

# Multiple ecological scales of host-parasite interactions

Noémie Erin



Max Planck Institute for  
Evolutionary Biology



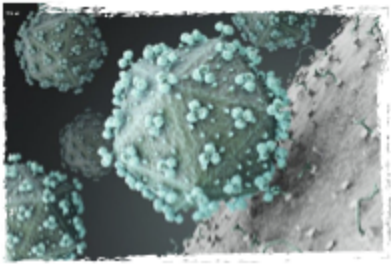
Thesis examination  
30<sup>th</sup> May 2017, Kiel





*Cymothoa exigua*

“A **parasite** is an organism that has evolved morphological or physiological adaptations to live in or on a **host**, exploiting its nutrients and decreasing its fitness, but seldomly killing it.”



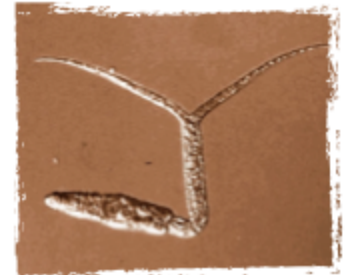
Virus



Fungus



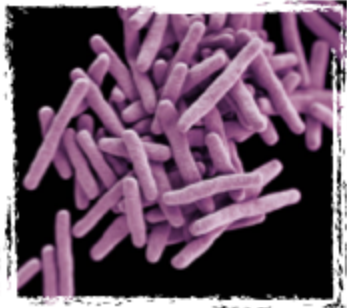
Cestodes



Trematodes



Insects



Bacteria



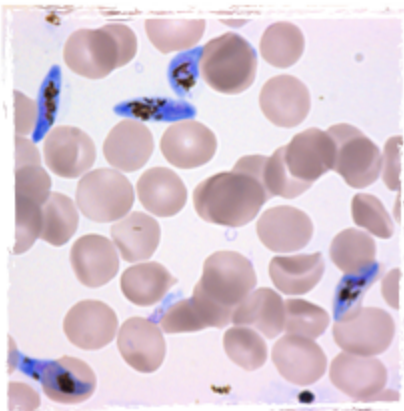
Arachnids



Acanthocephalans



Nematodes



Protozoan



Plants



Crustaceans



Bird

30-50% of species are parasitic  
All organisms are parasitised

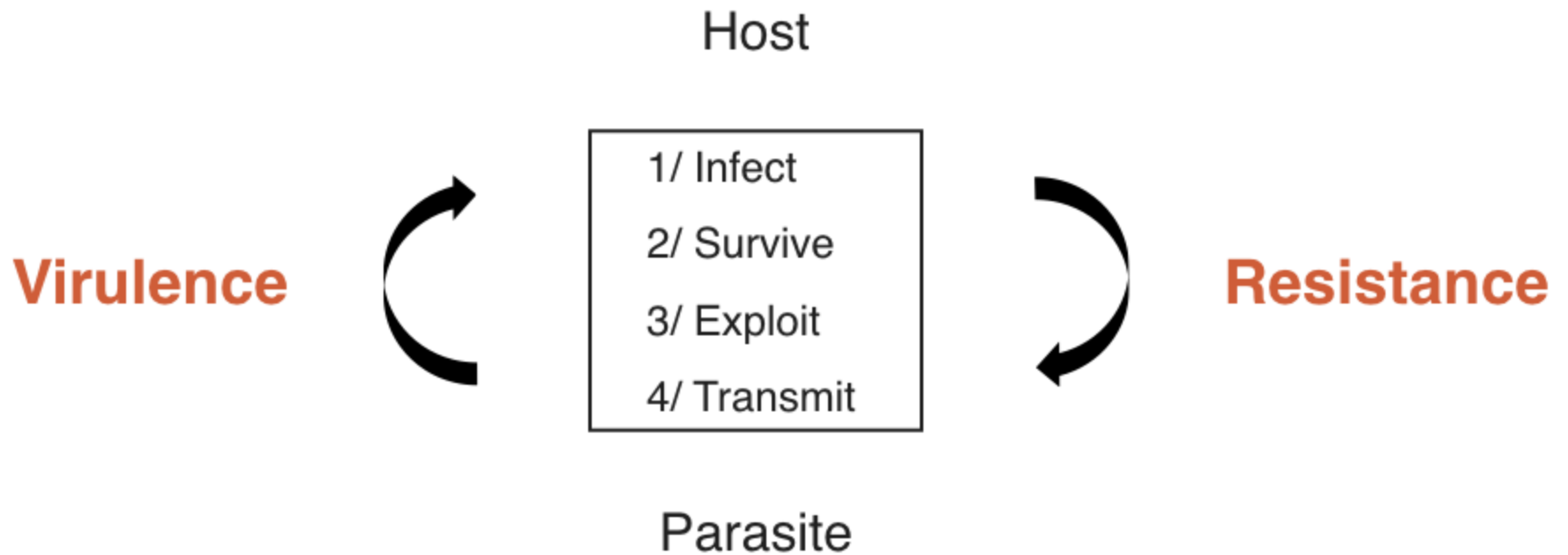
## **Important ecological & evolutionary implications!**

