CHAPTER 8

SOME GENERAL CONSIDERATIONS

The success of an organism depends largely on its capacity to compromise with the environment. Different animals have aquired varying degrees of independence from the environment, but at the same time, they are linked together in a dynamic state of relationship with the external conditions. Since animals cannot change their environment they must adjust themselves to it. In a sense, some animals do change their environment, as when they migrate during unfavourable conditions, but that again calls for an internal adjustment in the organism. Others enter a state of suspended animation- diapause, hibernation or aestivation, to cope up with the unfavourable environmental conditions. Anthrenus vorax is a good example of the organism's capacity to adapt. It neither migrates nor enters diapause. Yet it is distributed throughout the world, both in warm and temperate countries.

Temperature and availability of food are the two major factors which influence all organisms. A. vorax can feed on hide, horn, hair, hoof, feather and nail of different animals. They have therefore attracted man's attention because they attack woolen clothes, upholstery, carpets, and so on. We have found them feeding on wheat pellets when starved. One of the assets of such varied food habits is that it helps maintain the adaptability of the species by establishing a wide spectre of environmental circumstances. Patel (1958) observed that originally Anthrenus larvae must have fed on hides, skins, wool, hoofs, horns, feathers etc., of cadavers found lying on the ground in the open, in the same way as other carrion feeding genera of the Dermestidae and the other related families still do. It seems possible that right from ancient times when man built a house and hoarded skins, hides, horns and bone-implements this proved so ideal for the development of Anthrenus larvae, that they have slowly become a house-hold pest (Patel, 1958). Now they are mostly found in house-holds, stores, museums and depots. The adults still live outdoors, frequenting flowers and probably feeding on pollen. We have also recorded them from bird's nests. Like A.verbasci they seem to be attracted to bird's nests where they can lay eggs amidst the feathers used in nest building. Swifts' nests are very ideal, for they contain considerable amount of mucoid material on which the larvae can feed.

Two related species, Anthrenus verbasci and Trogoderma granarium are known to diapause in the larval stage. A. verbasci shows a clear annual rythm of activity - a rapid rate of growth and moulting during summer and rest during winter (Blake, 1958). Some larvae complete their life cycle in one year with only one period of diapause whereas the others show two periods of diapause and follow a two year cycle. This cycle of activity was shown to be regulated by an internal rythm, which persists even when development takes place under constant physical conditions in the laboratory (Blake, 1958). Short and long photoperiods, which are known to be responsible for the onset of diapause in many insects, were shown to have no influence in the development of this insect.

Trogoderma granarium, on the other hand, shows a weak facultative diapause. In Punjab (India) Barnes and Grove (1948) recorded that the number of generations per annum is probably five, the length of the life cycle varying with the season. The average period of life cycle was 27 days during the time of general activity. They are most active from May to August; from September onwards the period of life cycle lengthens and in December, January and February they remain in a hibernating condition (Barnes and Grove, 1948). In British malt stores, Burges (1959a) found two types of larvae at favourable temperatures, one group which pupate about a month after hatching and the other which enter a state of diapause when they are apparently full grown. The diapause larvae can persist for a very long time, often more than four years. The most interesting feature of the diapause in this insect is that they feed for short periods between long periods of dormancy, and moult occasionally. The diapause could also be broken by gradual as well as abrupt increases in temperature (Burges, 1962).

A. vorax, though do not enter a state of diapause offers some interesting comparisions. Under unfavourable conditions of food, as when they are fed on unsupplemented wool or hog bristles, the larval period is considerably attenuated, this period being as long as 333 days (Ayappa et al ., 1957) as against the 36 days when they were reared on muscle supplanted with yeast as in the present study. Lower temperatures are also known to lengthen the larval period (Ayappa et al., 1957; Patel, 1958). One must pause to consider whether we are dealing with the same phenomenon in all these three insects, perhaps in varying degrees. Could we say that the diapause of the other two beetles, T. granarium and A. verbasci is nothing but a greater development of the capacity exhibited by A. vorax to regulate its development in accordance with the external conditions of food and temperature? It is possible that if the favourable and unfavourable external conditions alternate with definite intervals, and if this pattern remains constant for a long period, then, the organism may get this rhythm of cyclic development incorporated into their normal way of life in course of time, which once developed, may remain unaffected by external conditions, thus giving rise to the obligatory diapause. The diapause of the dermestid beetles is an interesting problem and a comparative study of the physiology and regulation of development in these three closely related species, A. verbasci, showing obligatory diapause, T. granarium, showing a weak facultative diapause and A. vorax, with no diapause, but possessed with a great adaptability in the length of life cycle, will lead to a better understanding of the phenomena of insect diapause.

