

# Brood sorting by ants

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Ludi van Leeuwen  
Corine Nijhof

Advanced Self-Organisation  
of Social Systems

# Main character

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# Family picture

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egg

medium

large

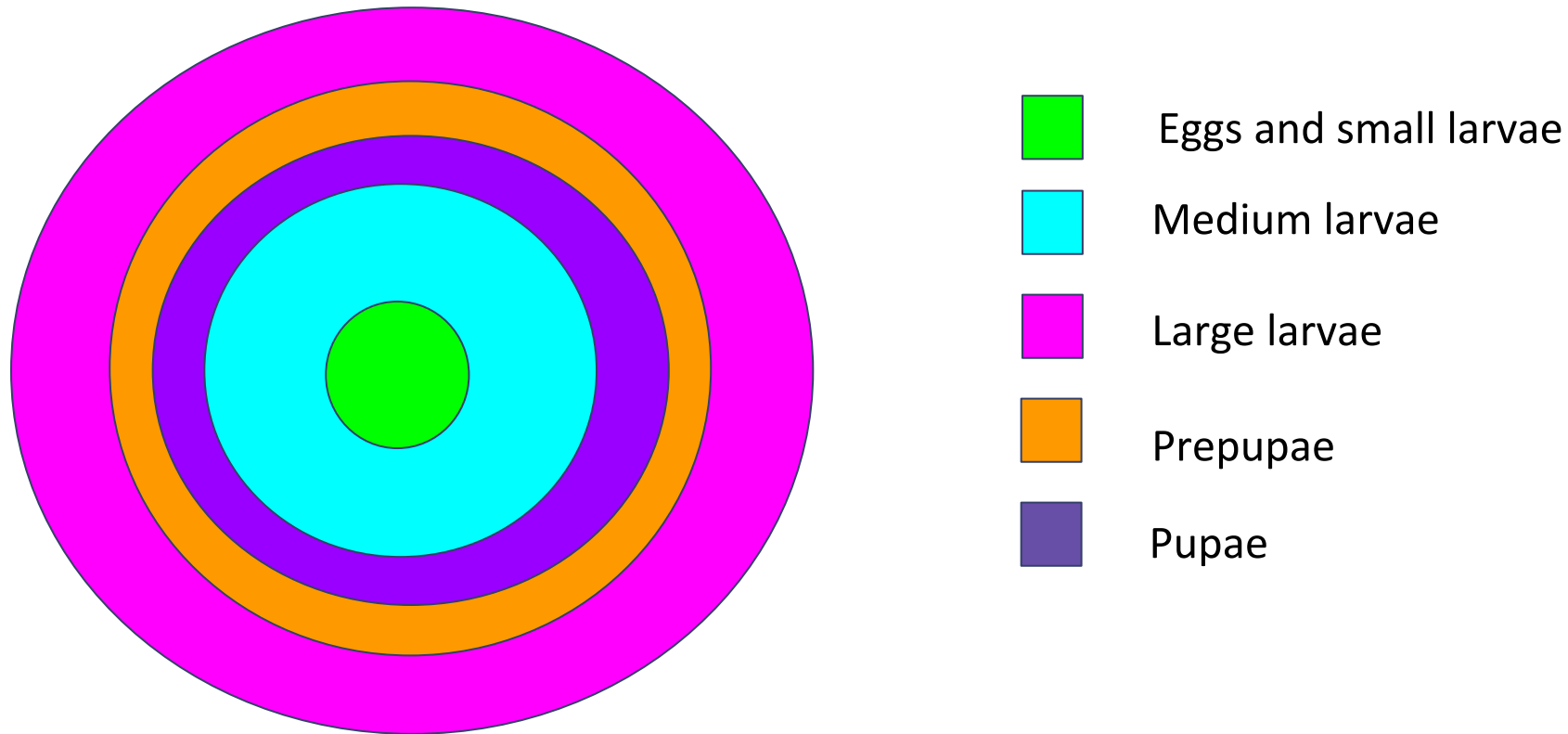
pre-pupae

pupae



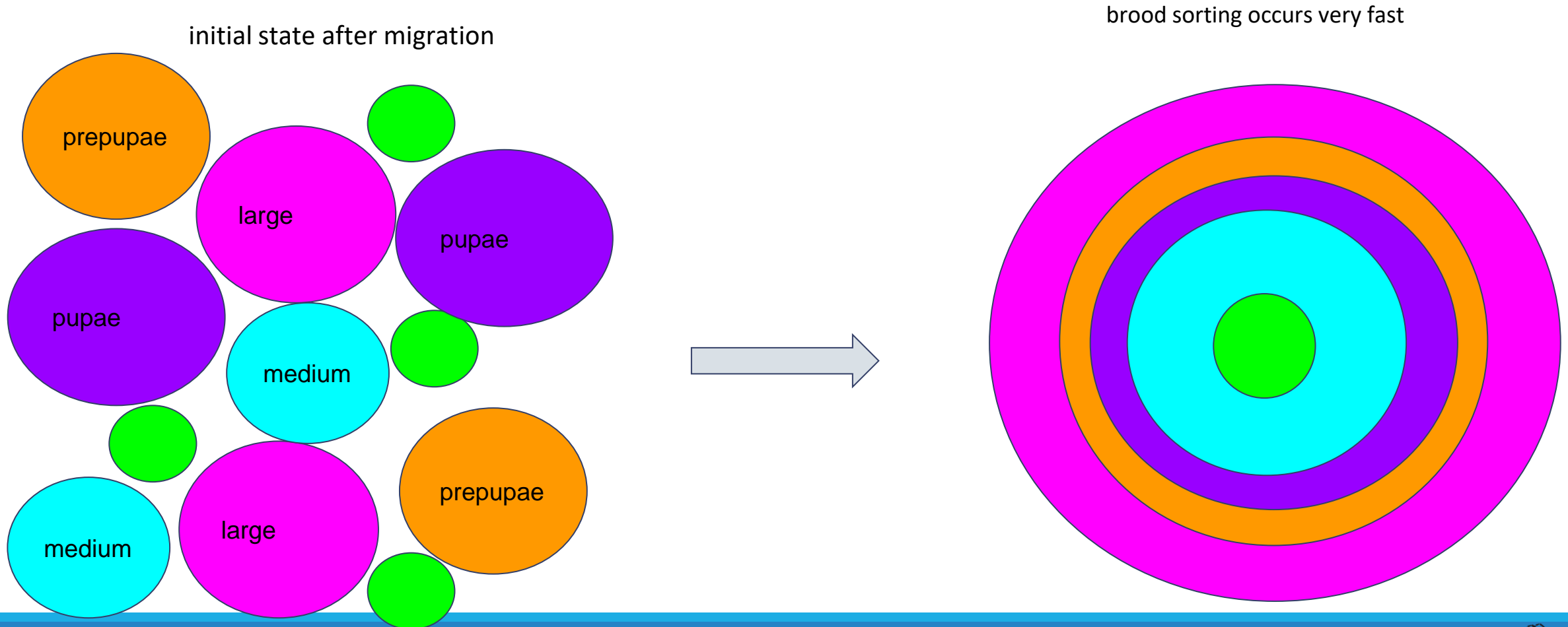
# Empirical data (Sendova-Franks 2004)

- Brood is sorted in concentric annuli (rings)



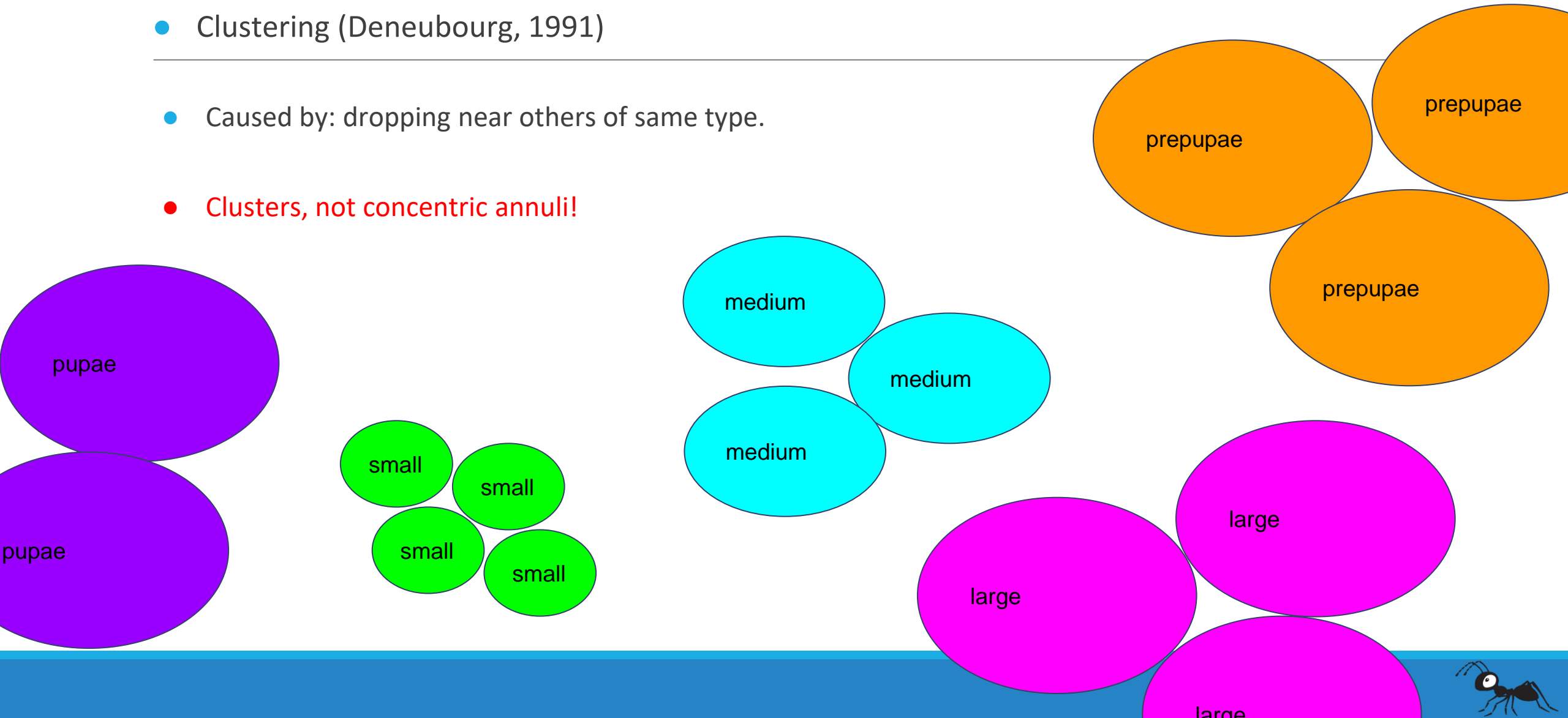
# Question

- What is the cause of this brood organisation?



