Behavioural Science Institute

January 2022
Behaviour & Evolution Seminar

What is the shape of plasticity?

evolutionary models of incremental development

Nicole Walasek (presenter)
Willem Frankenhuis
Karthik Panchanathan

Radboud University

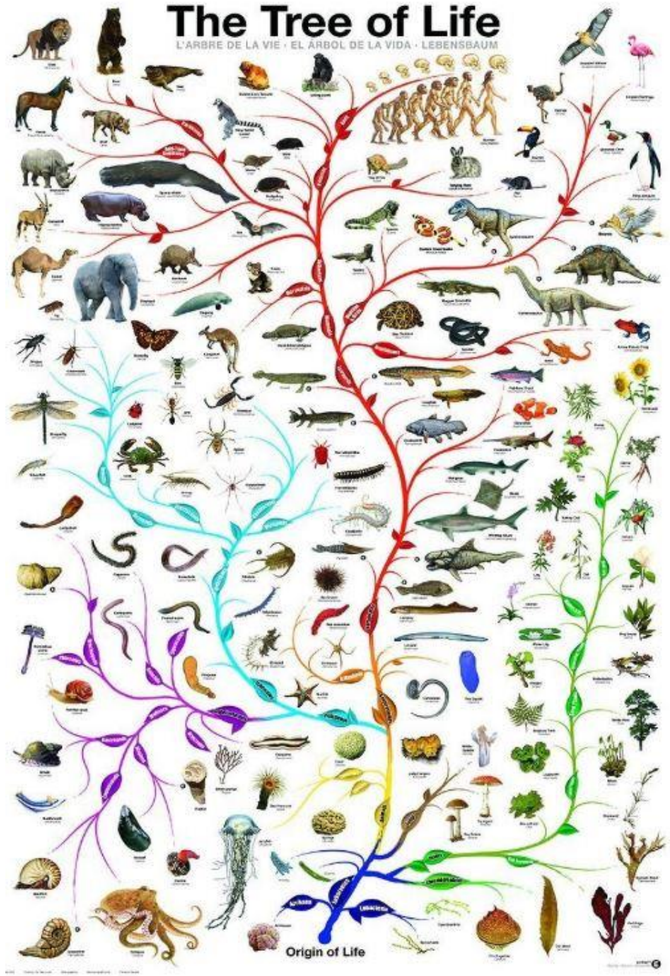
Individuals are shaped by experiences

Individuals are shaped by experiences

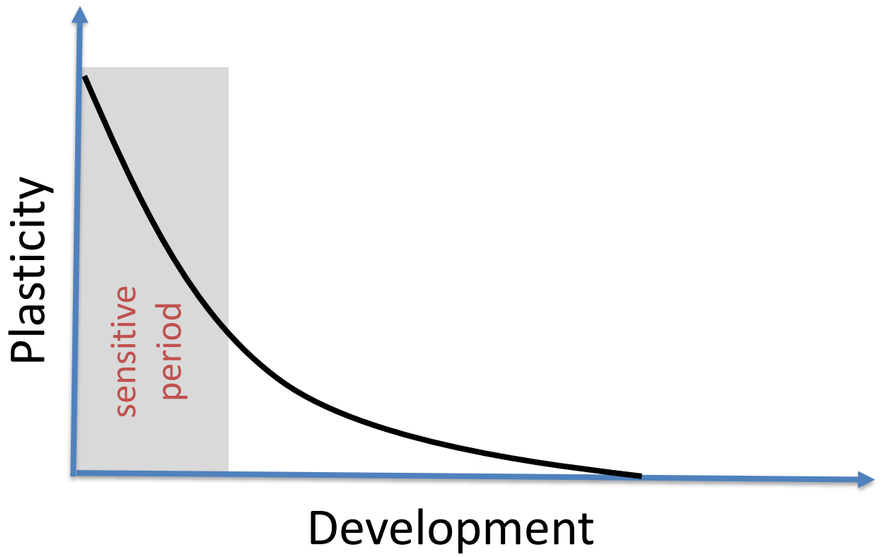
Time periods during which the impact of experience is greatest are called **sensitive periods**

Individuals are shaped by experiences

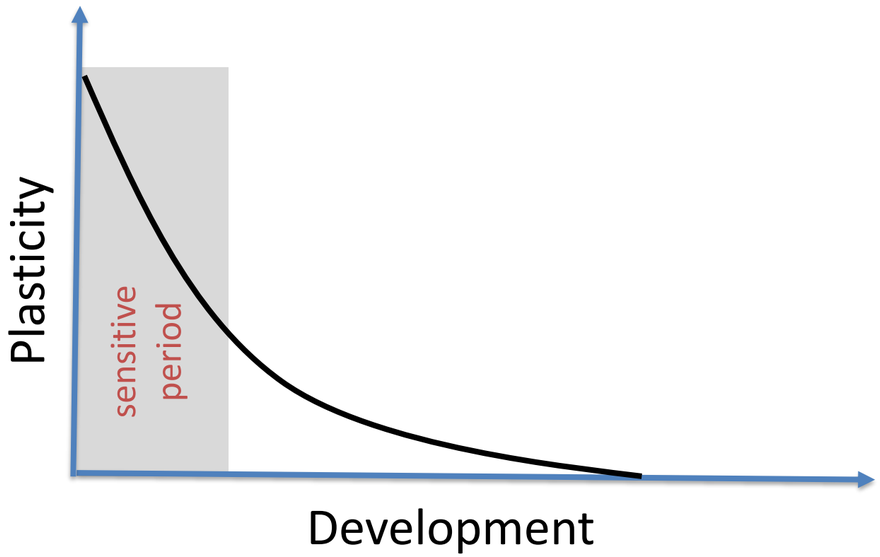
Time periods during which the impact of experience is greatest are called **sensitive periods**

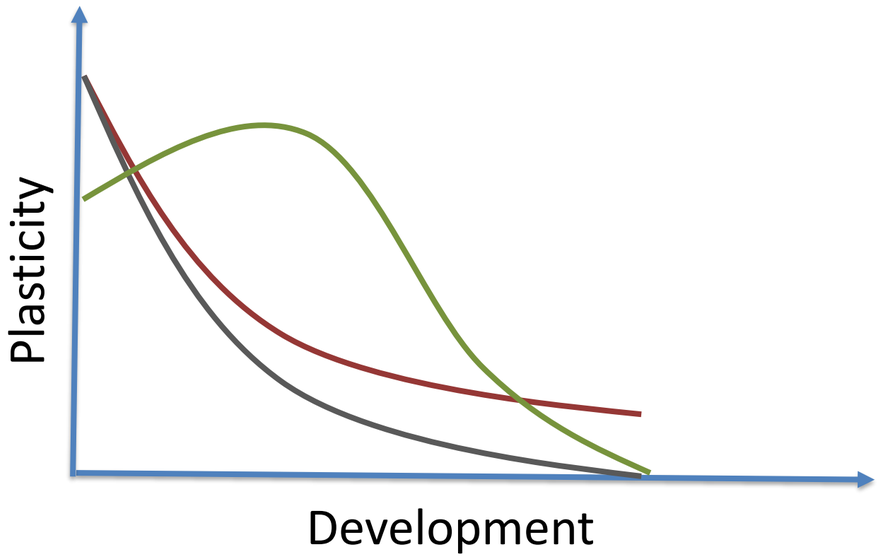


Individuals are shaped by experiences



Individuals are shaped by experiences





Shapes of plasticity

Individuals are shaped by experiences **early in life**

Individuals are shaped by experiences **early in life**

Individuals are shaped by experiences **early in life**

Individuals are shaped by experiences **early in life?**

Gabard-Durnam & McLaughlin (2019)
Beecher & Brenowitz (2005)
Hansen et al. (2018)

Individuals are shaped by experiences **later in life**

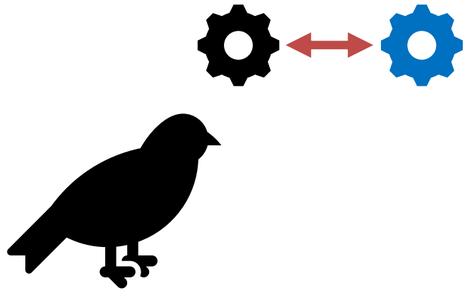
Individuals are shaped by experiences **later in life**

Individuals are shaped by experiences **later in life**

Larsen & Luna (2018)
Gobes et al. (2019)
Sachser et al. (2018)