It is perhaps pertinent, in this connection, to mention the following observation on A. vorax. In the course of the present studies it was observed that during the winter season in Baroda, when the temperature falls to 10 - 20°C, in those cultures maintained at room temperatures, the emerging adults failed to lay eggs. Examination by dissections showed that the ovaries remained in a rudimentary state. However, when they were transferred to an incubator at 32°C, the ovaries developed promptly and eggs were produced. This specific inhibition of ovarian development at low temperatures may be considered an ovarian diapause and may perhaps be controlled by an endocrine mechanism, the normal operation of which fails to be triggered at low temperatures. One finds a striking parallel here, between this phenomenon and the effects of exposure of the female to a dose level of 3 kilo rad. of gamma radiation, in that in both instances the effects are reversible. This is not to suggest any similarity of the mode of action, which might be entirely different in these two instances.

Among the metabolic adaptations of this insect, the high fat content (53.7 $\pm$ 1.5 % of the dry weight) and the low water content (47.77% of the body weight) of the larva deserve special mention. The large percentage of fat is particularly interesting in view of the fact that the larval diet consists mainly of protein. The fat body seems to possess an active system for the deamination of aminoacids and the synthesis of lipids from the resulting keto acids. The fat body also shows some adaptations at the organizational level. Thus the basic unit of which it is composed is the 'globular configuration' with a nucleus, a central globule of neutral triglycerides and surrounding peripheral globules. The exact nature of the peripheral globules is not clear. However, as discussed earlier, they seem to have some special role in intermediary metabolism, probably as centres of deamination of aminoacids and synthesis of fat. The present study on the fat body of this insect has raised a controversial point as to the nature of the so-called 'albuminoids' of the insect fat body and calls for a more extensive study of the fat body with the aid of some of the modern tools such as the electron microscope.

The greater emphasis on the metabolism of fat is understandable as a metabolic adaptation. The larvae which feed on dry materials and live in dry habitats are constantly faced with the problem of water conservation. They have to depend mainly on metabolic water, as the water present in the food is extremely low. In the related beetle, Dermestes vulpinus , Fraenkel and Blewett (1944) observed that the water balance is maintained by consuming more food and retaining the water produced in metabolism. Fat is a convenient form in which energy as well as water could be stored. Storage of fat in large amounts is common in other animal too which are faced with a pressing need for the conservation of water.

The high fat content will also enable the insect to undergo long periods of starvation. Storage of fat has also to be considered an adaptation for its reproductive phase. Fat constitutes the major raw-material for egg production. A large percentage of the fat which is synthesised and stored in the larval phase persists in the newly emerged adult (Chapter 5).

This enables autogenous egg production which ensures survival of the species, even when the adults fail to find suitable feeding conditions. As a matter of fact, feeding of adults is absolutely unessential for the continuance of the species under laboratory conditions.

The high fat content seems to be a common biochemical feature of dermestids in general. The only other analysis available at present is that of Dermestes where it has been shown that the fat content of the larva amounts to 47% of the dry weight of the insect (Sinoda and Kurata, 1932). It is known that A. verbasci is also capable of producing eggs autogenously (Blake, 1961). Fat may also have some importance in the sustainance of the diapause condition both in A. verbasci and T. granarium.

