# INTRODUCTION

*Anthrenus vorax* Waterhouse (*flavipes* Lec.) is a common pest of stored organic materials such as wool, leather, horn, dried fish and museum specimens like insects, stuffed birds and mammals. It is widely distributed in India and though believed to be indigenous to the Oriental region, has now acquired a more or less cosmopolitan distribution.

The group of dermestid beetles is one of great economic importance, which comprises, besides *Anthrenus vorax*, a number of major pests such as *Trogoderma granarium*, which destroys large stocks of wheat in India, *Dermestes vulpinus*, a destructive pest of dried fish and hides, *Anthrenus museorum*, which feeds on dried plants, and other pests of lesser economic importance like *Trogoderma parabile*, *Anthrenus verbasci* and *Attagenus piceus*. Much of the damage is caused by the voraceous feeding of the larvae. The biology of a few dermestid beetles (*T. granarium*, *D. vulpinus*, *A. vorax*, *A. verbasci* and *Attagenus piceus*) have been studied by various authors in considerable detail. Among these studies, the recent work of Burges on *T. granarium* consisting of an excellent series of papers (1957, $1959_a$, $1959_b$,1960,1962) on the biology and ecology under natural conditions in malt stores, the occurrence of diapause larvae at constant temperature and their behaviour, and the feeding, growth and respiration of the diapause larvae, deserves special mention. A detailed investigation of the biology of *Anthrenus verbasci* with special reference to the diapause and the regulation of development

was made recently by Blake (1958, 1961).

However, the physiological and metabolic aspects of this interesting group of insects have received little attention except for some studies on the metabolism of sterols in D. vulpinus (Fraenkel et al.,1941; Bloch et al., 1956; Clayton and Bloch, 1963) and some nutritional studies on T. granarium (Pant, 1953, 1956; Pant et al., 1958; Pant and Pant, 1960, 1961) and D. vulpinus (Gay, 1938). An analysis of the aminoacid content of A.vorax was reported by Chatterji and Sarup (1960). Sinoda and Kurata (1932) studied the composition of the ether extract of the larvae and adults of Dermestes.

The dermestids in general, possess certain remarkable adaptations to live under varied nutritional and environmental conditions, which are well exemplified by Anthrenus vorax. They can therefore thrive on a wide variety of organic materials without imbibing water, withstand fairly wide variations in temperature and humidity and survive long periods of starvation when the food supply fails. The egg production is autogenous, the majority of eggs being laid without feeding, which is a definite advantage for the survival of the species.

All such adaptations at the biological level should necessarily be the expression of a more intricate adaptation at the physiological and metabolic level, an understanding of which should be of help in the control of this pest. It was with a view to throw some light on these physiological and metabolic aspects of Anthrenus vorax the present work was undertaken.

Particular emphasis was placed on the metabolism of fat and some functional aspects of the fat body because of the overwhelming importance of this metabolite in such critical periods of insect life as moulting, metamorphosis and reproduction, and in such environmental adversities like scarcity of food and water and high fluctuations of temperature.

The work presented here falls broadly into four categories - some observations on the biology of A. vorax under laboratory conditions, the histological and histochemical organization of the larval fat body, certain biochemical and enzymic changes during metamorphosis and some effects of gamma radiation on the larval and post-larval stages.

The first chapter gives a very general and concise account of the systematic position, general morphology and stages of development of the insect, so as to facilitate reference of certain structures and stages mentioned in subsequent chapters. While studying the morphology, a hitherto unrecorded finding of the presence of a spermathecal gland in the female was made and is briefly described.

A. vorax provides a good example of the organism's capacity to adapt itself to varied environmental conditions. Thus the food and other external conditions influence the duration of the entire life cycle and of the different developmental stages and fecundity. Largely due to this, the available data on their biology showed considerable amount of discrepancy and it was therefore found necessary, to standardise the conditions

in which they were reared. Feeding experiments with different substances led to the development of a suitable and convenient medium for their maintainance in the laboratory. Physiological studies become meaningful only when carried out in relation to known events in the biology of the organism. Therefore a study on their biology under laboratory conditions was made as a necessary prelude to the physiological and biochemical studies. The results of these experiments are presented in Chapter 2.

