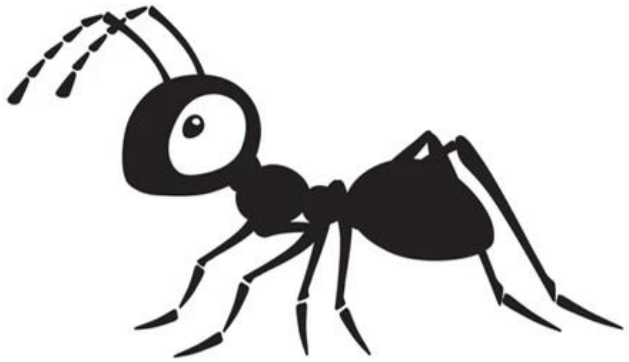


Brood sorting by ants

Ludi van Leeuwen
Corine Nijhof

Advanced Self-Organisation
of Social Systems

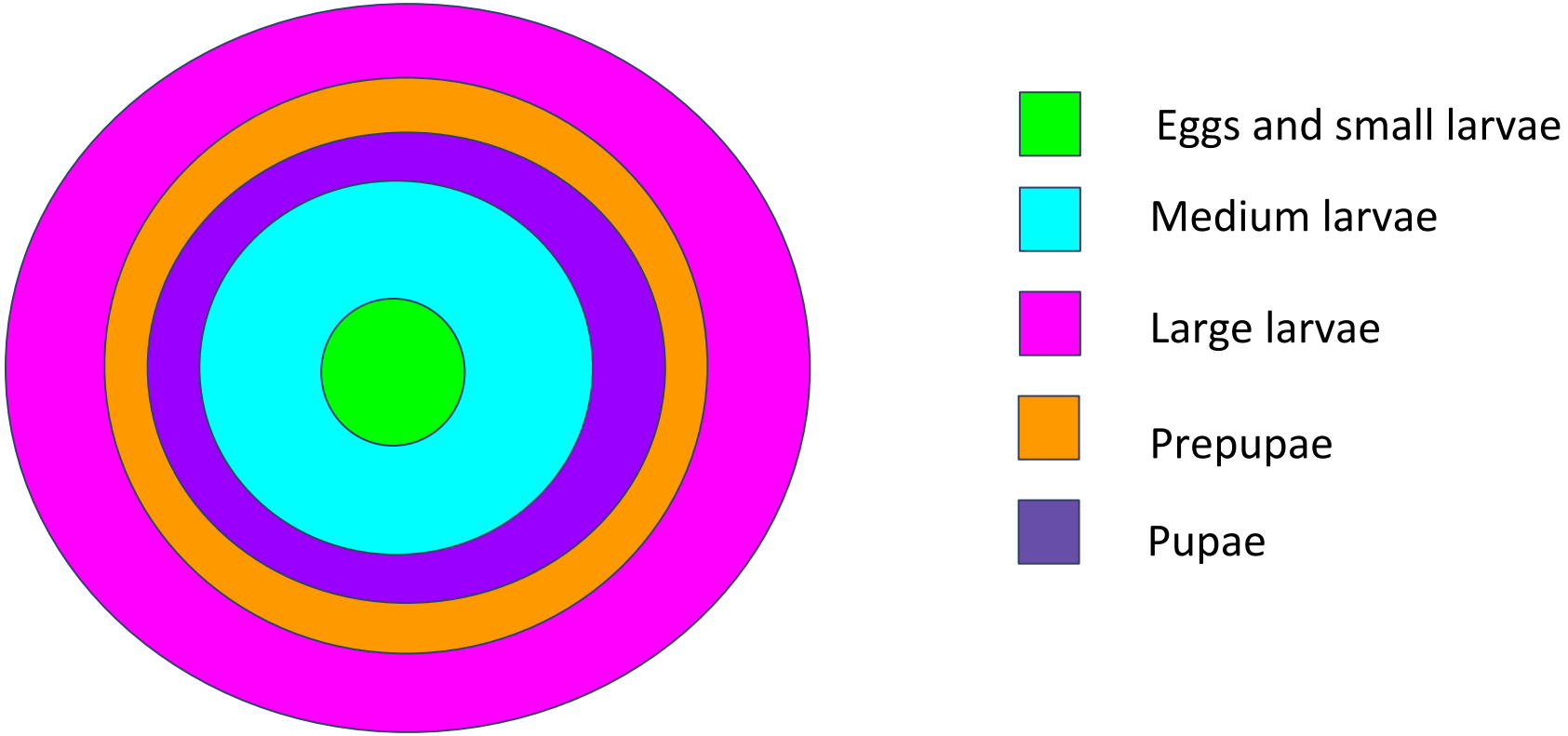
Main character

Family picture

Egg medium large pre-pupae pupae

Empirical data (Sendova-Franks 2004)

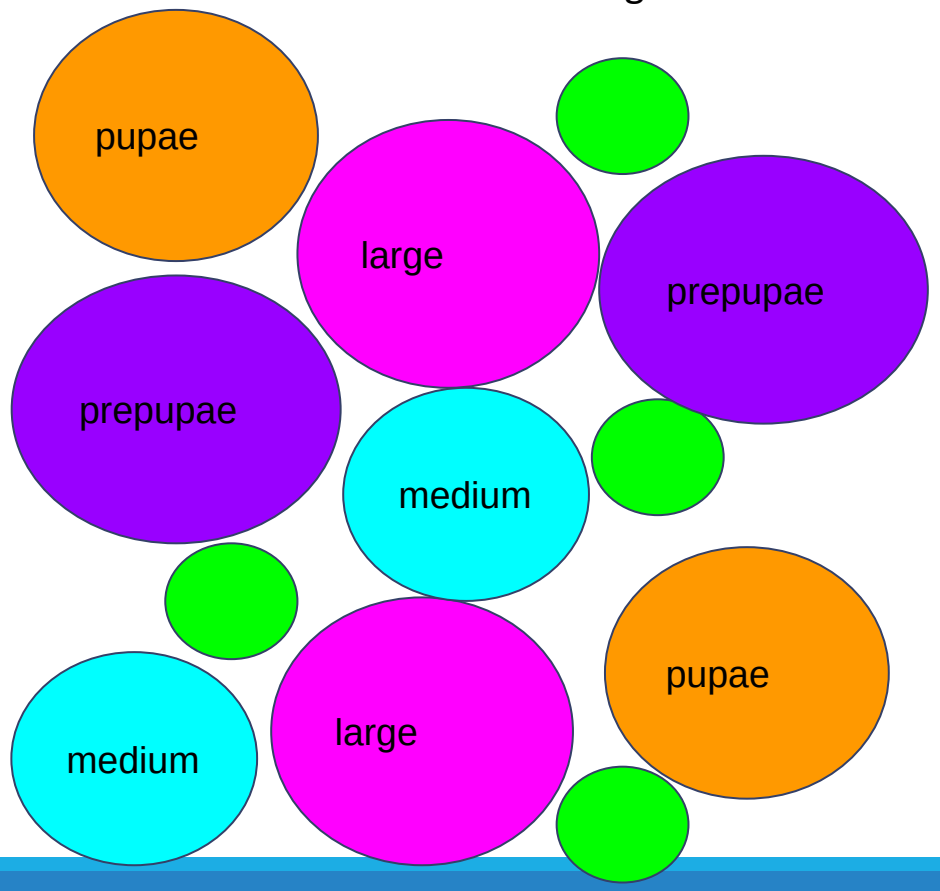
- Brood is sorted in concentric annuli (rings)



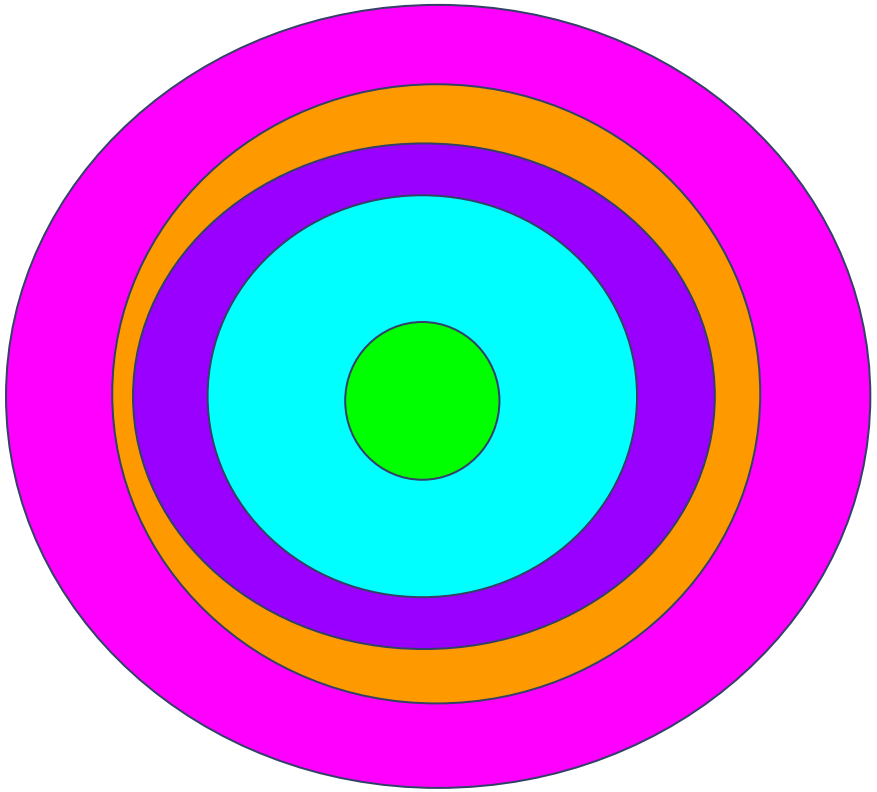
Question

- What is the cause of this brood organisation?