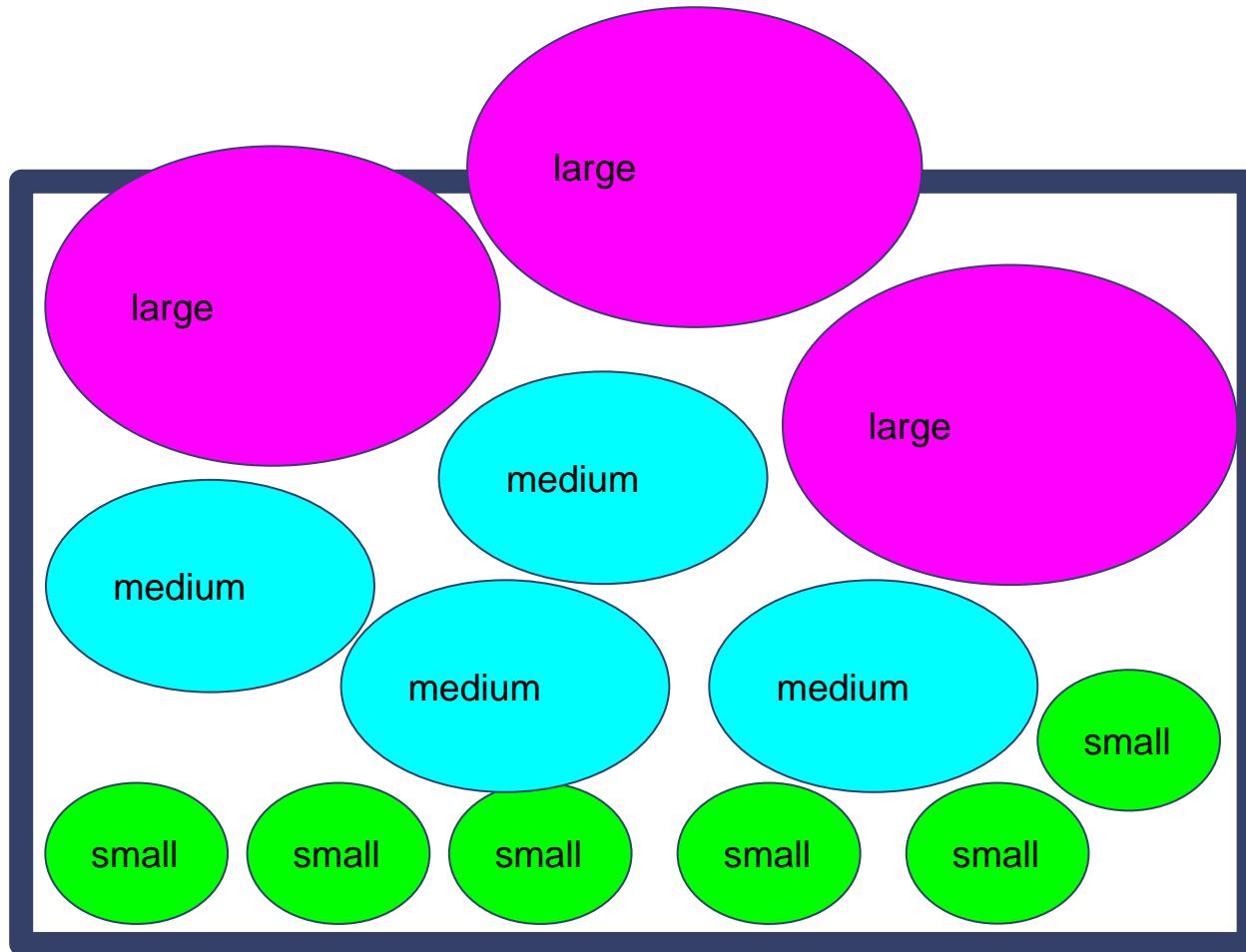
# Alternative hypotheses

- Clustering (Deneubourg, 1991)
- Caused by: dropping near others of same type.
- Clusters, not concentric annuli!



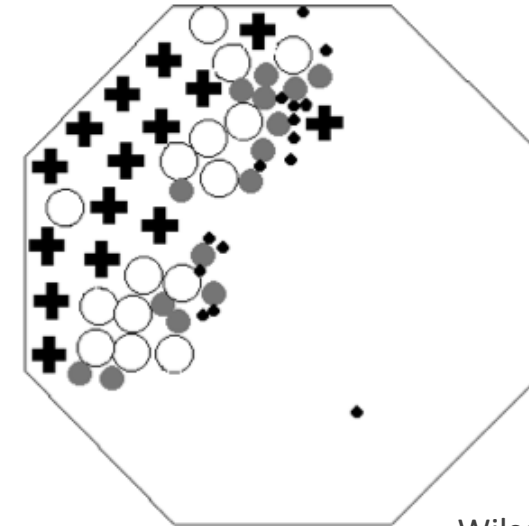
# Alternative hypotheses

- Muesli effect (Barker & Grimson, 1990)



- Small items can pass, larger can't

Empirical results (by simulated robots)



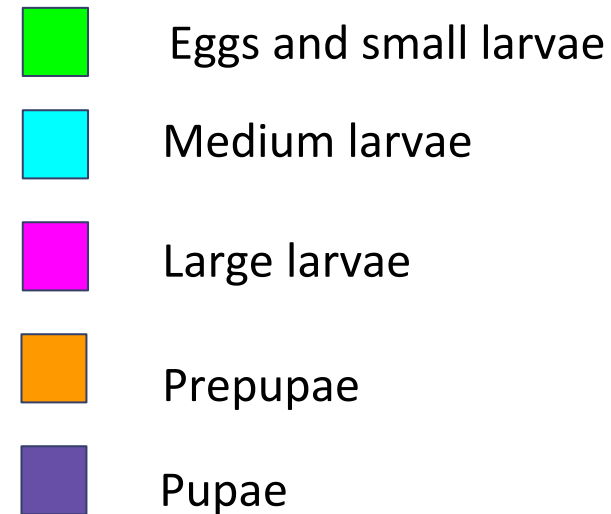
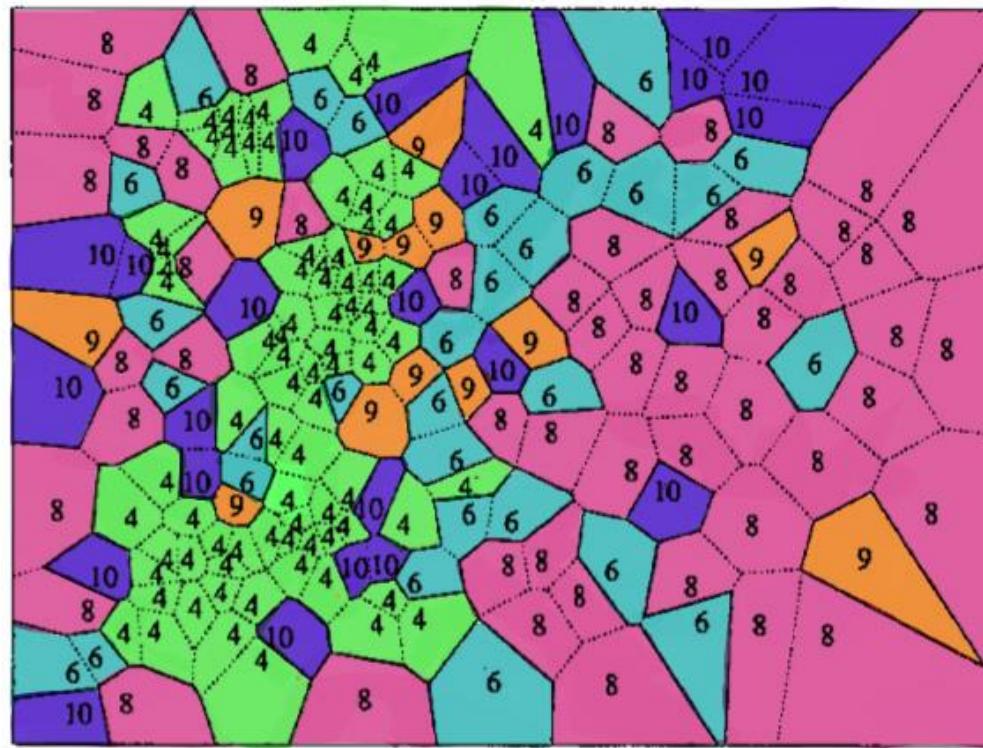
No concentric annuli!

Wilson (2004)



# Sendova and Franks Hypothesis

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



D (AFTER)

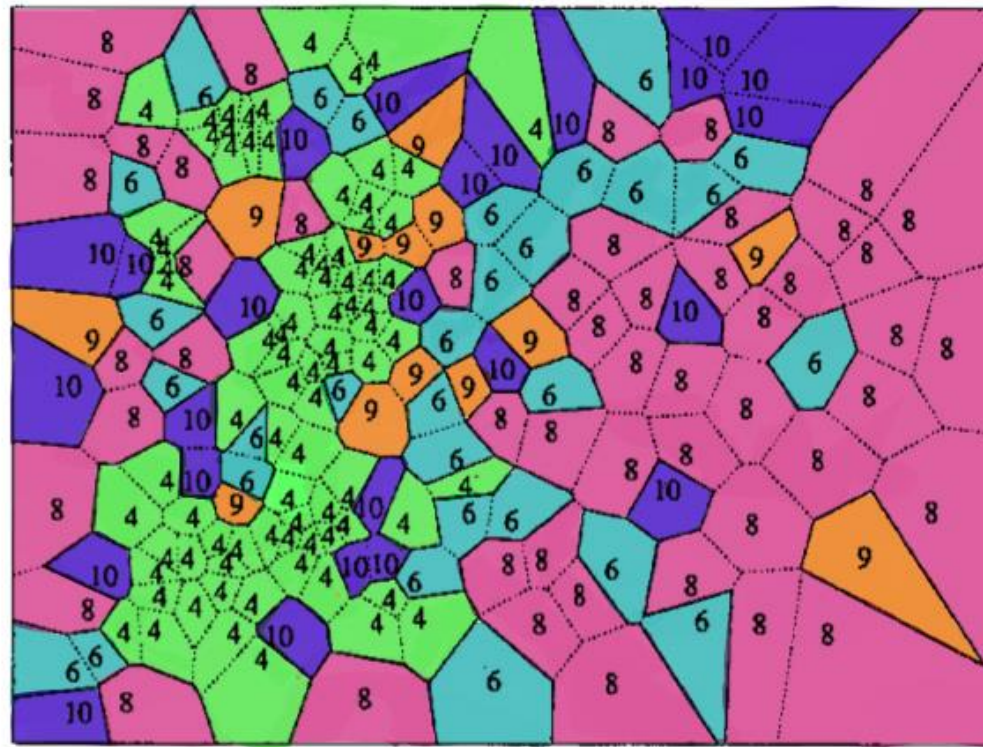
Franks (1992)



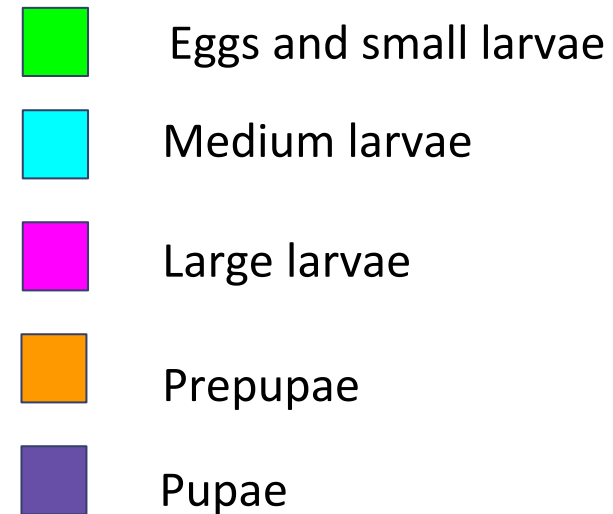


# Hypothesis

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



D (AFTER)