ecological speciation

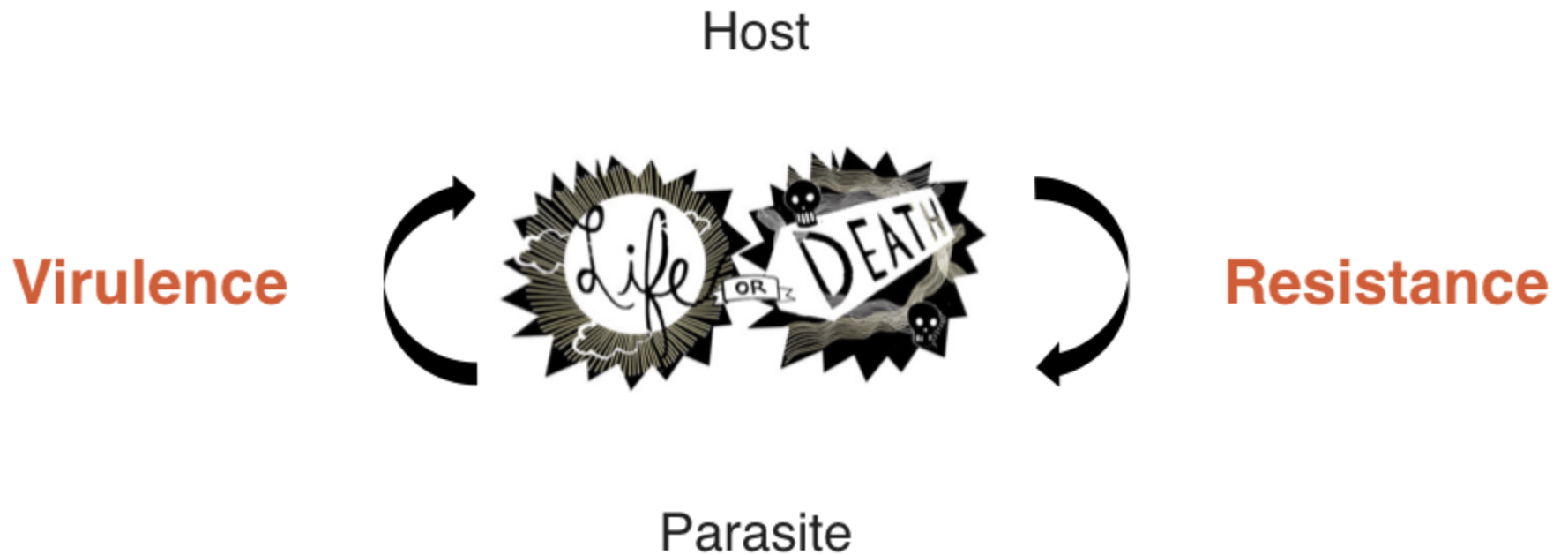
genetic diversity

sexual reproduction

# Host-Parasite interactions

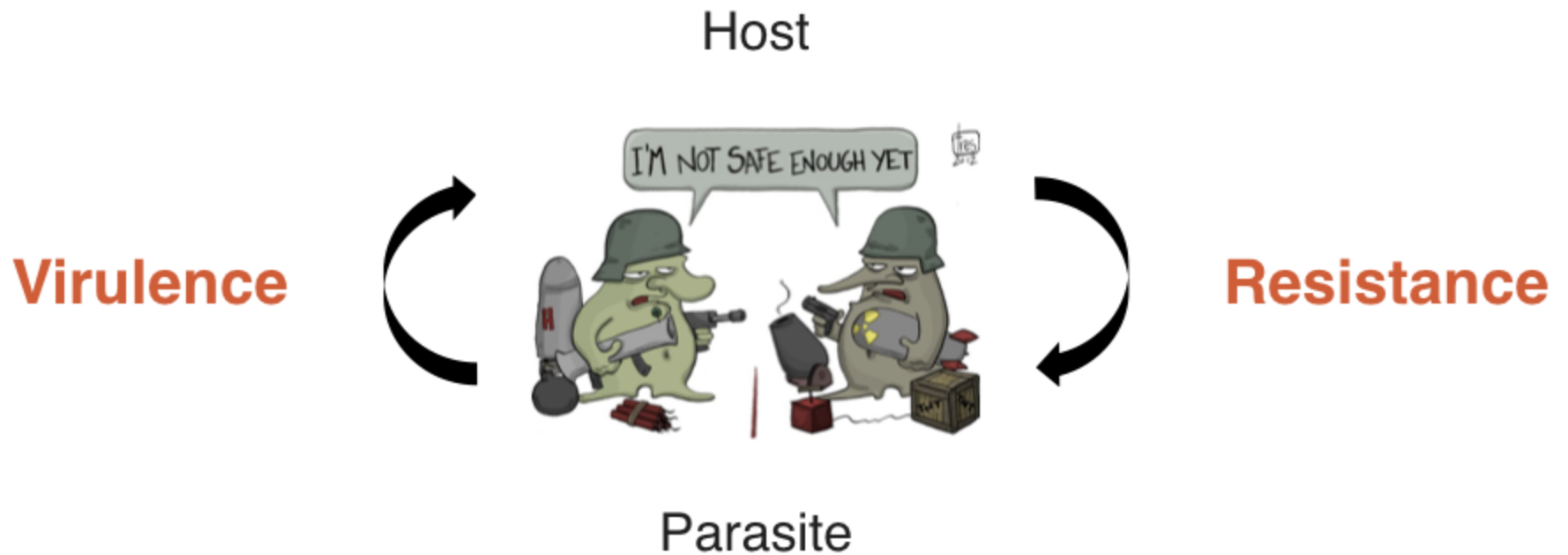


# Host-Parasite interactions



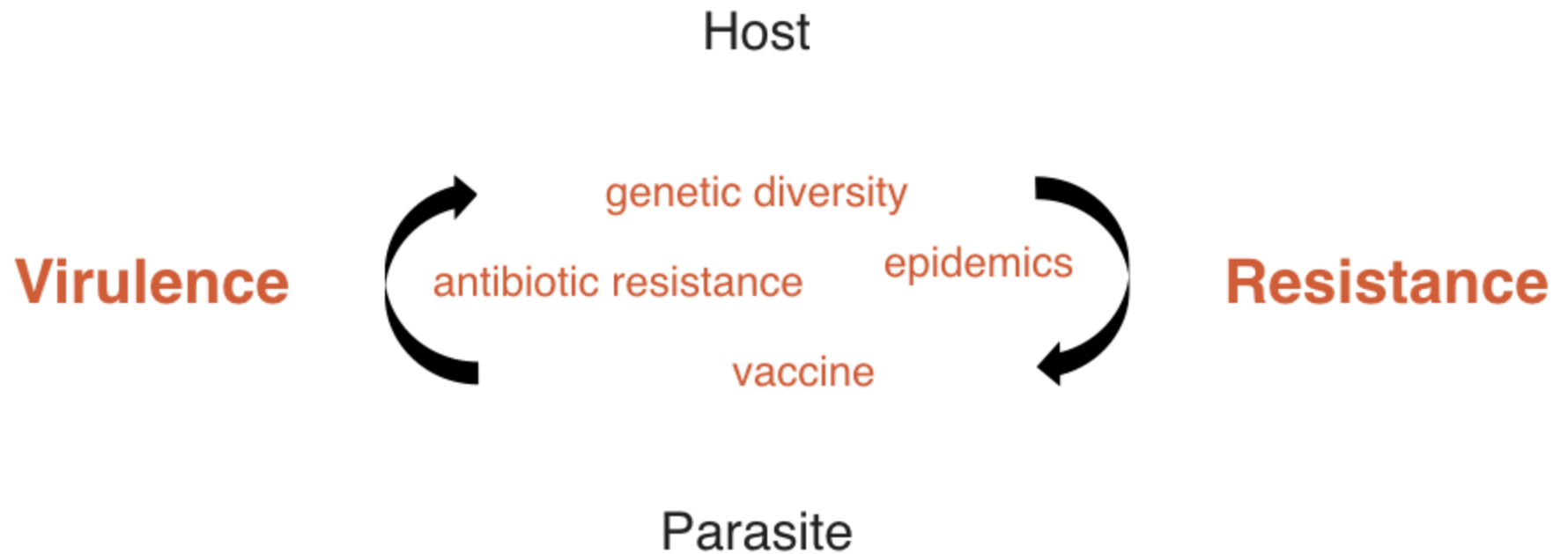


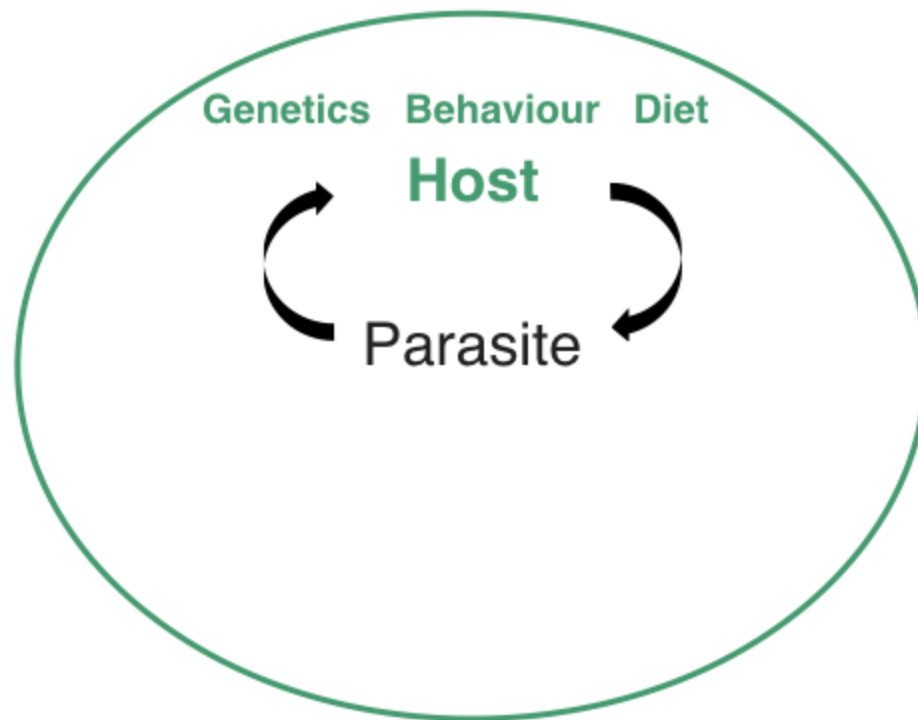
# Host-Parasite interactions

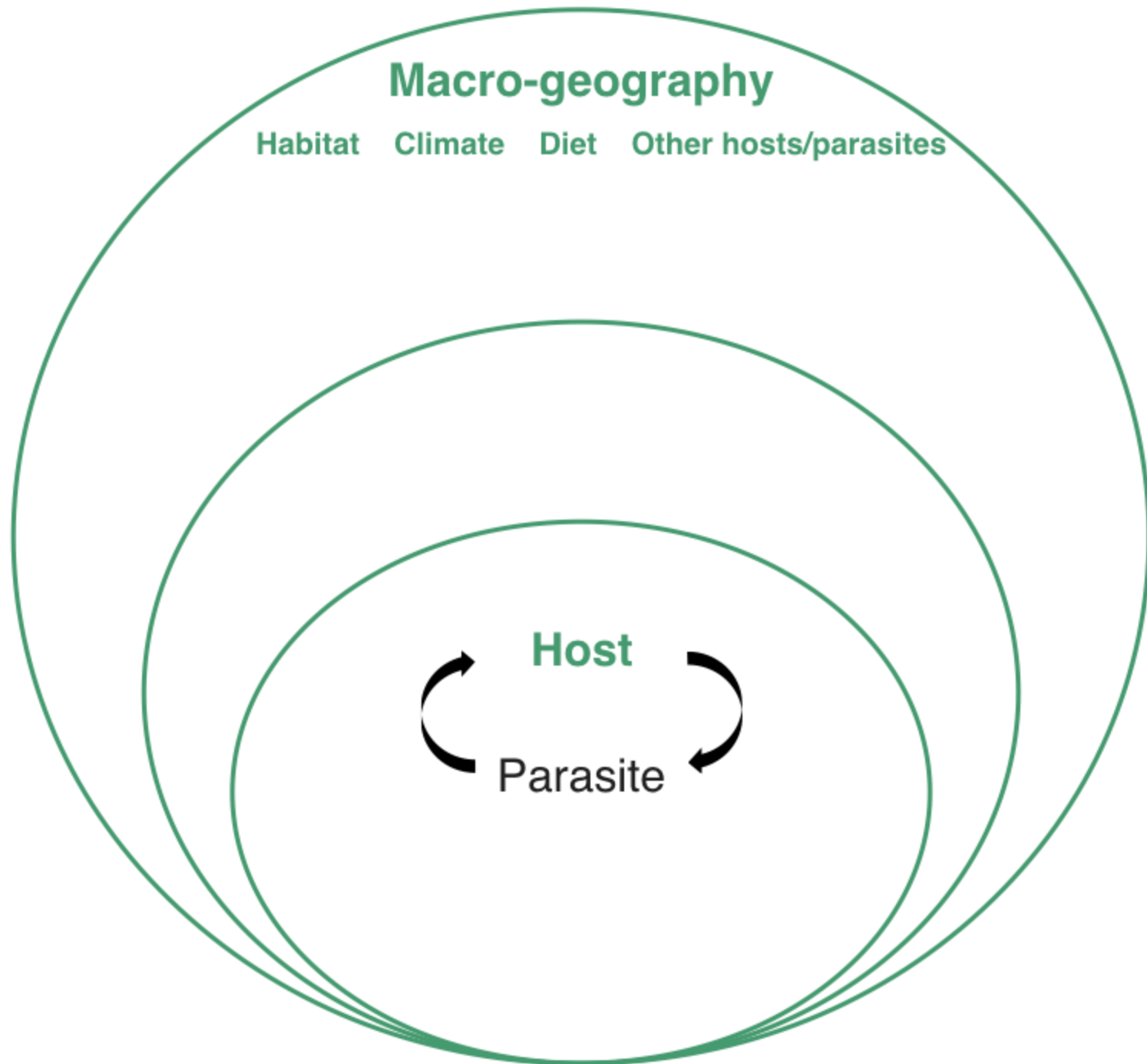


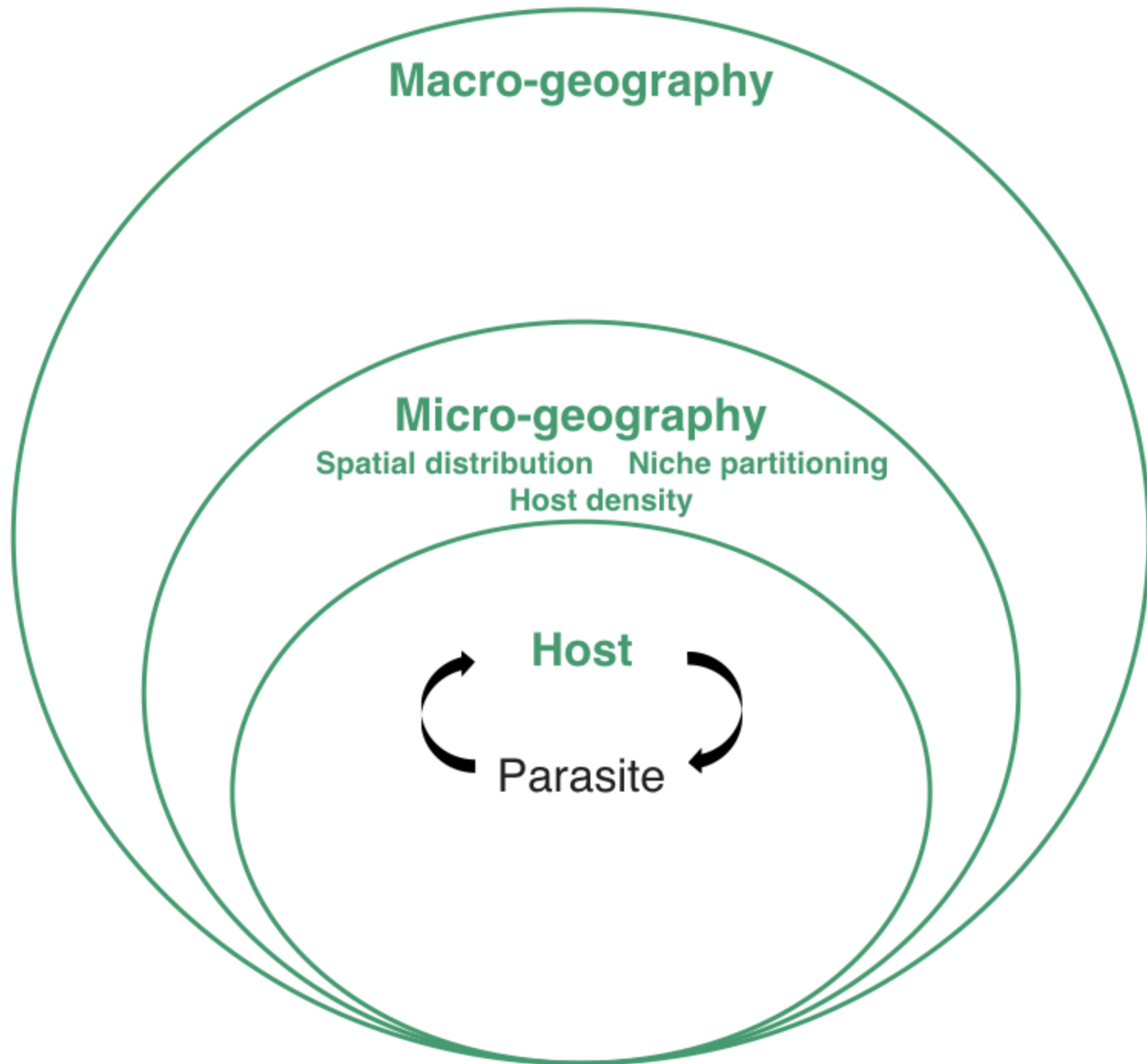
Coevolutionary arms race

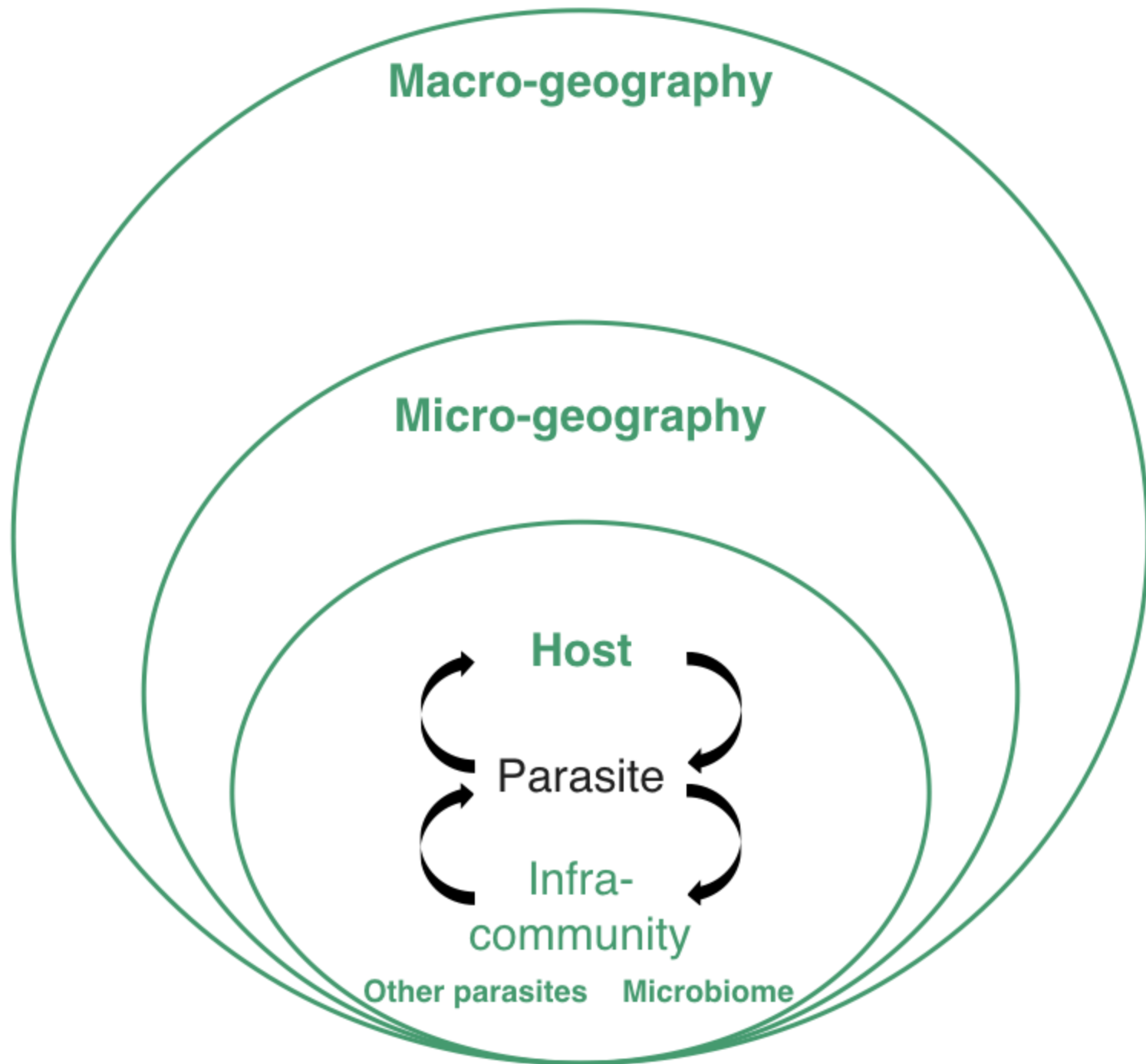
# Host-Parasite interactions

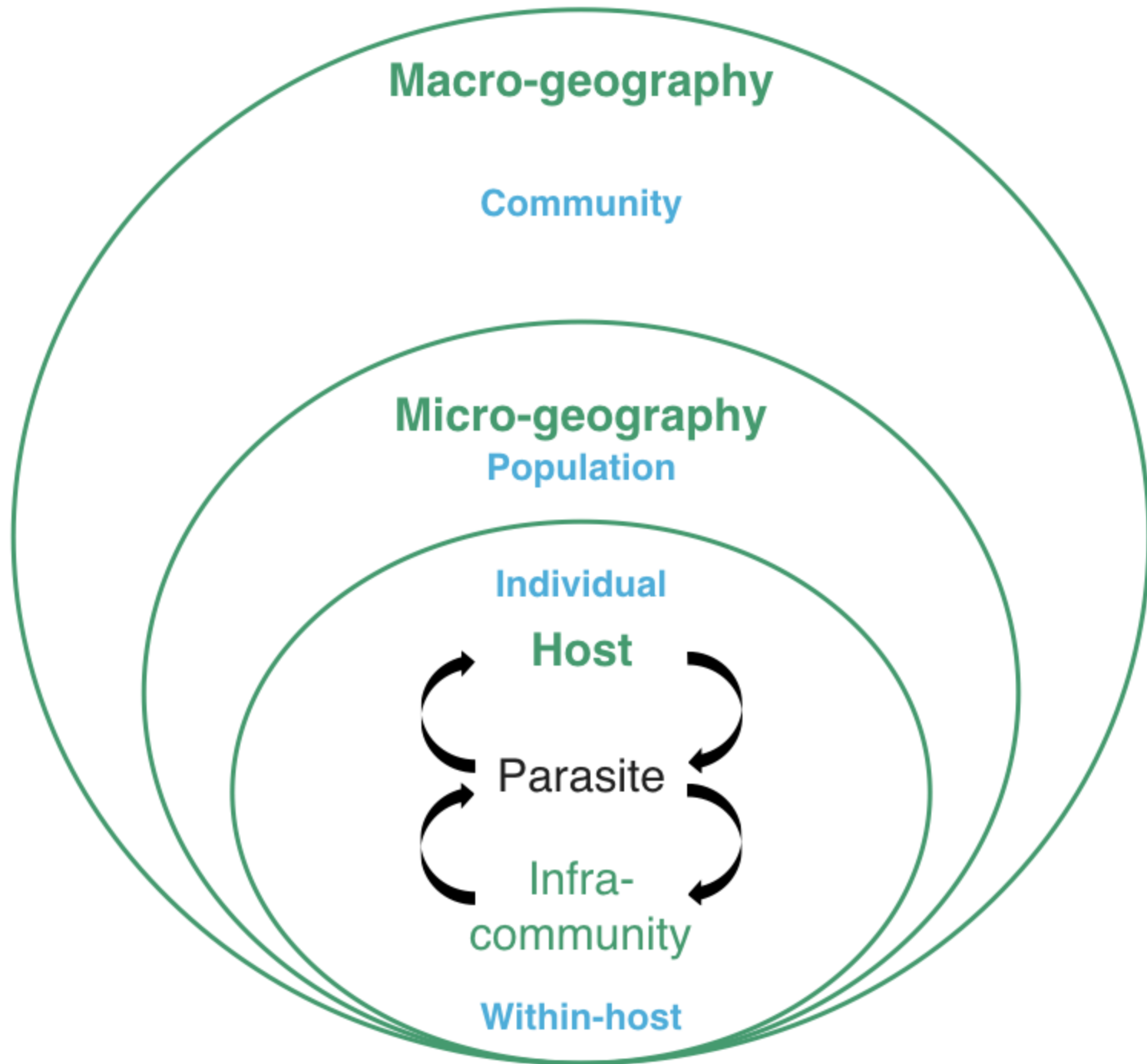


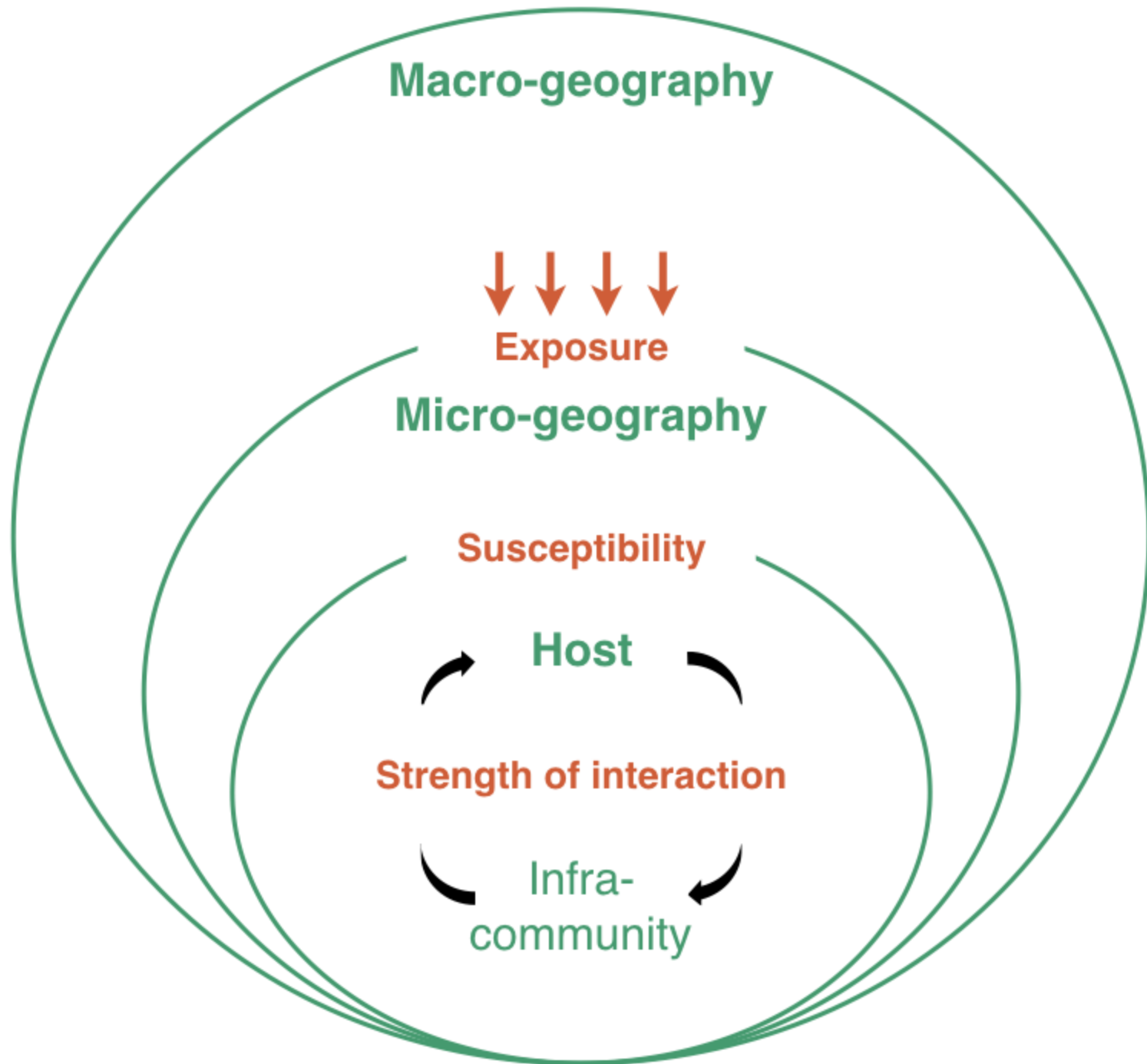