initial state after migration



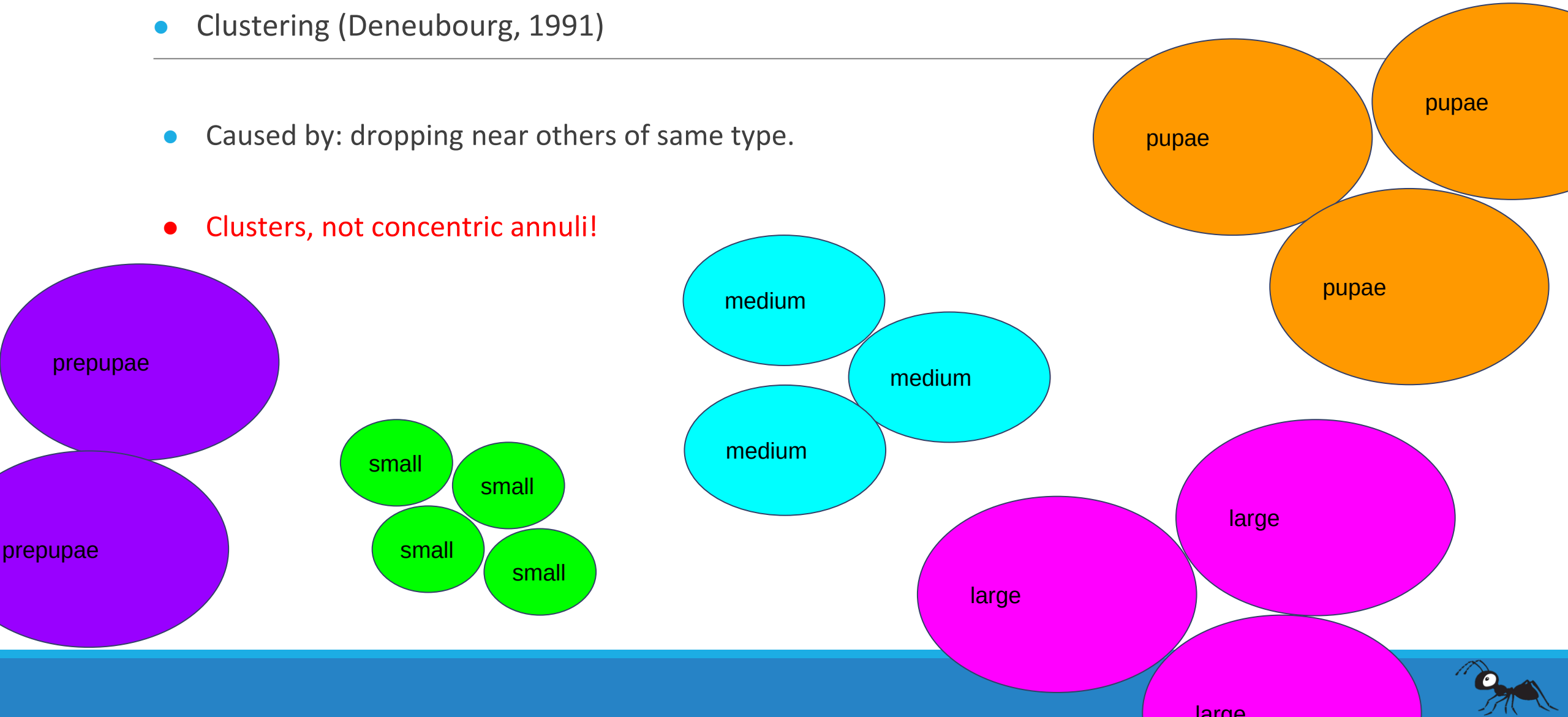
brood sorting occurs very fast



Alternative hypotheses

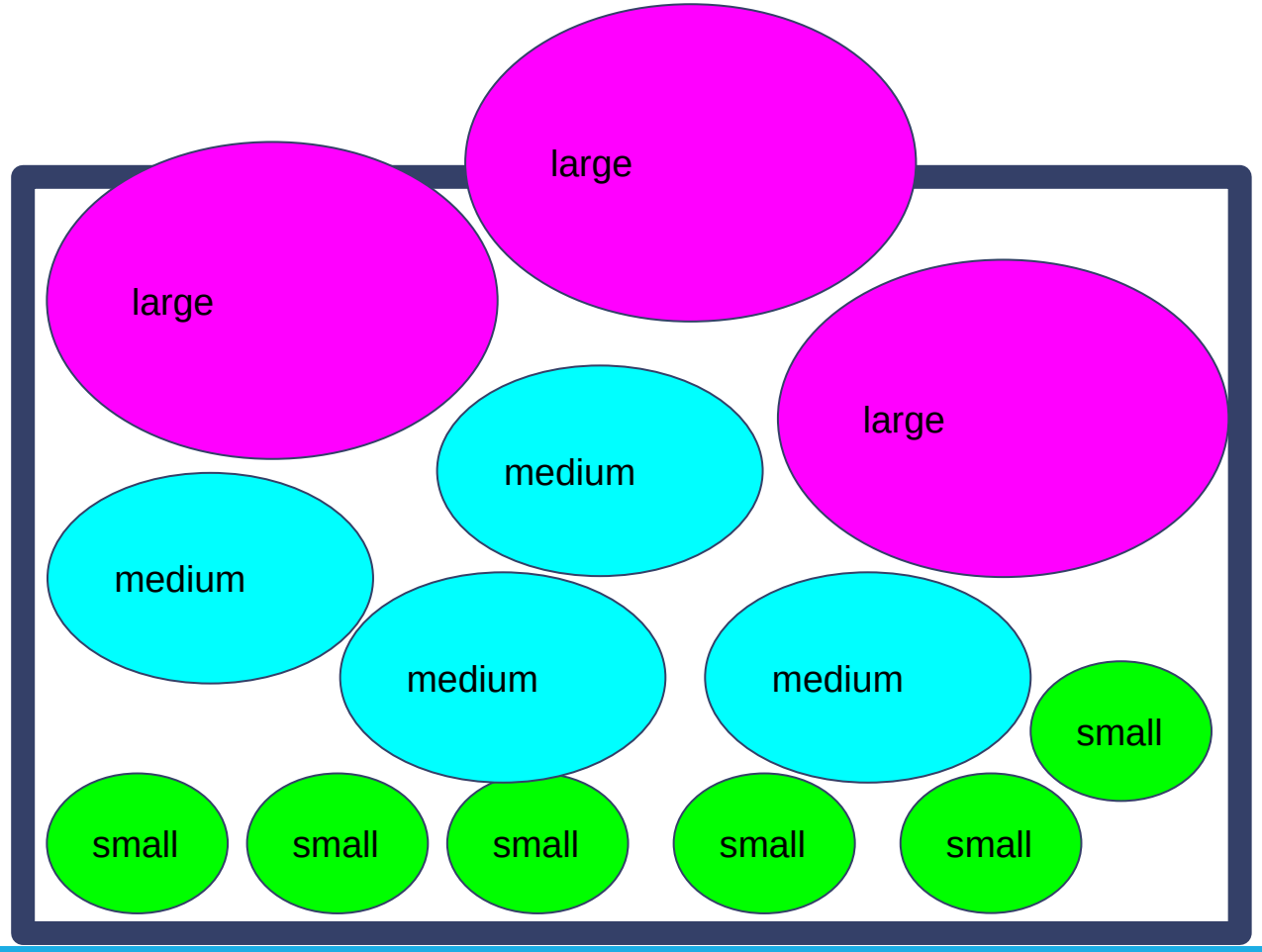
- Clustering (Deneubourg, 1991)

- Caused by: dropping near others of same type.
- Clusters, not concentric annuli!



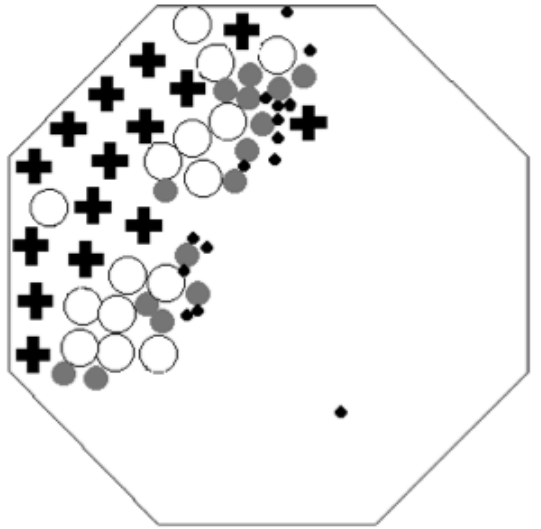
Alternative hypotheses

- Muesli effect (Barker & Grimson, 1990)



- Small items can pass, larger can't

Empirical results (by simulated robots)

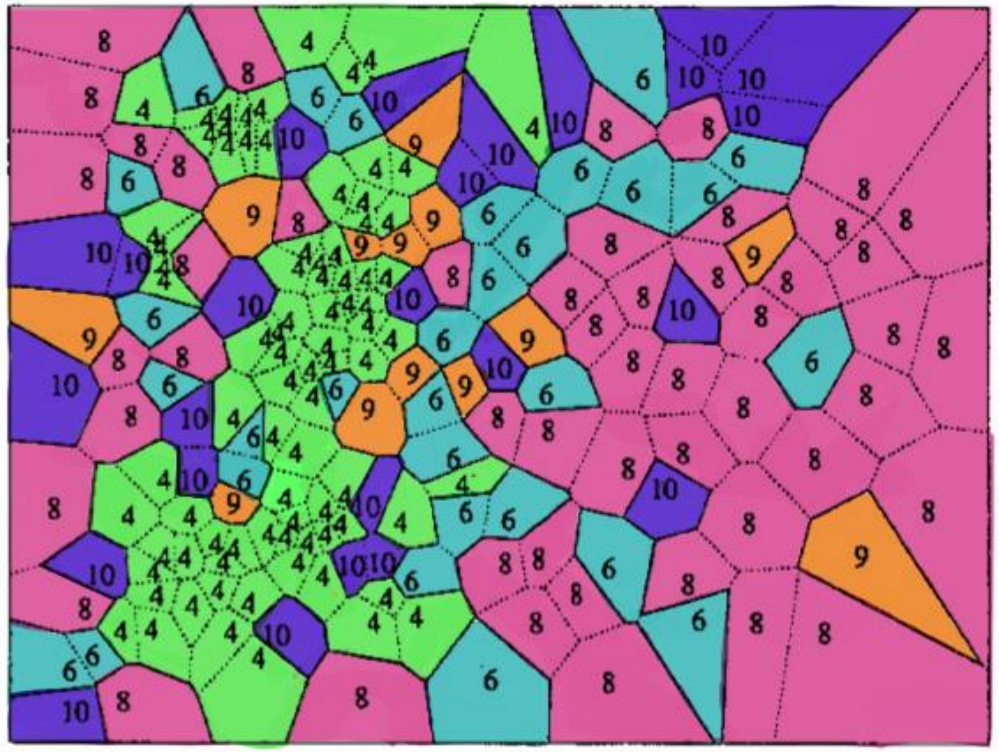


No concentric annuli!

Wilson (2004)

Sendova and Franks Hypothesis

- Differential diffusion - each brood type is spaced out according to its domain of care.



D (AFTER)

Franks (1992)

Eggs and small larvae

Medium larvae

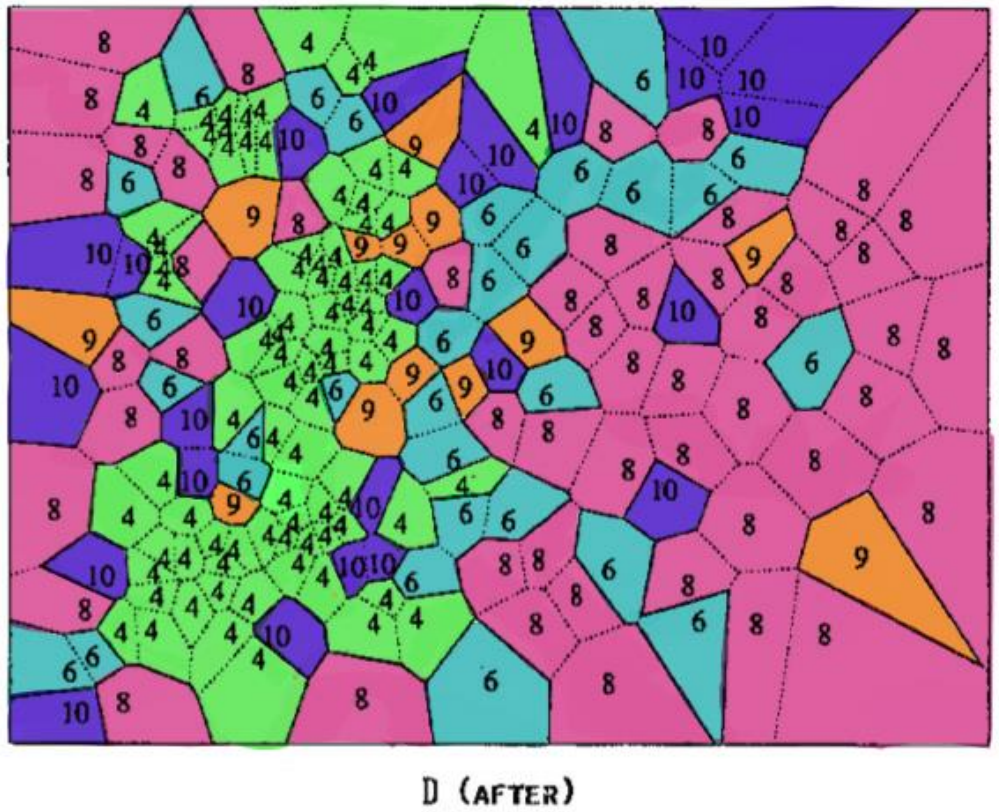
Large larvae

Prepupae

Pupae

Hypothesis

- Domain of care ~ to amount of care that brood needs



D (AFTER)

Eggs and small larvae

Medium larvae

Large larvae

Prepupae

Pupae

Eggs, pupae and prepupae are clustered very close together, medium and large larvae are on the outside, and need more space.

Hypothesis

- Domain of care ~ to amount of care that brood needs

Care eggs and larvae:
Feeding and cleaning

Care (Pre)-Pupae: No feeding, only cleaning

for illustration purposes only - this is not the right species of ant

Hypothesis

- Care ordering: Large larvae > Medium larvae ~ Prepupae ~ Pupae > Small larvae and eggs.

- Evolutionary explanation: more energy invested in large larvae, hence need more care.

Hypothesis

- Care ordering: Large larvae > Medium larvae ~ Prepupae ~ Pupae > Small larvae and eggs.

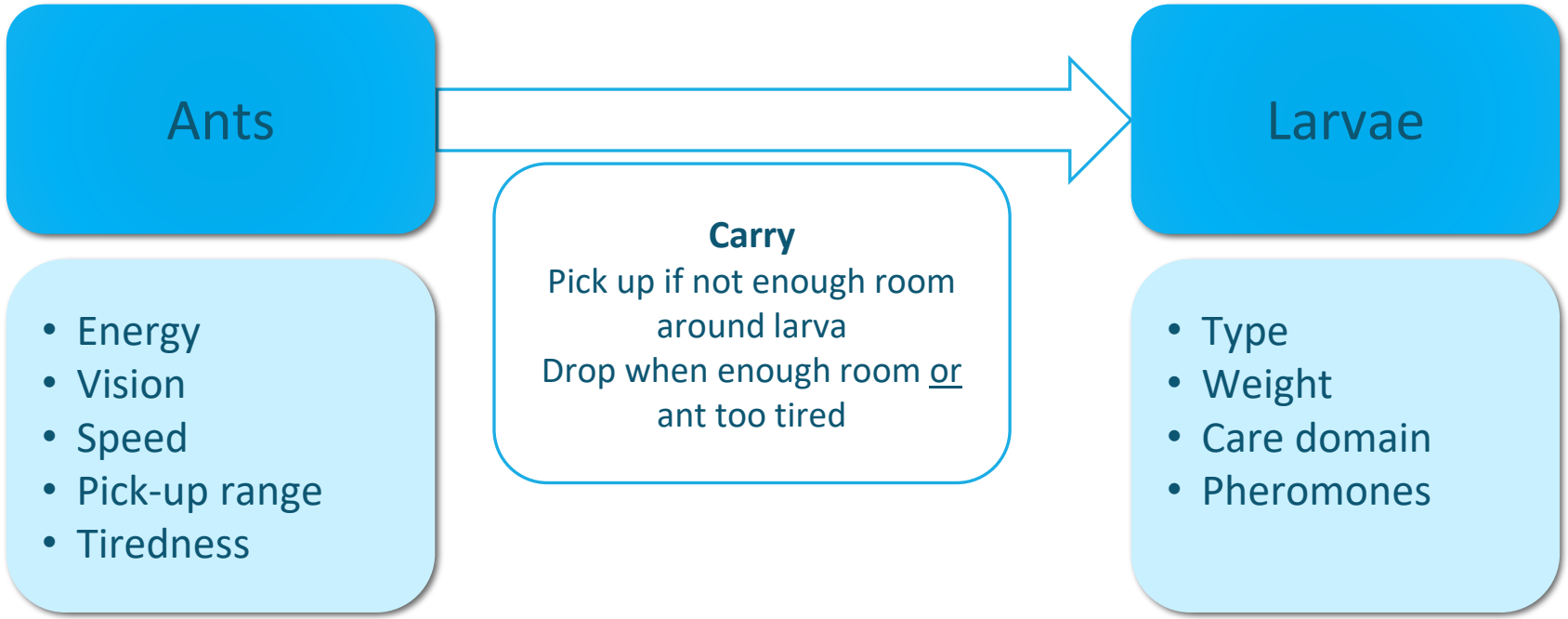
- Simple rules:
  - Pick brood up if overcrowded according to domain of care.
  - Drop brood if not overcrowded anymore.