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



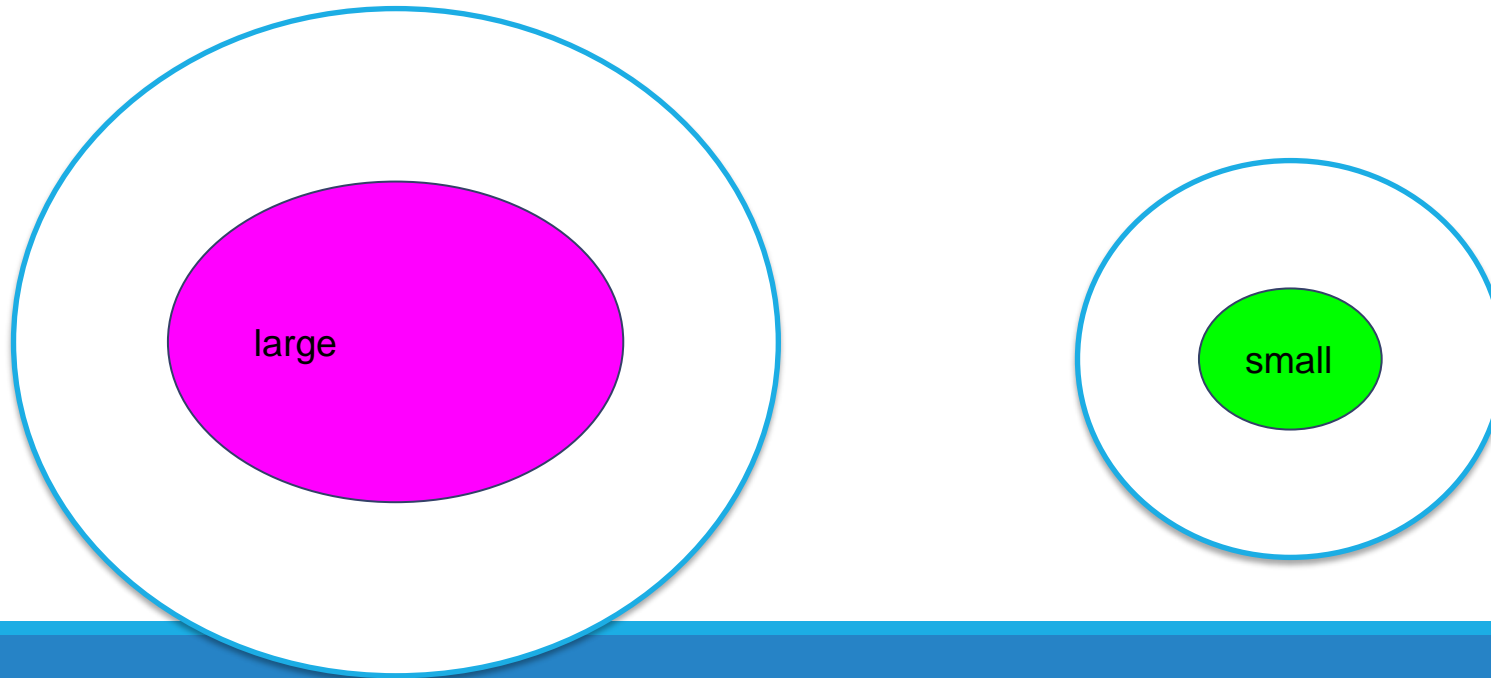
Care (Pre)-Pupae: No feeding, only cleaning



# Hypothesis

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- 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

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- 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

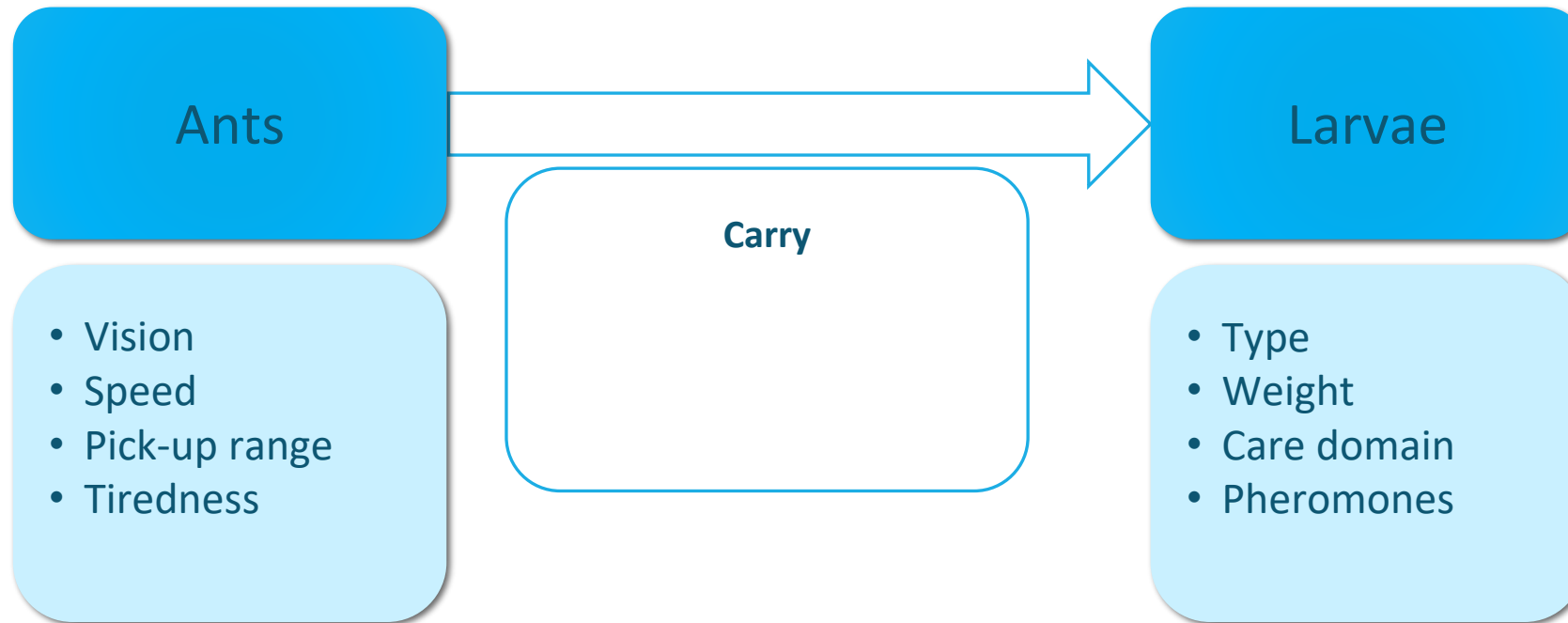
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- Care ordering: Large larvae > Medium larvae ~ Prepupae ~ Pupae > Small larvae and eggs.
- Simple rules:
  - Pick brood up if overcrowded according to domain of care.
  - Drop brood if not overcrowded anymore.
  - + tiredness - ants carry small/light brood easier than large/heavy brood.



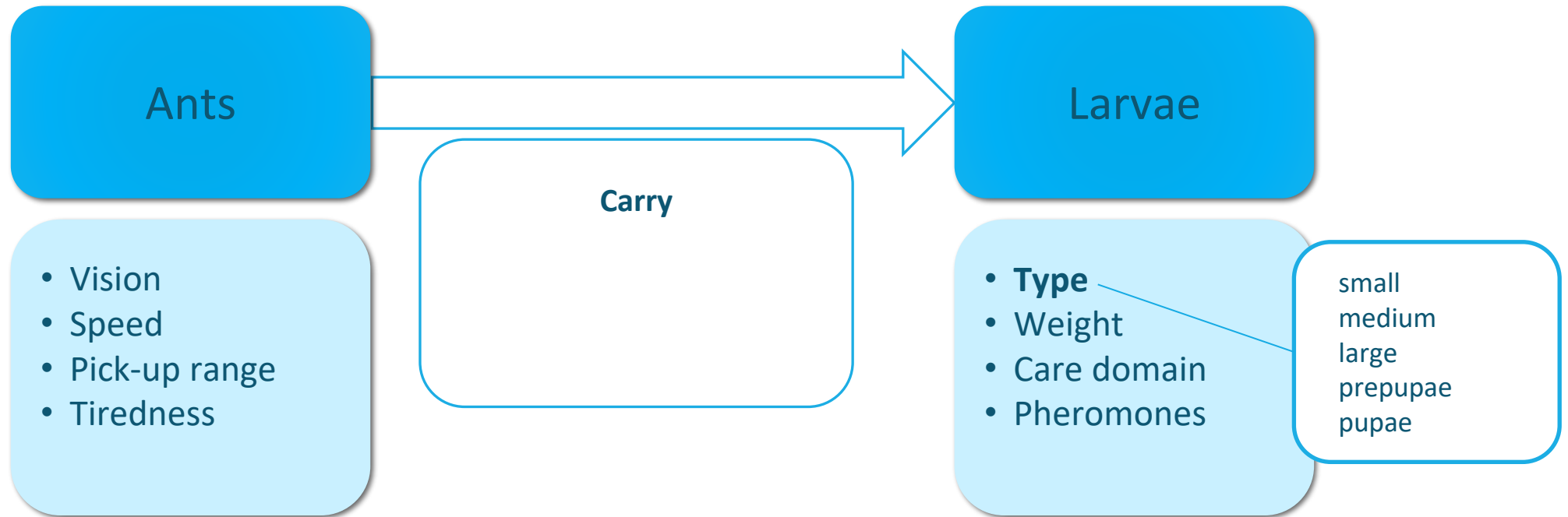
# Model

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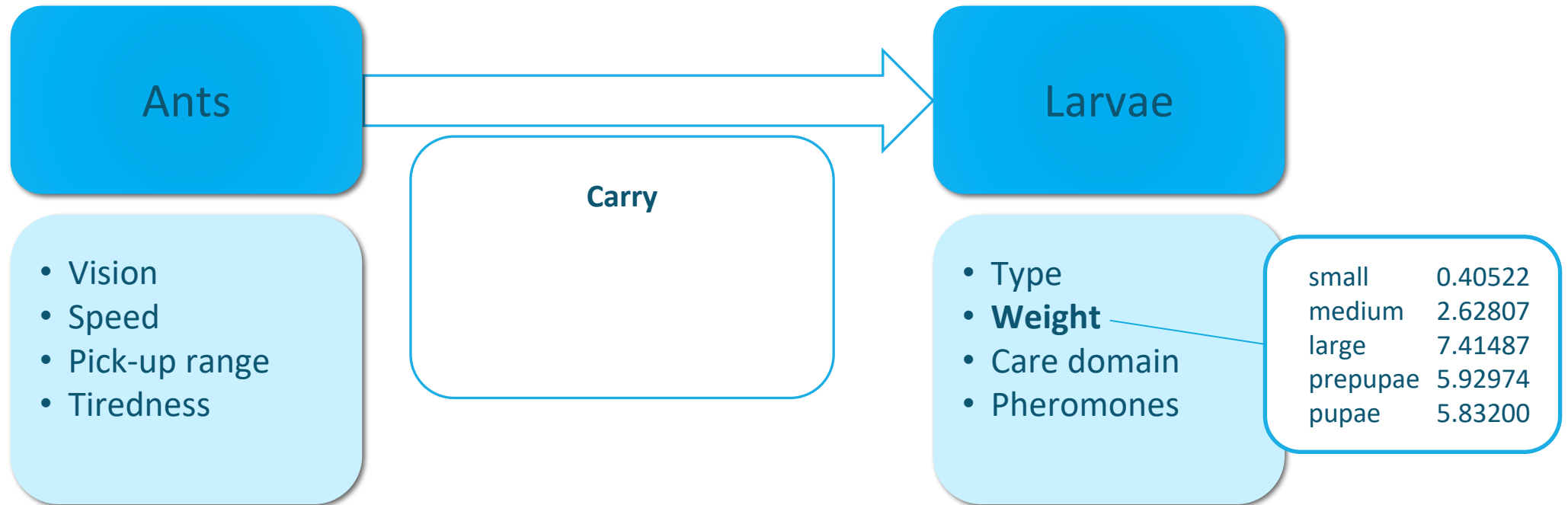
# Model