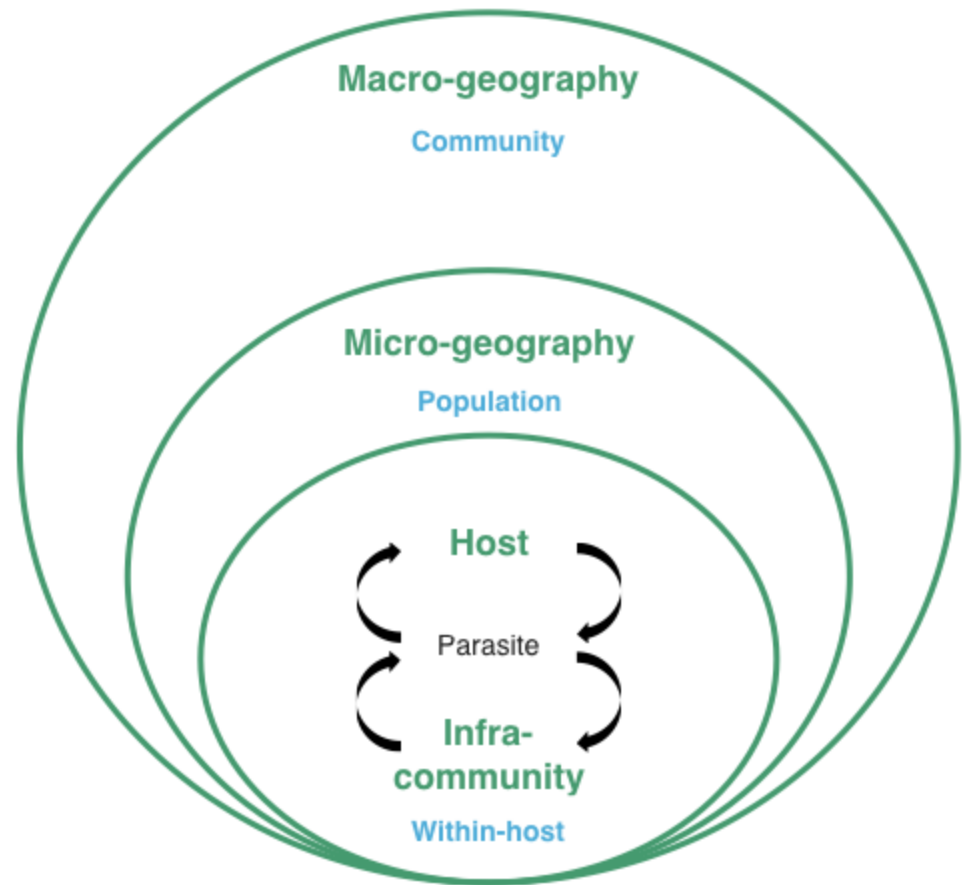


# Host-Parasite interactions

## 1/ Community & populations

## 2/ Populations

## 3/ Within-host



# Host-Parasite interactions

## 1/ Community & populations



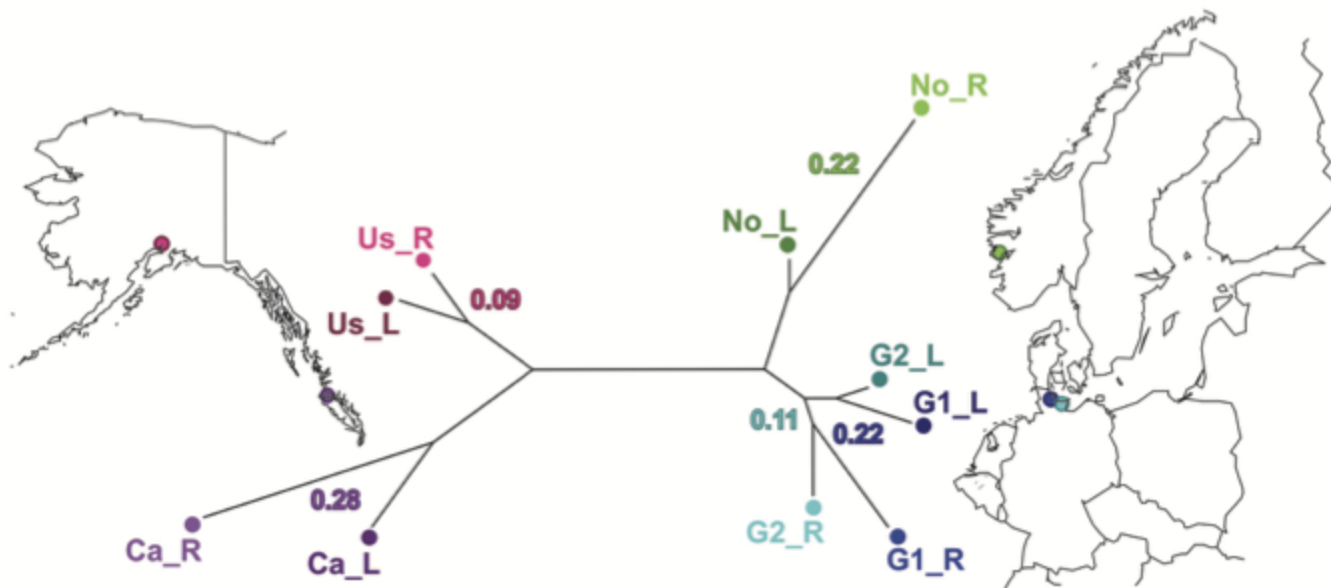
Parasite-mediated divergence

## 2/ Populations

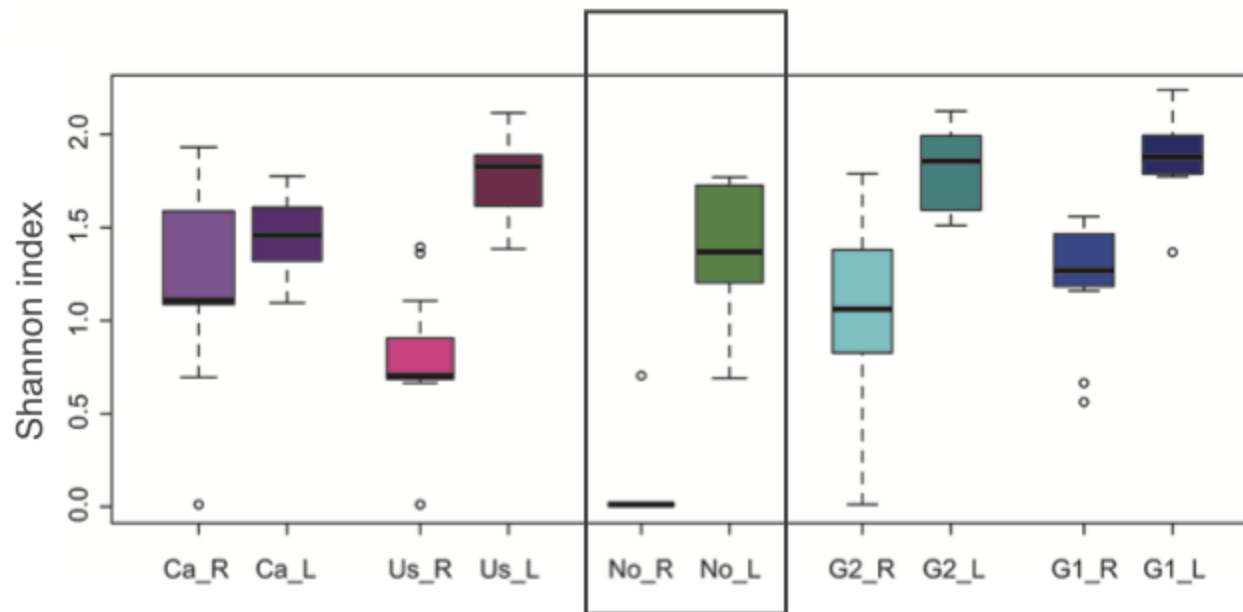
## 3/ Within-host

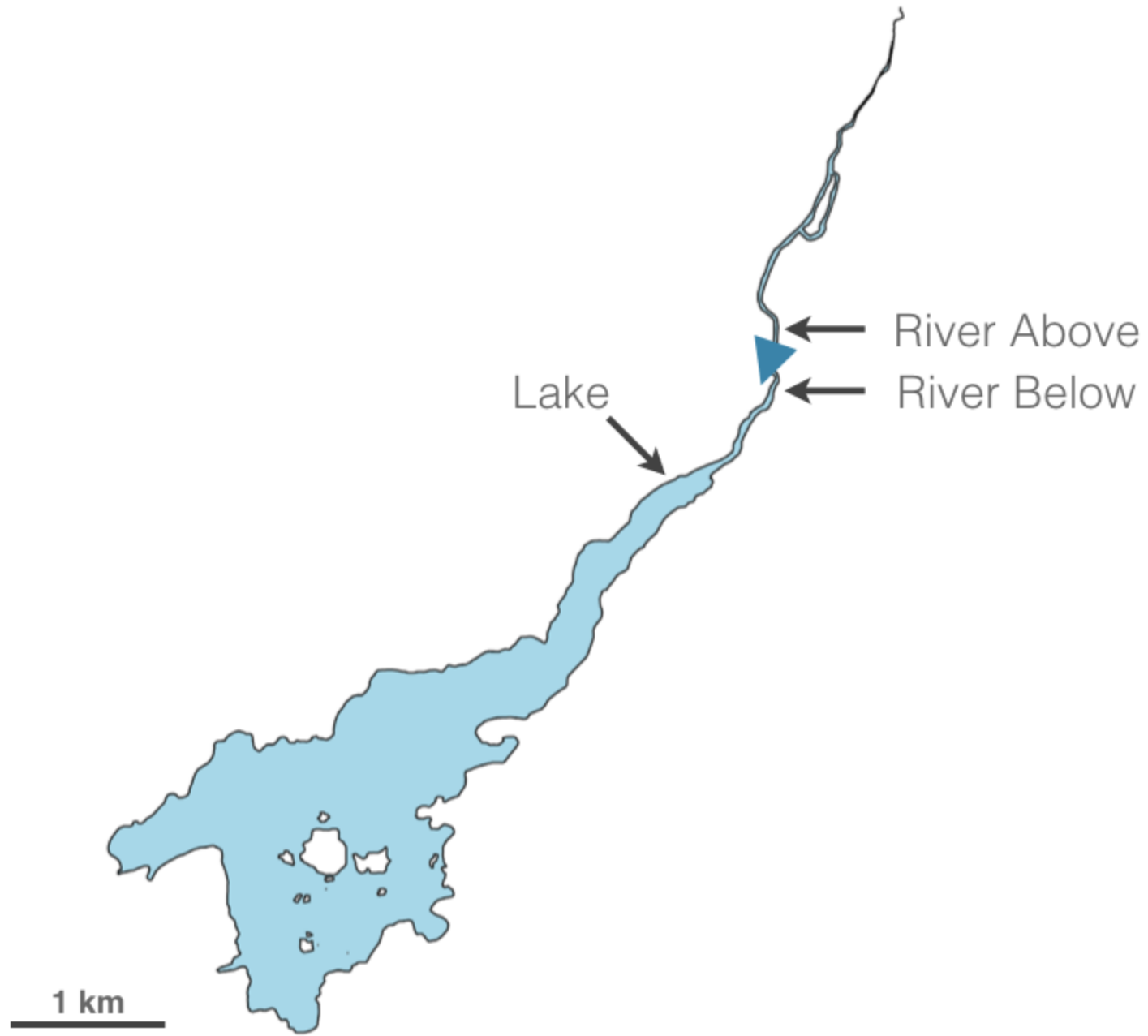
# Three-spined stickleback

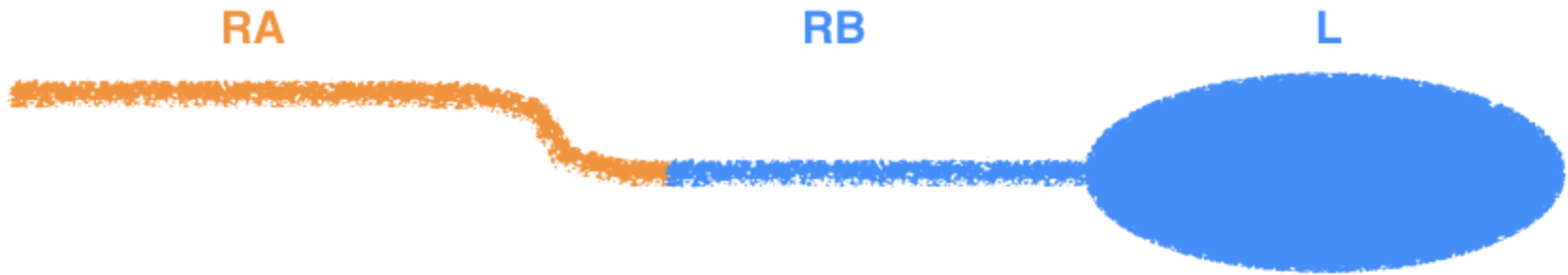




**Norwegian populations**







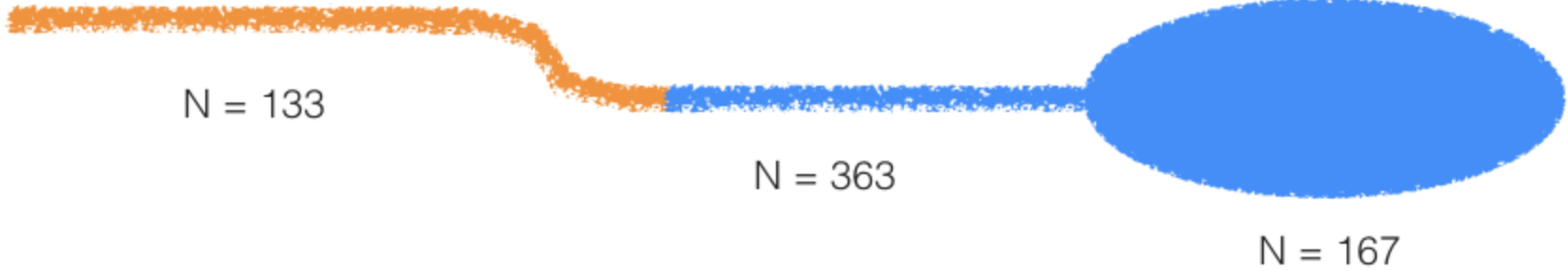
4 years field survey:

- Host population genetic structure
- Parasite communities

RA

