appear partly to be due to a gradual fading away of the individual flowers, since those nearer the centre of the cluster which are the latest to open have the deepest colour, while the outermost are the palest. Spectroscopic examination of the individual flowers in a cluster reveal that the absorption appearing in the spectral region between 500 mμ and 600 mμ which is responsible for the observed colour is very weak in the flowers which appear a pale pink, and is almost complete in those which exhibit a brilliant colour. The relative intensity of the absorption appearing in the green sector from 500 mμ to 560 mμ and in the yellow sector from 560 mμ to 600 mμ is also highly variable. The observed colour appears to be most saturated when the yellow sector is completely absorbed. This is indeed a general feature in all floral colours.

The spectrophotometer record reproduced above was made in the Instruments Section of the Indian Institute of Science to the authorities of which the author's thanks are due.

CELLULAR HETEROGENEITY AND METABOLIC ADAPTATION IN THE FLIGHT MUSCLES OF DRAGONFLIES

J. C. GEORGE

Department of Zoology, University of Guelph, Guelph, Ontario, Canada

IT is well known that the vertebrate skeletal muscle consists of two basic types of fibre, red (Type 1) and white (Type 2). In the pigeon pectoralis muscle, the red fibres are characterized by their small diameter, higher content of myoglobin, fat, mitochondria and, lipolytic and oxidative enzymes. The white fibres have larger diameter, higher content of glycogen and glycolytic enzymes. The former are adapted for aerobic metabolism and metabolize fat as the chief fuel. The latter are adapted for anærobic metabolism for metabolizing glycogen. The pigeon pectoralis muscle consists of only the red and white fibres, the intermediate forms that are found in other vertebrate muscles being absent. The white fibres are present in the periphery of the muscle fasciculus and the red fibres which have a greater blood supply occur towards the interior. The pectoralis muscle of the sparrow on the other hand, consists of only the red fibres. The fibres in the superficial region of this muscle, however, have been shown to contain more glycogen and phosphorylase and less fat and succinic dehydrogenase than the fibres in the deeper part of the muscle. Thus the pigeon and sparrow pectoralis muscles represent in avian flight musculature, two lines of evolution in cellular architecture and functional adaptation. Similar parallelism in the evolution of the pectoralis major muscle in bats has also been indicated.[1,2] Recently, Kallapur[3] reported the occurrence of two types of fibre, one larger and more sudanophilic than the other in the leg muscle of two species of cockroaches *Blatella germanica* and *Periplaneta australasiæ*. The former type of fibre resembles the third type of fibre, large, red, and containing high concentrations of fat, lipase and succinic dehydrogenase described by Nene and George[4] in the avian supinator muscle.

In the case of the flight (basalar and dorsoventral) muscles of dragonflies too, parallel trends in the nature of their fibre composition as observed in the pectoralis muscle of some birds and bats could be recognized.[5] The two types of fibre, the small (20–30 μ in diameter) and the large (40–70 μ in diameter) in the dragonfly *Pantala flavescens* may be compared to the red (Type 1) and white (Type 2) fibres respectively of the pigeon pectoralis muscle. There is, however, a difference between the pattern of distribution of these fibre types in the muscles of the two animals. In the pigeon muscle, the large white fibres mostly occur at the periphery of the muscle fasciculus, and in the muscle as a whole, the superficial region has a considerably larger population of white fibres than in the deeper part.[2] In the flight muscle of *Pantala flavescens*, however, the large fibres show a scattered distribution. The fibre composition of the flight muscles of the two dragonflies *Aeshna* sp.[6] and *Anotogaster sieboldii*[7] correspond to that of the pectoralis of the sparrow.[5] In *Anotogaster sieboldii*, the peripheral fibres in a fasciculus have been shown to contain lower levels of oxidative enzymes than the deeper fibres.[7] The fibre composition of the flight muscle of *Brachythemis contaminata* is similar to that of the flight muscle of *Anotogaster sieboldi* and is also comparable to that of the pectoralis muscle of the sparrow in that the peripheral fibres contain more glycogen but less fat and oxidative enzymes. Recently, Bhat[8] reported differences in the intensity of staining for fat and glycogen in the fibres of the flight muscle of *Brachythemis contaminata*. However, he does not mention which flight muscle was studied. The basalar and dorsoventral muscles in this dragonfly have the same fibre architecture and the photomicrographs presented therefore seem to be representative of these two muscles. The presence of a greater amount of glycogen in the peripheral fibres and a higher level of fat in the inner fibres of a muscle fasciculus, is by no means an unique feature seen in these muscles since the peripheral fibres in the sparrow pectoralis muscle also contain more glycogen and less fat than the deeper fibres.[2] Moreover, these observations would be more meaningful for a better understanding of muscle structure and function if they are viewed in the broad spectrum of cellular heterogeneity and metabolic adaptation in skeletal muscles in general.

In contrast to the vertebrate skeletal muscle, the insect flight muscle with its profuse supply of tracheoles in addition to blood, is essentially a highly ærobic tissue. In terms of fuel consumption and oxygen uptake, the insect flight muscle is the most active tissue known.[6] Weis-Fogh[6] considers muscular pumping of blood essential in all active wing muscles and the high concentrations of trehalose and of lipids in the insect blood as an adaptation to flapping flight. In this context the recent discovery of special myofibrils attached to the capillary wall in the pigeon pectoralis muscle is suggestive of the importance of muscular pumping as an effective process for the supply of oxygen and metabolites to the contracting muscle.[9] In the insect flight muscle, adequate supply of the fuel for energy during the initial period of muscular activity could be obtained through the combined effect of the presence of a high concentration of trehalose in the blood and of the muscular pumping.[6] In prolonged muscular activity however, fat would be the preferred fuel.[10,11] It should be of interest to know if the large fibres in the flight muscle of *Pantala flavescens* and the peripheral fibres in the muscle of the other dragonflies (*Aeshna* sp., *Anotogaster sieboldi, Brachythemis contaminata*) would preferably metabolize carbohydrate and continue to do so while the smaller or the inner fibres, as the case may be, metabolize fat as the chief fuel during prolonged muscular activity. It is known that in cockroaches[12] and in locusts[6] the supply of trehalose is completely used up initially during prolonged flight, after which fat becomes the fuel. In the pigeon pectoralis muscle the white glycogen-rich fibres were shown to be depleted of their glycogen reserves within ten minutes of electrical stimulation of the muscle while the glycogen content of the red fat-utilizing fibres showed slight increase.[13] The increased synthesis of glycogen in the red fibres may be to provide a continuous supply of oxaloacetate for the oxidation of fatty acids for energy in these fibres. The white fibres have been characterized as fast-twitch fibres and the red as slow-twitch fibres, the former indulging in phasic contractions for short durations of time and the latter in prolonged activity.[9]

It has been shown recently that in insects there is a preflight activity during which the temperature of the thorax is considerably increased.[14] During this "warmup" period there is no visible wing movement. Perhaps, the contractile activity of the specialized glycogen-utilizing fibres in the muscle may be responsible for the generation of the required preflight heat.

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