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# Model

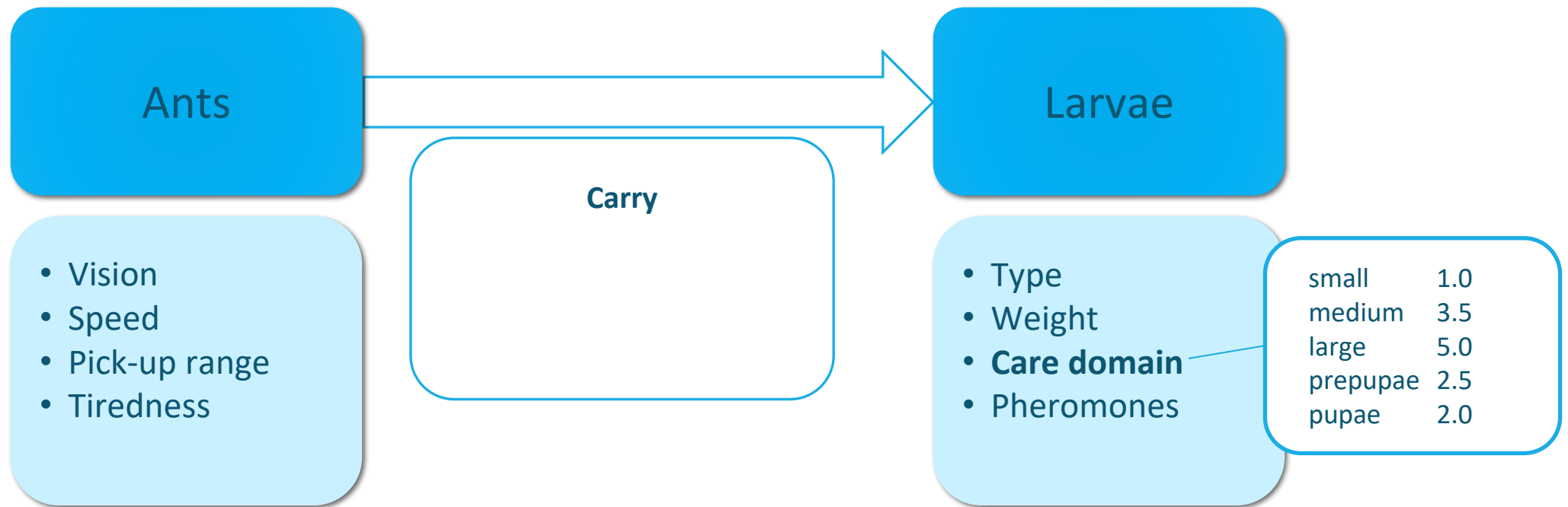
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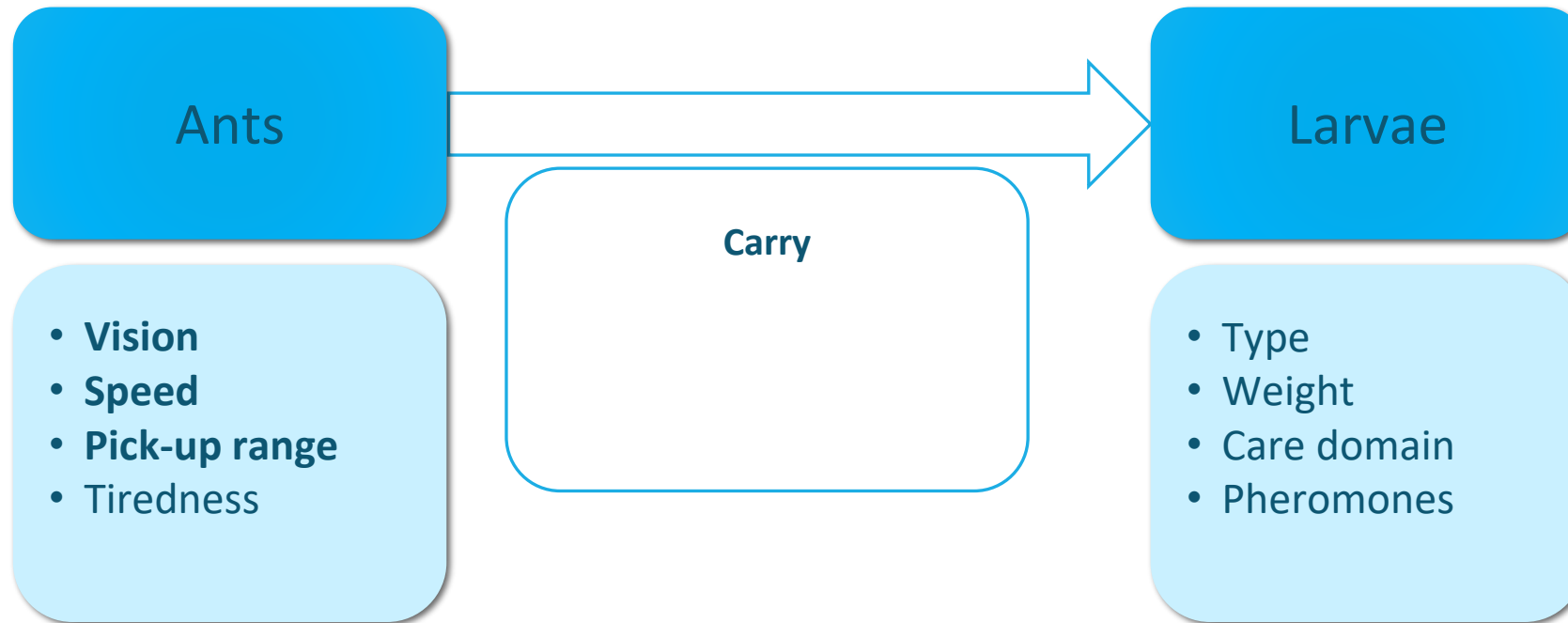
# Model

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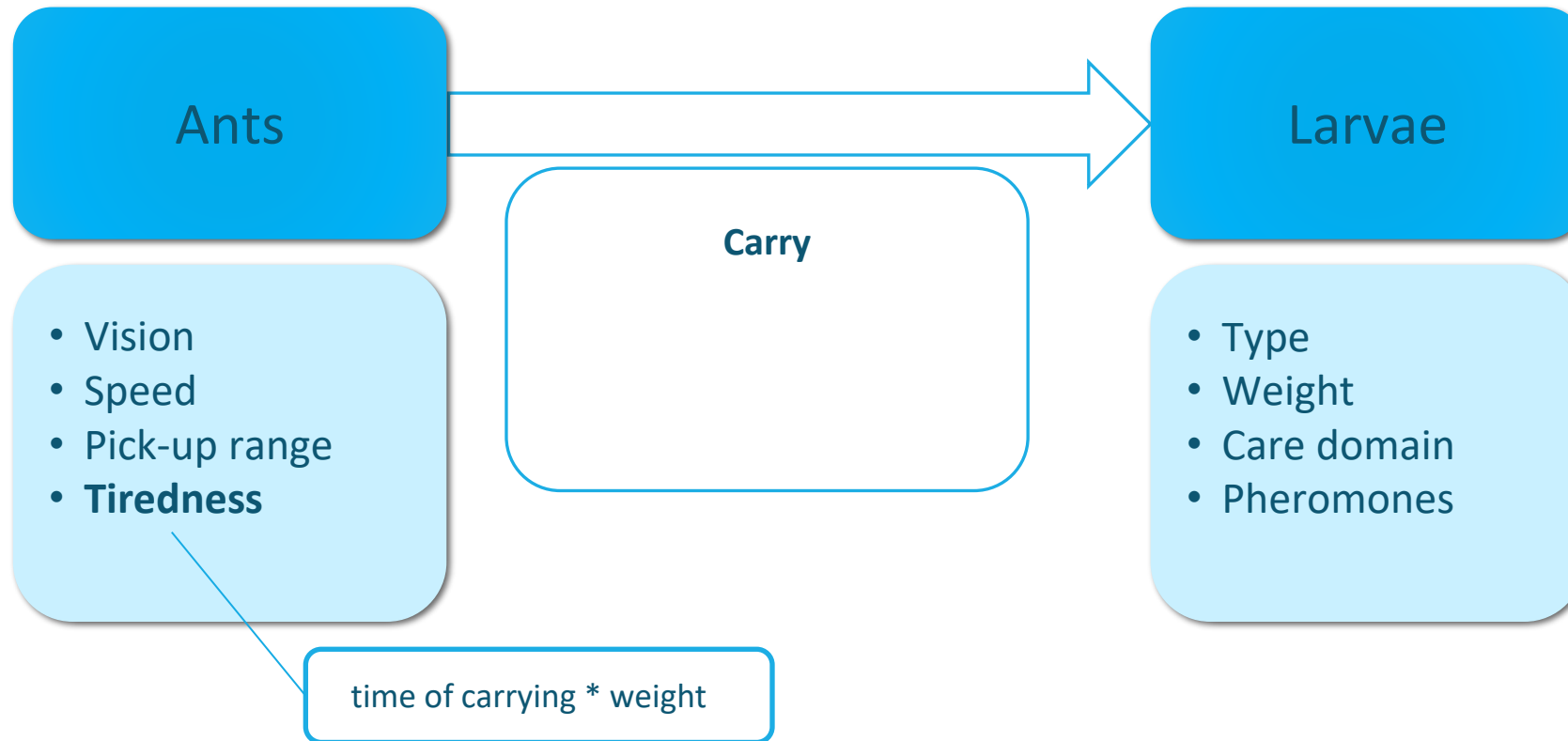
# Model

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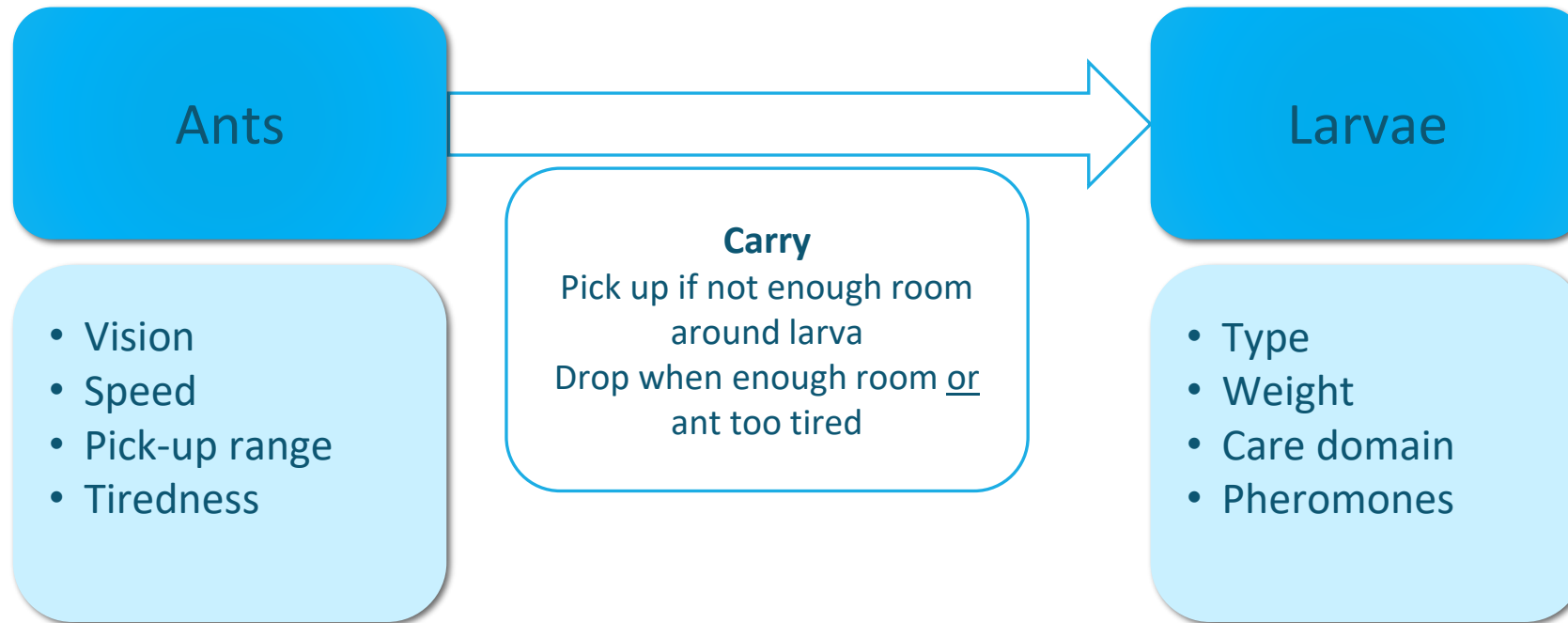
# Model