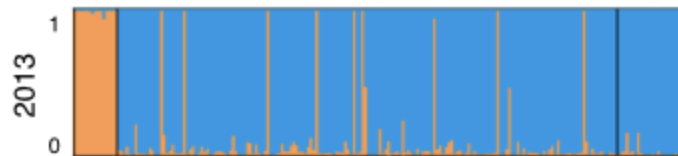
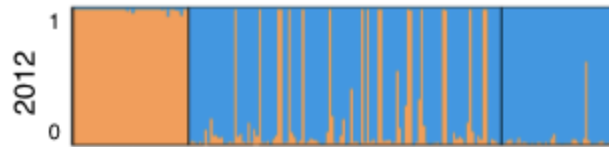
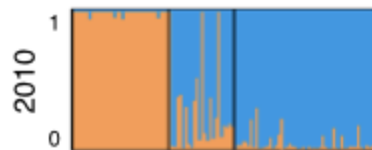
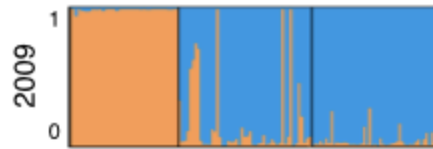
RB

L

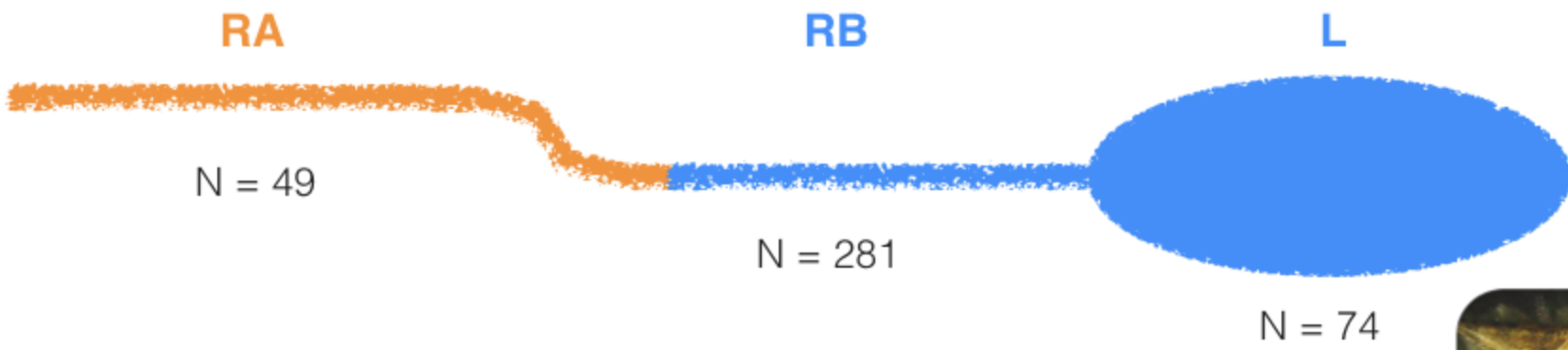


8 microsatellites  
K = 2

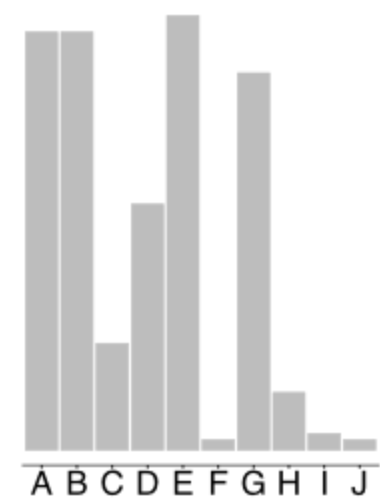
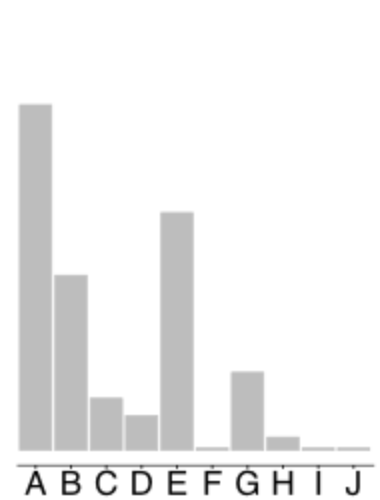
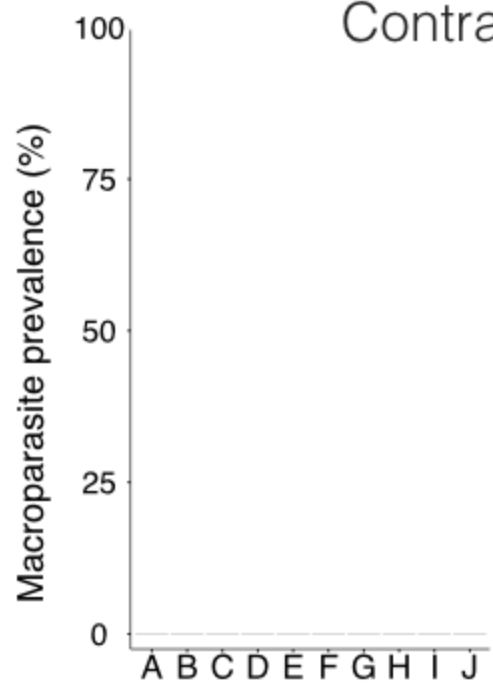
10% migrants (N = 34)  
4% admixed (N = 16)



Population genetic structure



Contrasting macroparasite communities



Macroparasite species

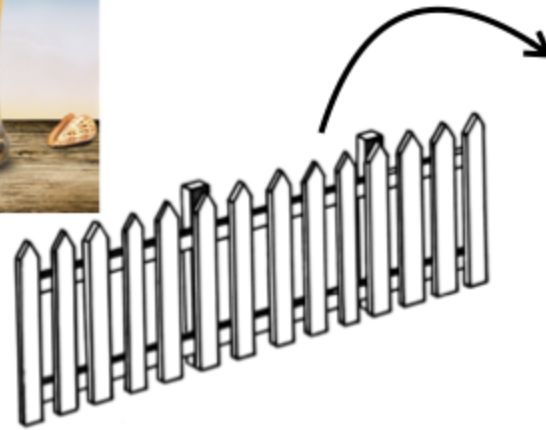
- 4 Cestode species
- 4 Trematode species
- 2 Nematode species