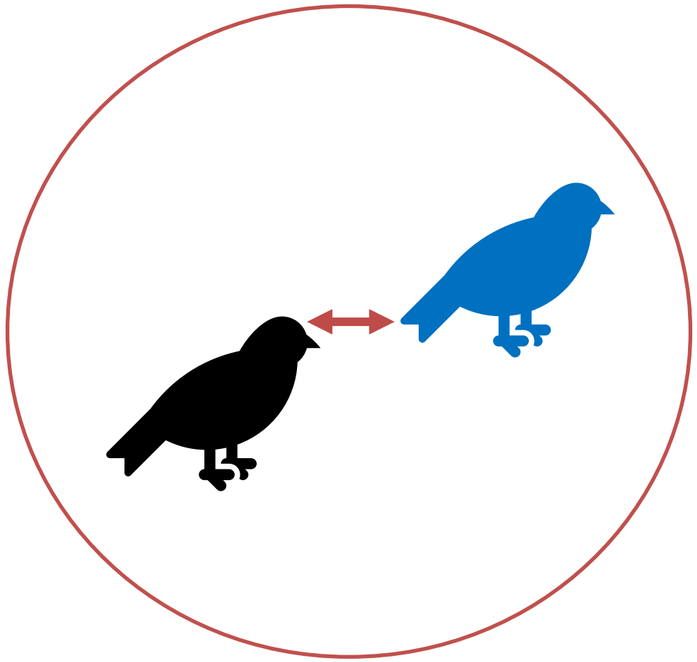
Variation everywhere

Variation everywhere



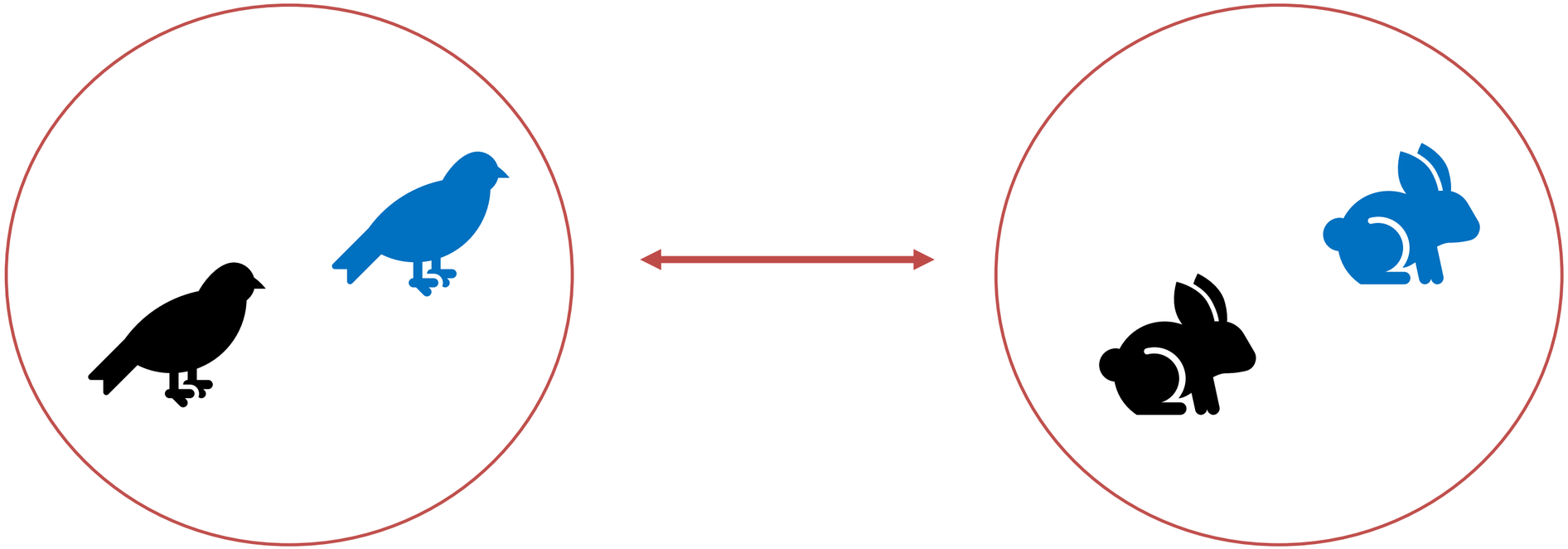
between traits, within individuals

Variation everywhere



between individuals,
within species

Variation everywhere



between species

Why is there variation everywhere?

What are the selection pressures that have shaped variation in sensitive periods between species, individuals and traits?

Mathematical models

What have we learned from existing models?

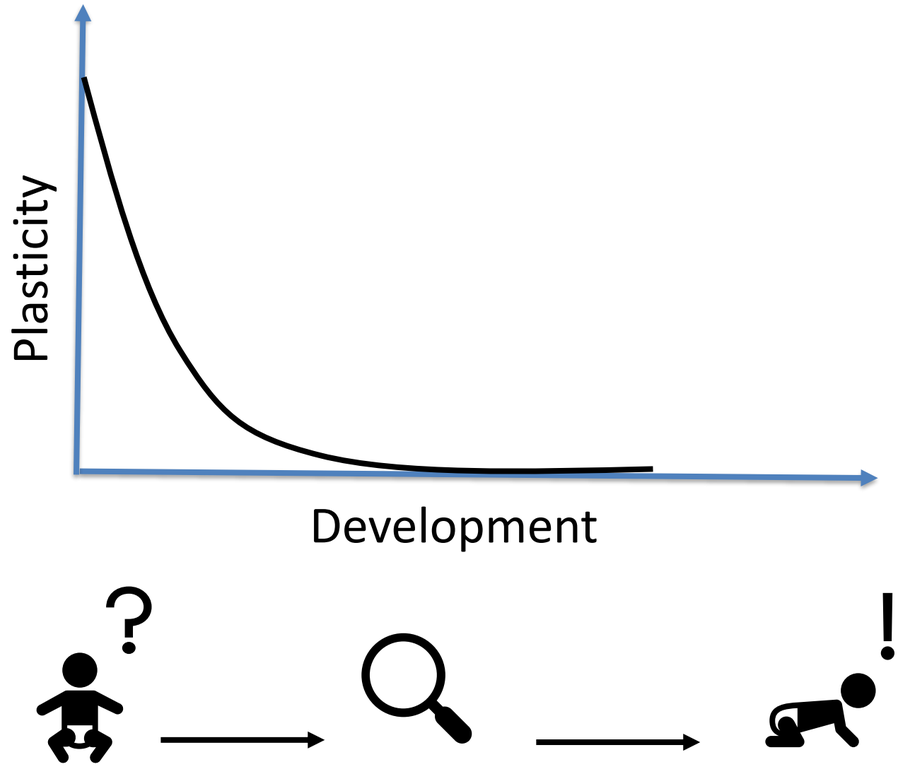
What have we learned from existing models?

Plasticity depends on information about the environment

reviewed in:
Frankenhuis & Walasek (2020)
Frankenhuis & Fraley (2017)
Fawcett & Frankenhuis (2015)

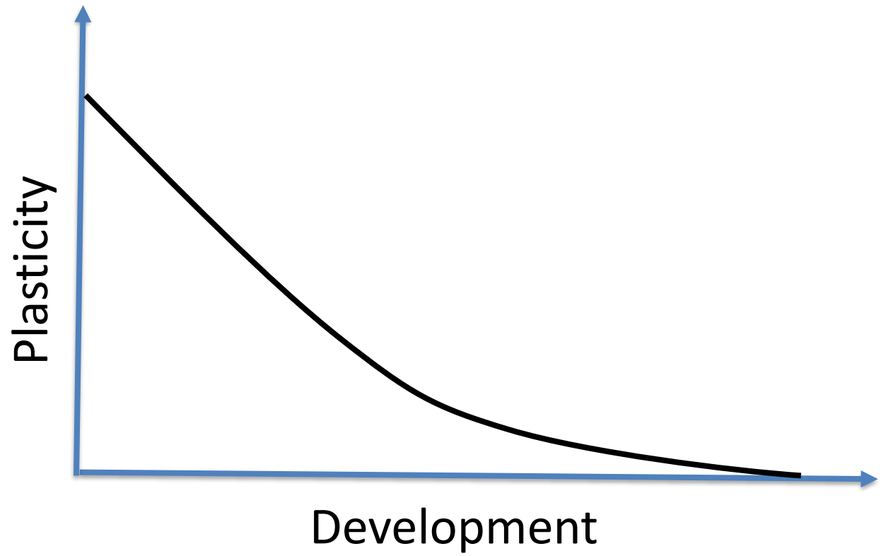
What have we learned from existing models?