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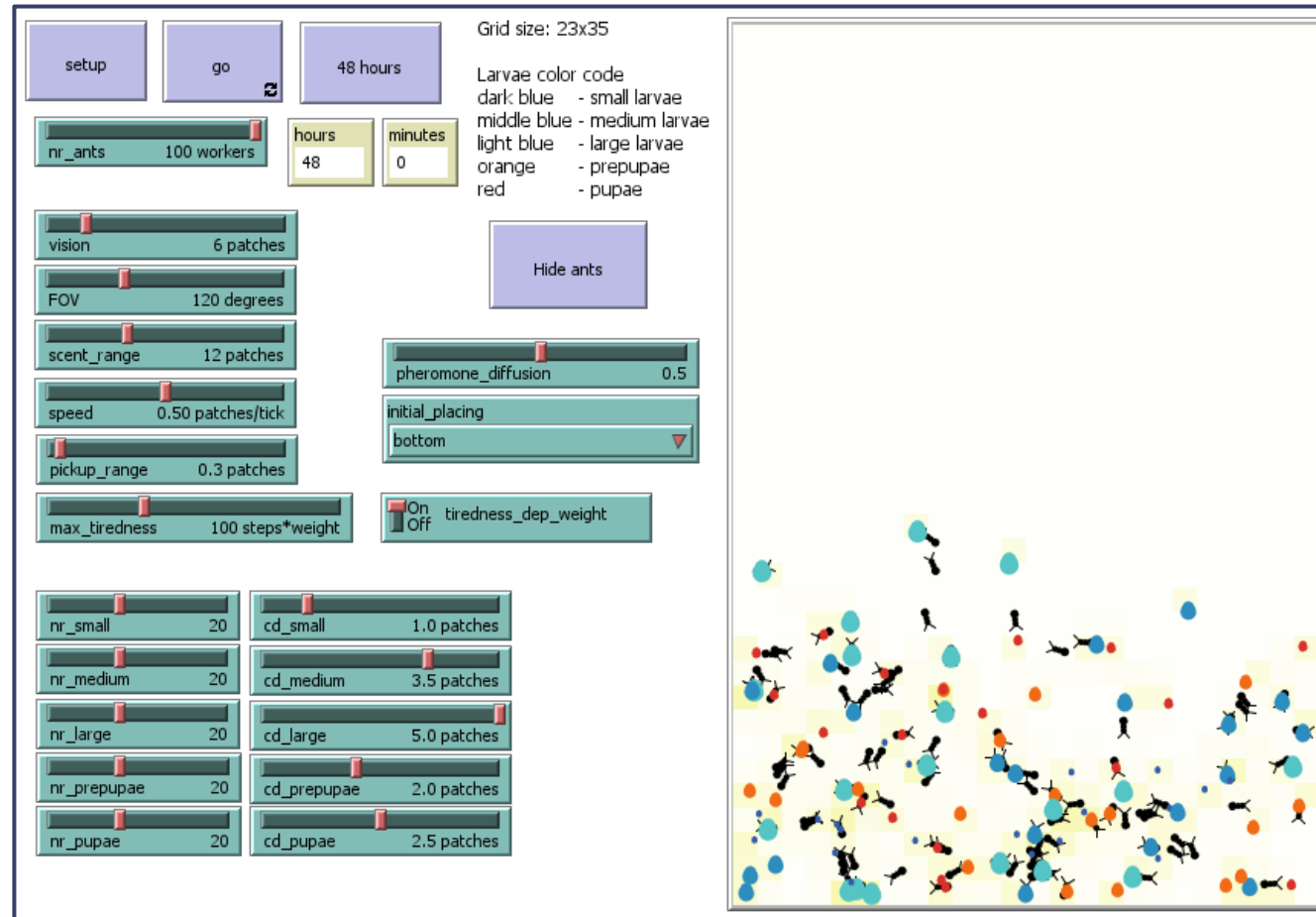


# Model

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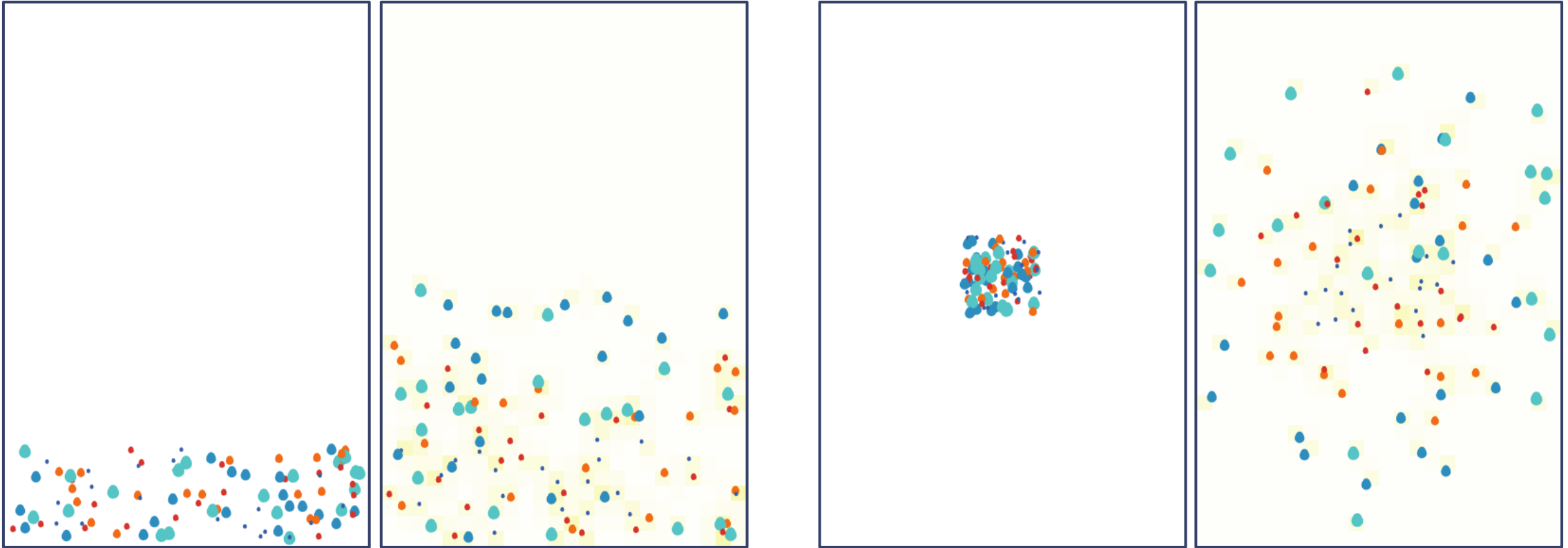


# Model demonstration

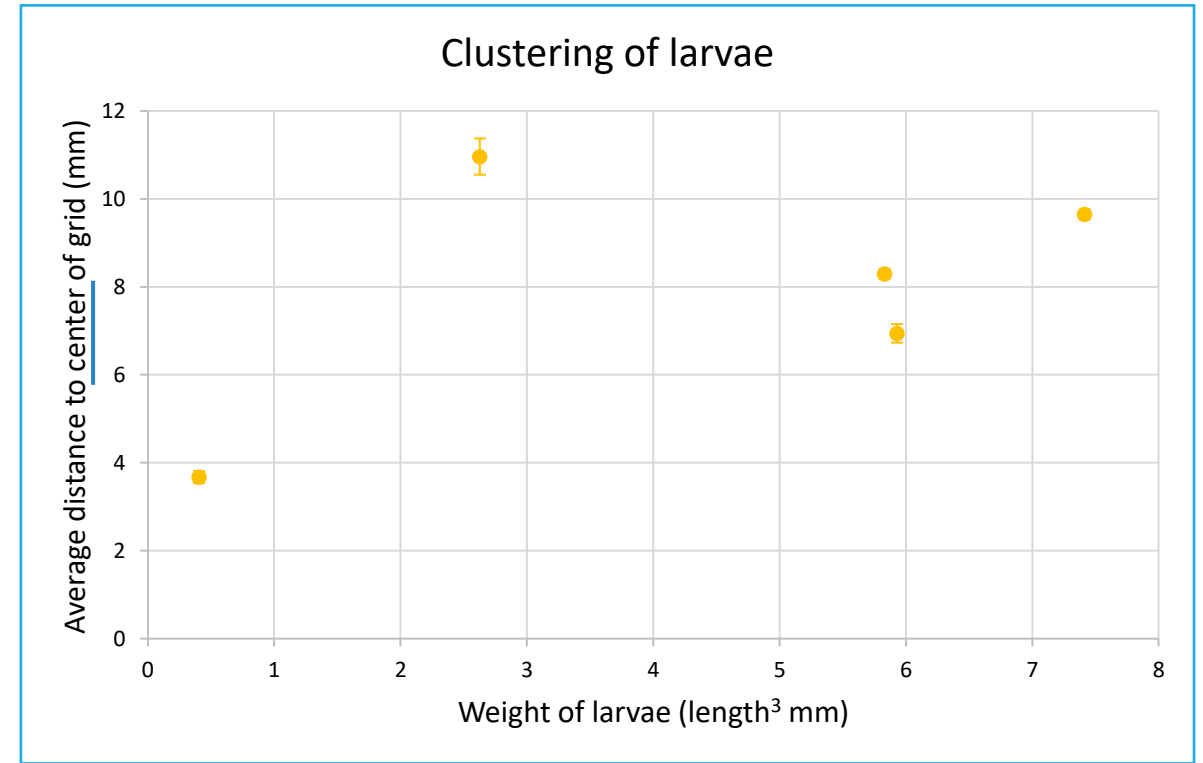
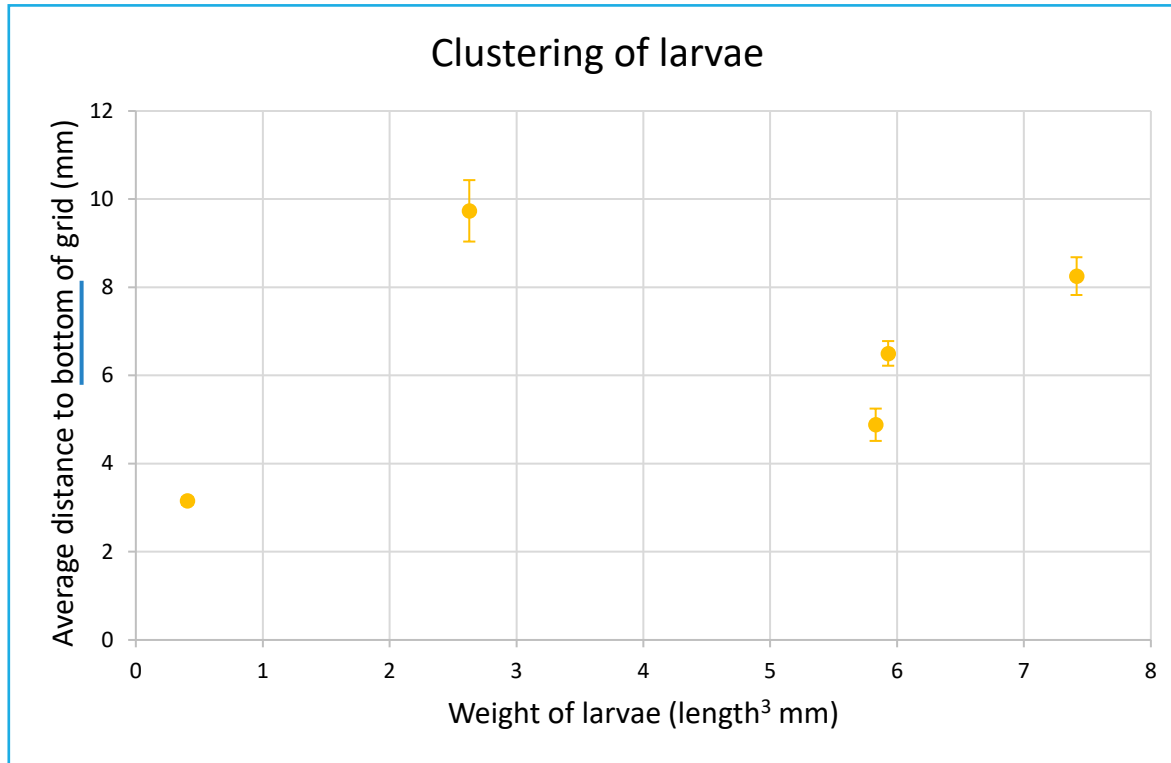


