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Physiological diversity in insects: large scale patterns

by

Abraham Addo-Bediako

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……..to my daughter, Yaa with love.

"Trust in the Lord with all your heart, and do not lean on your own understanding. In all your ways acknowledge Him, and He will make your paths straight. Do not be wise in your own eyes; fear the Lord and turn away from evil" (Proverbs **3**, 5-7).

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ABSTRACT

This thesis concerns physiological diversity in insects at large scales. Specifically, it is about interspecific variation in thermal tolerances, water loss, development and metabolic rate across the globe, the way this variation is partitioned at higher taxonomic levels, and, in those cases where body mass is regularly reported, the relationship between the variable of interest and body size. The rationale for the investigation is the increasing need for information concerning various physiological assumptions that macroecologists routinely make, and to demonstrate that studies of large scale variation in physiological traits may provide insights into comparative physiology that are less apparent from small scale studies. It is shown that insect upper thermal limits vary much less than lower thermal limits, resulting in an increase in tolerance breadth with latitude. Although this result provides some support for the physiological tolerance assumption of the climatic variability hypothesis proposed to explain Rapoport's rule, it does highlight the range of variation found in insects and the need for coupled information on tolerances and geographic range size. There is also significant variation in desiccation resistance such that water loss rates tend to be positively related to rainfall. Moreover, the nature of this variation indicates that there are profound differences between xeric and mesic species. While water loss rate and metabolic rate covary as a consequence of their independent covariation with body mass in mesic species, this is not the case in xeric species. In the latter, there is a strong relationship between the residuals of the water loss rate-body mass and metabolic rate-body mass relationships, and water loss rate is much reduced. Moreover, because metabolic rate does not differ significantly between xeric and mesic species of a similar size, respiratory transpiration in xeric species constitutes a greater proportion of total water loss than can be expected in a similar-sized, mesic species. Latitudinal variation in insect development rate is also investigated and here there is little variation. Development rate in insects is generally higher in species from higher latitude than those from lower latitude. In the case of lower development threshold (LDT) and sum of effective temperatures (SET), the lower latitude species which frequently encounter relatively high and uniform temperatures had higher LDT and lower SET as compared with species from higher latitudes, although there was no significant difference in SET between different latitudes. The environmental temperatures included in the model had a significant effect on the rate of development and LDT but not SET. Based on the results there is an evidence of adaptation to both temperature and length of the reproductive season. This provides some support for the polemical idea of latitudinal compensation in development rate. Metabolic cold adaptation (MCA) in insects also remains controversial. After removing the effects of trial temperature and body mass, it is shown that environmental temperature significantly influences interspecific variation in metabolic rate in the direction predicted by MCA. This adaptation also takes the form of an increase the slope of the metabolic rate–temperature relationship in Northern, but not in Southern, Hemisphere species. Using these studies, and those from the literature on insect thermoregulation, it is clear that there is often a bias to the geographic extent of available empirical data. Likewise, much variation in insect physiological tolerances is partitioned at higher taxonomic levels, which has important implications for comparative physiology. Intriguingly, data on the full range of variables reviewed here are available for only three species. Furthermore, despite its importance, body size is regularly reported in only some kinds of investigations (metabolic rate, water loss rate), whereas in others (upper lethal temperature, cold hardiness, development) this variable is often ignored. In short, this thesis shows that although large scale comparative physiology can contribute considerable understanding to both physiology and ecology, there is much that remains to be done.