Hypothesis

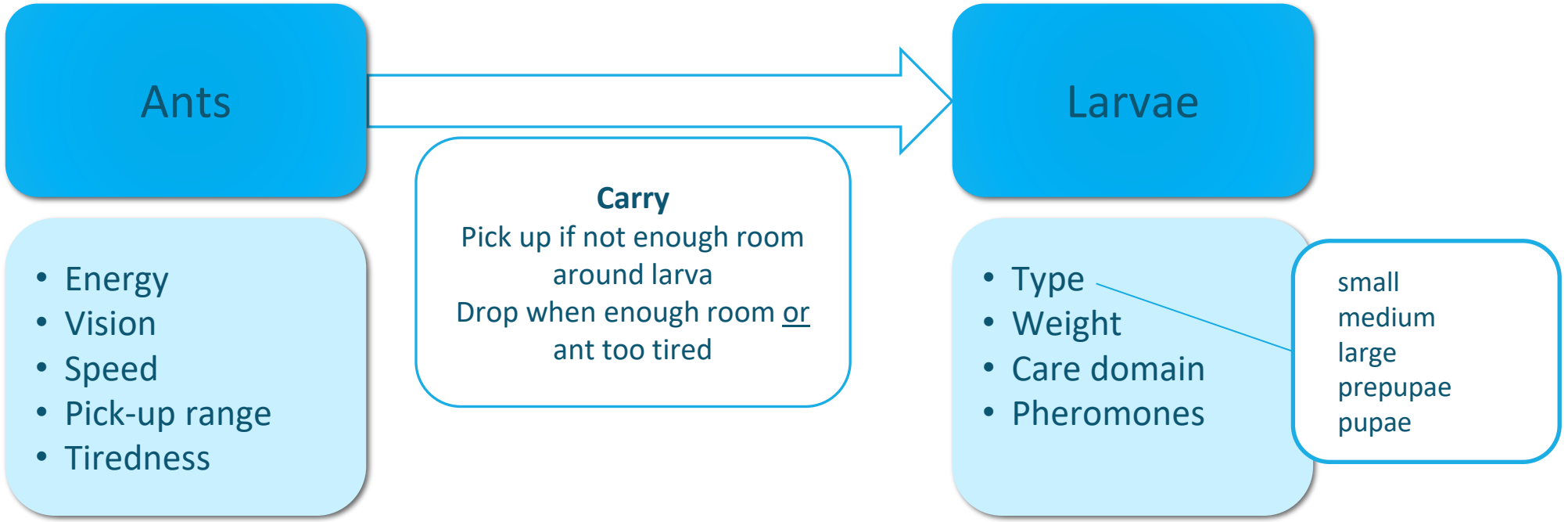
- Care ordering: Large larvae > Medium larvae ~ Prepupae ~ Pupae > Small larvae and eggs.

- Simple rules:
  - Pick brood up if overcrowded according to domain of care.
  - Drop brood if not overcrowded anymore.
  - + tiredness - ants carry small/light brood easier than large/heavy brood.

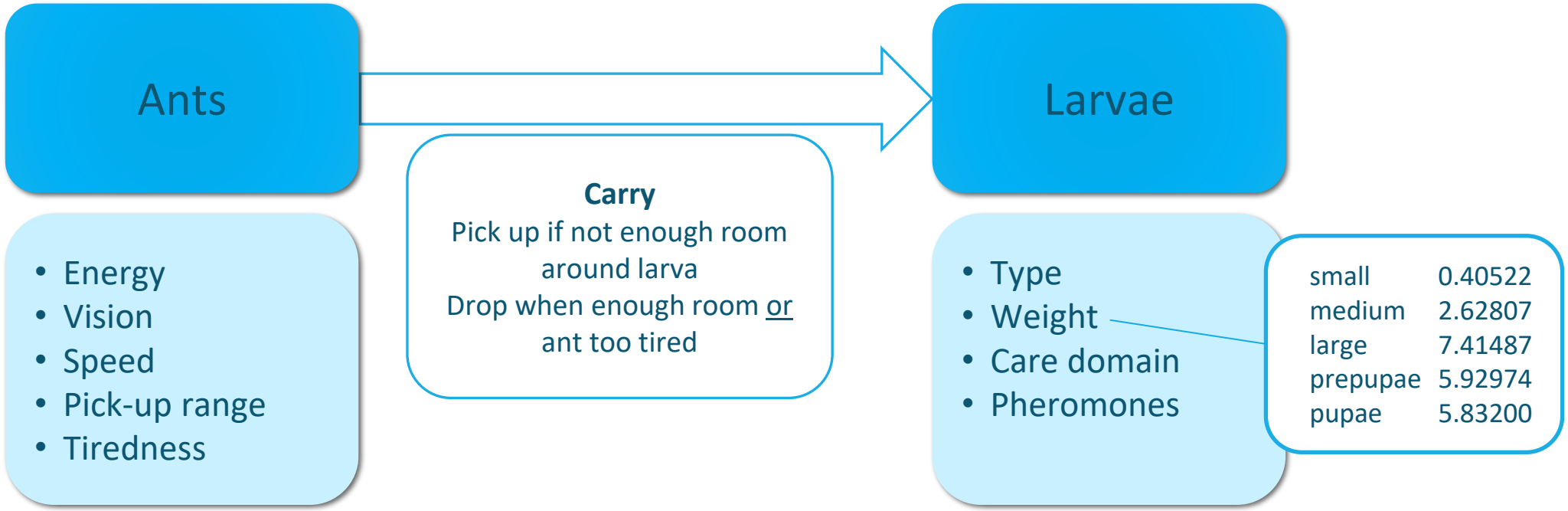
Model


Ants
Larvae
Carry
Pick up if not enough room around larva
Drop when enough room or ant too tired
• Energy
• Vision
• Speed
• Pick-up range
• Tiredness
• Type
• Weight
• Care domain
• Pheromones

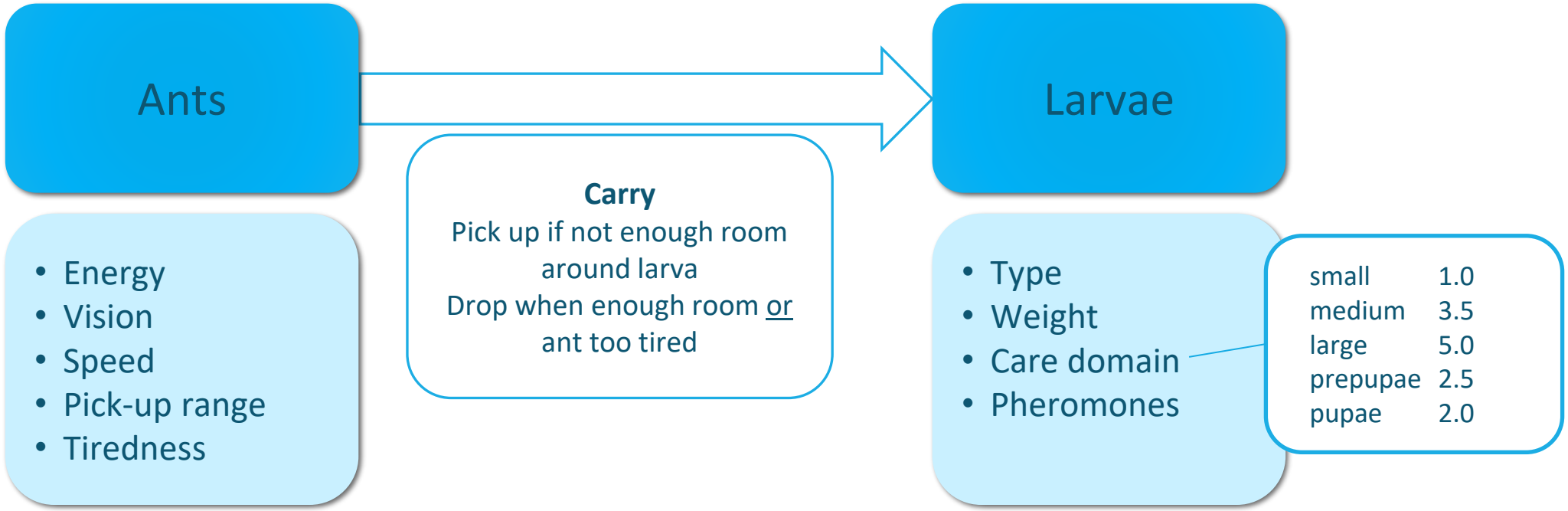
Model


Ants
Larvae
Carry
Pick up if not enough room around larva
Drop when enough room or ant too tired
• Energy
• Vision
• Speed
• Pick-up range
• Tiredness
• Type
• Weight
• Care domain
• Pheromones
small
medium
large
prepupae
pupae

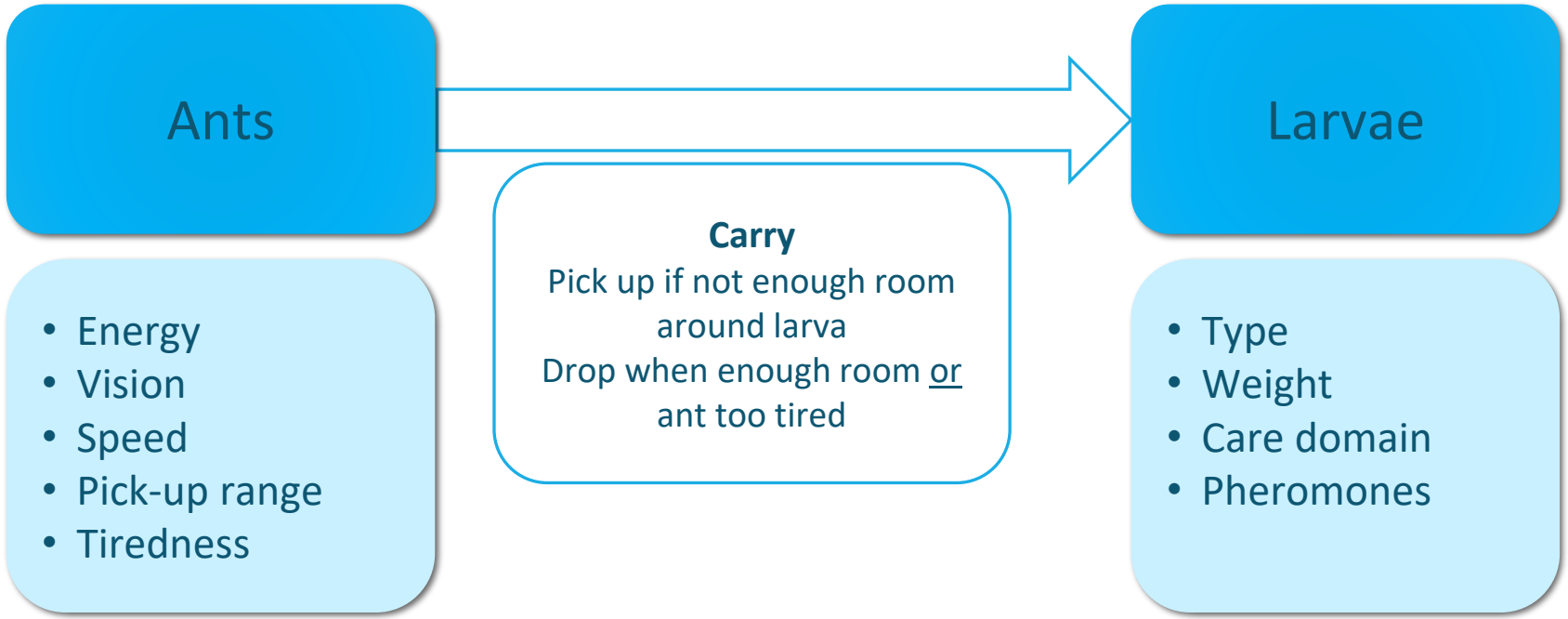
Model


Ants
Larvae
Carry
Pick up if not enough room around larva
Drop when enough room or ant too tired
• Energy
• Vision
• Speed
• Pick-up range
• Tiredness
• Type
• Weight
• Care domain
• Pheromones
small 0.40522
medium 2.62807
large 7.41487
prepupae 5.92974
pupae 5.83200

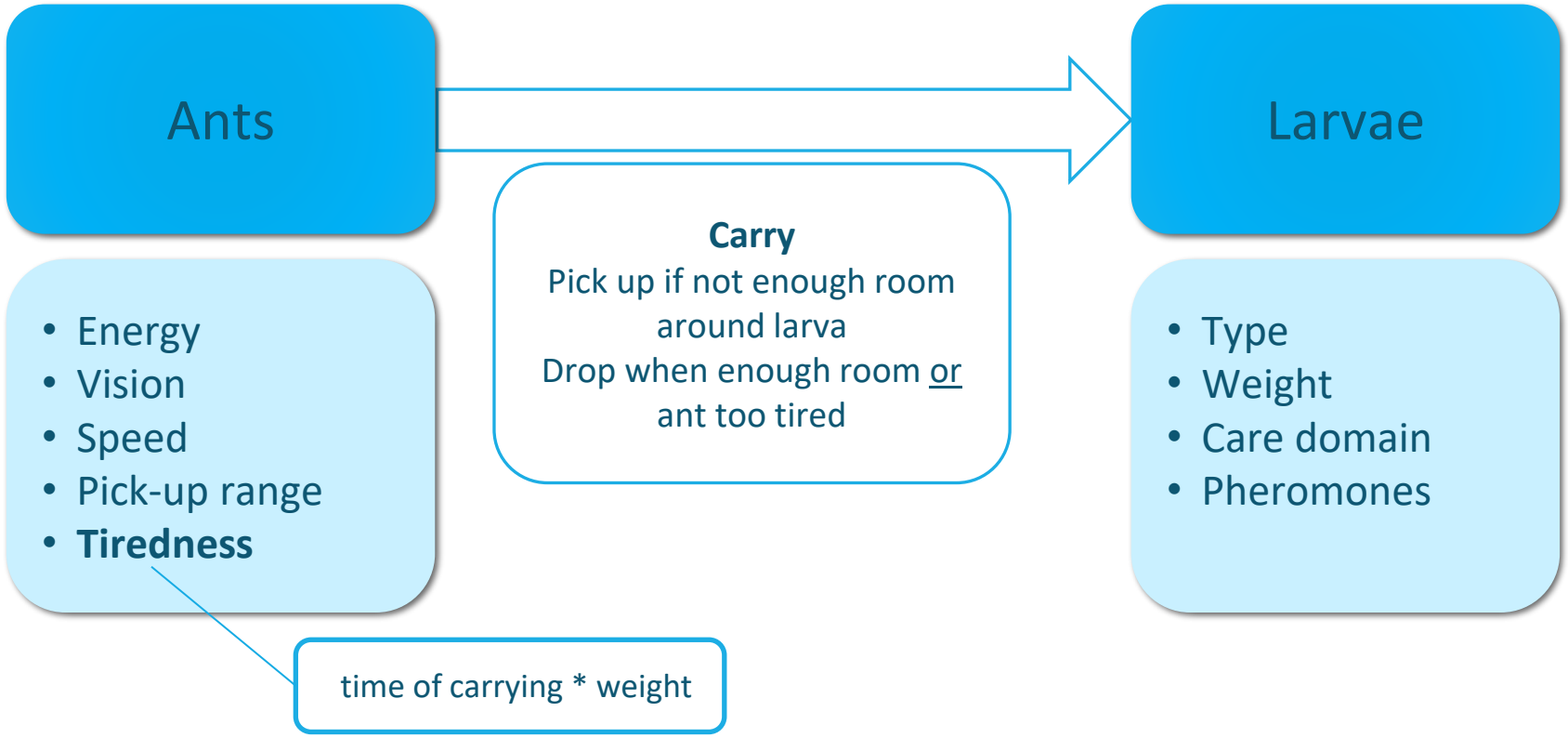
Model


Ants
Larvae
Carry
Pick up if not enough room around larva
Drop when enough room or ant too tired
• Energy
• Vision
• Speed
• Pick-up range
• Tiredness
• Type
• Weight
• Care domain
• Pheromones
small 1.0
medium 3.5
large 5.0
prepupae 2.5
pupae 2.0