# Initial placing bottom vs. center

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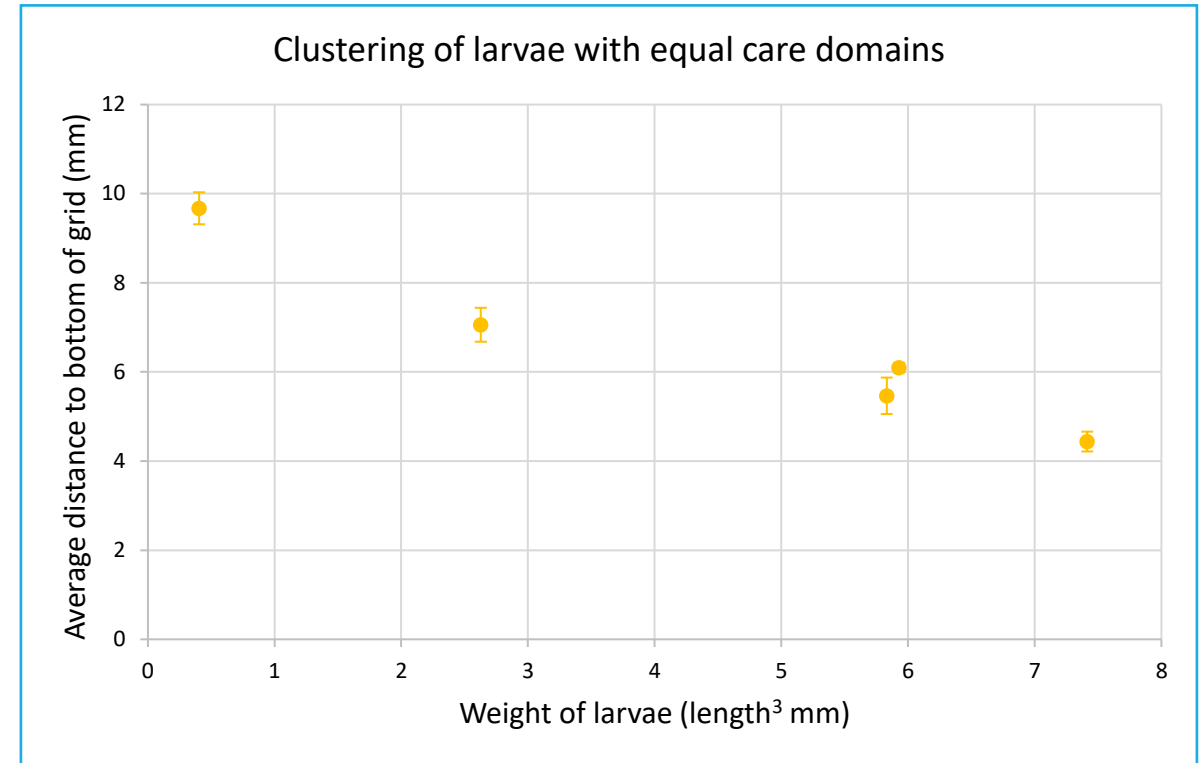
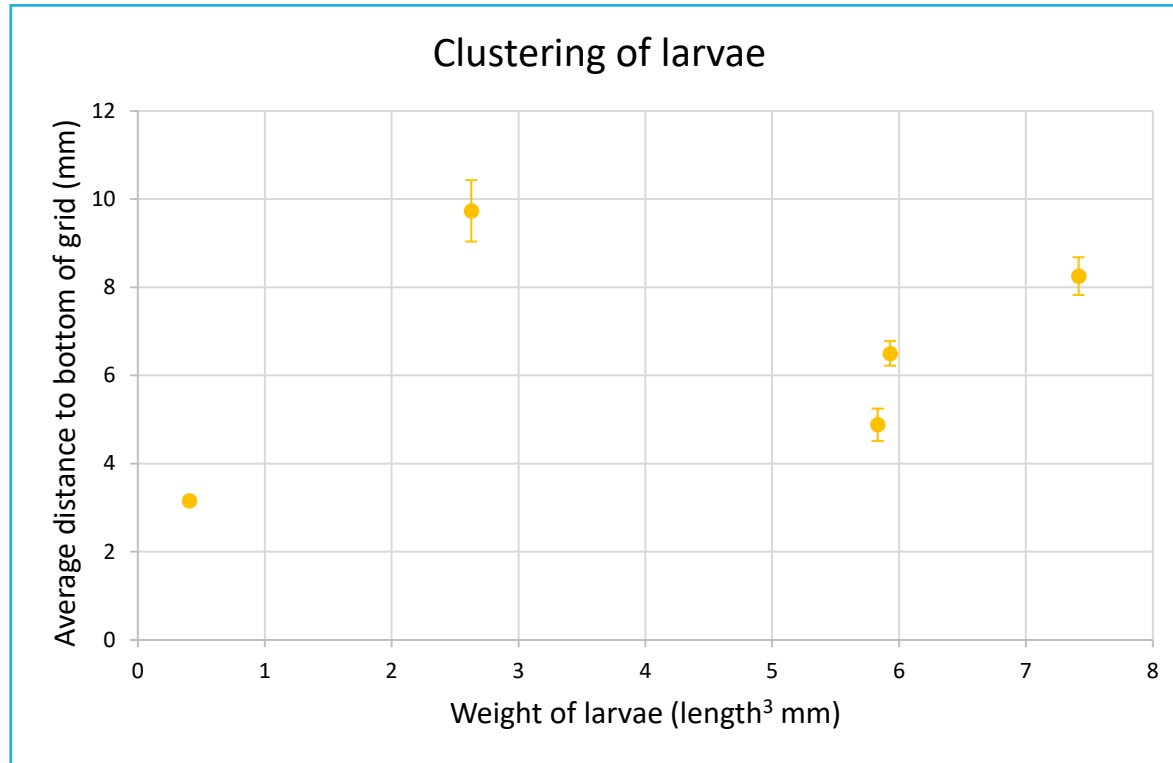


# Initial placing bottom vs. center



# Care domain proportional to weight vs. equal for all larvae

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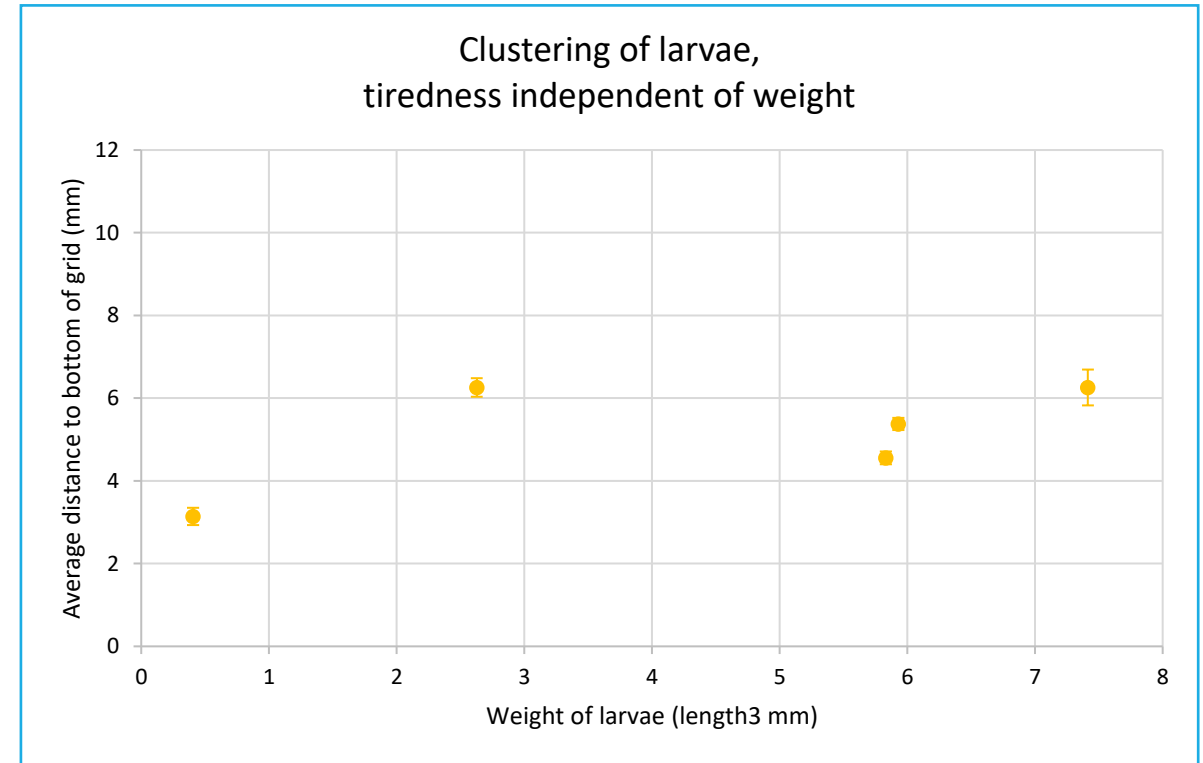
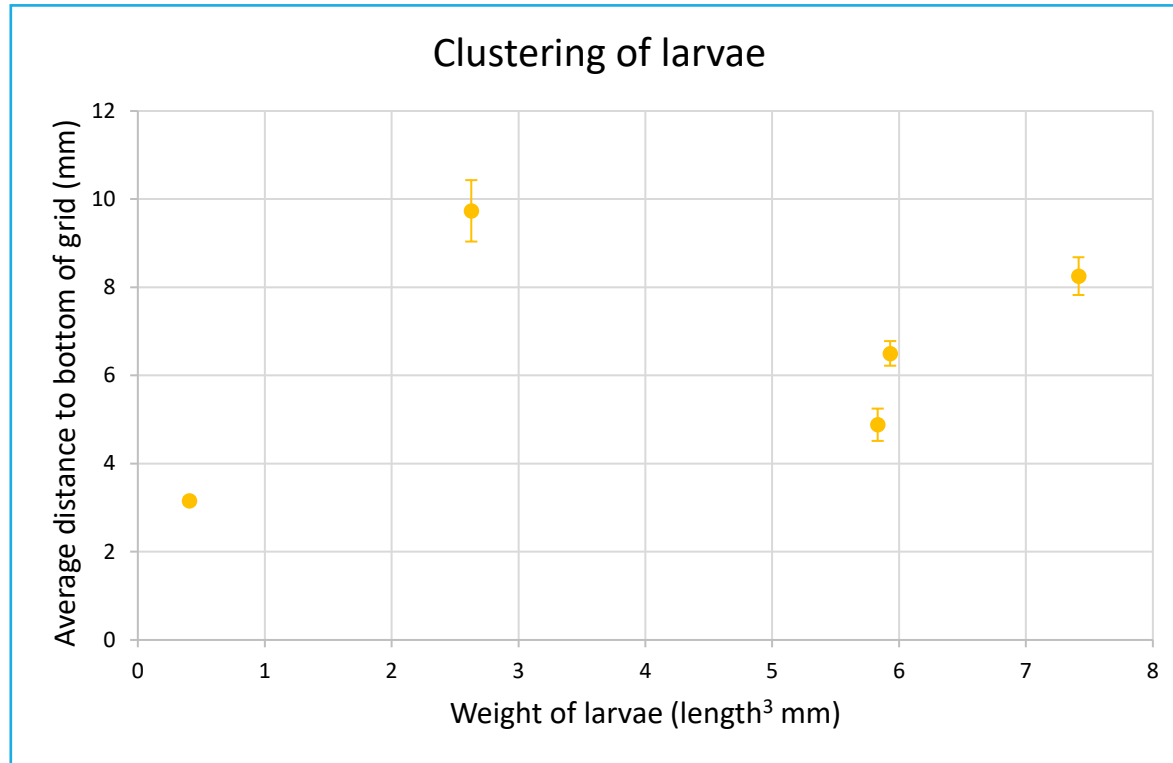