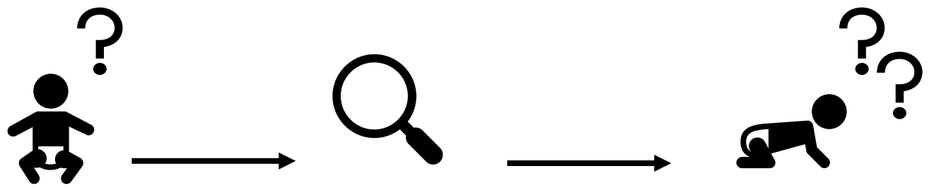
Plasticity depends on information about the environment



What have we learned from existing models?

Plasticity depends on information about the environment





What have we learned from existing models?

Plasticity depends on information about the environment

Tooley et al. (2021)
Chen & Meliza (2020)
Freund et al. (2013)

Existing models

All models assume that the **quality of information is constant** across development. All but one of the models assume a **stable environment** throughout development

Fischer et al. (2014)

Existing models

All models assume that the **quality of information is constant** across development. All but one of the models assume a **stable environment** throughout development

Fischer et al. (2014)

Existing models

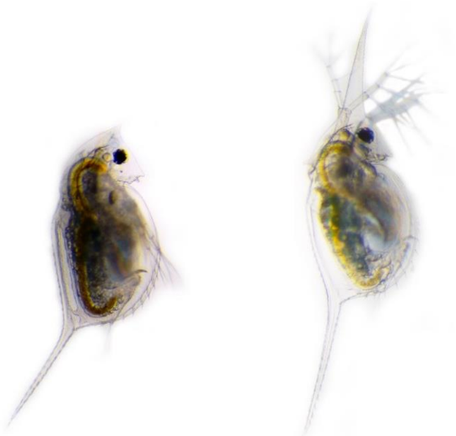
Existing models

leaves maximize sunlight intake

Maugarny-Calès & Laufs (2018)

Existing models

leaves maximize sunlight intake



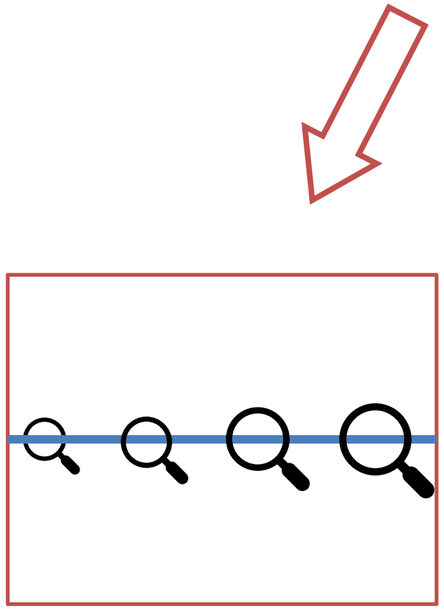
water fleas build protective helmets

Maugarny-Calès & Laufs (2018)
Agrawal, Laforsch, & Tollrian (1999)

Existing models

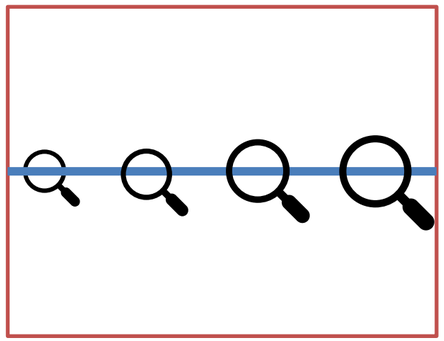
Do results change when relaxing these assumptions?

Varying cue reliability



cue reliability

Varying cue reliability



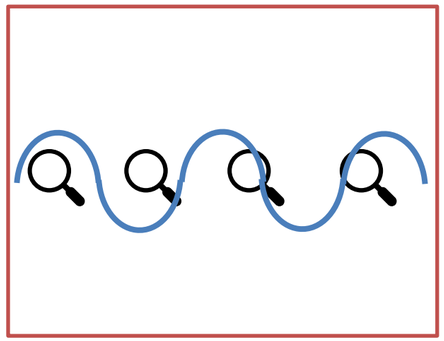
cue reliability

?

