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POLAR EVOLUTION: MOLECULAR GENETIC AND
PHYSIOLOGICAL PARAMETERS OF ANTARCTIC
ARTHROPOD POPULATIONS

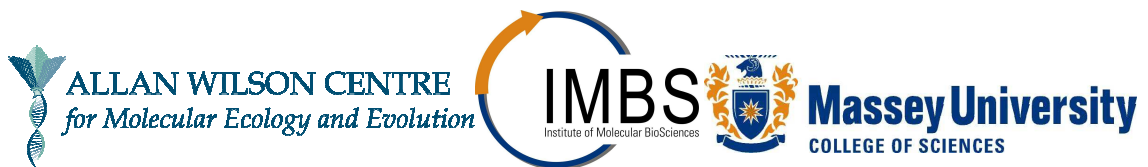
A thesis presented in partial fulfilment of the requirements for the degree of
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Ice floe off Cape Bird, with Adélie penguins on board; January 2007

*To move forward relentlessly in the quest for discovery;
And yet to not pass by the moments of perfect tranquillity*

ABSTRACT

This thesis is presented as a collection of research papers synthesising knowledge gained during the period of candidacy. Its underlying focus is the examination of evolution from a variety of perspectives for terrestrial arthropods (springtails) in an Antarctic setting. These perspectives include investigation of the ways in which springtail populations respond both physiologically and genetically to environmental variability over historical and contemporary time-scales. While the physiological and genetic may seem two worlds apart, this thesis recognises that, in reality the two are inextricably linked. Thus, when genetic differentiation between populations of the same species can be demonstrated, physiological differentiation of these populations may also be predicted (and *vice versa*). Therefore, across several locations and springtail species, physiological and genetic parameters of individuals and populations are examined both separately and, where possible, in concert.

The physiological aspect of this thesis focuses on the springtail *Gomphiocephalus hodgsoni* from continental Antarctica. In addition to providing the first metabolic rate data for a continental Antarctic springtail, seasonal variation in metabolic rates is examined across multiple temporal and spatial scales to evaluate the ways in which individuals and populations respond to environmental variability. Metabolic activity in this species is intricately linked to a variety of factors, both intrinsic and extrinsic. These include biological function, temperature profiles in the local microclimate, and body mass and genetic differences among populations.

In the genetically-focused aspect of this thesis, population genetic patterns of *G. hodgsoni* from several continental locations and *Cryptopygus antarcticus antarcticus* from locations across the Antarctica Peninsula are compared. Here, the importance of differing evolutionary histories in influencing patterns of contemporary genetic population structure is highlighted. While both species have been similarly affected genetically by Pleistocene (2 Ma – present) glacial cycling, it is clear that differences in timing of colonisation events and subsequent population expansions have left distinct genetic signatures in each species. In a separate molecular study, phylogenetic analyses are employed to study members of the circum-Antarctic springtail family Isotomidae.

The genetic ancestry among these closely related species is shown to reflect a diverse evolutionary origin in the Miocene (23 – 5 Ma), subsequent to which both vicariant and dispersal processes have been important. Phylogenetic re-constructions tease out the relationships among sister species, and the identification of several genetically distant lineages suggests that a revision of current species designations is required.

Finally, two studies that integrate the physiological and molecular genetic are presented. First, metabolic rate variation across several locations on sub-Antarctic Marion Island in the springtail *Cryptopygus antarcticus travei* is examined. This variation is related to the genetic structure of populations to show that historical and contemporary environmental characteristics have left their trace in the expression of both genetic and physiological variability of these populations. Second, the perceived association between metabolic rate and genetic (mutation) rate is investigated more closely - a sophisticated Bayesian correlation analysis detects that there is an indirect relationship between metabolic rate and underlying species phylogeny in *C. a. travei*.

Thus, the physiological and molecular genetic elements of this thesis test or advance important hypotheses within their own fields, and the integrated approach applied is a new step in interpreting evidence of physiological adaptation in Antarctic species. In its multi-faceted approach to evolutionary studies, this thesis enhances understanding of the current picture of springtail evolution in polar environments.

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CHAPTER ONE:
THESIS INTRODUCTION