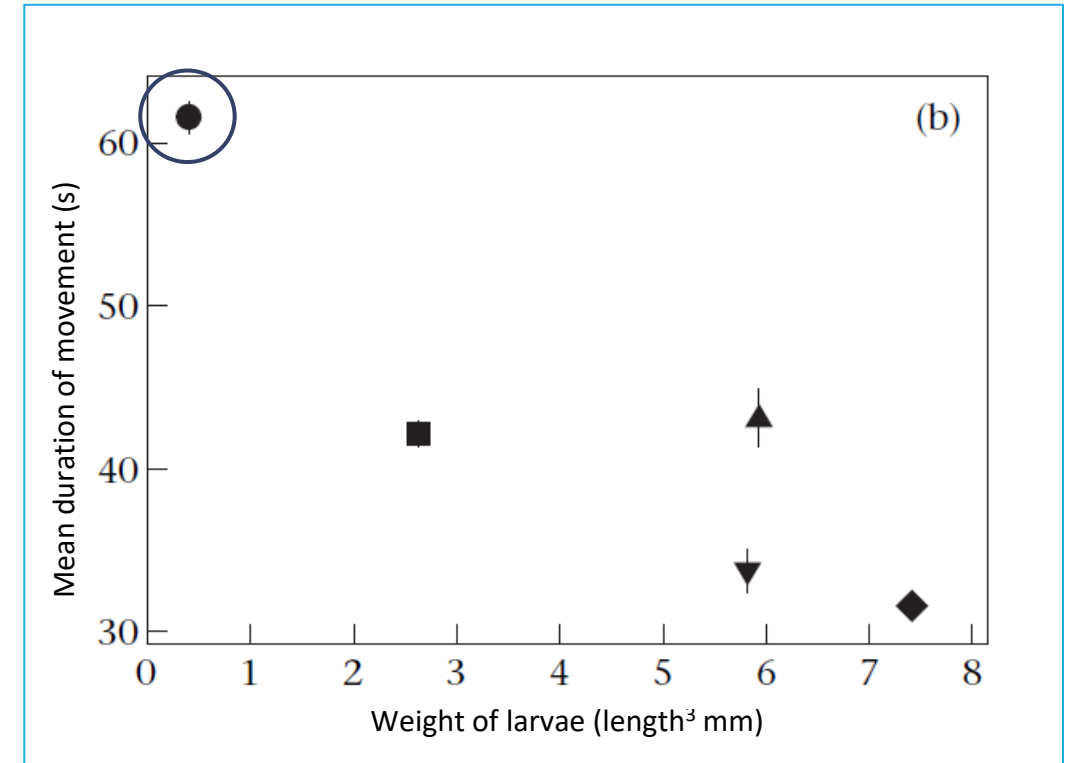
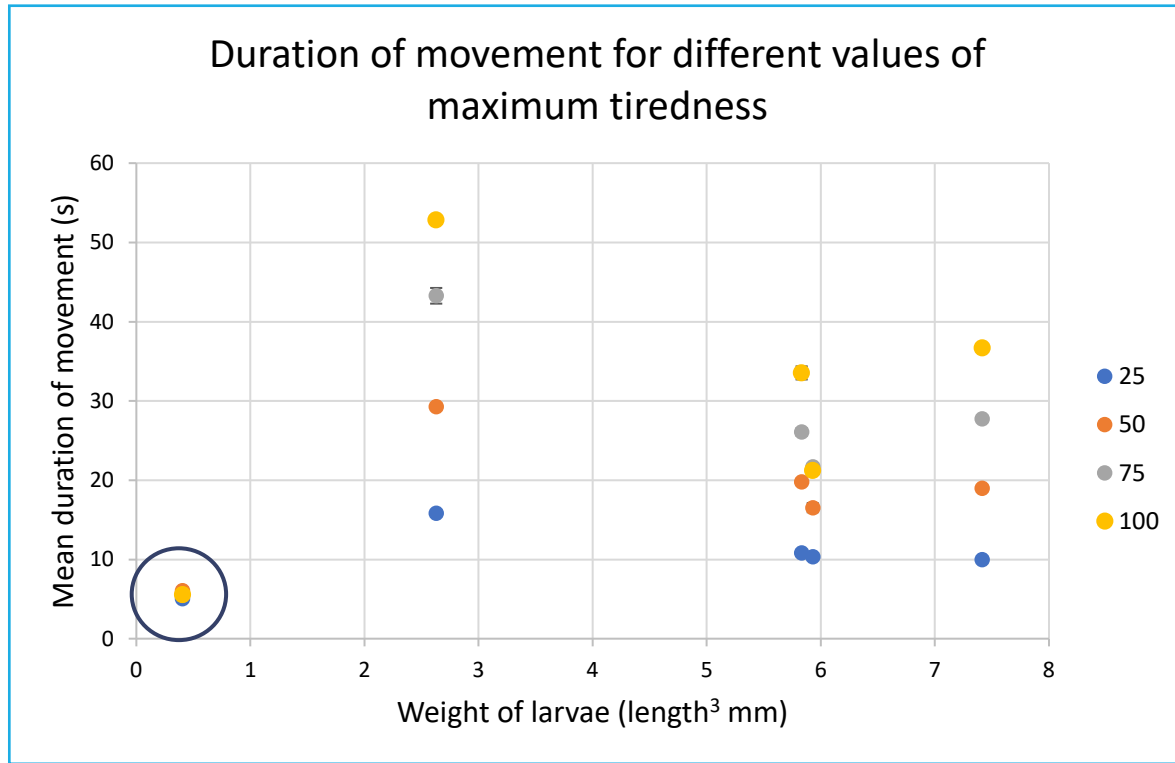
# Tiredness

## dependent on weight vs. equal for all larvae

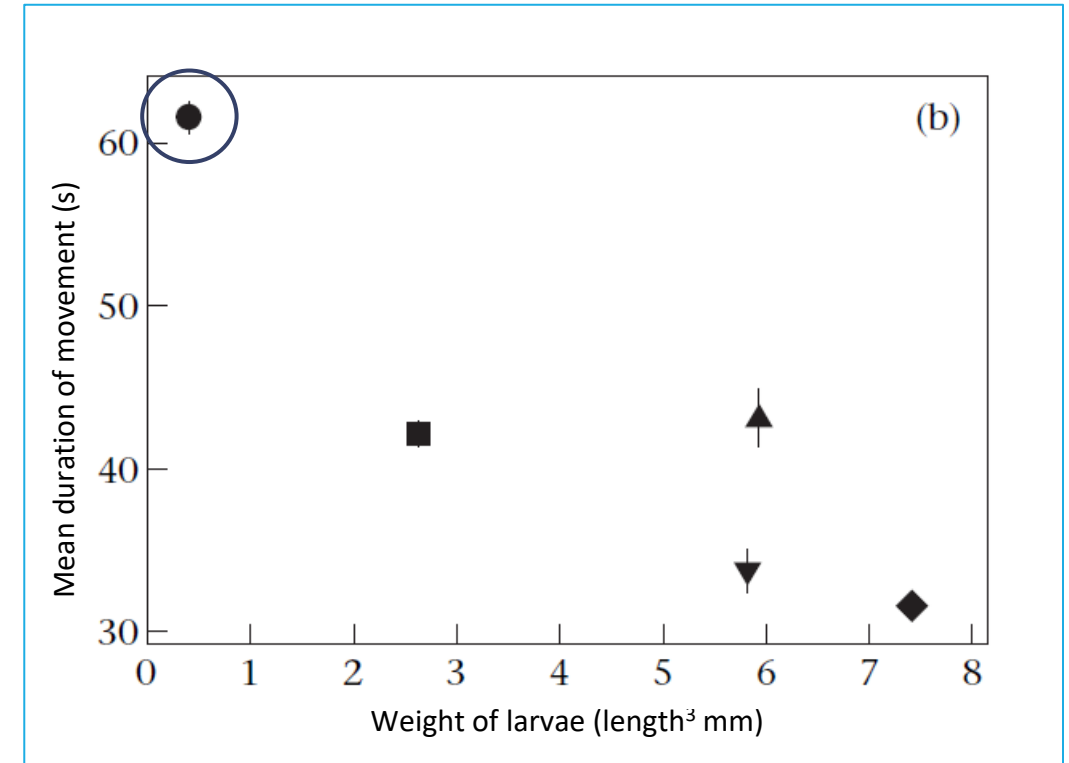
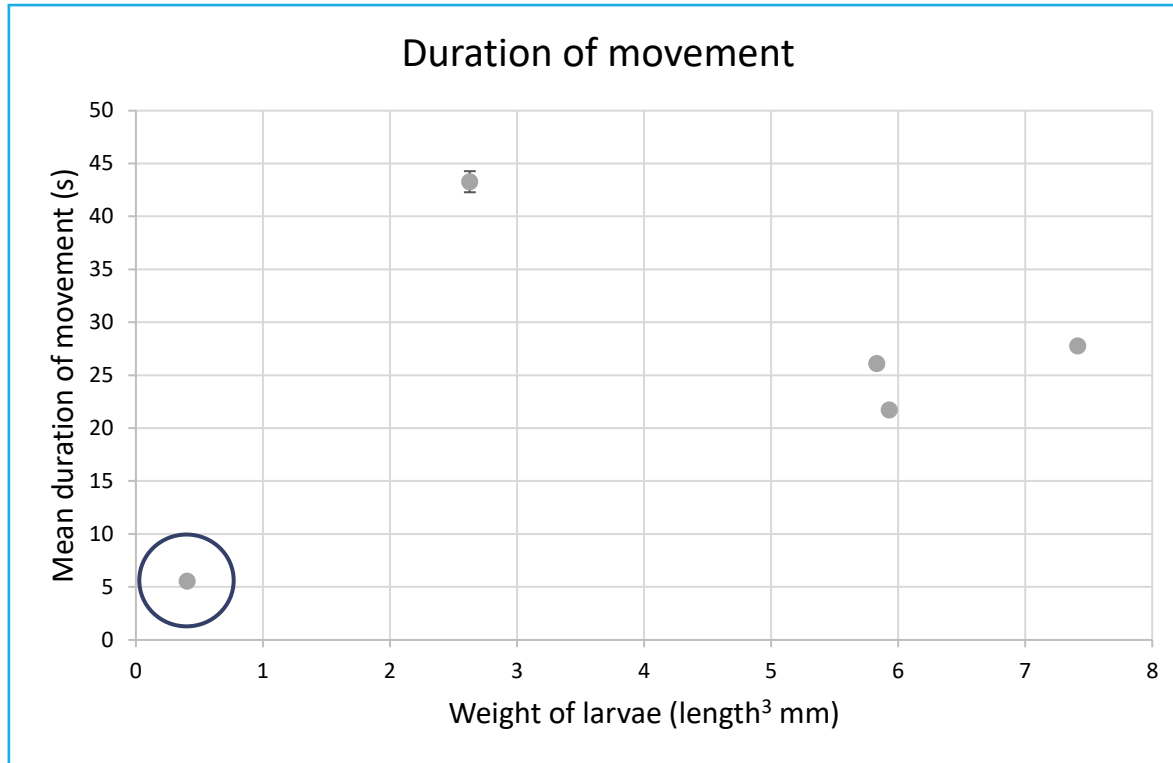
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# Mean duration of brood movement by ants model vs. empirical