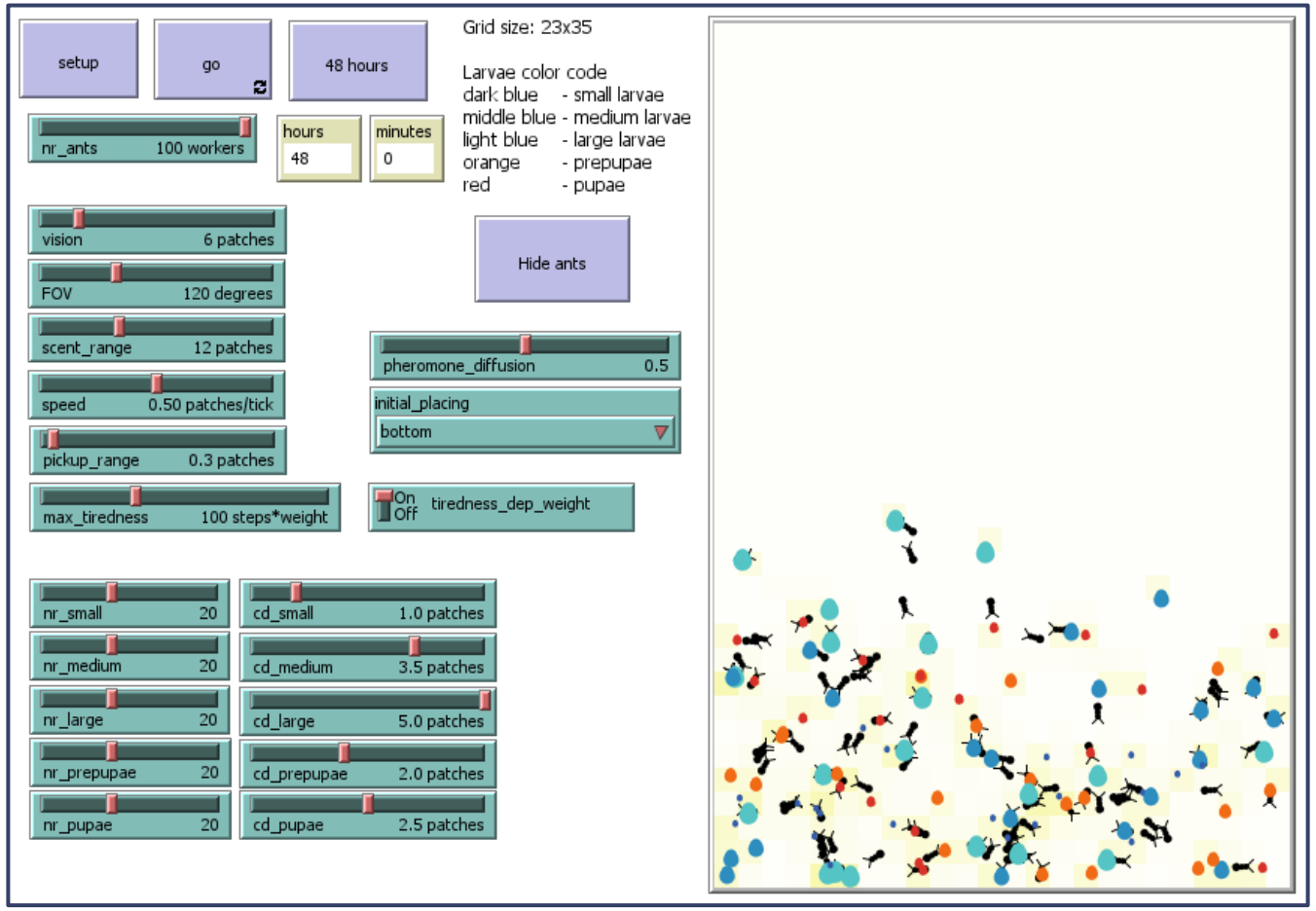
Model


Ants
Larvae
Carry
Pick up if not enough room around larva
Drop when enough room or ant too tired
• Energy
• Vision
• Speed
• Pick-up range
• Tiredness
• Type
• Weight
• Care domain
• Pheromones

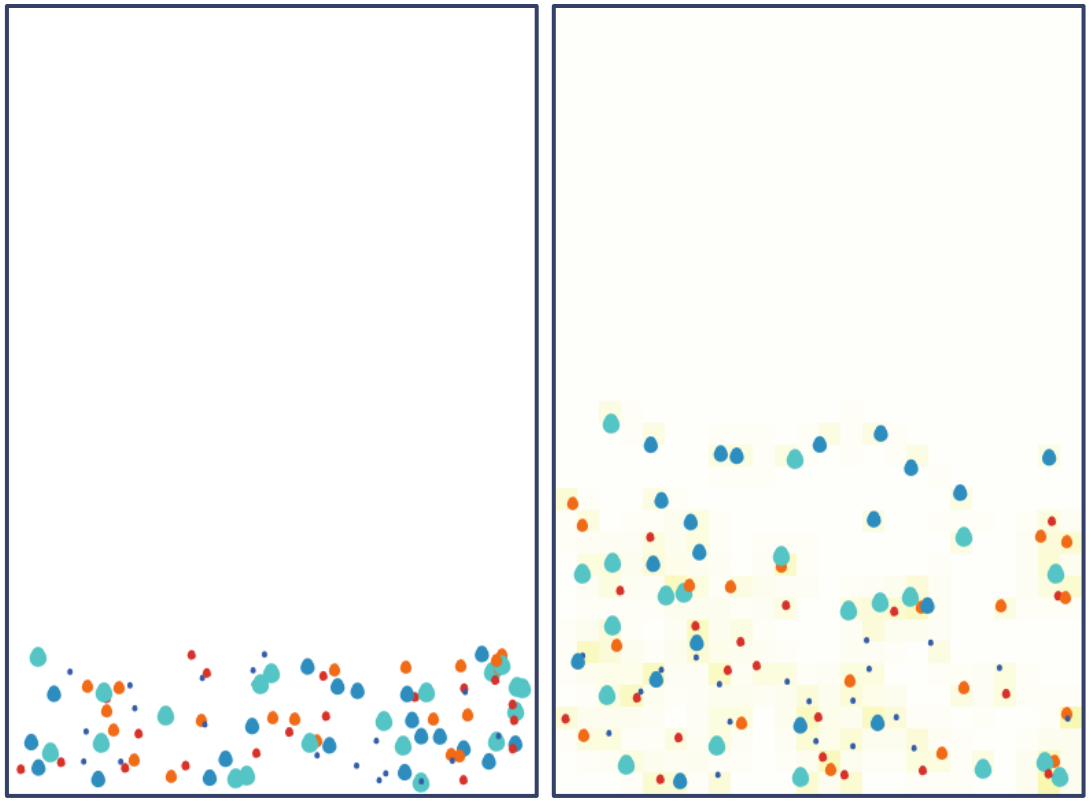
Model

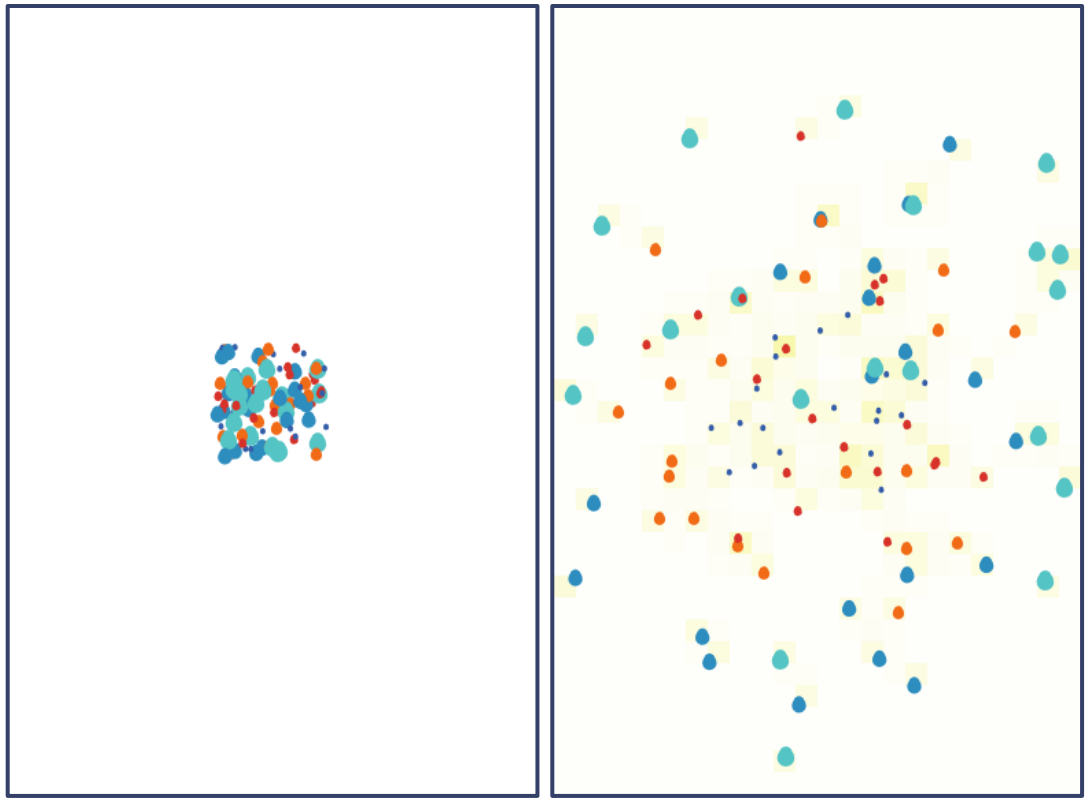

Ants
Larvae
Carry
Pick up if not enough room around larva
Drop when enough room or ant too tired
• Energy
• Vision
• Speed
• Pick-up range
• Tiredness
• Type
• Weight
• Care domain
• Pheromones
time of carrying * weight