dangerous

safe

Varying cue reliability



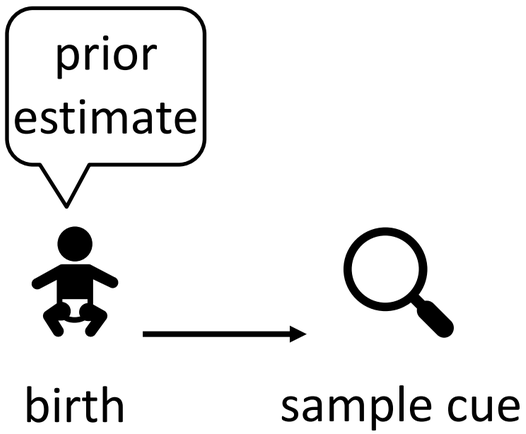
environmental state

The general model

The general model

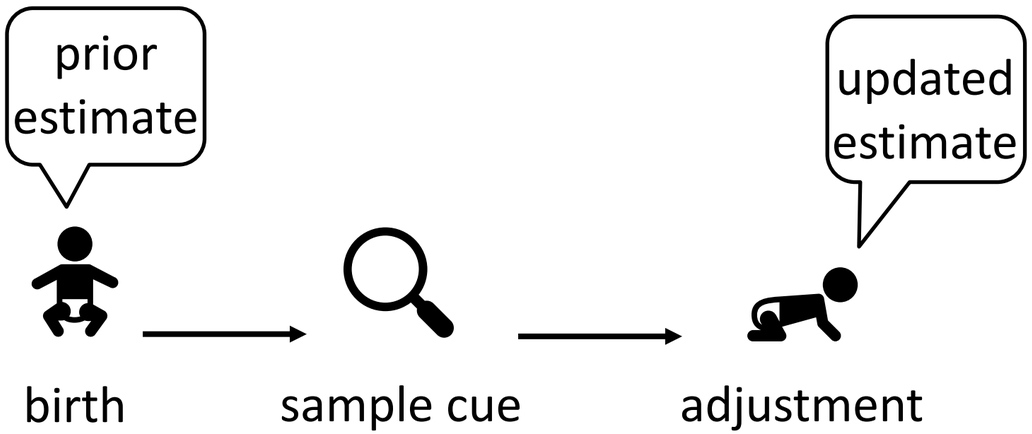
development

The general model



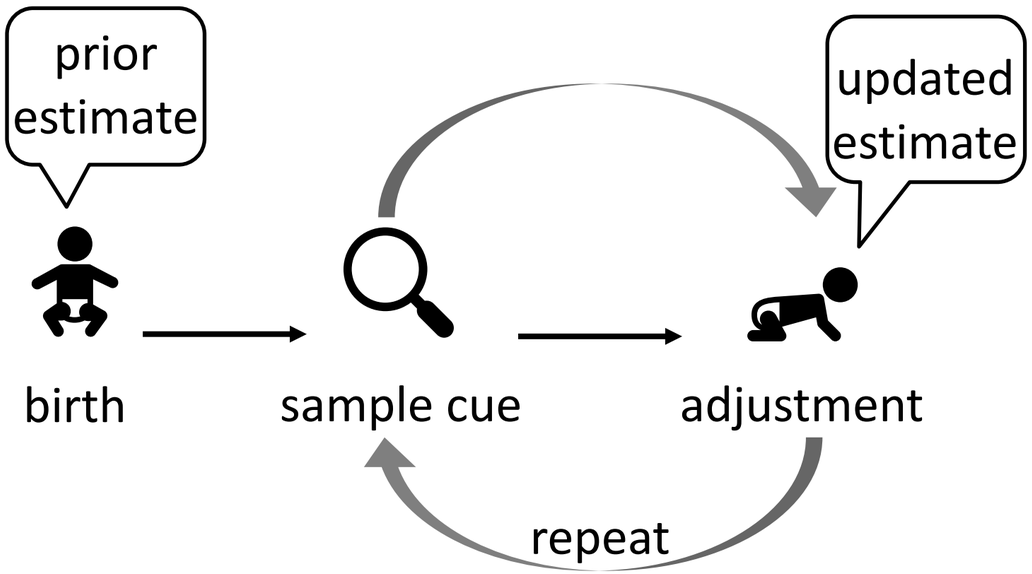
development

The general model



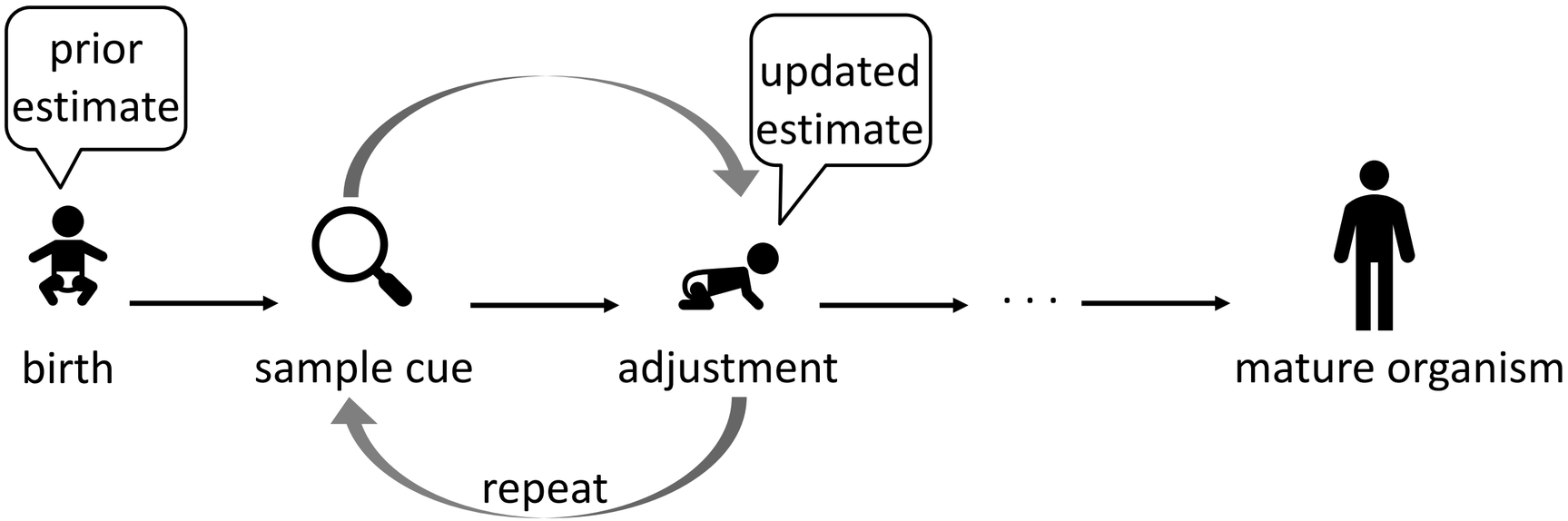
development