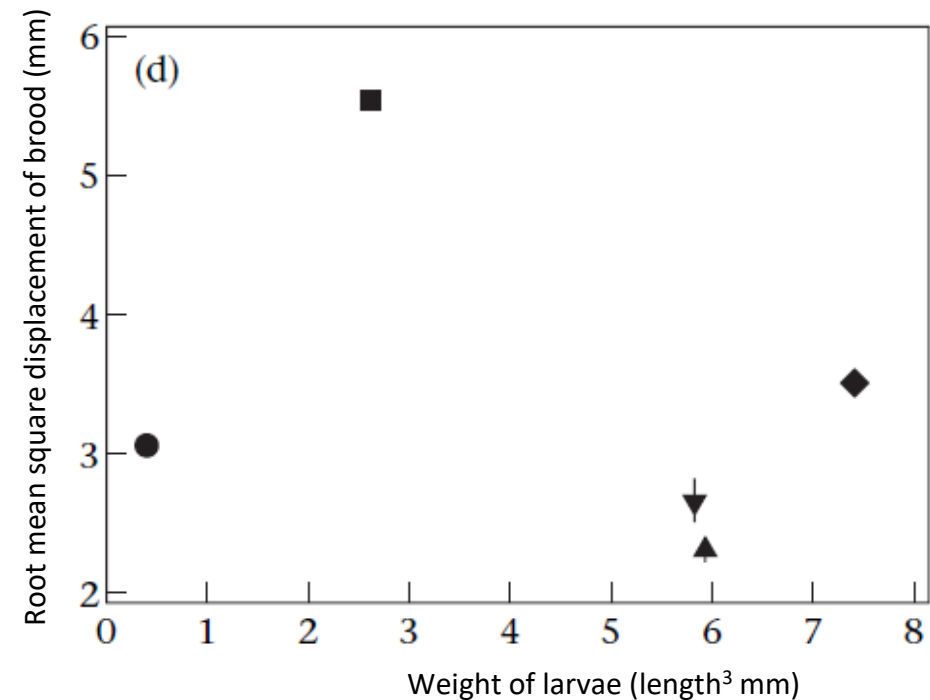
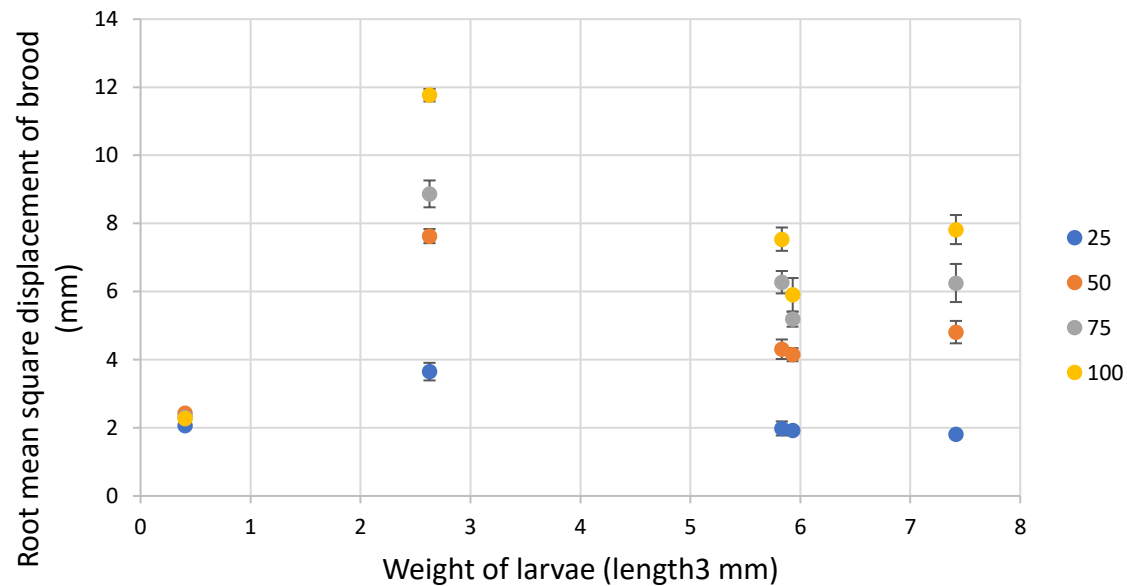
# Mean duration of brood movement by ants model vs. empirical



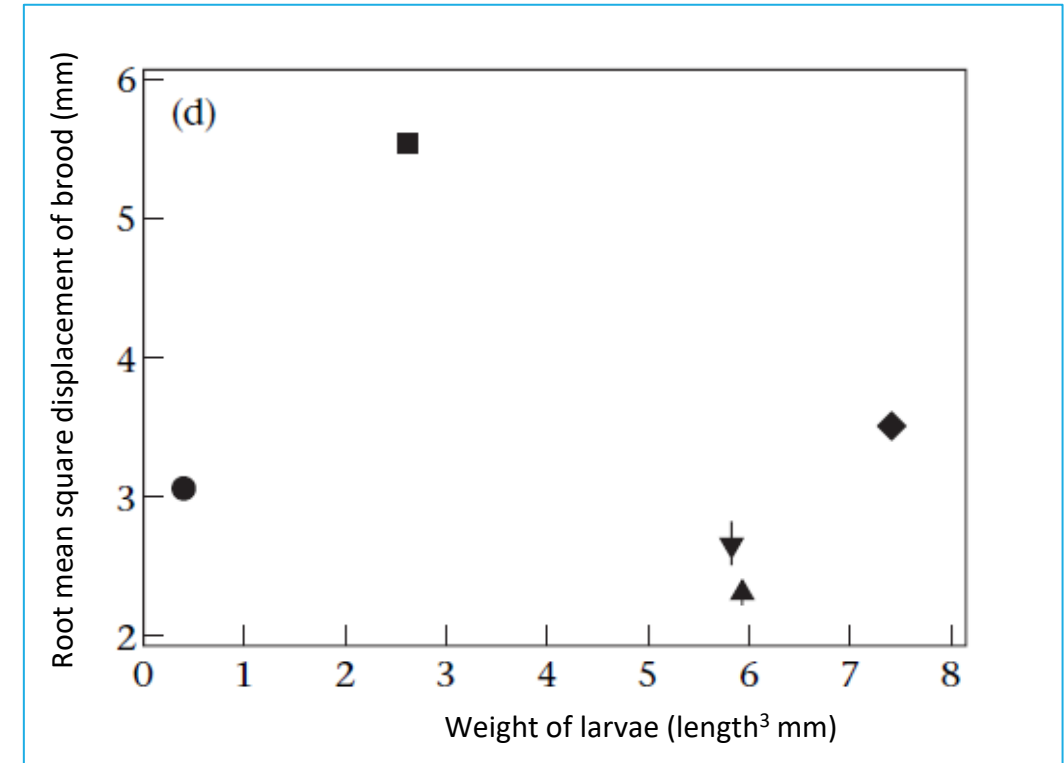
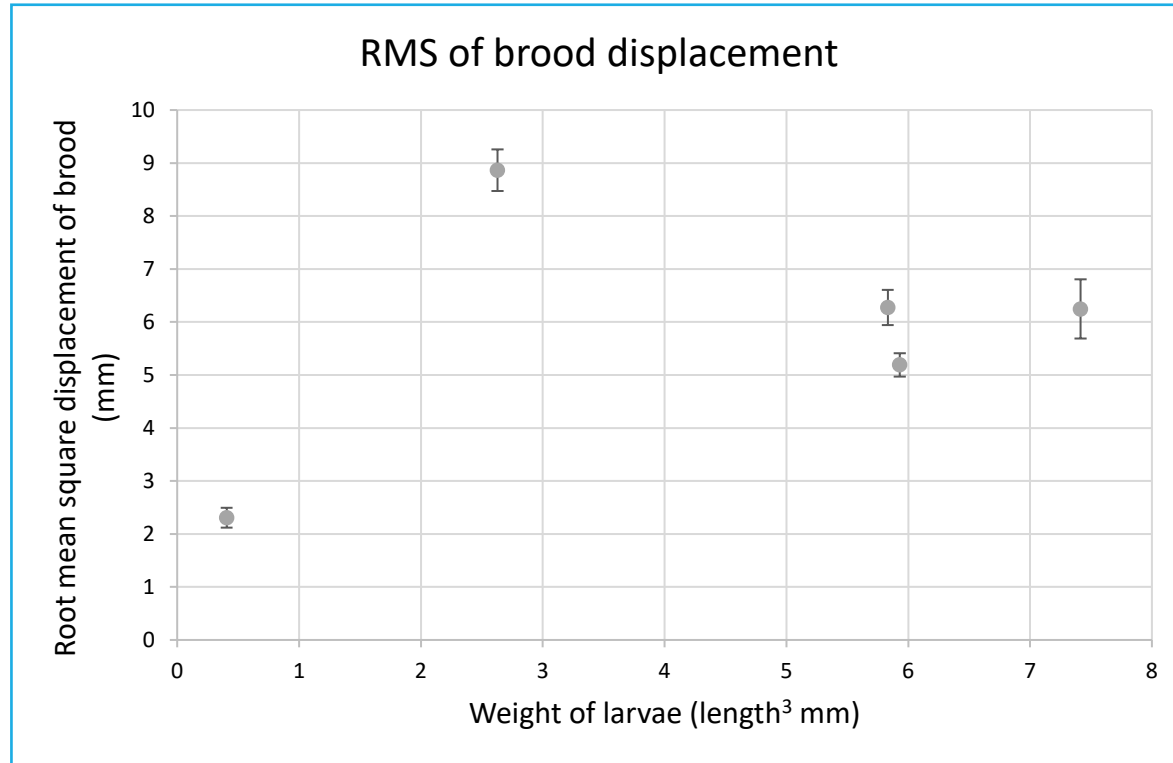
# RMS of brood displacement model vs. empirical (Sendova-Franks, 2004)

$$RMS = \sqrt{\frac{1}{n} \sum_i d_i^2}$$

RMS of brood displacement for different values of maximum tiredness



# RMS of brood displacement model vs. empirical



# Summary of results

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	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 <i>care domain</i> affect sorting?	Yes – with equal care domains of larvae sorting happens only based on weight	MANOVA $F(5, 144044) = 14575, p < 0.05^{***}$
Does <i>tiredness</i> affect sorting?	Yes – with equal tiredness for larvae sorting is less clear	MANOVA $F(5, 144044) = 237, p < 0.05^{***}$



# Conclusion

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- Model shows
  - Different care domains cause brood sorting
  - Influence of tiredness because of weight is much smaller than of care domain in brood sorting
  - Lighter larvae can be carried longer, but aren't because of small care domain



# Discussion

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- Model agrees with empirical data on
  - Larvae with more weight can be carried less far
  - Larvae with bigger care domain end up more towards periphery
  - Structure!
- Model disagrees with empirical data on
  - Even though small larvae can be carried further, they are not

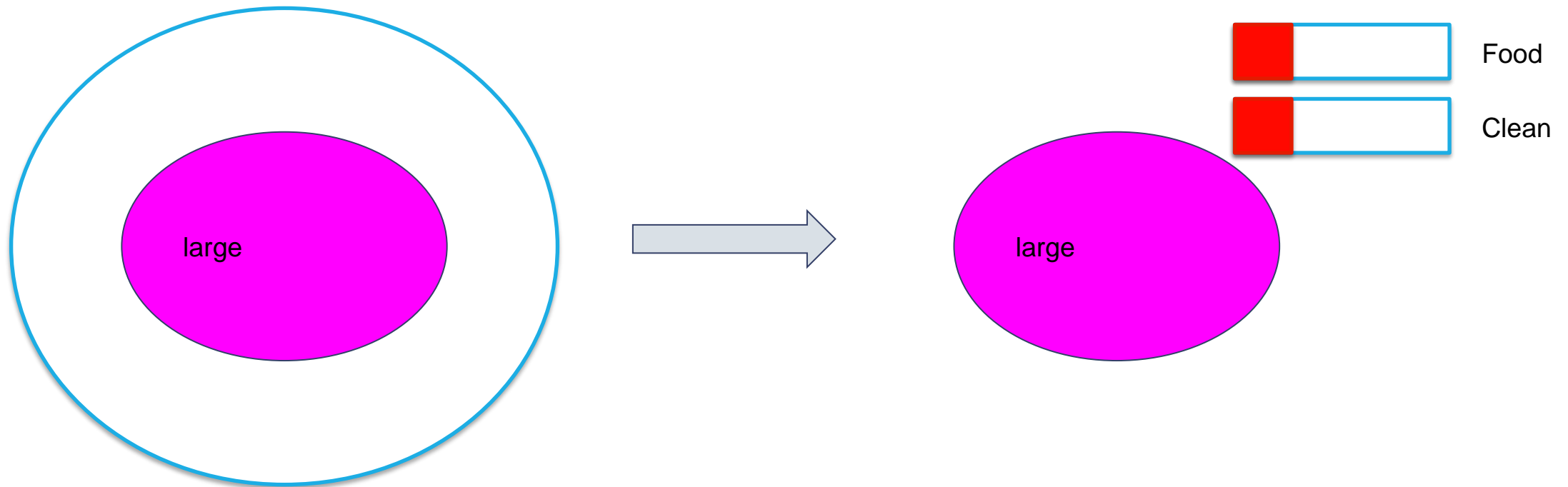




# Further research

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- 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?



# 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.

## Questions?