Model demonstration

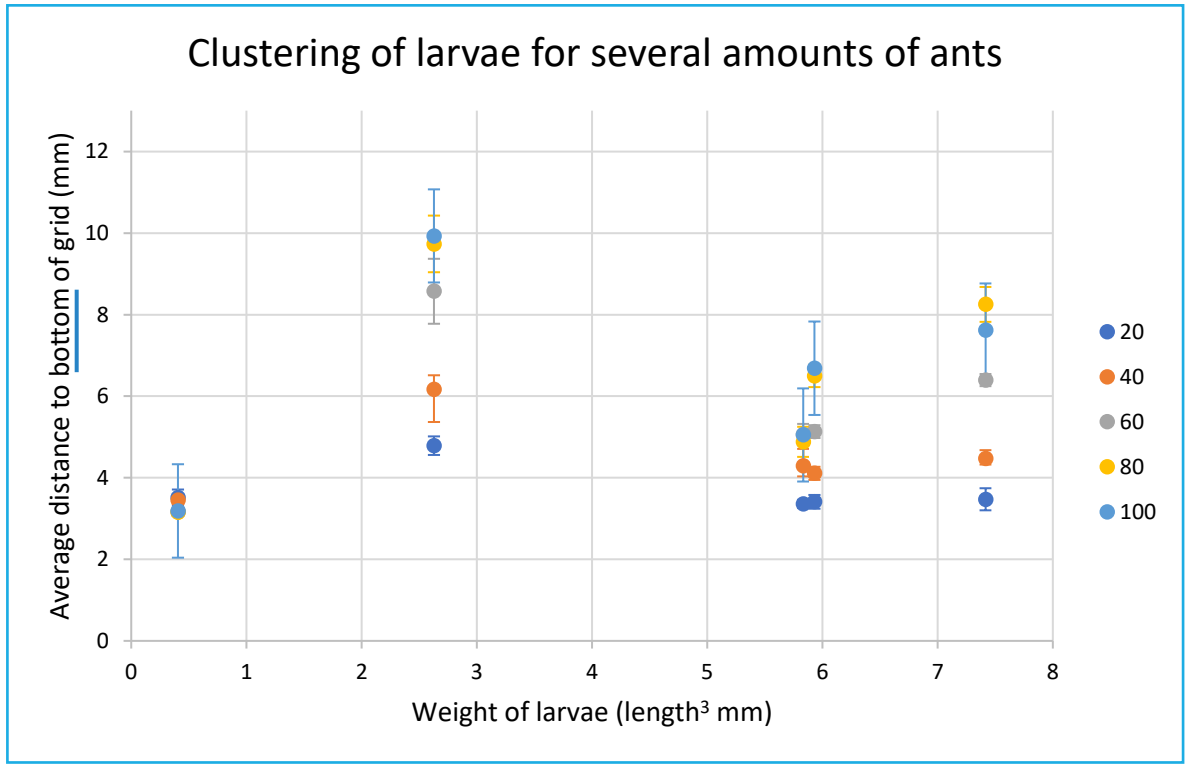


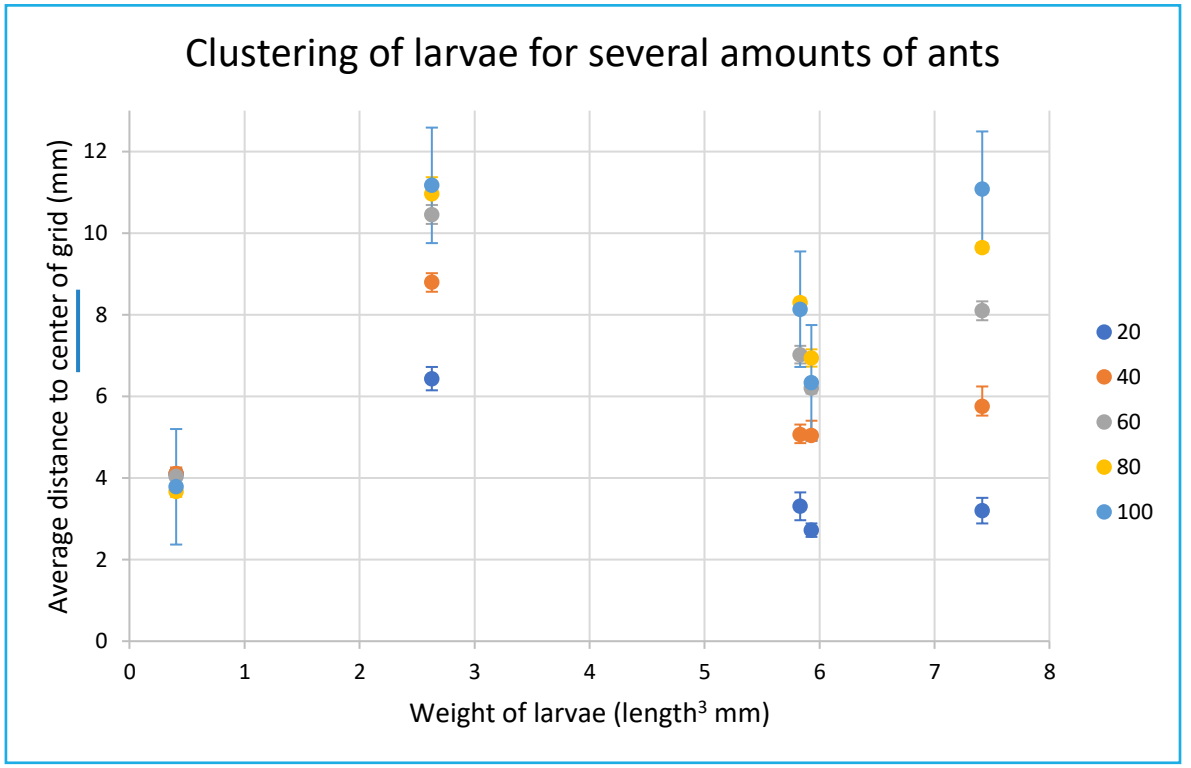
Initial placing
bottom vs. center



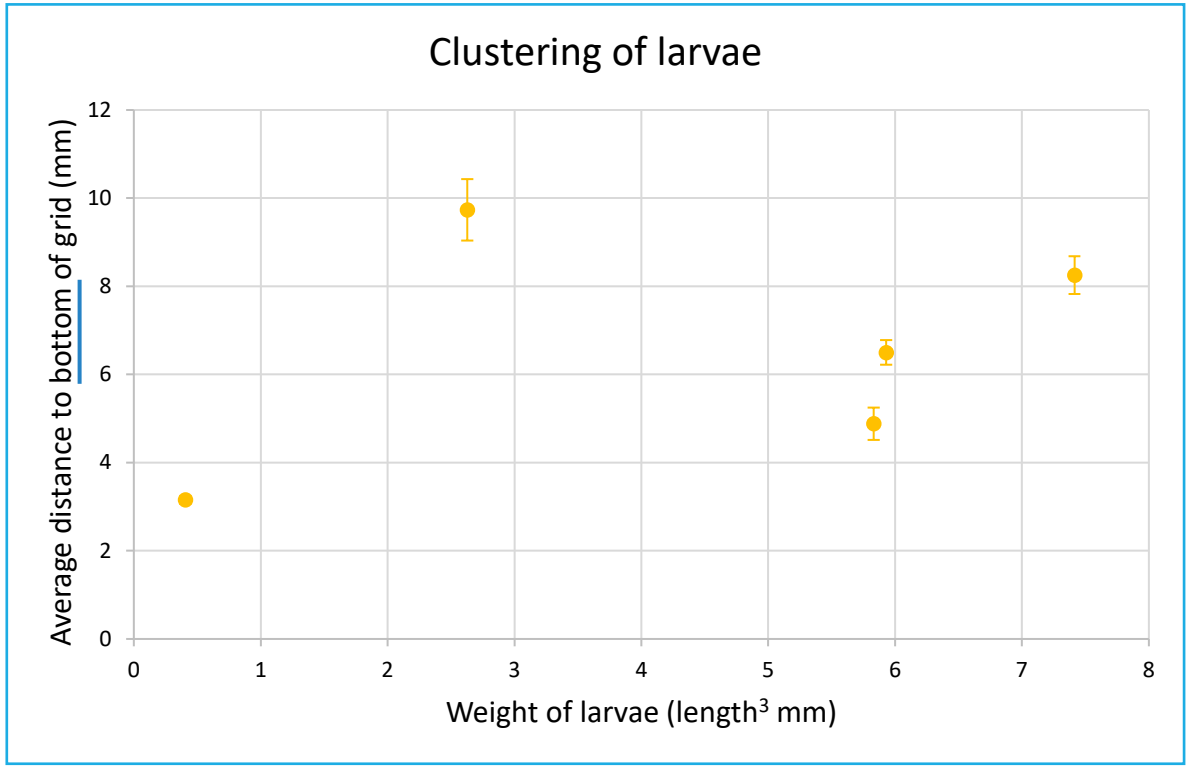


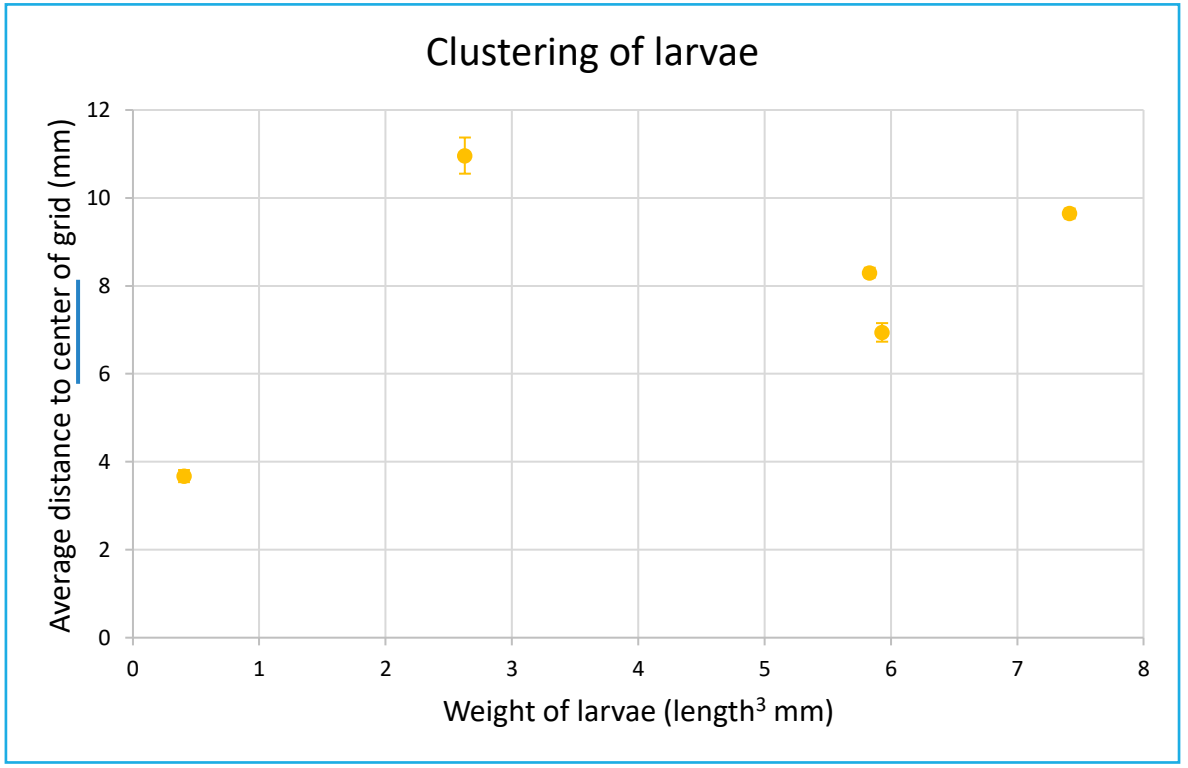
Initial placing
bottom vs. center



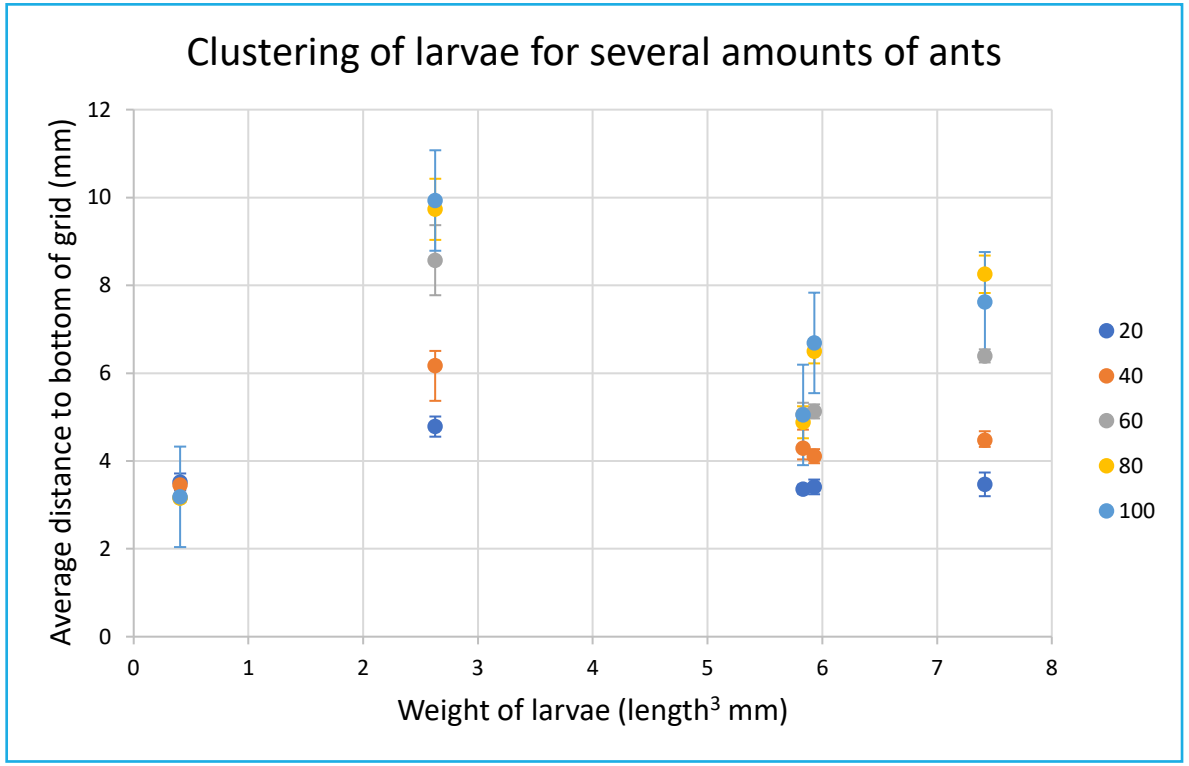


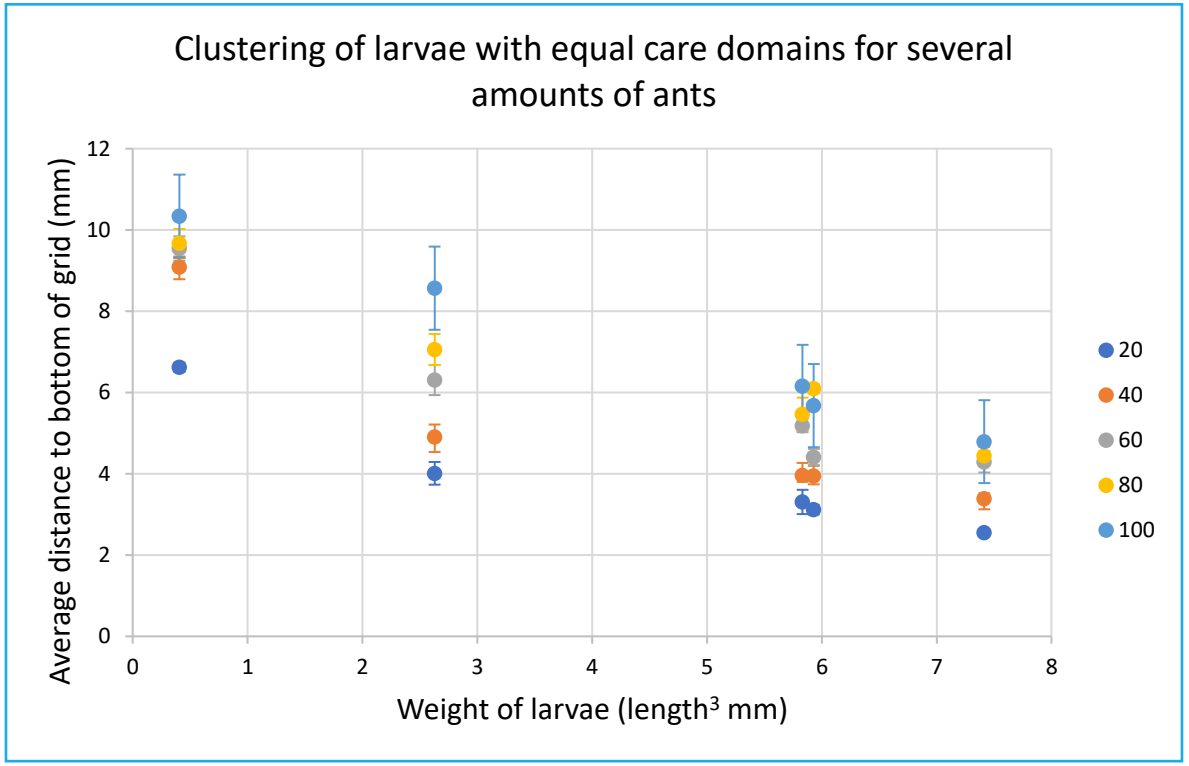