The general model



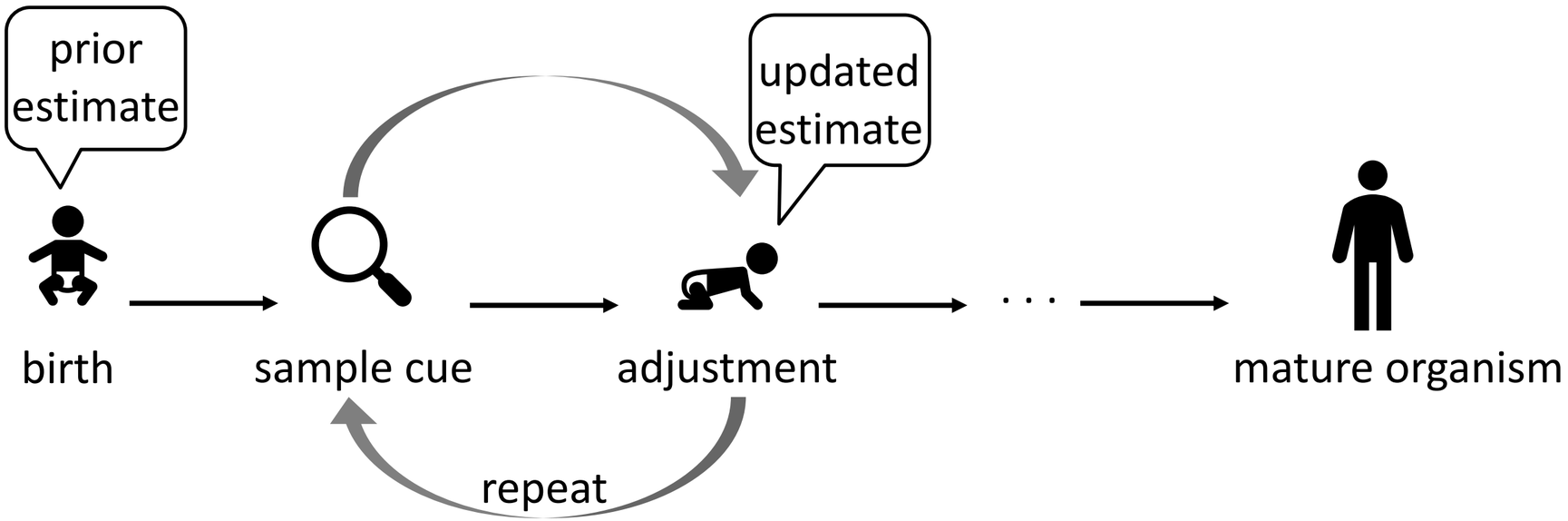
development

The general model



development

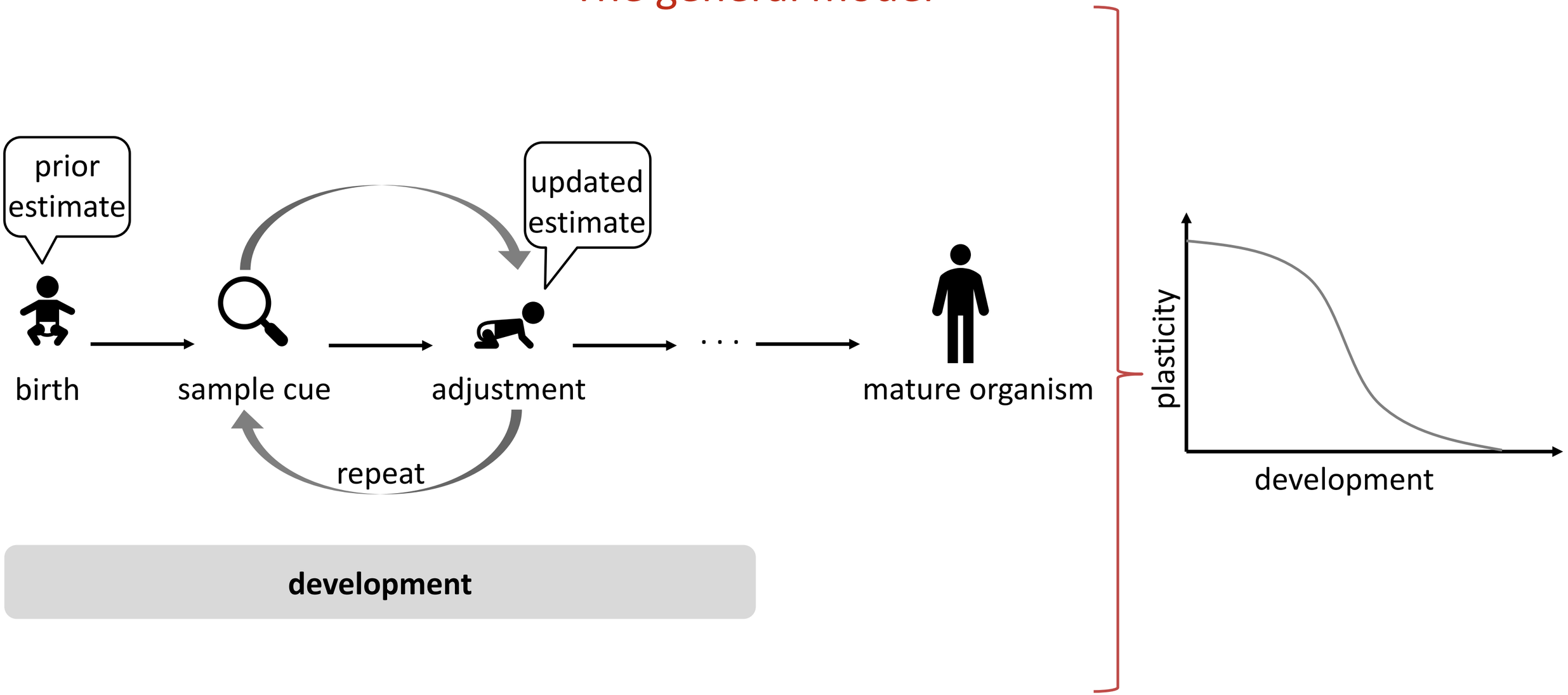
The general model



optimal policies

development

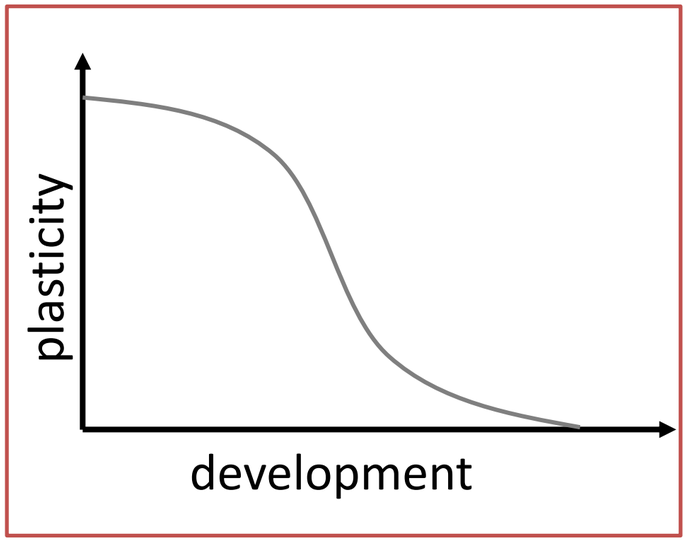
The general model



development

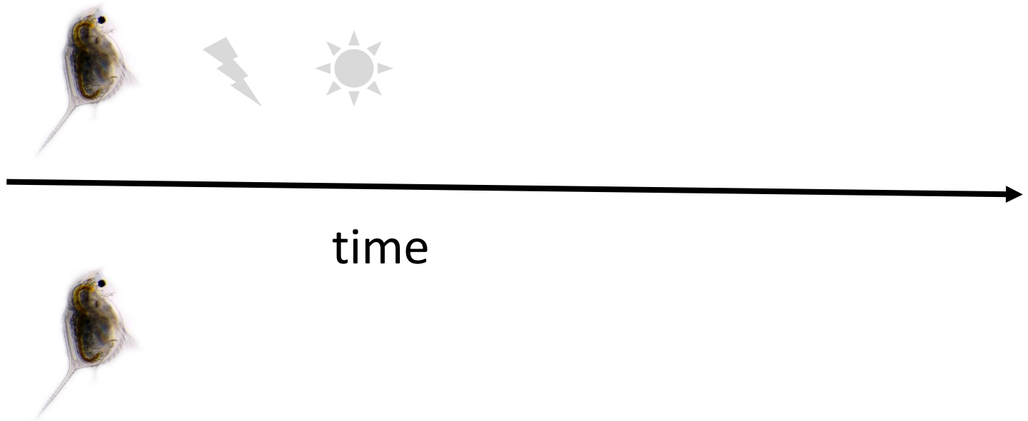
Quantifying plasticity