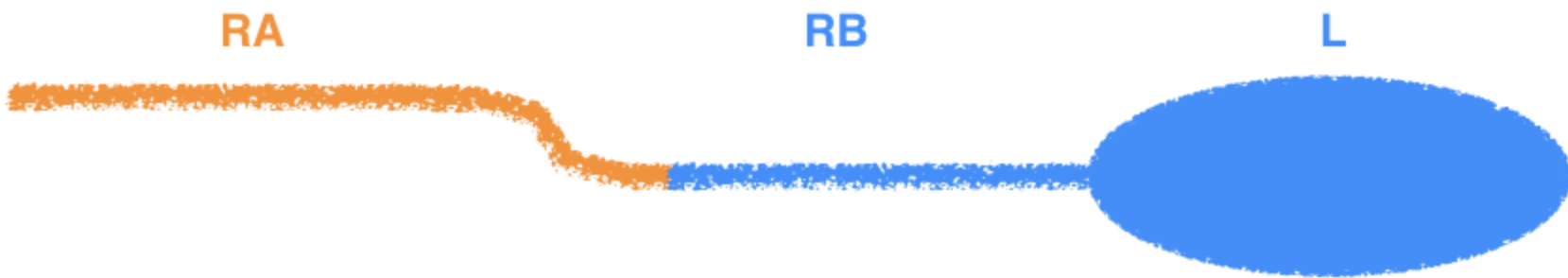
RA

RB

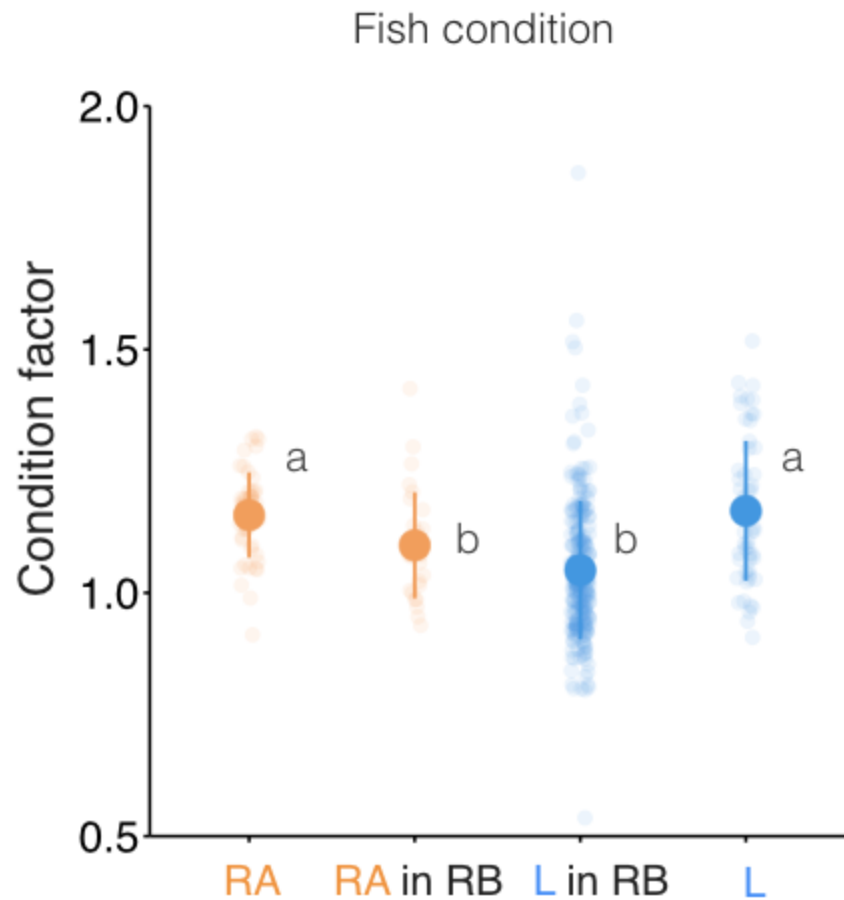
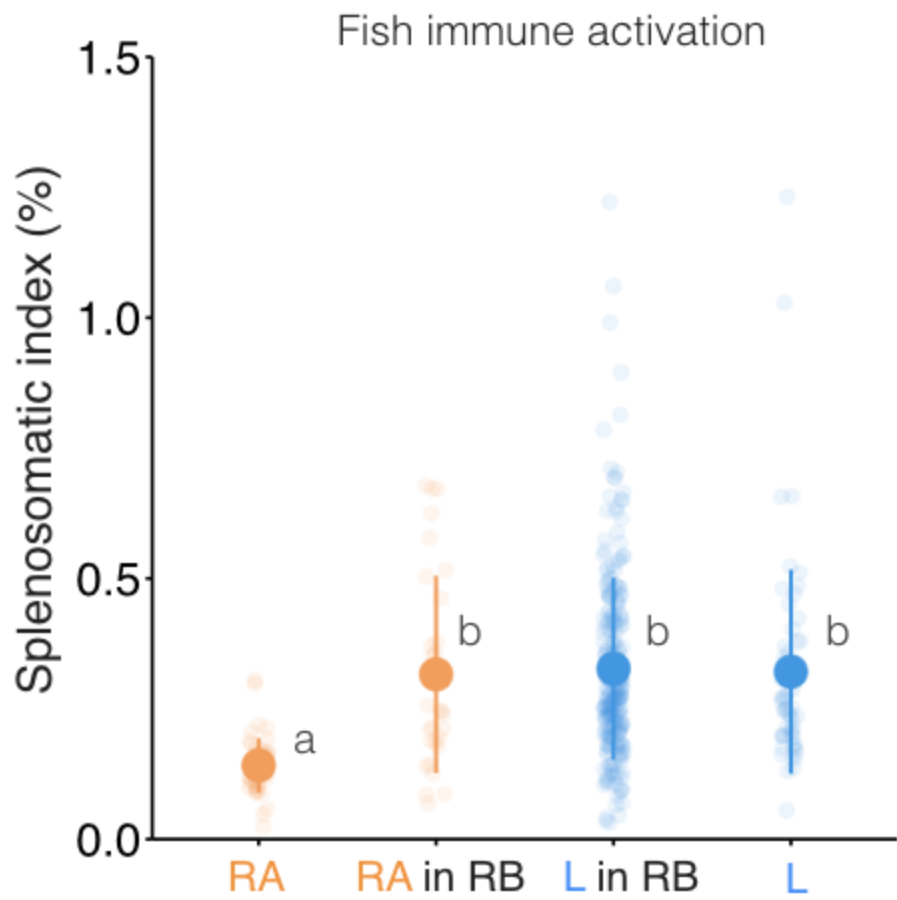
L



Parasite community



Immune cost too high for migrants?



# Experimental exposure to assess parasite resistance

RA

vs.

L

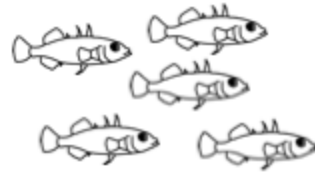


Wild caught fish

Lab-bred fish families



x



**RA**

N = 5

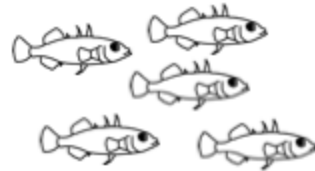
**Lake**

N = 5

**Hybrids**


N = 2x4

# Lab-bred fish families

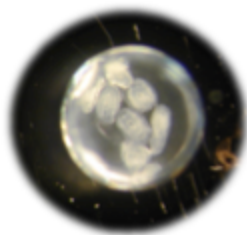


*Eye fluke*  
(Generalist parasite)



100 x 

Parasite intensity



*Cestode*  
(Specific parasite)

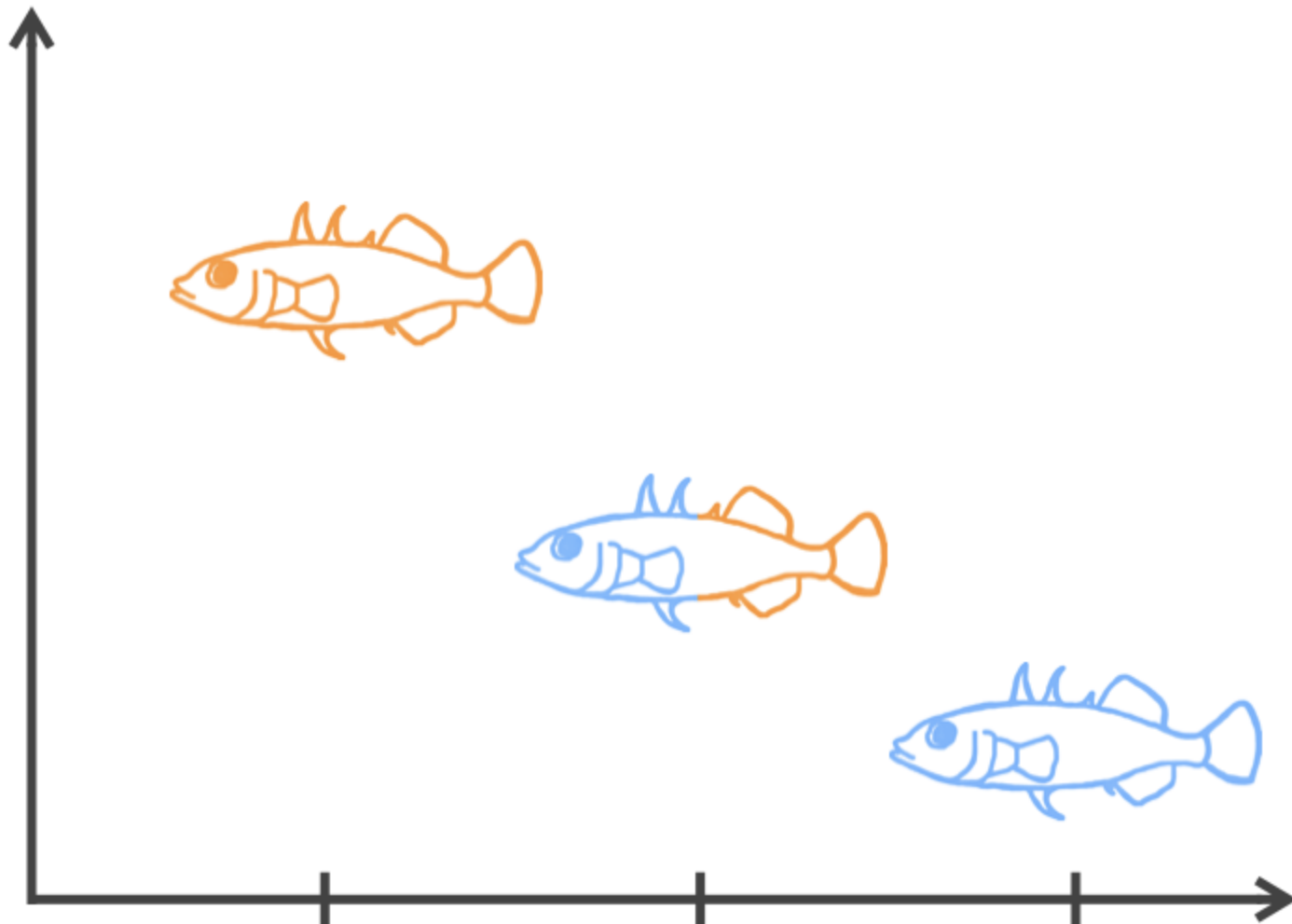


1 x 

$$\frac{\text{worm weight}}{\text{fish somatic weight}} = \text{Parasite index}$$



