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Social modulation of ageing in termites

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DOI:
[10.33612/diss.233551297](https://doi.org/10.33612/diss.233551297)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2022

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Lin, S. (2022). *Social modulation of ageing in termites*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen. <https://doi.org/10.33612/diss.233551297>

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Social modulation of ageing in termites

Silu Lin

The research in this thesis was carried out at the Evolutionary Biology & Ecology group from the University of Freiburg (Germany), and the Theoretical Research in Evolutionary Life Sciences group (TRÊS) from the Groningen Institute for Evolutionary Life Sciences (GELIFES) of the University of Groningen (The Netherlands). Silu Lin was supported by a project awarded to Judith Korb and Ido Pen (KO1895/25-1) by the Deutsche Forschungsgemeinschaft funded within the framework of the Research Unit FOR2281. The printing of this thesis was funded by the University Library and the Graduate School of Science and Engineering of the University of Groningen.

ISBN: 978-94-6423-931-7

Printed by: ProefschriftMaken || proefschriftmaken.nl

Layout by: Silu Lin & ProefschriftMaken || proefschriftmaken.nl

Cover design by: Silu Lin & ProefschriftMaken || proefschriftmaken.nl

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 groningen



Social modulation of ageing in termites

PhD thesis

to obtain the degree of PhD at the
 University of Groningen
 on the authority of the
 Rector Magnificus Prof. C. Wijmenga
 and in accordance with
 the decision by the College of Deans

and

to obtain the degree of PhD at the
 Albert-Ludwigs-University Freiburg
 on the authority of the
 Dean of the Faculty of Biology Prof. S. Albers
 and in accordance with
 the decision by the doctoral chair Prof. A. Hiltbrunner.

Double PhD degree

This thesis will be defended in public on

Tuesday 23 August 2022 at 16.15 hours

by

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born on 22 October 1994
 in Shanxi, China

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"It is remarkable that after a seemingly miraculous feat of morphogenesis, a complex metazoan should be unable to perform the much simpler task of merely maintaining what is already formed."

George Williams

Abstract

Life on earth varies tremendously in its ageing trajectories. While human beings struggle with ageing, some animals have evolved mechanisms to cope with it. One of the most striking examples is the social insect queen (and the termite king), which can live up to 30 years and lay up to 20,000 eggs per day. These social insect reproductives are able to achieve a long lifespan without sacrificing reproduction, confounding the almost universal trade-off between longevity and fecundity in the animal kingdom. Understanding how and why the longevity/fecundity trade-off is contradicted in social insects potentially holds the key to longevity for all lifeforms.

Throughout this thesis, I aim to document and understand the role of sociality in reshaping ageing in termites. To investigate both the proximate and ultimate causes of the reversal of the longevity/fecundity trade-off, I adopted multiple approaches, including experimental manipulation, gene expression profiling, and mathematical modelling. Specifically:

- 1) I uncover a single gene network that encompasses all hallmarks of a social insect queen at the molecular level. Many genes from this network are known in regulating the longevity-fecundity trade-off. Additionally, it includes genes that are involved in chemical communications. This study provides the first strong molecular evidence that links social communication with ageing.
- 2) I show that although resource availability affects the maintenance-reproduction trade-off in a termite with low social complexity, there seems to be no causal link between maintenance and reproduction for individuals. However, colonies exhibit a trade-off between maintenance and reproduction when food is deprived.
- 3) Using individual-based simulations, I show that extrinsic mortality and the degree of sociality are important factors that affect differential ageing between reproductives and workers.

I thereby propose a conceptual framework for examining the social effect on ageing. It comprises factors that induce social effects on ageing, genetic mechanisms that enable social effects on ageing, as well as evolutionary forces that drive differential social effects on ageing. Such a framework could help future research into how sociality reshapes ageing in termites, social insects, and beyond.

Publications

Lin, S., Werle, J., & Korb, J. (2021). Transcriptomic analyses of the termite, *Cryptotermes secundus*, reveal a gene network underlying a long lifespan and high fecundity. *Communications biology*, 4(1), 1-12.

Korb, J., Meusemann, K., Aumer, D., Bernadou, A., Elsner, D., Feldmeyer, B., ... & So-Long consortium. (2021). Comparative transcriptomic analysis of the mechanisms underpinning ageing and fecundity in social insects. *Philosophical Transactions of the Royal Society B*, 376(1823), 20190728.

Contents

Chapter 1. Introduction	1
1.1 Why do organisms age?	2
1.2 How to not age?	5
1.3 Outstanding questions	8
1.4 Outline of this thesis	8
Chapter 2. Live fast, die old: what makes a queen?	11
2.1 Introduction	13
2.2 Results and Discussion	18
2.3 Methods	32
2.4 Data availability	38
2.5 Acknowledgments	38
2.6 Author contributions	40
Chapter 3. The individuality of a colony	41
3.1 Introduction	44
3.2 Methods	46
3.3 Results	49
3.4 Discussion	53
3.5 Author Contributions	56
3.6 Acknowledgements	56
3.7 Data Accessibility	56
3.8 Supplementary Materials	57
Chapter 4. Effects of sociality and extrinsic mortality on ageing	61
4.1 Introduction	63
4.2 Methods	69
4.3 Results	76
4.4 Discussion	79
4.5 Author Contributions	84
4.6 Acknowledgements	84
4.7 Data Accessibility	84
4.8 Supplementary materials	85
Chapter 5. Synthesis	97
5.1 How and why does sociality change ageing?	98
5.2 Examining social effects on ageing	103
Bibliography	106
Summary	129
Samenvatting	132
Acknowledgement	136