Experimental twin studies

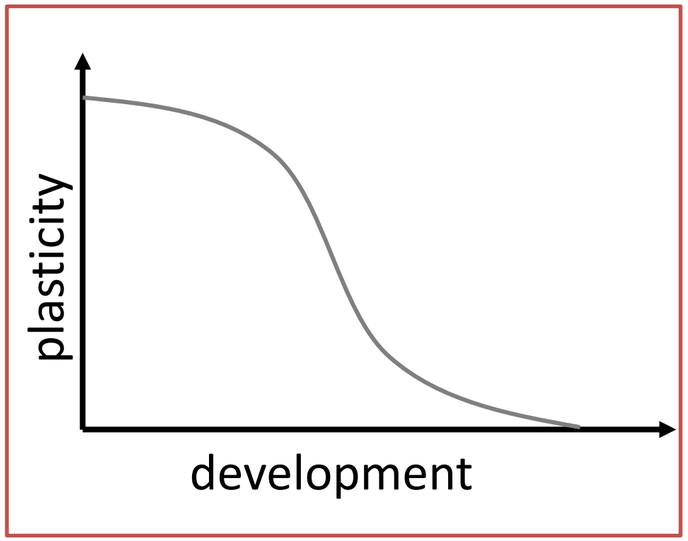


Quantifying plasticity

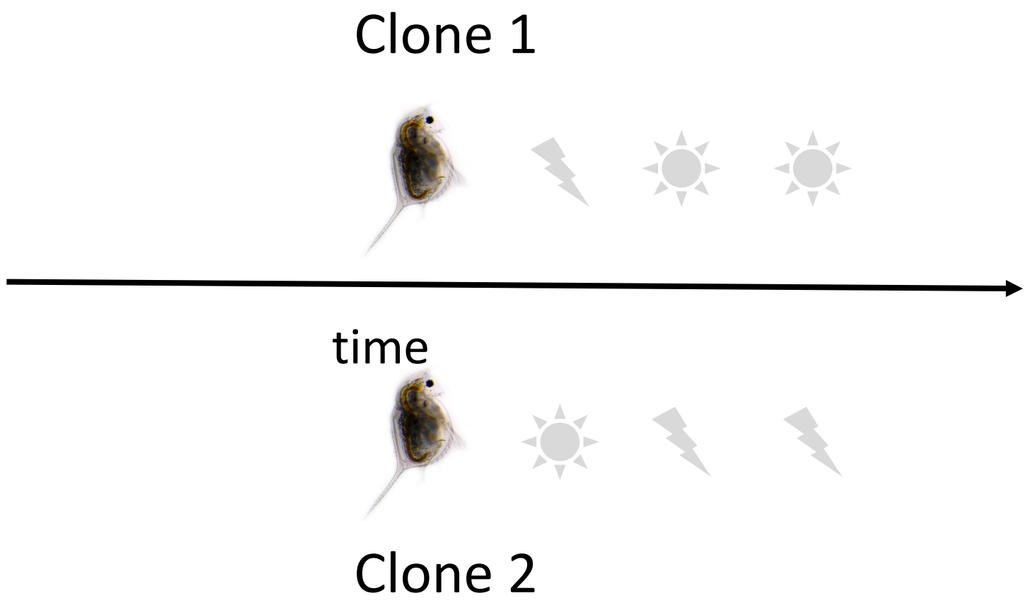
Clone 1

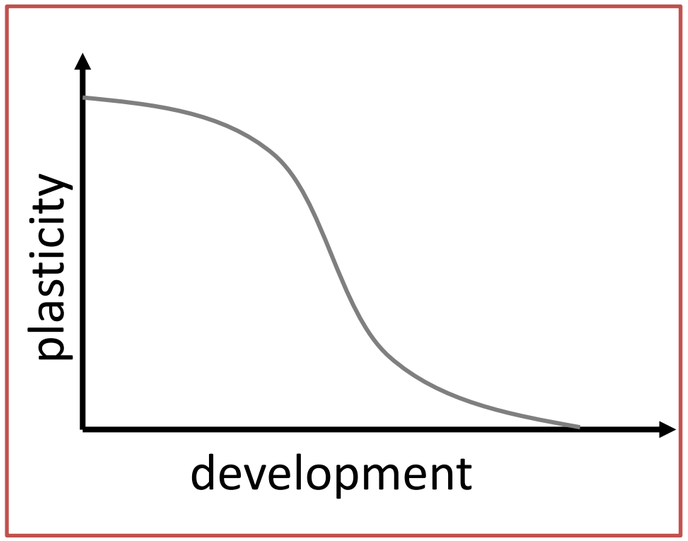


Clone 2

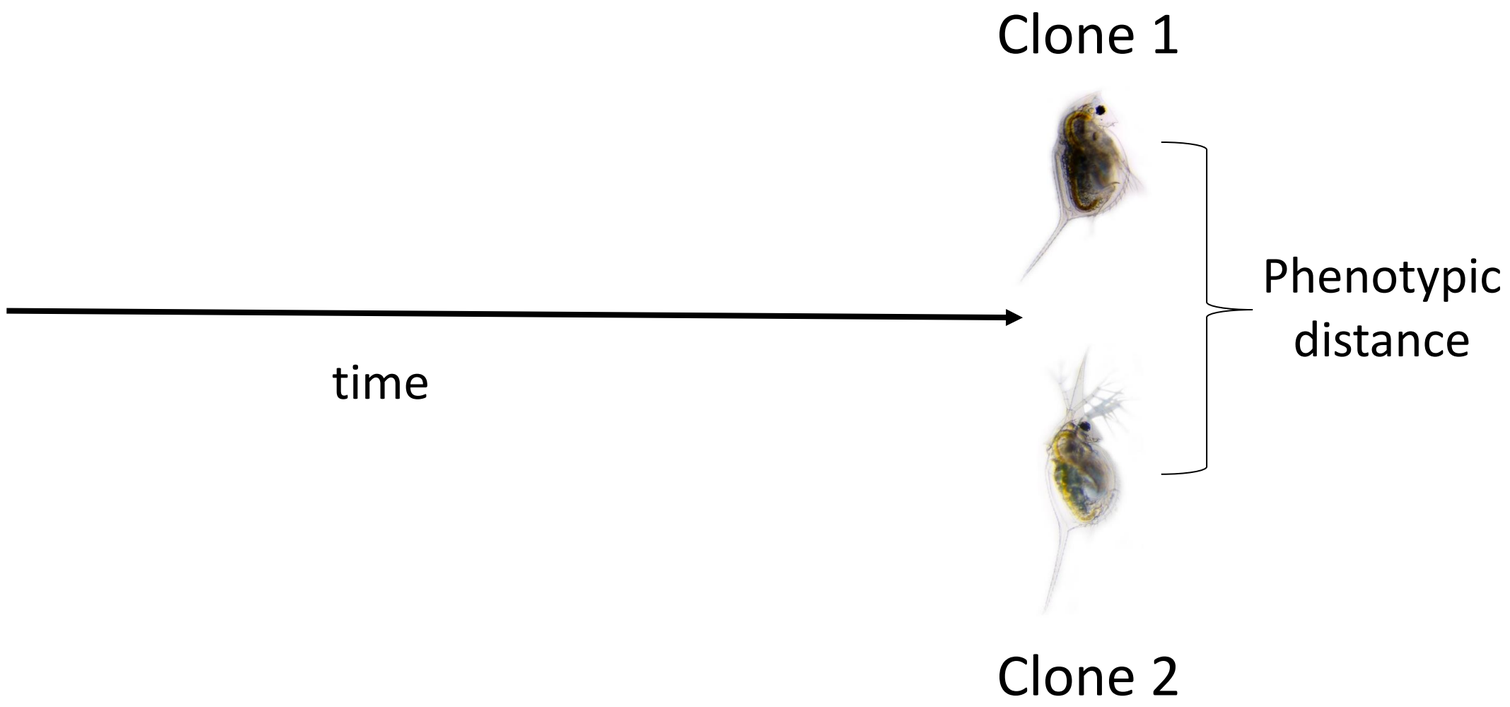


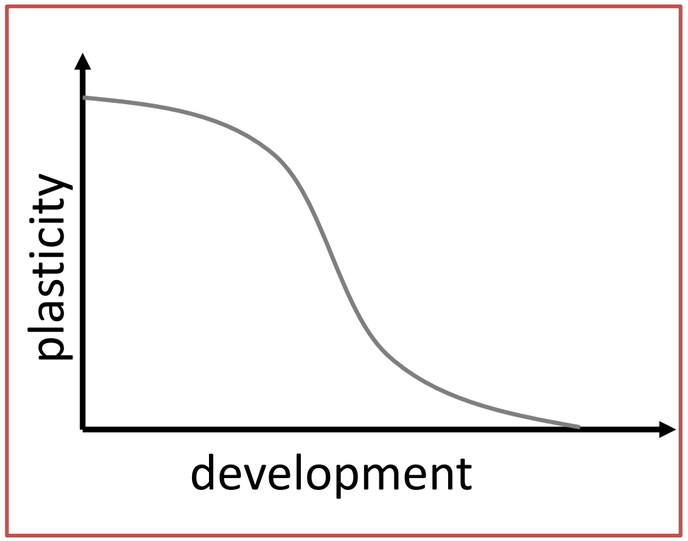
Quantifying plasticity



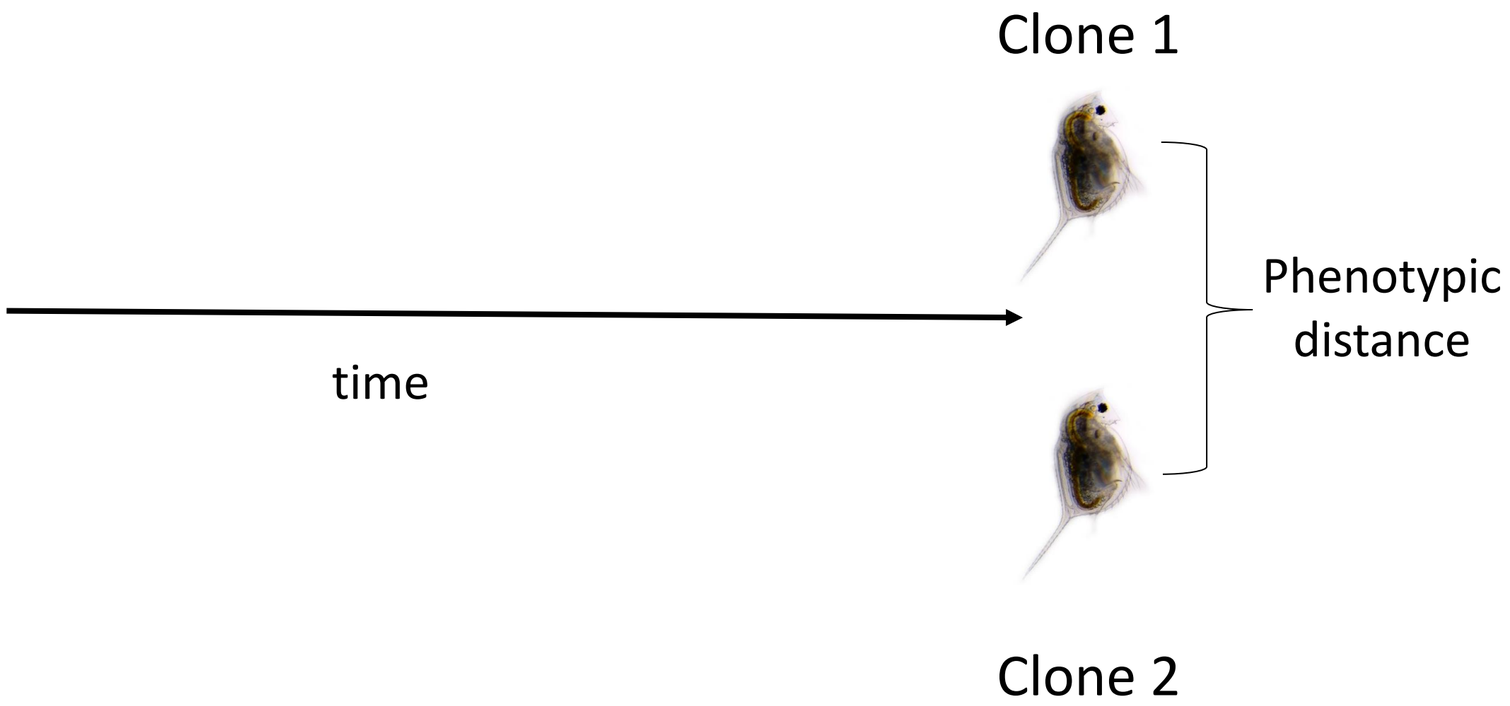