The next two chapters are devoted to a study of the histological and histochemical organization of the larval fat body. The fat body of none of the dermestid beetles has been studied so far, though insect fat body is now recognized as an important centre of intermediary metabolism, comparable in function to the vertebrate liver. While the fat body has its pre-eminent place as a repository of nutrient substances, it is also a dynamic tissue primarily concerned with the synthesis, storage and release of fats, carbohydrates and proteins. Much of our understanding about the manifold functions of the insect fat body has come, however, from the study of a few insects notably Schistocerca gregaria (Kilby and Neville, 1957; Desai and Kilby, 1958; Clements, 1959; George and Eapen, 1959; Candy and Kilby, 1961; George and Hegdekar, 1961; Tietz, 1961, 1962; Hines and Smith, 1963), Periplaneta americana (Vardanis, 1963), Prodenia eridania (Zebe and McShan, 1959), Poecilocera picta (Hegdekar, 1963), Aedes aegypti (Wigglesworth, 1942) and Rhodnius prolixus (Wigglesworth, 1958, 1963). In the present study, the histological organization of the fat body of A. vorax was studied and was found to be of

a specialized nature, having no cell boundaries and being composed of globular configurations consisting of a central fat globule and surrounding peripheral globules. The distribution of protein, neutral fat, phospholipids, glycogen, desoxyribonucleic acid, ribonucleic acid and uric acid was investigated histochemically and certain conclusions regarding the functional implications have been derived. Histochemical studies on some of the enzyme systems should have yielded more information regarding the various metabolic processes, but, unfortunately, the extreme fragility of the fat body of this insect limited the studies to only fixed material.

An analysis of the larval body showed a high percentage of fat, low contents of water and glycogen. The high fat content was particularly interesting, since the diet consists mainly of protein. T he quantitative changes in these two metabolites - fat and glycogen, during metamorphosis was studied. Utilization of fat during metamorphosis was noted. Synthesis of glycogen occurred during the prepupal stage, followed by its depletion during the pupal period. These investigations have thrown some light on the energy metabolism during pupal life (Chapter 5).

Since the enzyme, lipase is responsible for the hydrolysis of triglycerides into fatty acids and glycerol, a study of this enzyme should throw light on the metabolism of fat. Lipase activity has been studied in many of the fat utilizing tissues such as the flight muscles of birds, bats and insects (George

and Scaria, 1956; George, Susheela and Scaria, 1958; George, Vallyathan and Scaria, 1958; George and Bhakthan, 1960a, b, c.), the vertebrate heart (George and Iype, 1959, 1963) and the fat bodies of some insects (George and Eapen, 1959a&b; Hegdekar, 1963) and a direct relationship between this enzyme and the level of fat utilization has been established. In the present study, lipase activity was studied in the larva and in the subsequent developmental stages. Investigations were also made on the respiratory quotient of the larva and its capacity to oxidise fatty acids. The rate of oxygen uptake during metamorphosis was also studied. These studies have led to a better understanding of some of the metabolic processes in this insect which are discussed in Chapter 6.

Anthrenus vorax being a pest of many organic materials, it was thought desirable to study the effects of ionizing radiations, which, in recent years, have proved a promising tool for the control of many insect pests. Apart from observations on the susceptibility of the different stages to various doses, the influence of gamma radiation on the process of moulting, fecundity, fertility and ovarian development was studied. The inverse relationship of radiosusceptibility to the progress of tissue differentiation during the pupal period, suggested by the studies of Nair (1962) on house fly pupae, was also examined with reference to A. vorax.

Lastly, the various metabolic adaptations in A. vorax, as elucidated by the present series of investigations is discussed

and some problems and avenues for further studies are indicated. It should, however, be mentioned that in the few aspects of the metabolism of this insect that have been investigated in the present study, the complexity of its life processes is certainly revealed. Insects are known to possess some unique biochemical characteristics such as the occurrence in the haemolymph of high levels of aminoacids (Florkin, 1959), citrates (Levenbook and Hollis, 1961) and phosphates (Wyatt et al., 1963), the existence of the disaccharide trehalose as the major blood sugar instead of the ubiquitous glucose (Wyatt and Kalf, 1957) and the formation of αglycerophosphate as an end-product of glycolysis (Chefurka, 1958; Gilmour, 1961). The general lack of an integrated picture of the various metabolic processes in insects, in general, has contributed to limiting the interpretations of many of the results obtained in the present study under the realms of uncertainty. Nevertheless, we feel rewarded in the thought that these investigations have raised more questions and have pointed out some problems of wider interest in the physiology and biochemistry of insects.

The following papers were published, the last in joint authorship with Professor J. C. George, under whose guidance this work was carried out:

1. Observations on the biology of the dermestid beetle, Anthrenus vorax (W), under laboratory conditions. J. Anim. Morph. Physiol., 10, 1-14 (1963)
2. On the presence of a spermathecal gland in Anthrenus vorax (W). J. Anim. Morph. Physiol., 10, 78-79 (1963)
3. A histological and histochemical study of the larval fat body of Anthrenus vorax (W). J. Ins. Physiol., 10, 509-517 (1964)