Infection rate  
Parasite intensity  
Parasite index

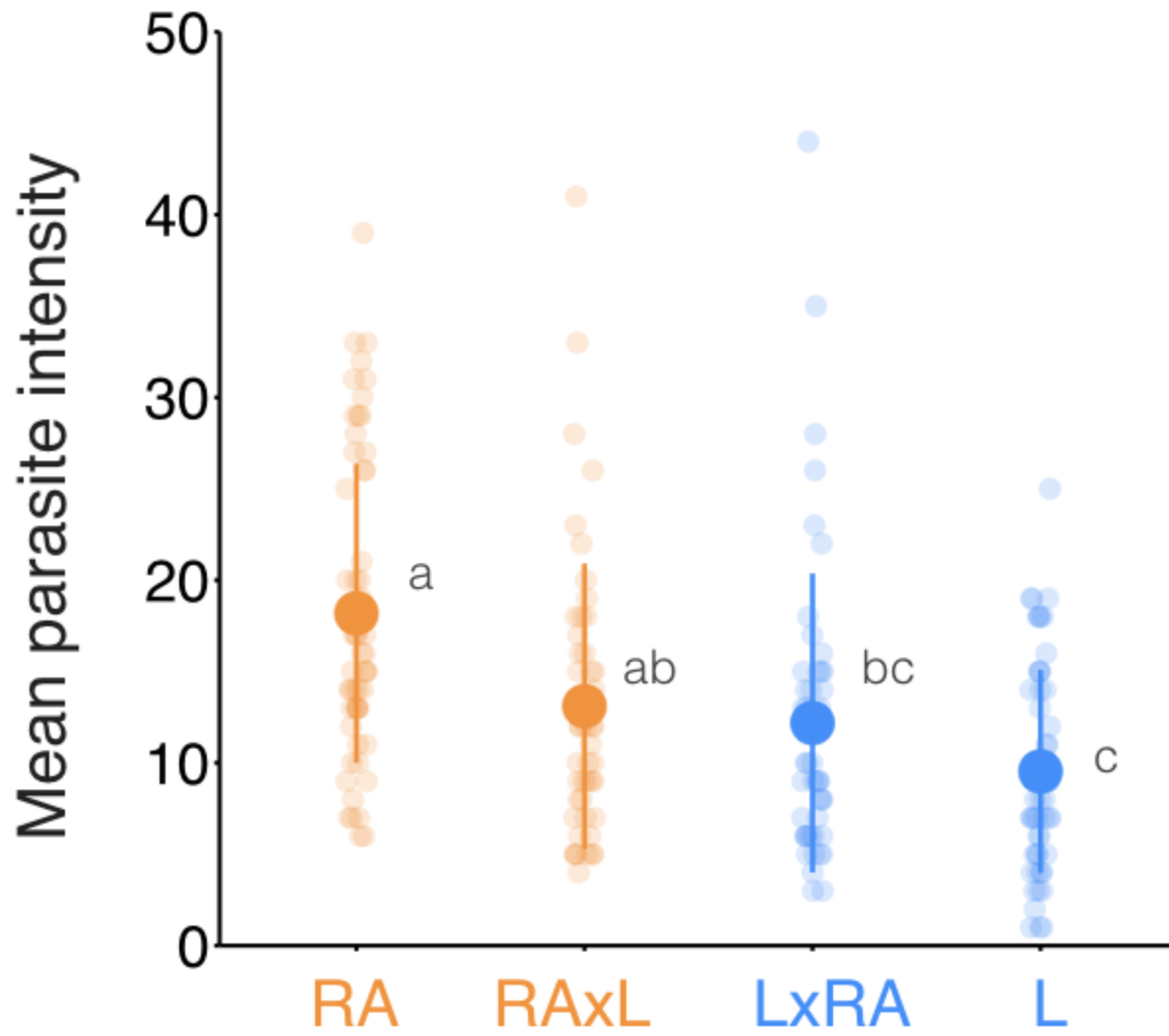


RA

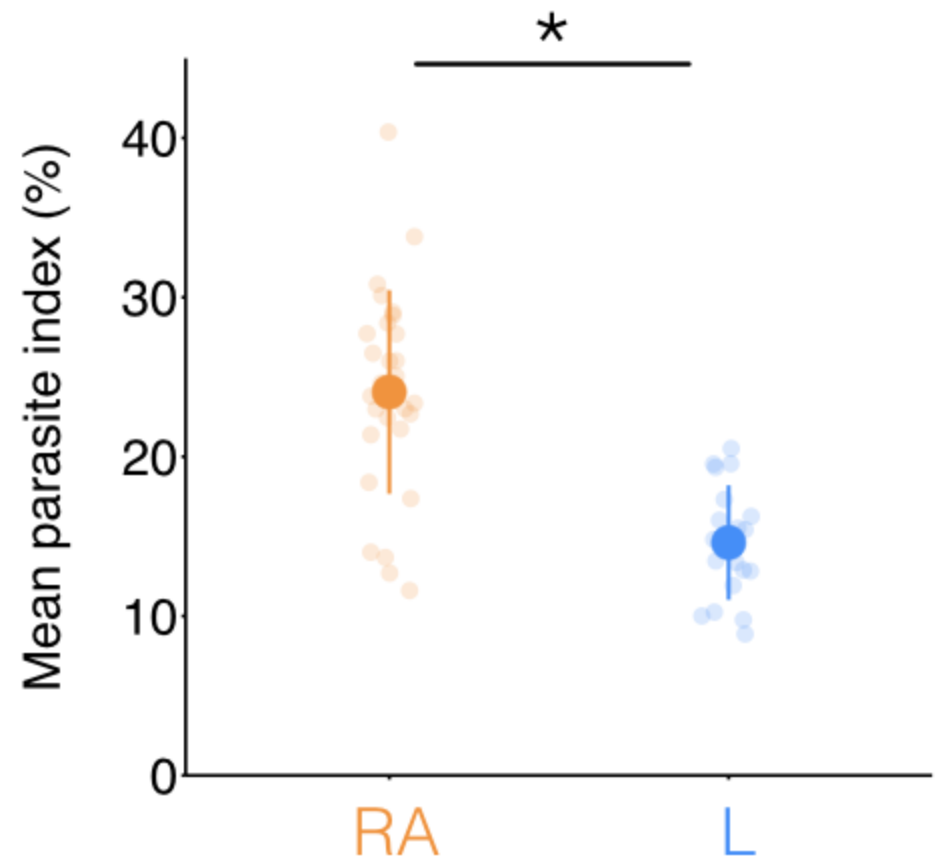
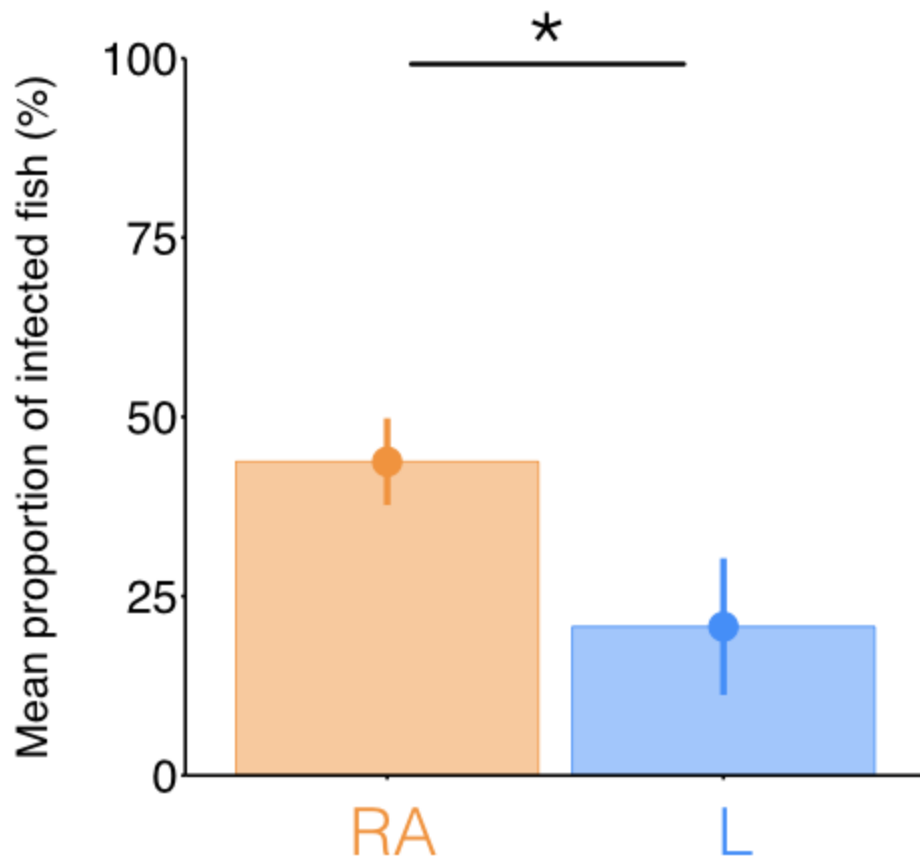
Hybrid