The importance of fat as a source, either directly or indirectly, of energy during the metamorphosis of A. vorax has already been pointed out (Chapter 5 & 6). Some general considerations on the problems of insect metamorphosis and the significance of the present studies of lipids and lipase in A. vorax during metamorphosis seems relevent here. Insect metamorphosis is a fascinating subject as there is no parallel in the biological world to the spectacular transformations brought about during this period. It has been extensively studied as a phenomenon which might contribute towards an understanding of the wider problem of morphogenesis. All problems in biology, whether morphological, physiological or behavioural depend ultimately on biochemical transformations. On the one hand we have a set of genes which is basically the same, while on the other hand we have such varied morphological expressions as the larva, pupa and adult, differing both in structure and function. Work carried out during the past few decades have clearly shown that insects possess a multiple potentiality, the realization of any one of these depending on the changing balance between the juvenile hormone and the moulting and metamorphosis hormone (ecdysone) (Wigglesworth, 1954). A wealth of new information on the effects brought about by insect hormones has resulted. Yet our understanding of the complex phenomenon of insect metamorphosis is far from complete. We do not yet know how specifically the insect hormones trigger the various morphological events. Undoubtedly, they must act ~~act~~ at the biochemical level. Controls may be exerted by repressing certain reactions and releasing certain others from repressions. Enzymes are the links where such controls may be exerted. The present study has pointed out that one of the chief functions of the larva is to synthesise large amounts of lipids. In the prepupal stage there is a shift in the metabolism, lipids begin to break down and glycogen starts accumulating. Could this be brought about by a primary action of the hormone on the enzyme lipase, changing its function from that of esterification to de-esterification? Of course, in the multitude of complex chemical changes which occur during metamorphosis the task of distinguishing between cause and effect is a difficult one. Gilmour (1961) suggested that the juvenile hormone may act as a co-factor necessary for the synthesis of a group of enzymes responsible for achieving the larval form and inhibiting the production of another group of enzymes responsible for the adult form. It may be pointed out here that one might well look forward for an effect of insect hormones on fat metabolism. Perhaps the juvenile hormone helps in some way the synthesis and storage of fat which is one of the chief functions of the larva and the ecdyson stimulates its utilization and synthesis of glycogen which are the prominent biochemical changes that take place during the initial stages of metamorphosis. This shift in the metabolism (ie. fat depletion and glycogen synthesis) is not an isolated characteristic of the metamorphosis of Anthrenus, but is commonly associated with the metamorphosis of many insects (Chapter 5). As indicated earlier, fat depletion and glycogen synthesis may perhaps be correlated to each other since either fatty acid or glycerol may be the source of glycogen formation. That synthesis of glycogen is under hormonal control was clearly demonstrated by L'Helias (1953) who found that removal of corpora allata from Dixippus resulted in an accumulation of glycogen. The mechanism of action of insect hormones is still in the realm of speculation. It has often been suggested that the primary site of action of these hormones is the nucleus (Wigglesworth, 1954; Gilbert and Schniederman, 1961; Ishizaki, 1963). Recent studies have shown that ecdyson can induce changes in appearance, and presumably in activity of the genetic material (Karlson and Sekeris, 1964). The selective activation and inactivation of the genes might then influence the enzymes, which in turn will exert their influence on metabolic reactions.

Finally a few observations on the alimentary canal of *Anthrenus* larva seems to be worthy of consideration. The histology of the alimentary canal of *Anthrenus* larva was studied by Möbusz (1897), but we have no knowledge about the functions of the various parts. In the course of the present investigation it was observed that there is considerable amount of fat in some regions of the hind-gut near the rectal gland. The epithelium is highly developed and obliterates the lumen. Large nuclei are present around which is a large number of tiny fat droplets. Small acid-haematein positive granules which stain even after pyridine extraction were found both in the alimentary canal and the malpighian tubules. It seems that the alimentary canal and malpighian tubules of *Anthrenus* larva have some role in intermediary metabolism. The importance of the gut and the malpighian tubules in intermediary metabolism was also stressed by the studies on mosquito larvae (Wigglesworth, 1942), which showed that sugars of many sorts were converted to glycogen in the alimentary canal. A study of the functional aspects of the alimentary canal in *Anthrenus* should provide some illuminating information.