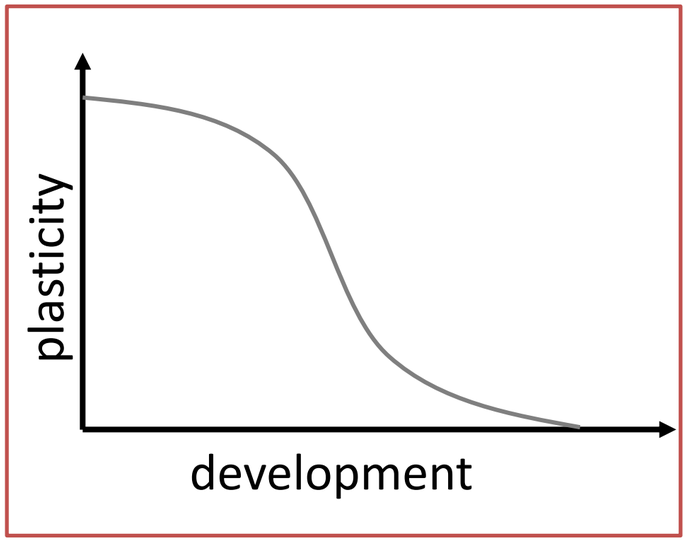
Quantifying plasticity



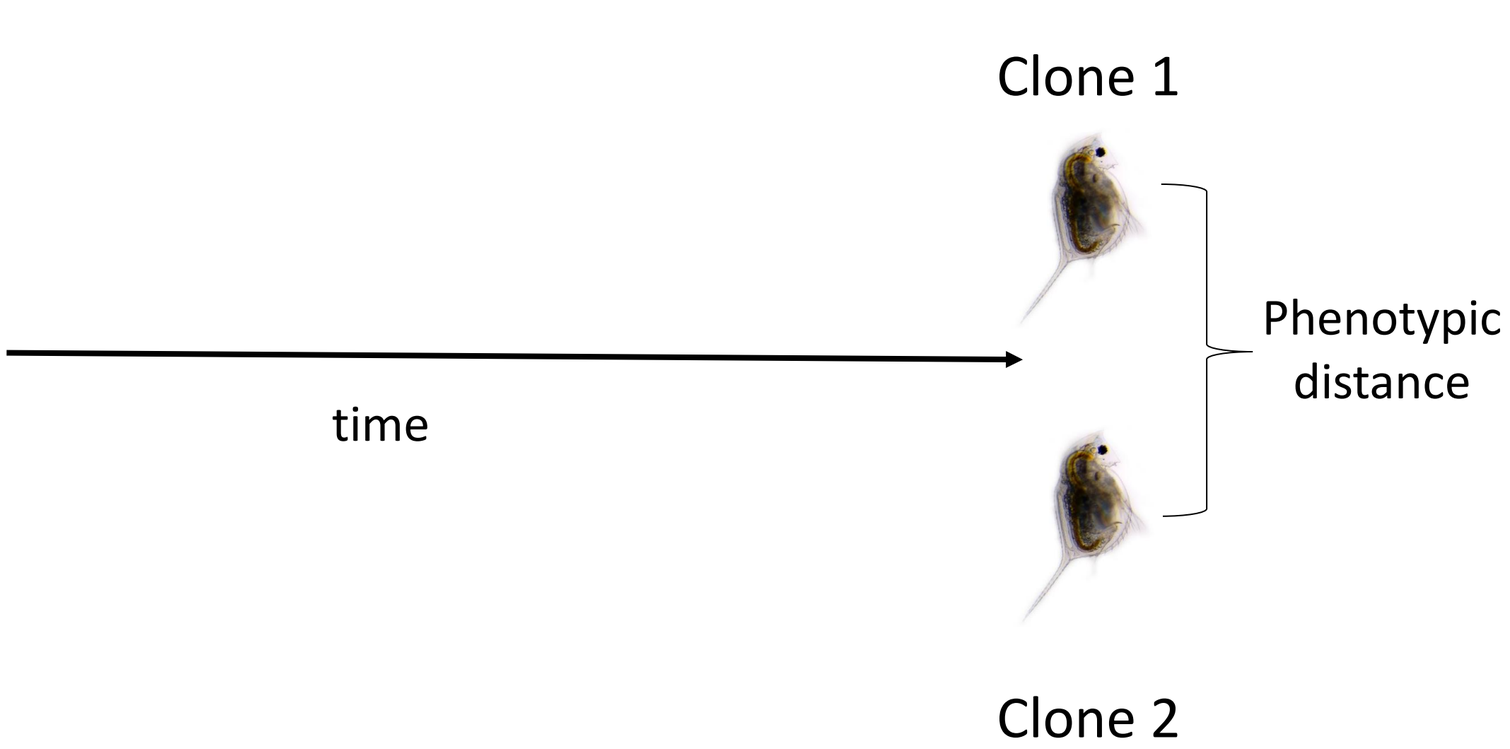


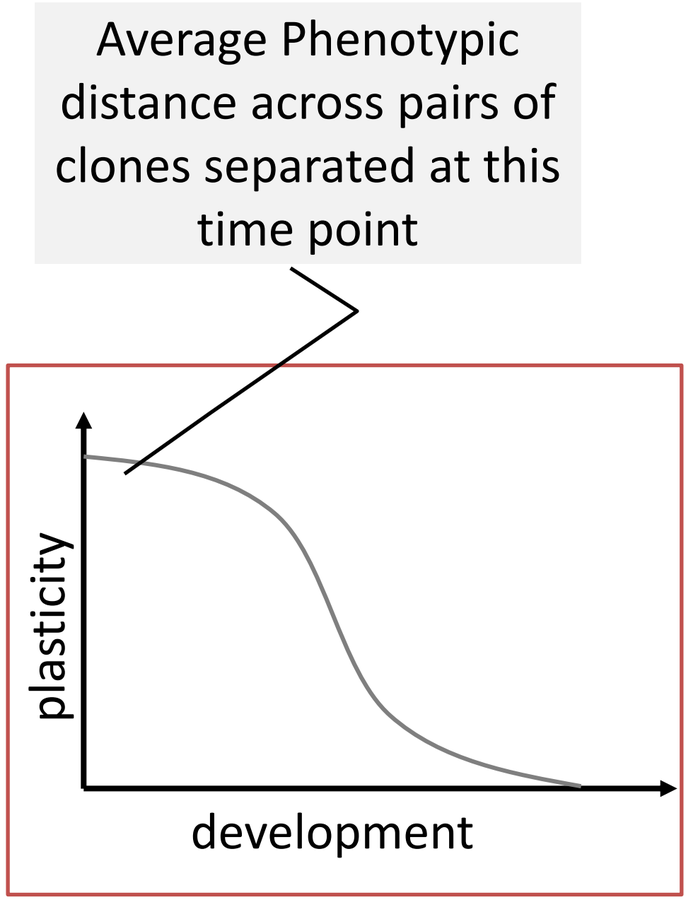
Quantifying plasticity





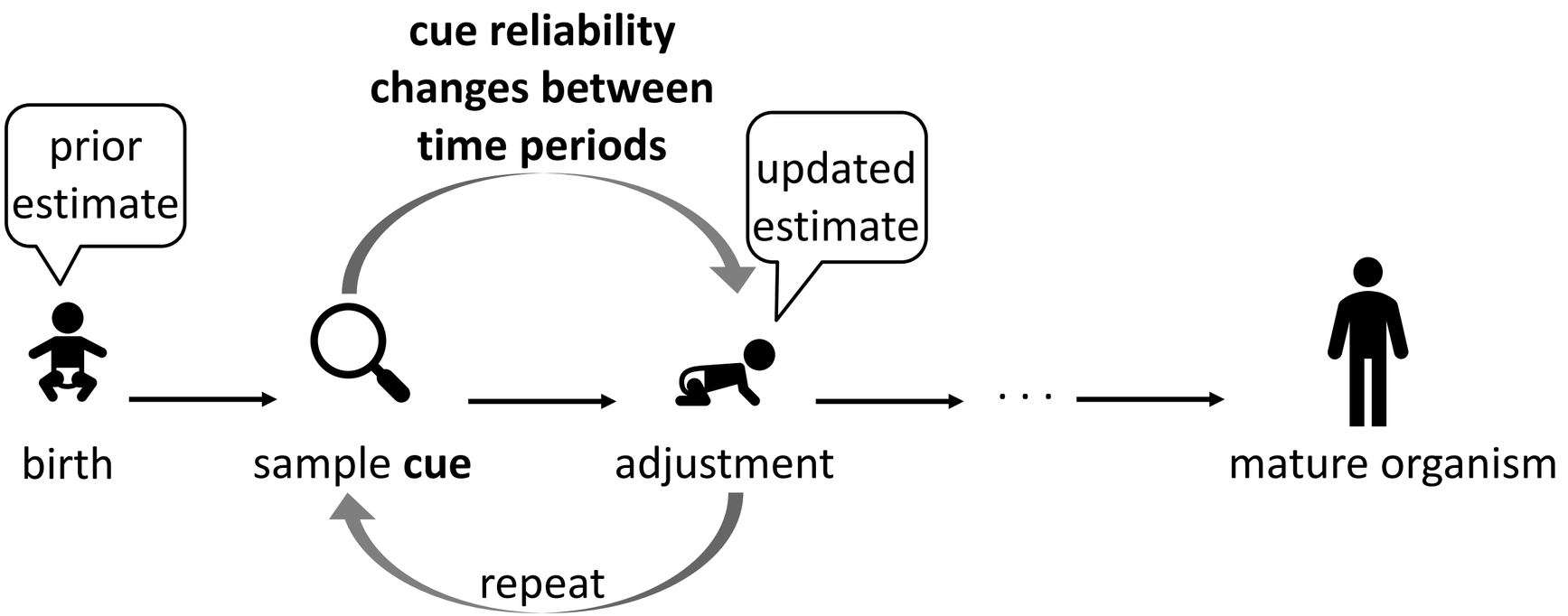
Quantifying plasticity

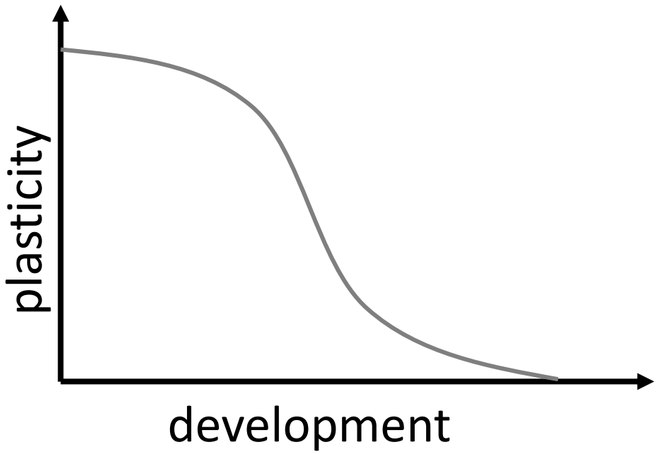




Model 1: changes in cue reliability