L

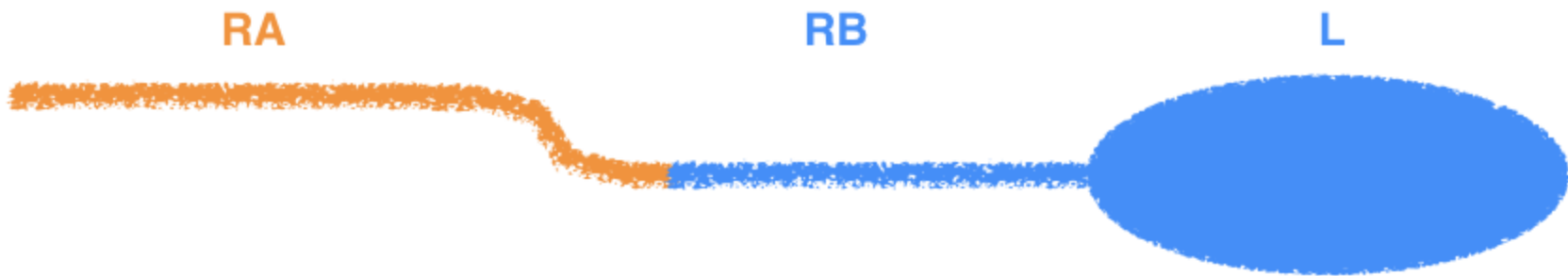
*Eye fluke*



*Cestode*

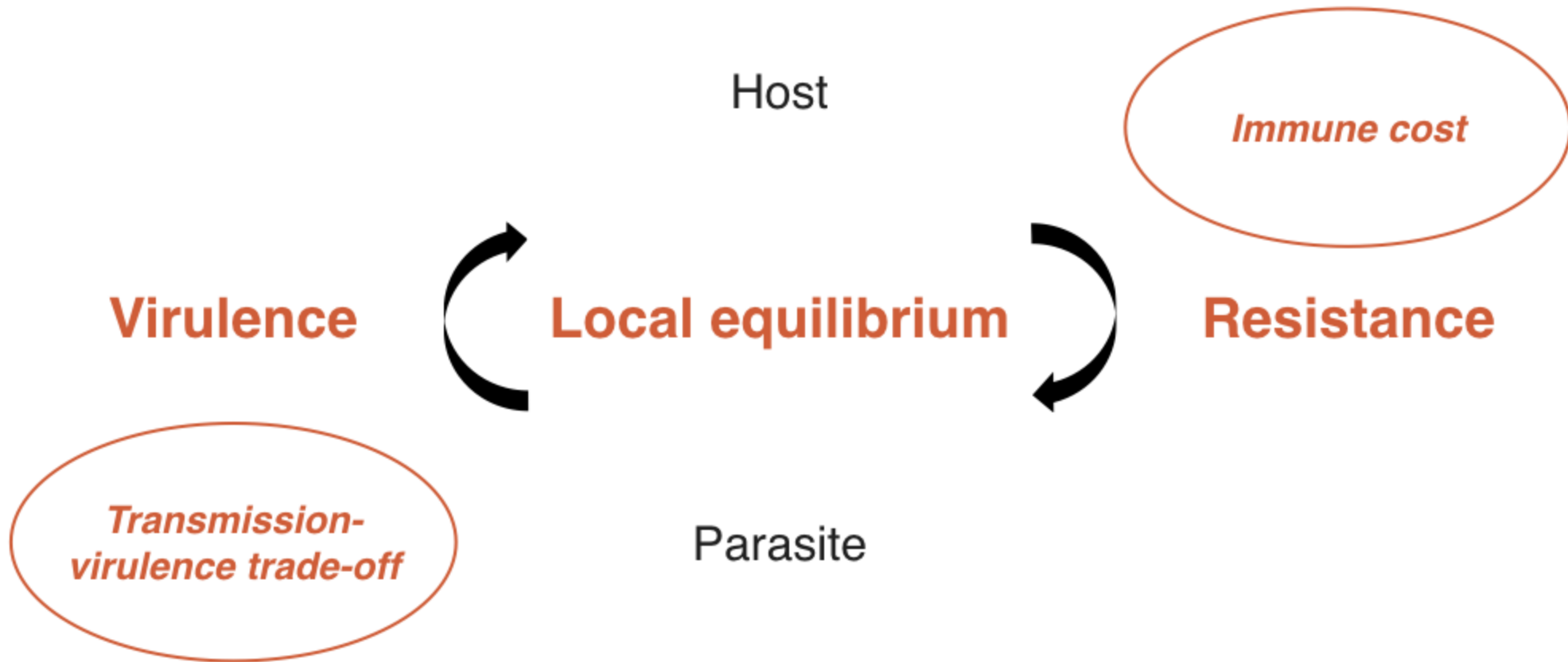






Parasite community

# Host-Parasite interactions



# Host-Parasite interactions

## 1/ Community & populations



Parasite-mediated divergence

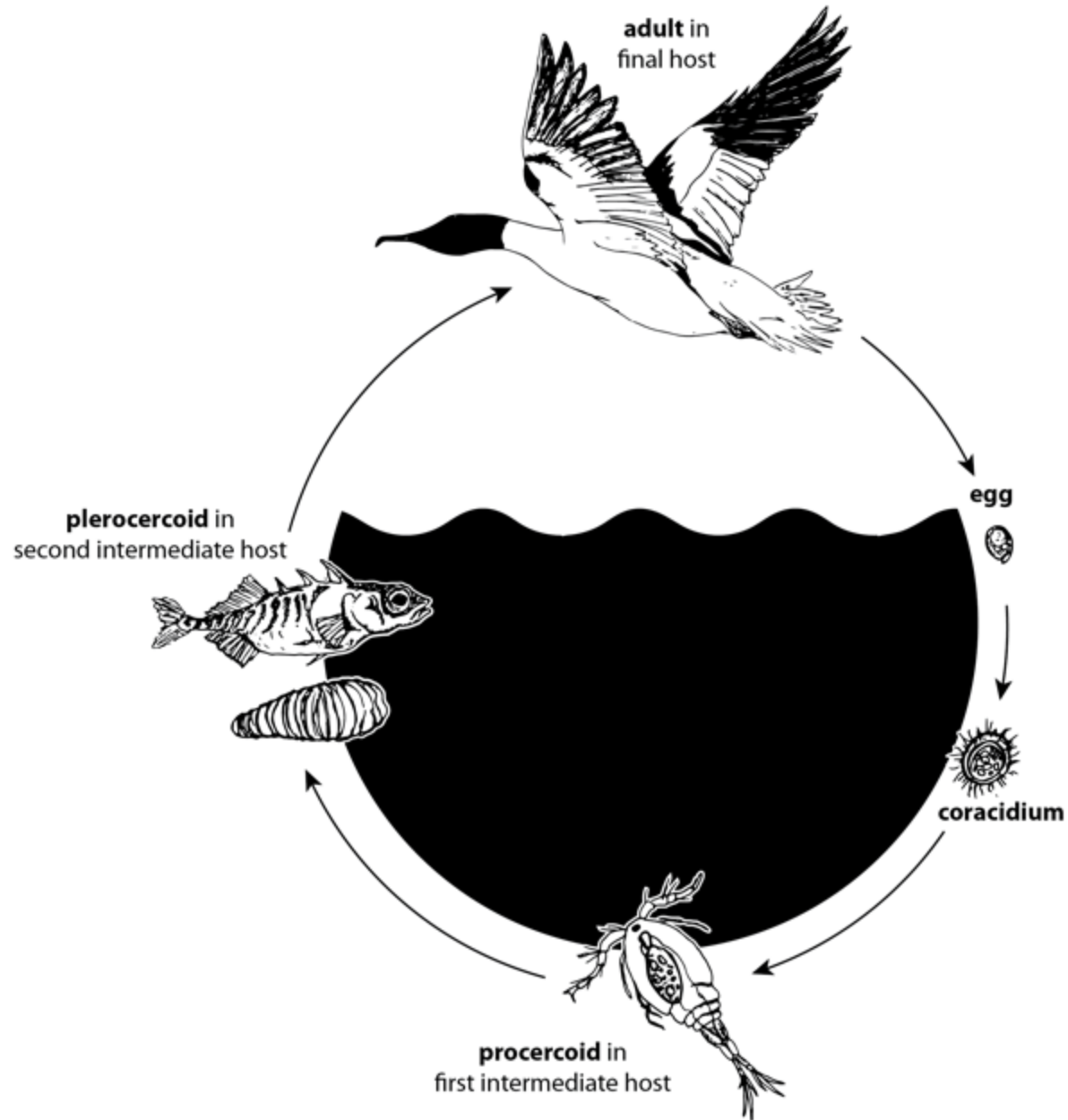
## 2/ Populations



Local adaptation

## 3/ Within-host

# *Schistocephalus solidus*



# *Schistocephalus solidus*



# *Schistocephalus solidus*

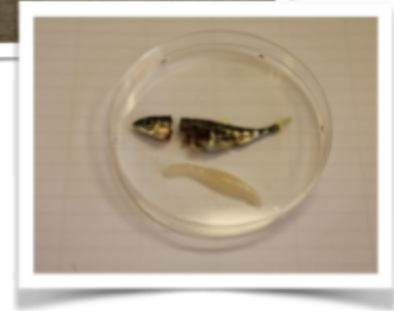
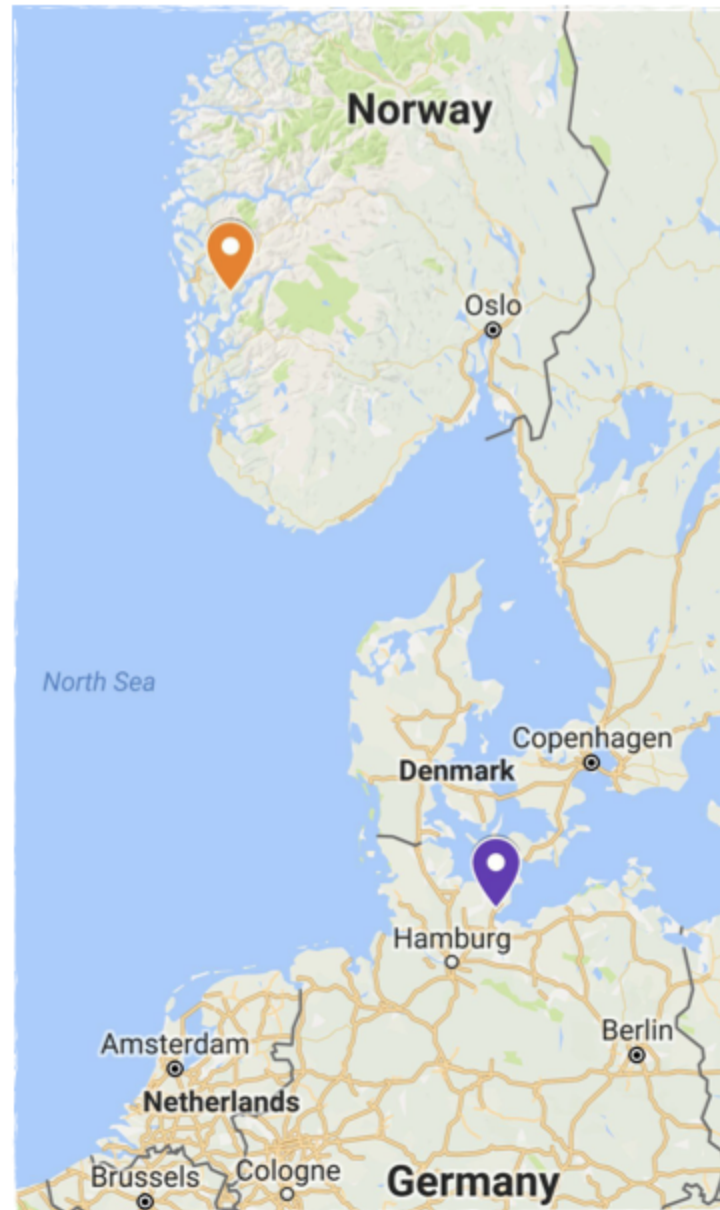
$$\text{Parasite index} = \frac{\text{worm weight}}{\text{fish somatic weight}}$$



Lake (NO) 

60%

Strong selection



Estuary (DE)

< 1%

Relaxed selection

Parasite DE

Parasite NO



Host DE



Host NO





	Parasite DE	Parasite NO
Host DE 	Sympatric	Allopatric
Host NO 	Allopatric	Sympatric

Parasite DE

Parasite NO

Host DE



Sympatric

Allopatric

Host NO



Allopatric

Sympatric

T0  
exposure

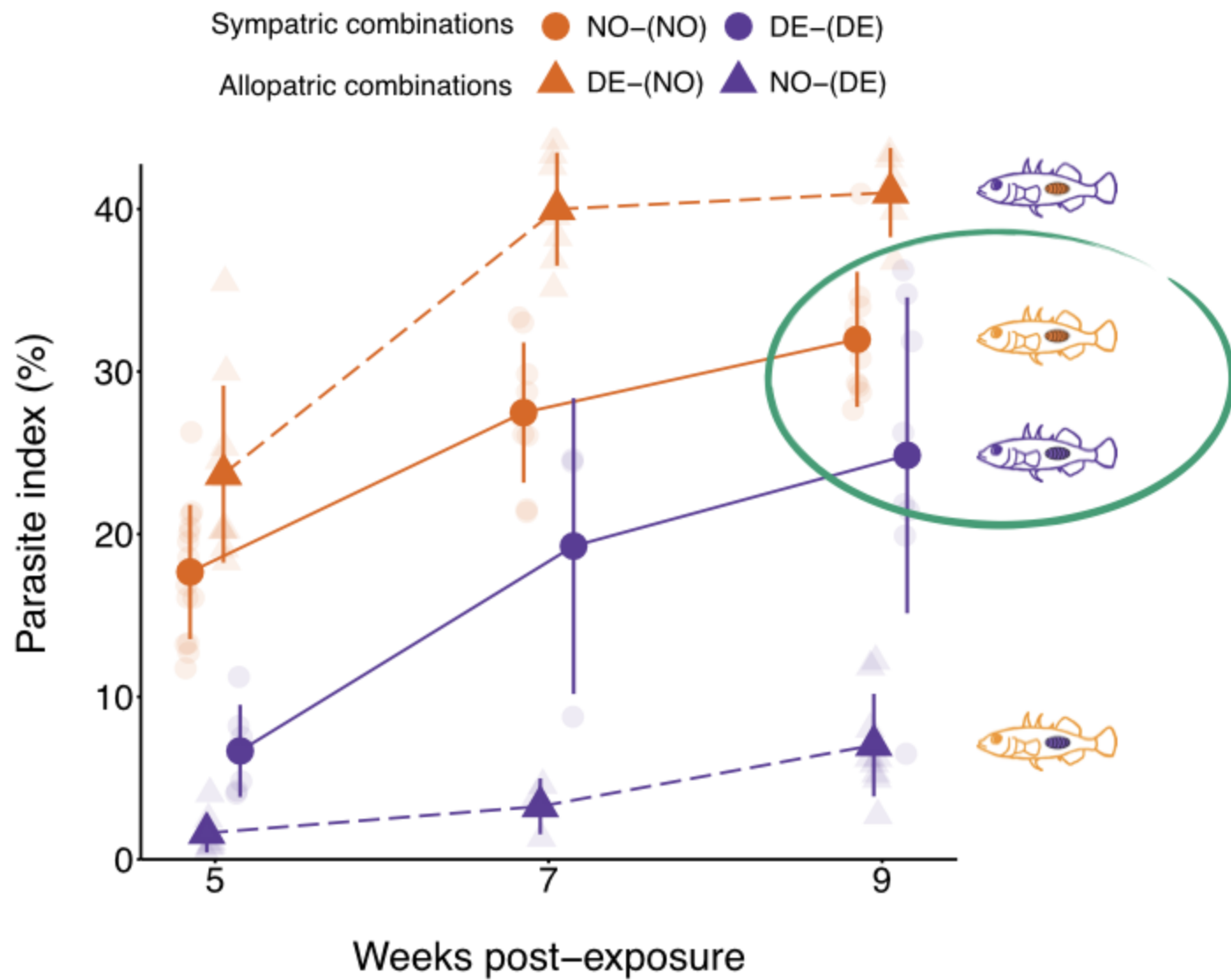






T1  
5 weeks

T2  
7 weeks

T3  
9 weeks





	Parasite DE	Parasite NO
Host DE	Optimal 	Over-exploitation 
Host NO	Under-exploitation 	Optimal 

Parasite DE

Parasite NO

Host DE

Optimal

Over-exploitation



Host NO

Under-exploitation

Optimal



# Host-Parasite interactions

## 1/ Community & populations



Parasite-mediated divergence

## 2/ Populations



Local adaptation

## 3/ Within-host



Virulence expression



Within-host competition influence virulence expression?



**High virulence (Hv)**  
Norwegian worm

vs.



**Low virulence (Lv)**  
German worm





Total parasite Index tPI = proxy for virulence

Discrete parasite index dPI = proxy for individual virulence



**High virulence (Hv)**  
Norwegian worm

vs.