Initial placing
bottom vs. center



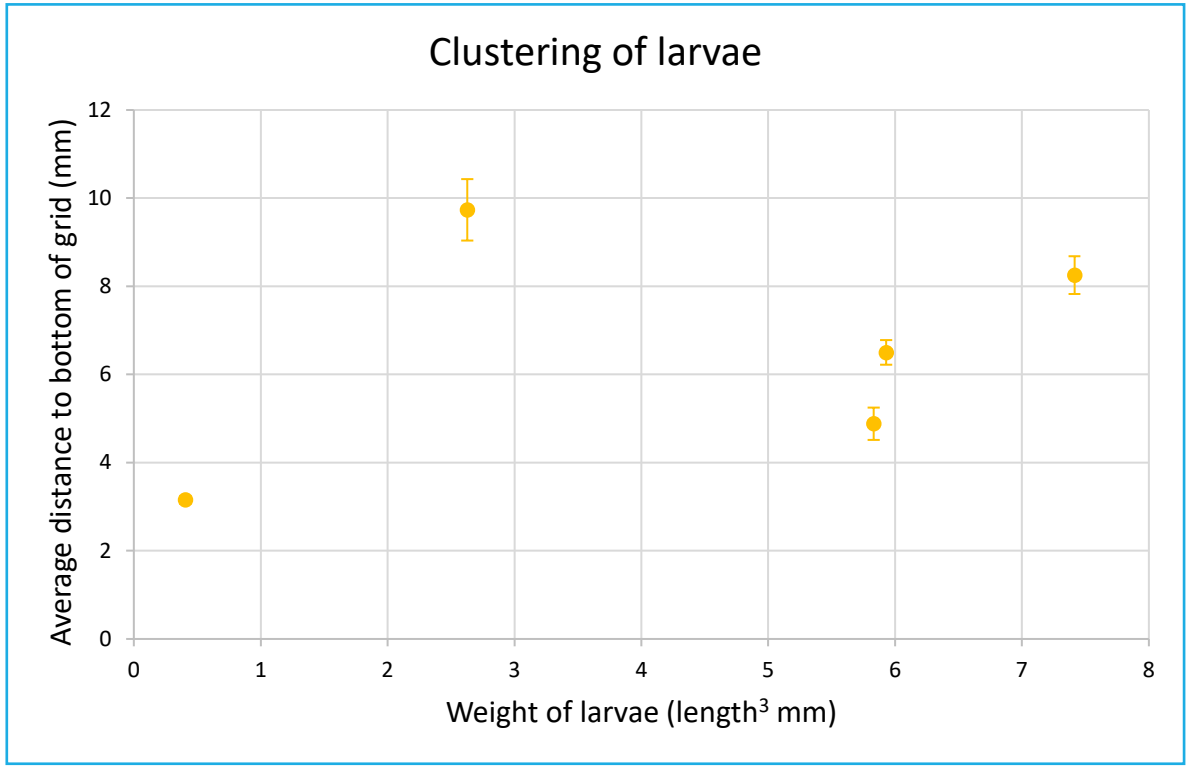


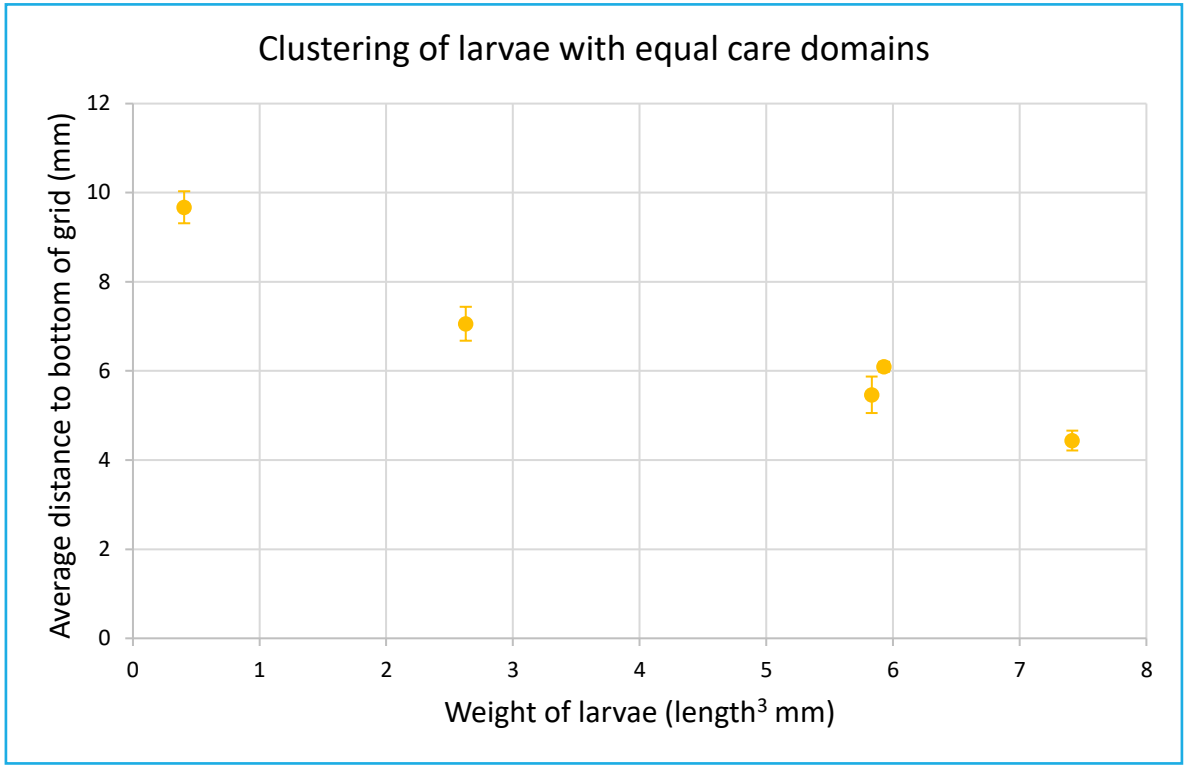
Care domain
proportional to weight vs. equal



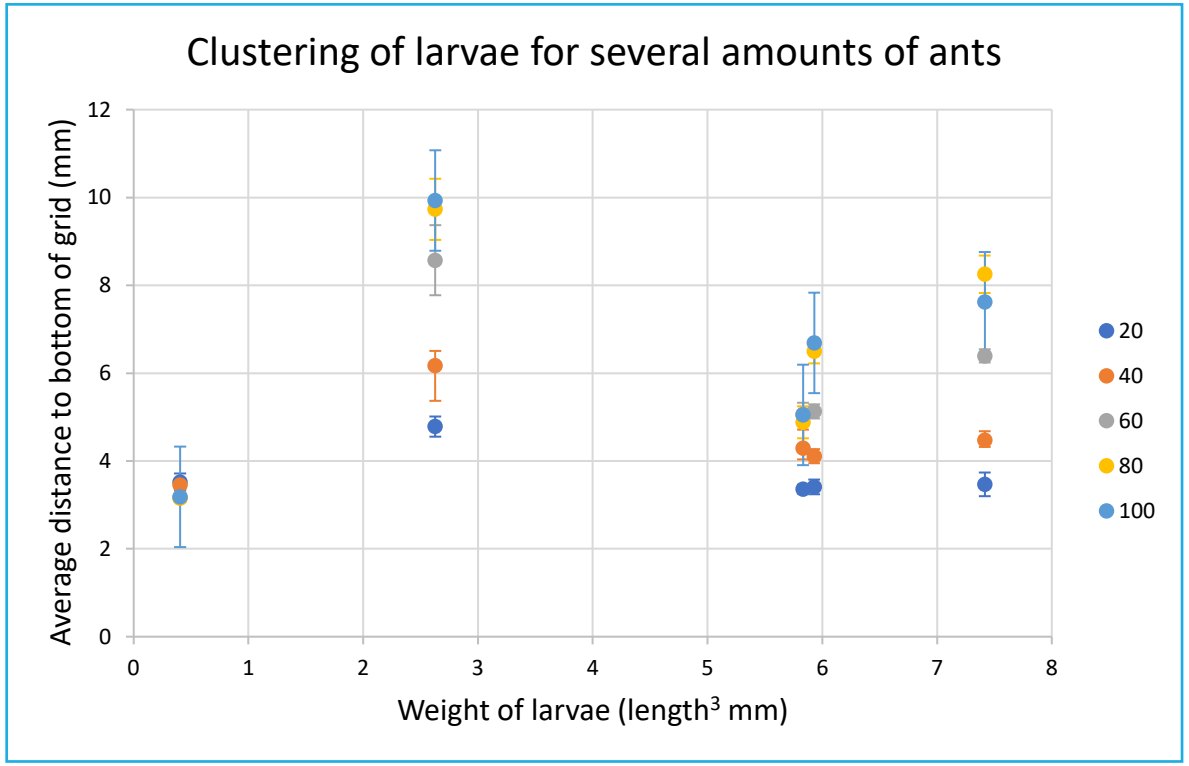


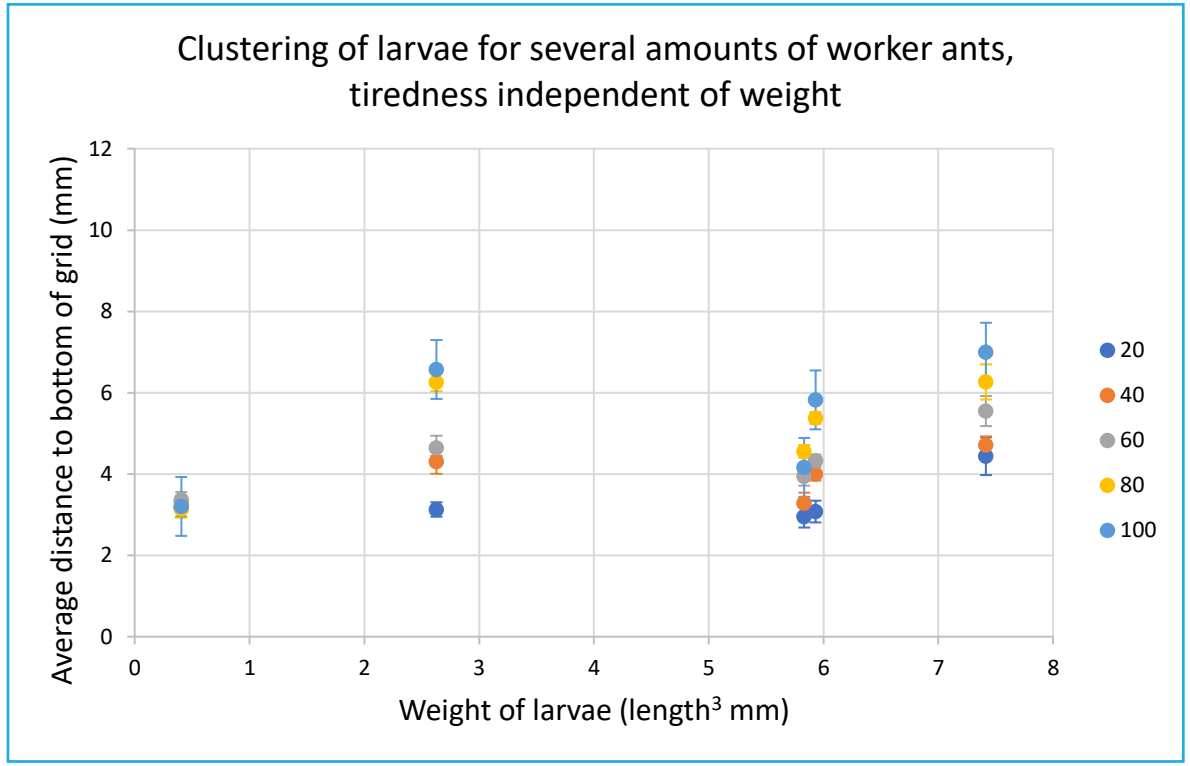
Care domain
proportional to weight vs. equal for all larvae



