of development is inversely proportional to temperature (Figure 22.1). Outside these temperature limits the rate of development no longer bears an inversely linear relationship to temperature, because of the deleterious effects of extreme temperatures on the enzymes that regulate metabolism, and eventually temperatures are reached (the so-called upper and lower lethal limits) where death occurs.

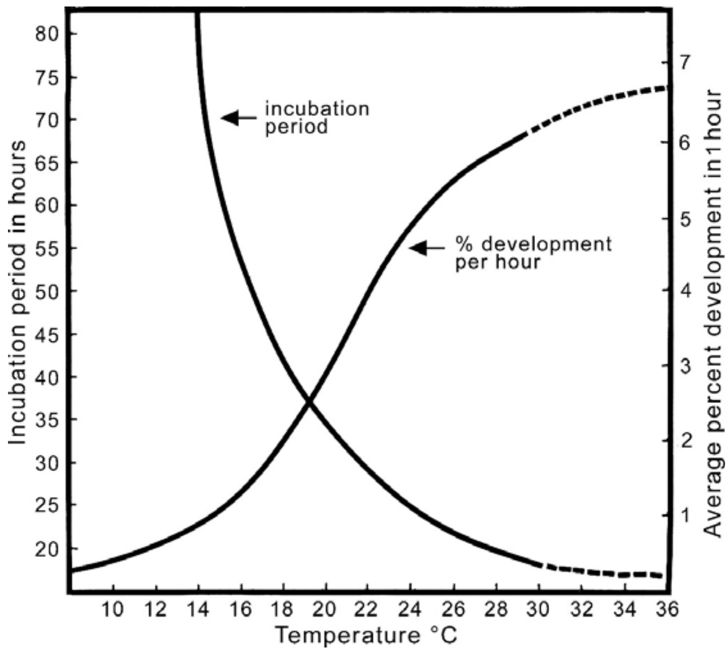

FIGURE 22.1. Relationship between temperature and rate of development in eggs of *Drosophila melanogaster* (Diptera). The two curves represent different ways of expressing this relationship, each being the reciprocal of the other. [After H. G. Andrewartha, 1961, *Introduction to the Study of Animal Populations*, University of Chicago Press. By permission of the author.]

Within the range of linearity the product of temperature multiplied by time required for development will be constant. This constant, known as the thermal constant or heat budget, is commonly measured in units of degree-days. This relationship will hold even when the temperature fluctuates, provided that the fluctuations do not exceed the range of linearity.

The temperature limits outside which development ceases and the rate of development at a given temperature vary among species, two seemingly obvious points that were apparently overlooked in some early attempts at biological control of insect pests. A predator that, on the basis of laboratory tests and short-term field trials, had good control potential was found to exert little or no control of the pest under natural conditions. Further study showed this to be related to the differing effects of temperature on development, hatching, and activity between the pest and its predator.

A broad correlation exists between the temperature limits for development and the habitat occupied by members of a species. For example, many Arctic insects that overwinter in the egg stage complete their entire development (embryonic + postembryonic) in the temperature range 0°C to 4°C, whereas in the Australian plague grasshopper, *Austroicetes cruciata*, development ceases below 16°C. This means that the distribution of a species will be limited by the range of temperature experienced in different geographic regions, as well as by other factors. However, the distribution of a species may be significantly greater than that anticipated on the basis of temperature data for the following reasons: (1) temperature adaptation may occur, that is, genetically different strains may evolve, each capable of surviving within a different temperature range; (2) the temperature limits of development may differ among developmental stages [this also serves as an important developmental synchronizer in some species (Section 2.3)]; and (3) the insect may have mechanisms for surviving extreme temperatures (Section 2.4).