**Low virulence (Lv)**  
German worm





Hv



Lv

Single infection

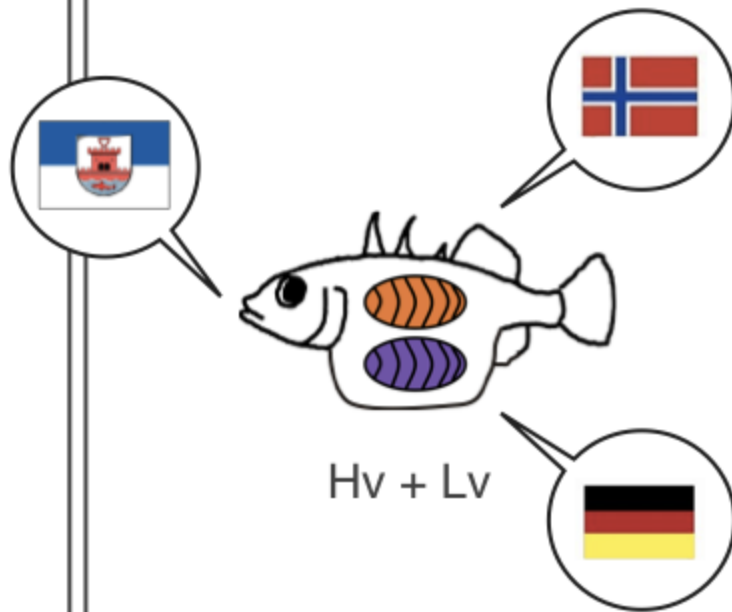


Hv + Hv



Lv + Lv

Double homologous infection

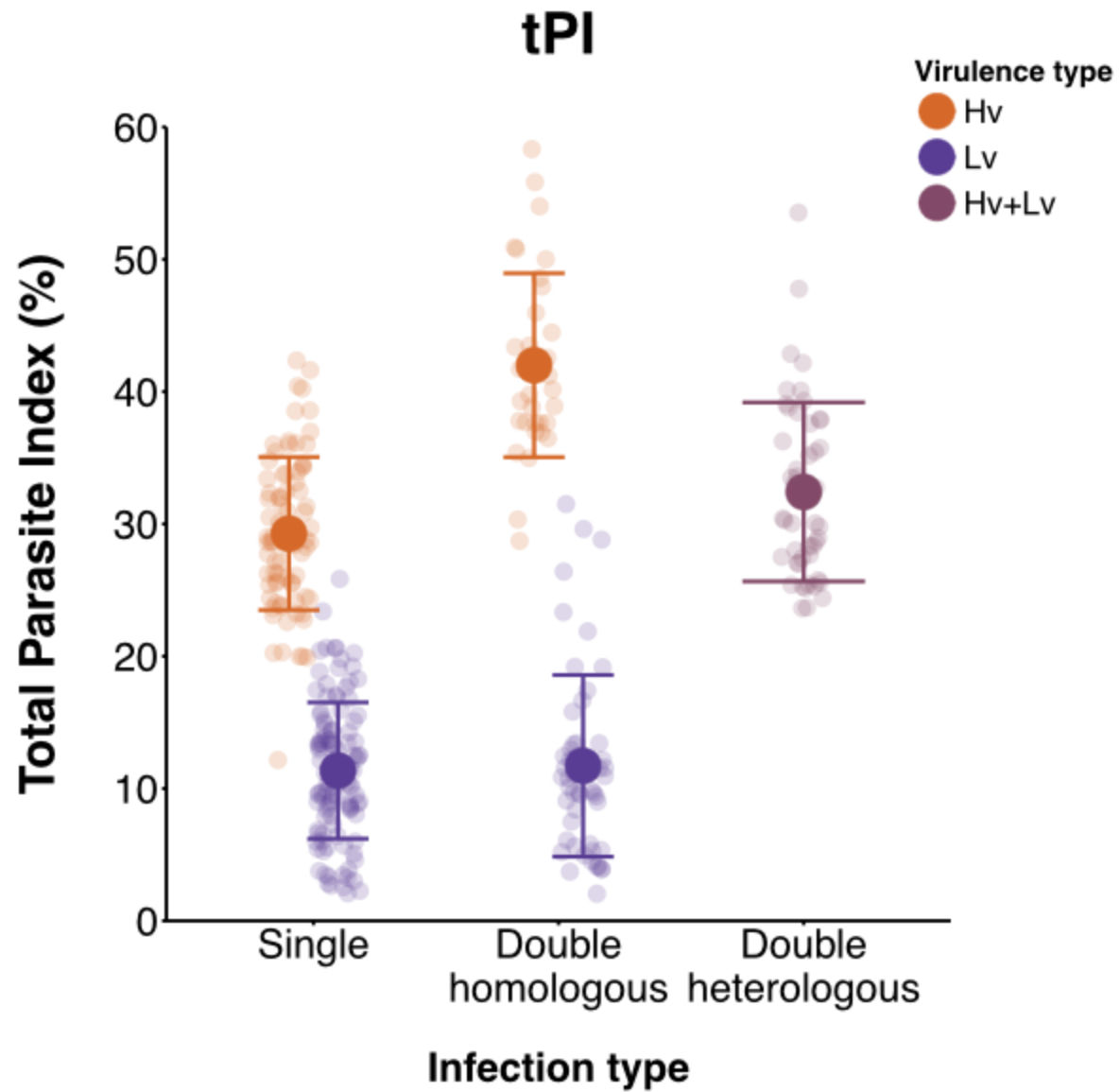


Hv + Lv

Double heterologous infection

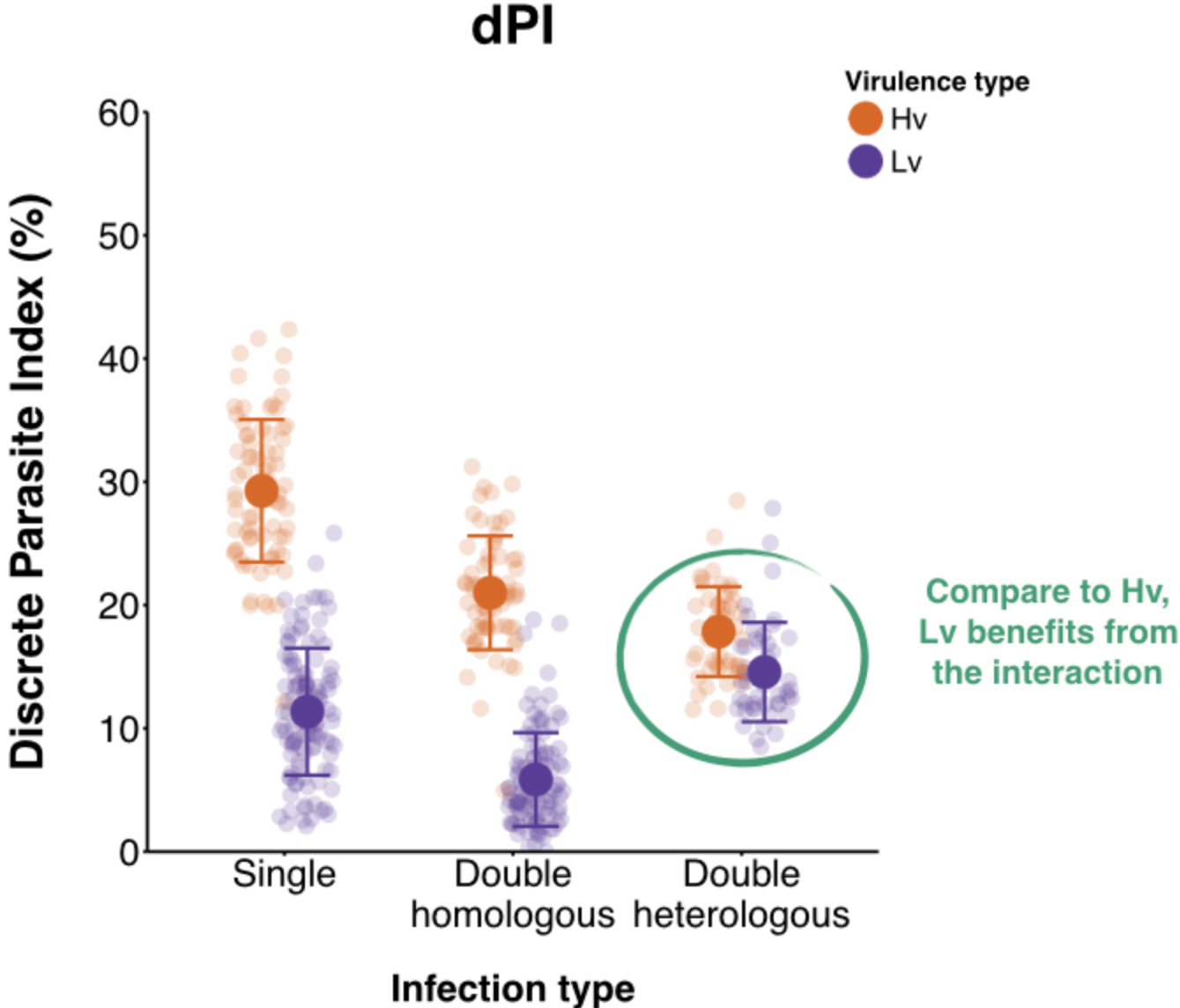
# Total Parasite Index

( $F_{4,321} = 354.502, p < 0.0001$ )



# Discrete Parasite Index

( $F_{5,453} = 325.807, p < 0.0001$ )





Host = pool of resources



Goods

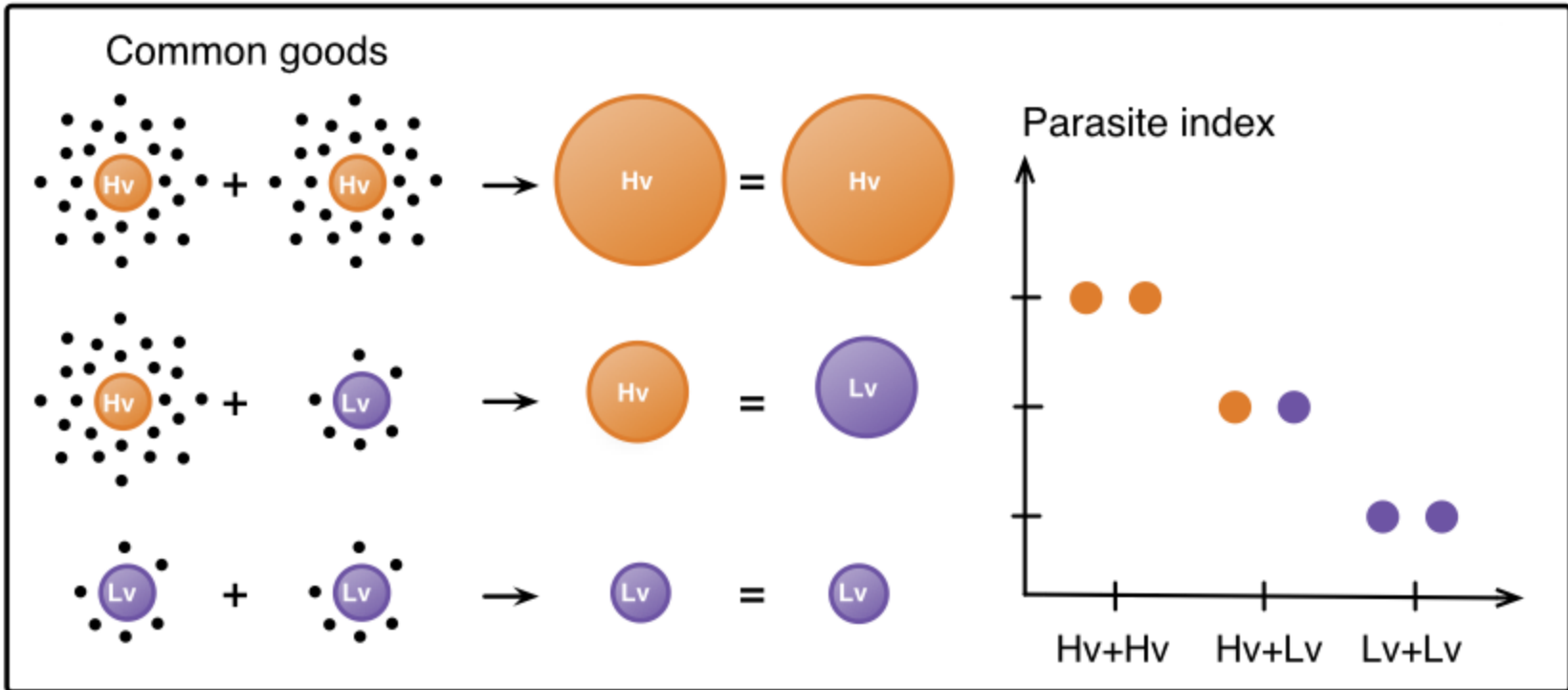
Common goods

*Rivalrous & non-excludable*



Nutrients

# Virulence Model





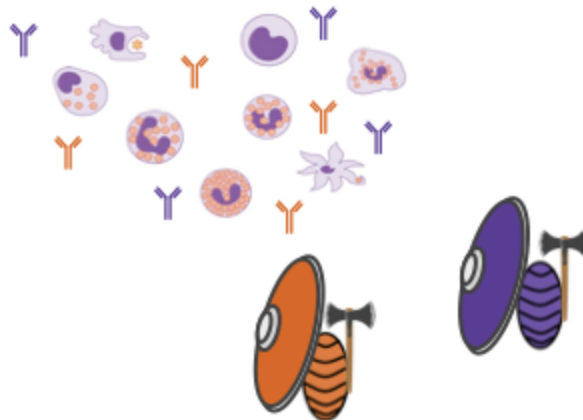
Host = pool of resources



Goods

Strain-specific goods

*Rivalrous & excludable*





Host = pool of resources



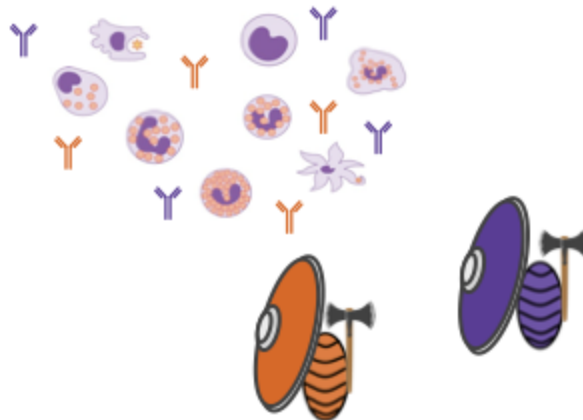
Goods

Secretory/excretory products:  
interfere with host immune response

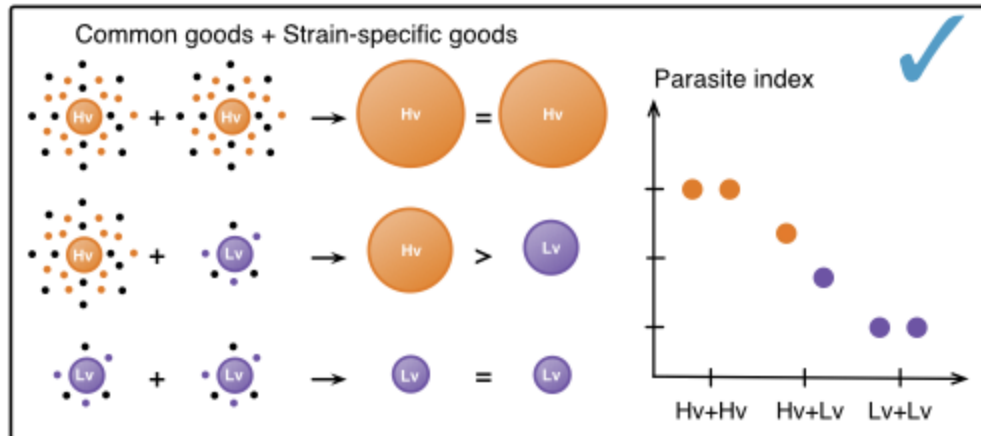
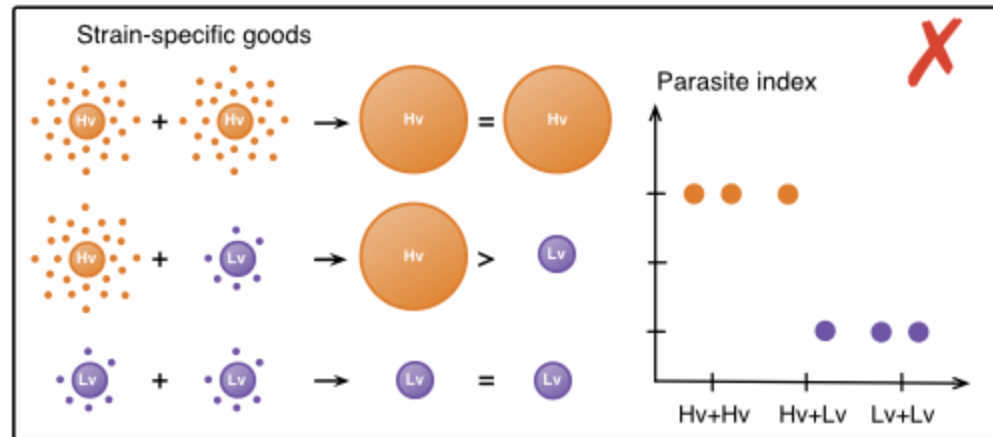
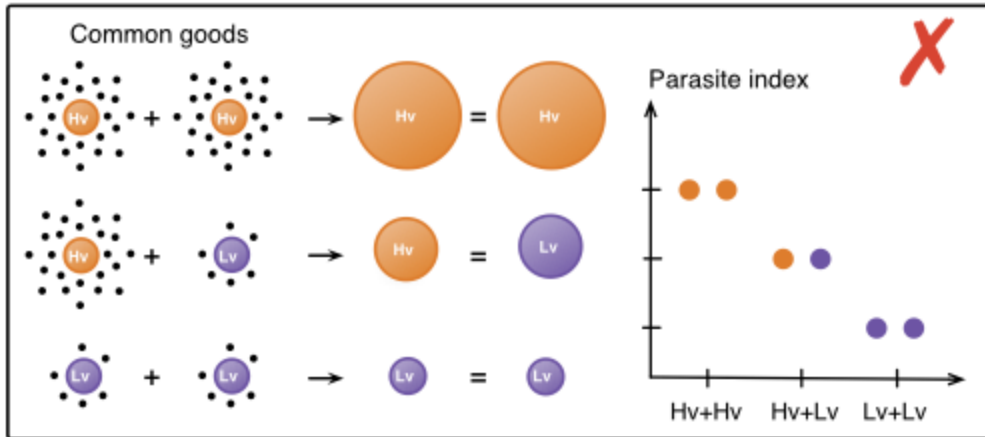
Scharsack *et al.* 2013 Fish & Shellfish Immunol  
Franke *et al.* 2014 Fish & Shellfish Immunol

Strain-specific goods

*Rivalrous & excludable*



# Virulence Model





# Host-Parasite interactions

## 1/ Community & populations



*Divergence in parasite exposure risk & immune cost can shape host immunocompetence*

## 2/ Populations



*Different co-evolutionary histories lead to local adaptation towards a similar relative resistance-virulence optimum*

## 3/ Within-host



Intra-specific competition in co-infection can affect expression of virulence

# Acknowledgements

## Supervision

Martin Kalbe

## Direction

Manfred Milinski

## Co-authors

*Max Planck for Evolutionary Biology, Plön, Germany*

Tina Henrich

Luke Phelps

Irene E. Samonte

*Bergen University, Bergen, Norway*

Per J. Jakobsen

*University of Texas, Austin, USA*

Jesse Weber

Kum Chuan Shim

Natalie C. Steinel

Daniel I. Bolnick

## Funding

Deutsche Forschungsgemeinschaft - DFG priority programme 1399 "Host Parasite Coevolution"

Max Planck Institute for Evolutionary Biology - Department of Evolutionary Ecology

## Scientific support

Christophe Eizaguirre

Tobias Lenz

Demetra Andreou

Joshka Kaufmann

Kenyon Mobley

Lutz Becks

Leslie Turner

Marc Ritter

Jörn P. Scharsack

Dan Benesh

Mahesh Panchal

David Rogers

Jaroslav Bryk

Arne Nolte

Arne Traulsen

## Technical assistance

Kerstin Brzezek

Anja Hasselmeyer

Daniel Martens

Gerhard Augustin

Gisela Schmiedeskamp

Ines Schultz

Michael Schwarz

Nina Wildenhayn

Regina Leipnitz

Stephanie Bartel

Sybille Liedtke

Witthe Derner



Max Planck Institute for  
Evolutionary Biology

Department of Evolutionary Ecology  
Parasitology Group