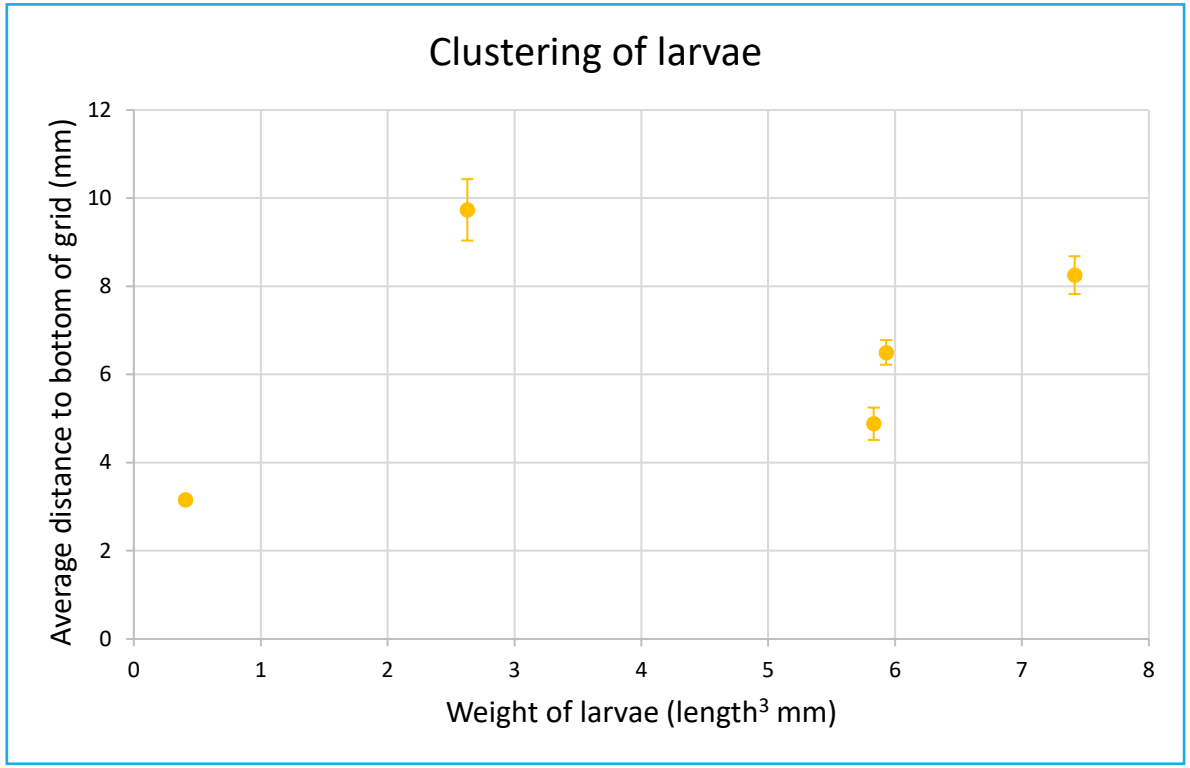


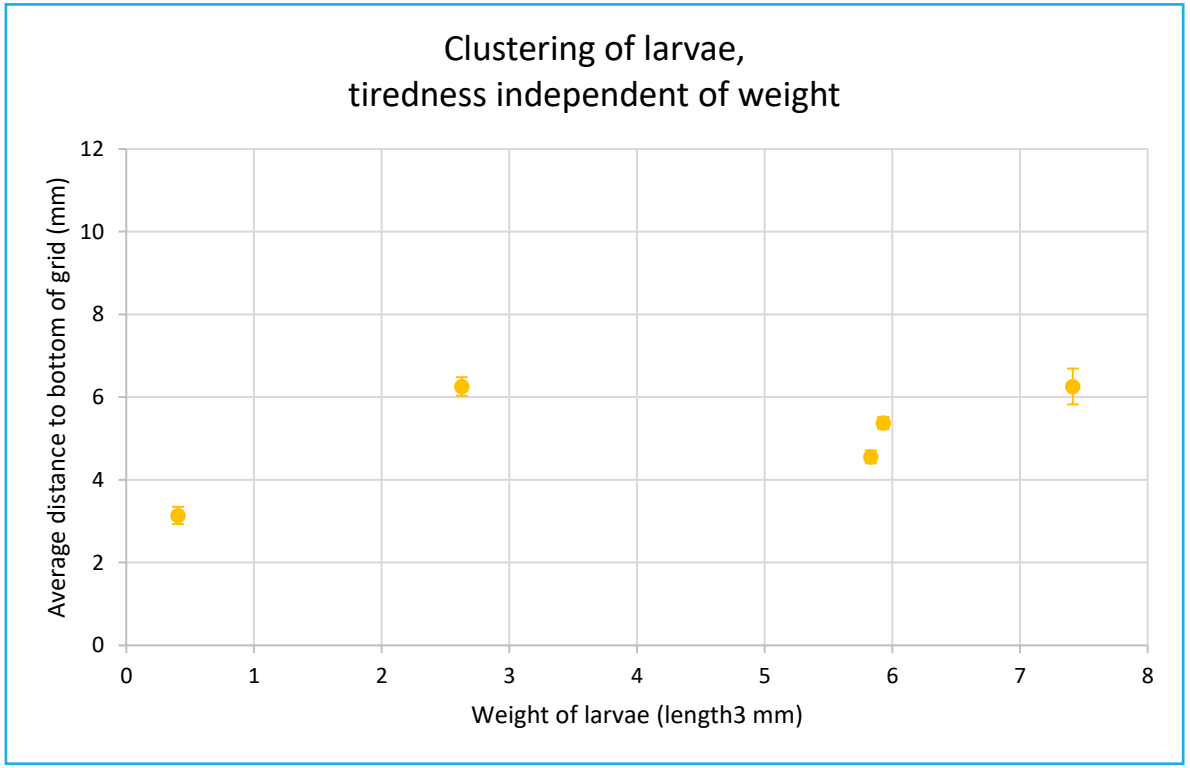
Tiredness
dependent on weight vs. equal for all larvae



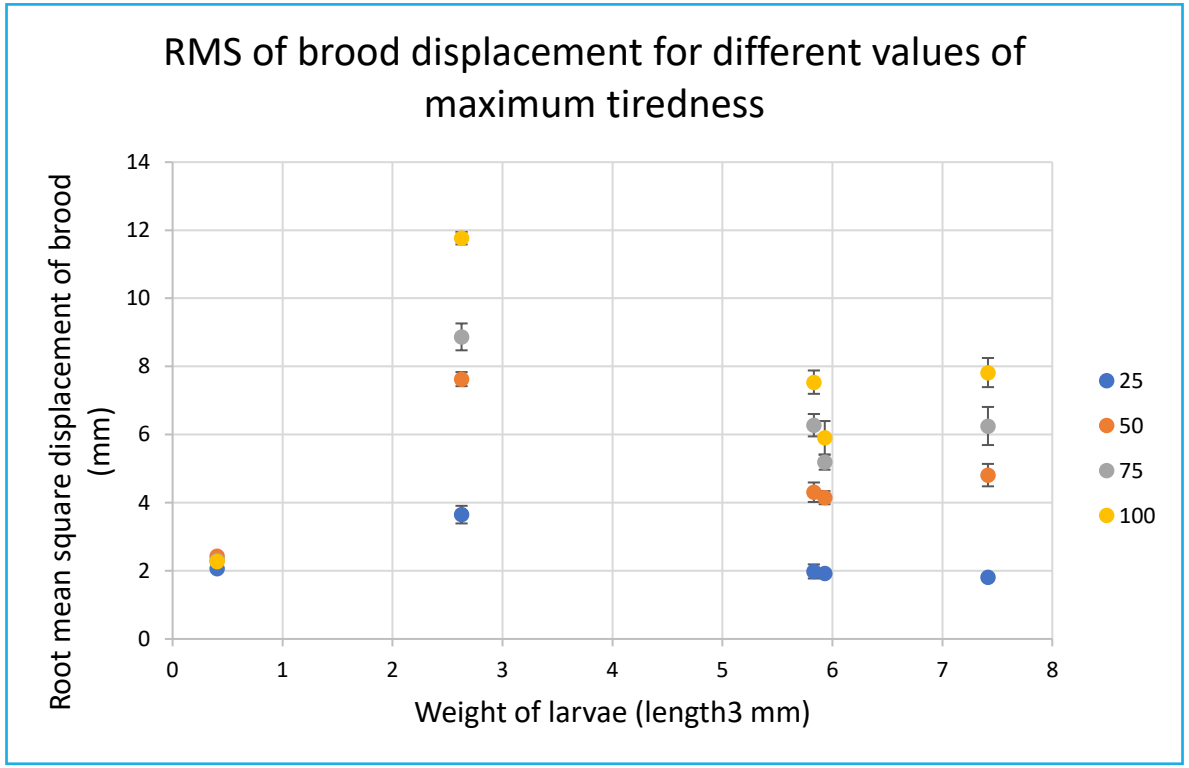


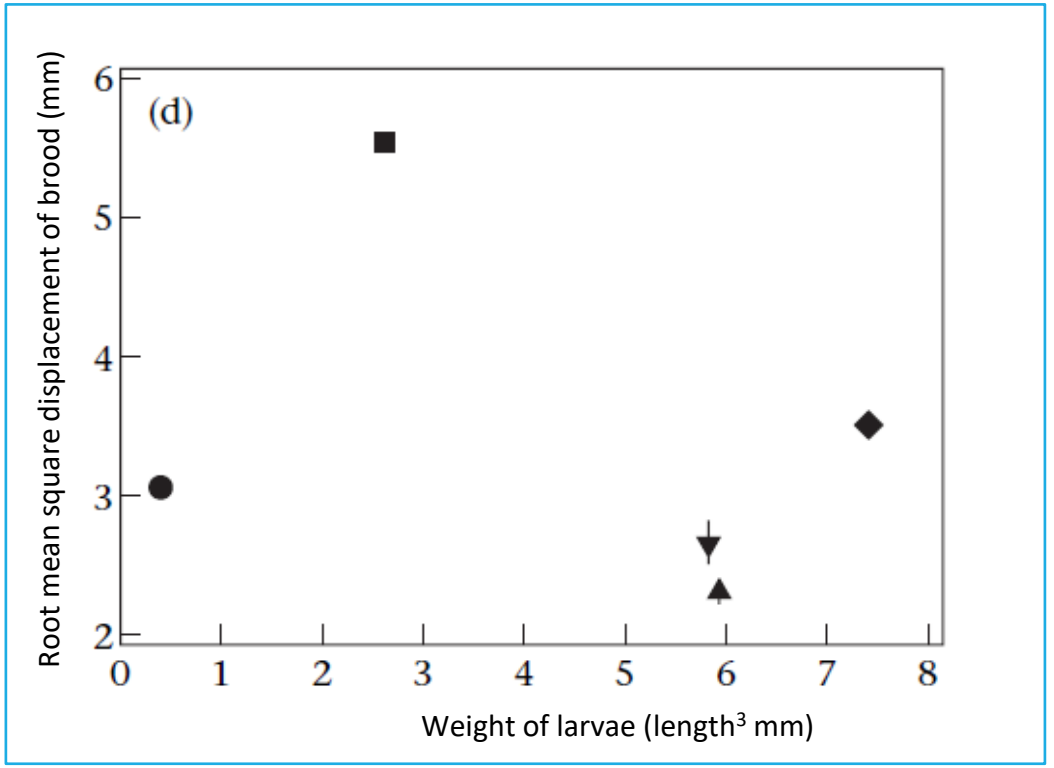
Tiredness
dependent on weight vs. equal for all larvae



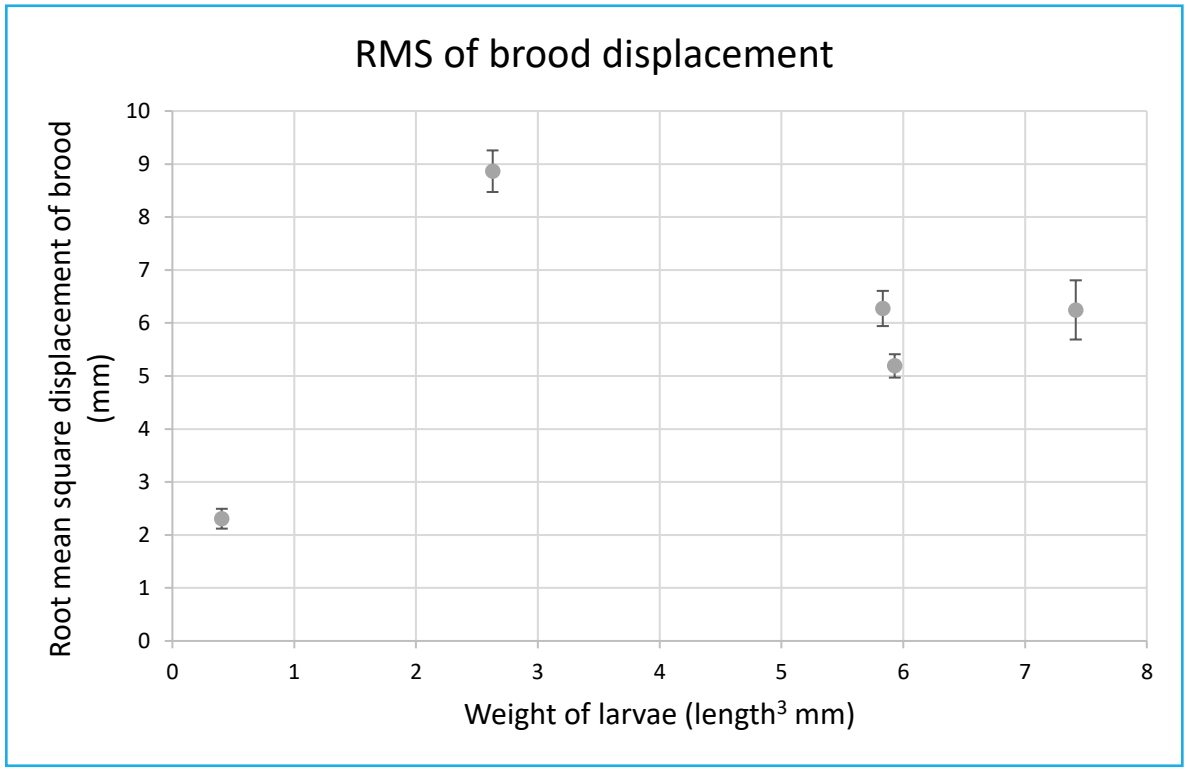


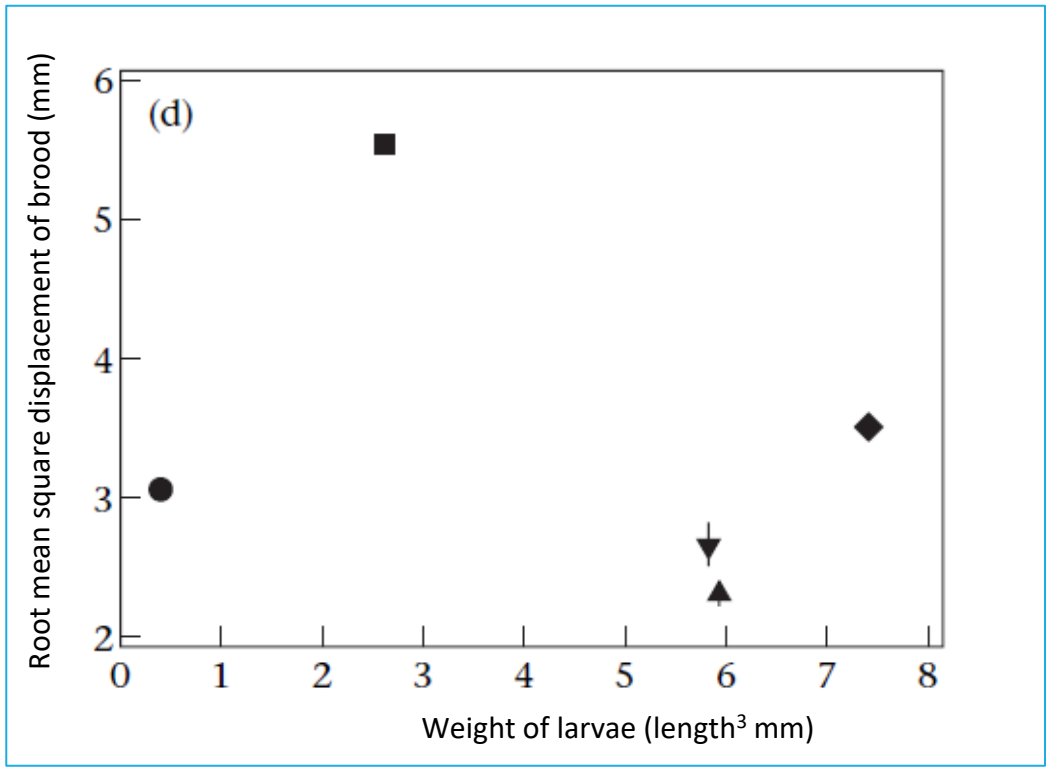
RMS of brood displacement
model vs. empirical (Sendova-Franks, 2004)



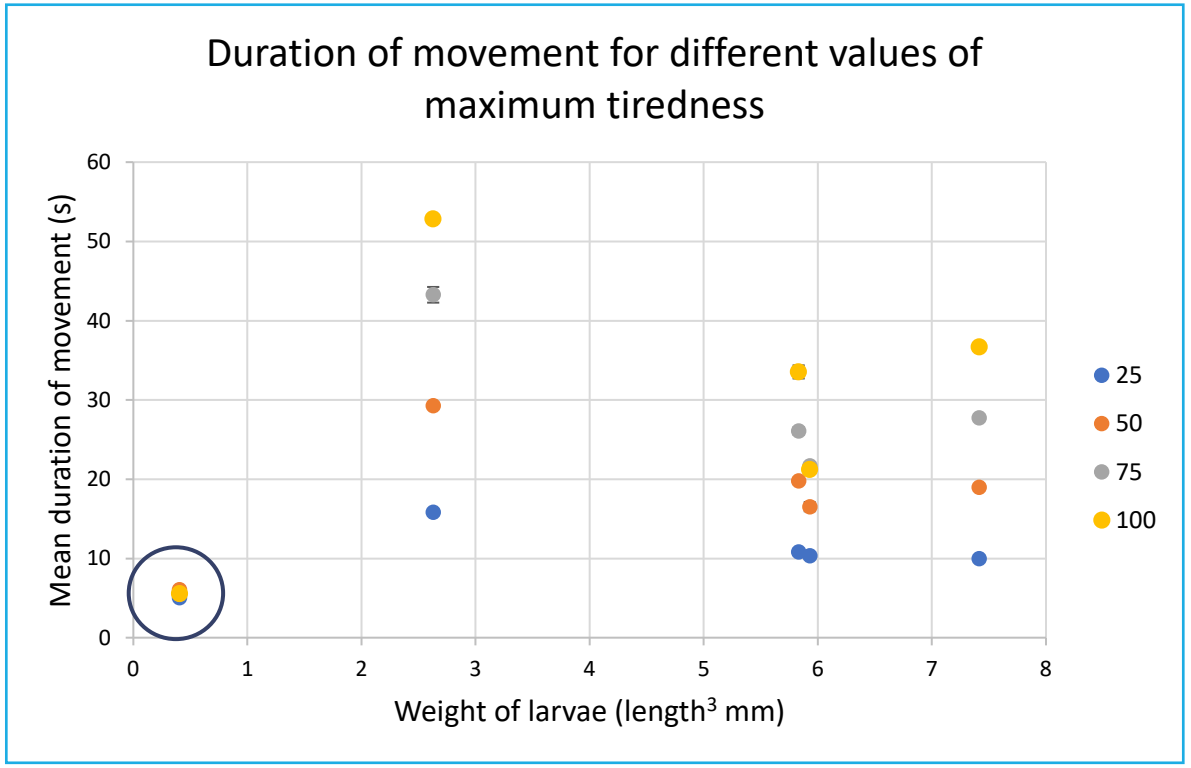


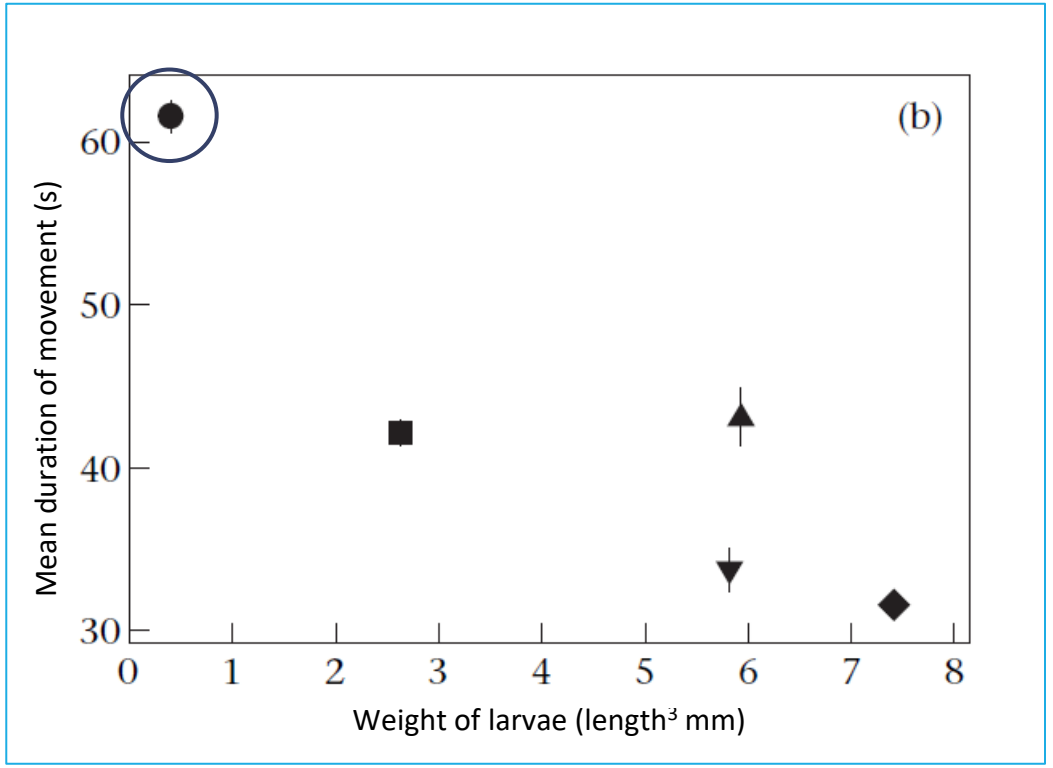
RMS of brood displacement
model vs. empirical



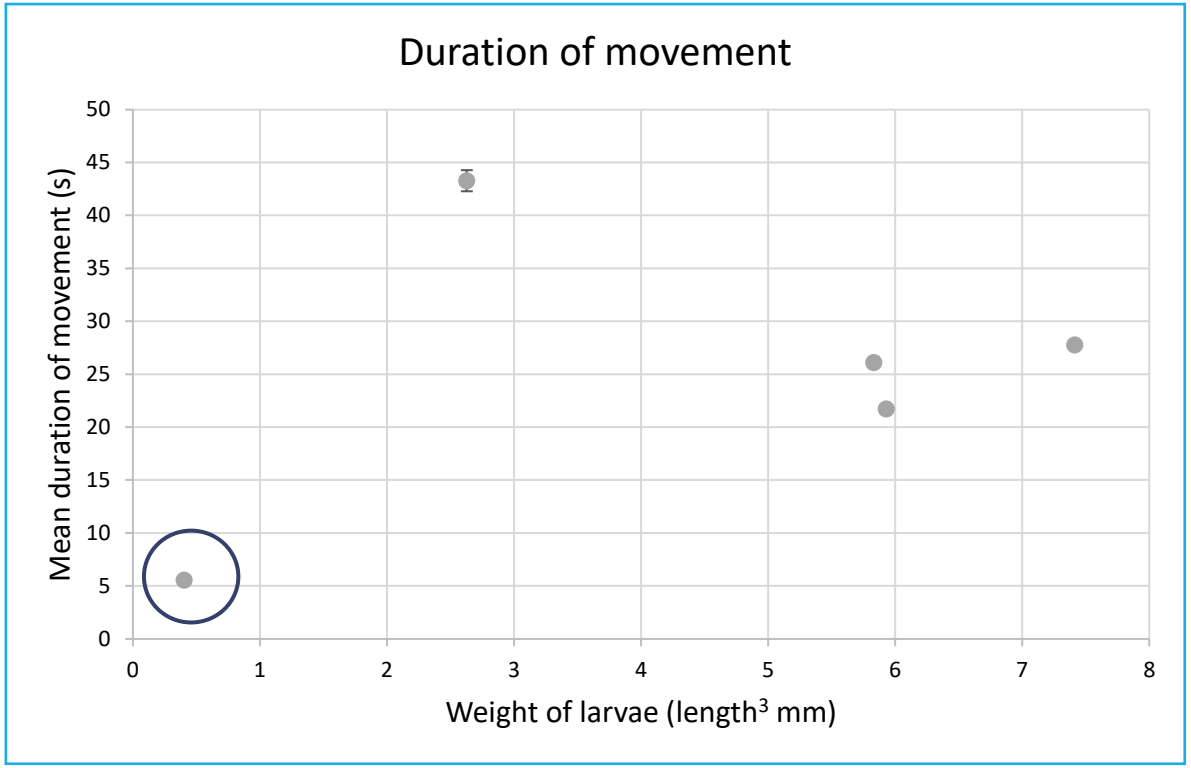


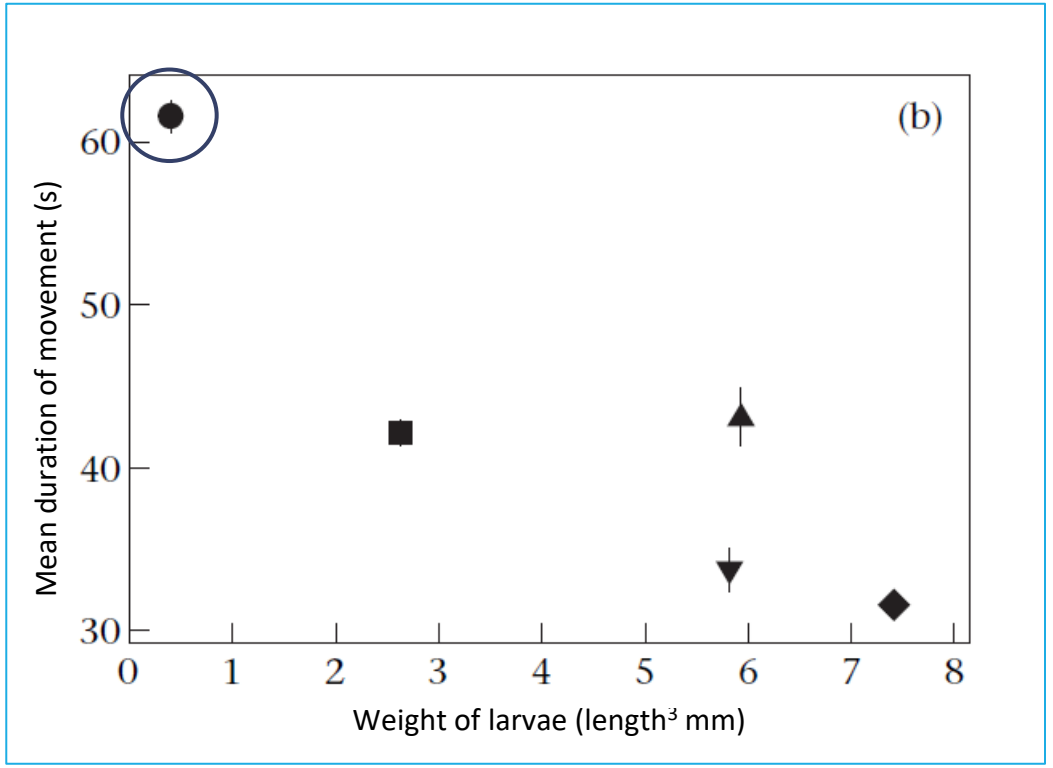
Mean duration of brood movement by ants model vs. empirical





Mean duration of brood movement by ants
model vs. empirical





Summary of results

	Answer	**Significance**
Does sorting occur?	Yes – difference in position between different types of larvae	F(4, 288095) = 32482, p < 0.05*** Adjusted for multiple comparisons
Does *care domain* affect sorting?	Yes – with equal care domains of larvae sorting happens only based on weight	MANOVA F(5, 144044) = 14575, p < 0.05***
Does *tiredness* affect sorting?	Yes – with equal tiredness for larvae sorting is less clear	MANOVA F(5, 144044) = 237, p < 0.05***

Conclusion

- Model shows
  - Different care domains cause brood sorting
  - Tiredness is less important than care domain in resulting brood sorting
  - Lighter larvae can be carried longer, but aren’t because of small care domain

Discussion

- Model agrees with article on
  - Larvae with more weight can be carried less far
  - Larvae with bigger care domain end up more towards periphery
  - Structure!

- Model disagrees with article on
  - Even though small larvae can be carried further, they aren't
    - Probable cause: small larvae are already "happy" where they are due to their small domain of care

Further research

- We took “domain of care” as a primitive, but can we get “domain of care” to emerge by modelling food requirement and cleaning requirements directly?
- Sendova and Franks discuss 2 different phases: 1 of direct, tight clustering, and 2 of spacing out - we only modelled phase 2 - can we model both phases?

References

Franks, N. R. & Sendova-Franks, A. B. 1992. Brood sorting by ants: distributing the workload over the work-surface. Behavioral Ecology and Sociobiology, 30, 109–123.

Sendova-Franks, A. B. et al. “Brood sorting by ants: two phases and differential diffusion”. Animal Behaviour, 68 (2004): 1095 - 1106. https://doi.org/10.1016/j.anbehav.2004.02.013

Wilson, M. et al. “Algorithms for Building Annular Structures with Minimalist Robots Inspired by Brood Sorting in Ant Colonies.” *Autonomous Robots* 17 (2004): 115-136.