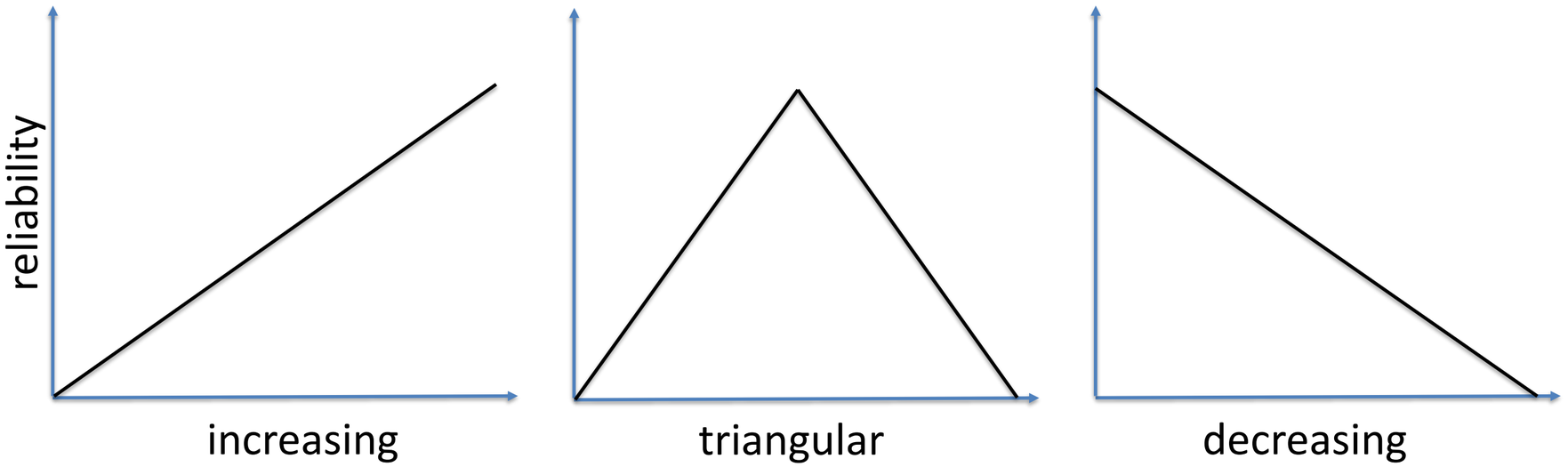
Model 1: changes in cue reliability



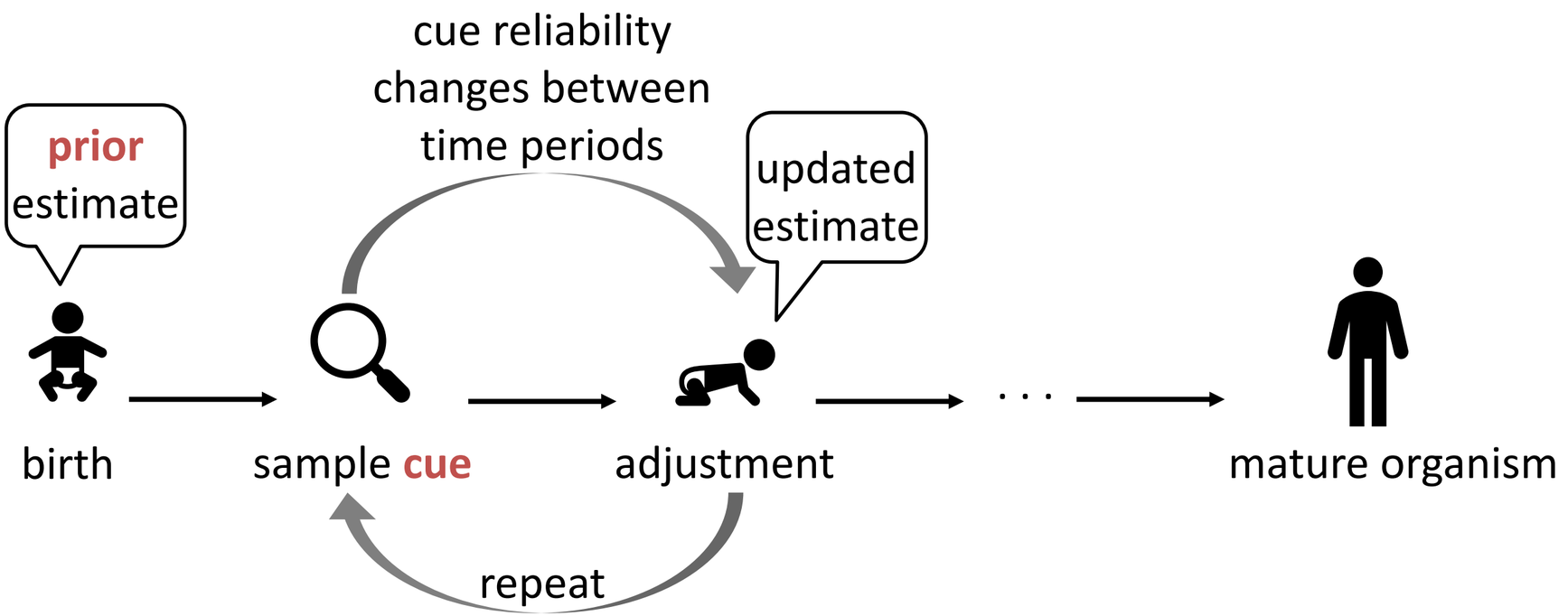


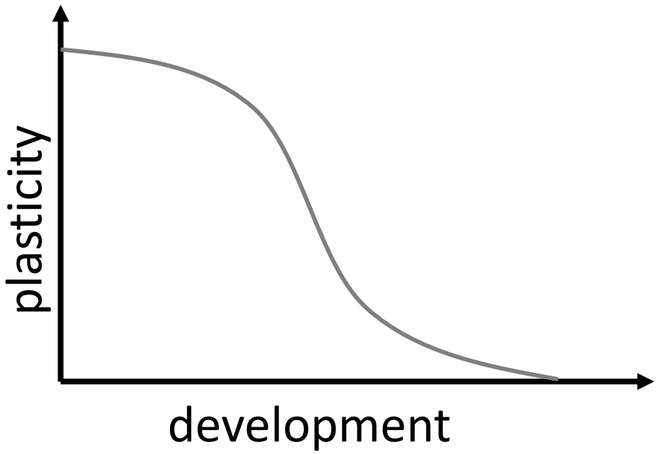
development

Model 1: changes in cue reliability



Model 1: changes in cue reliability

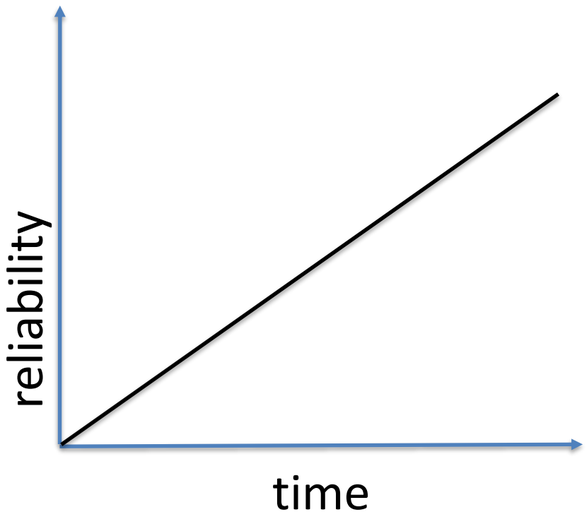




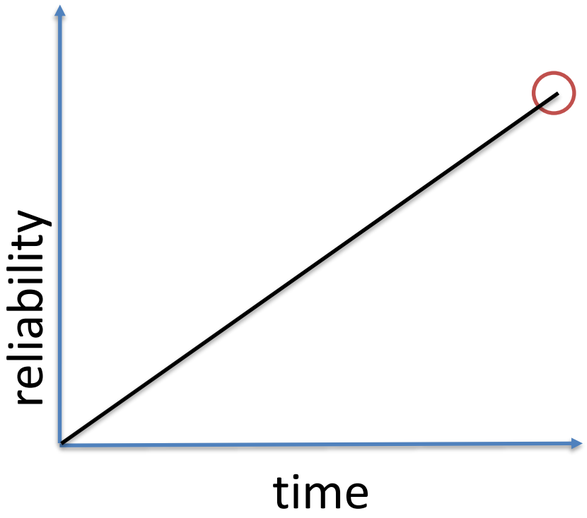
development

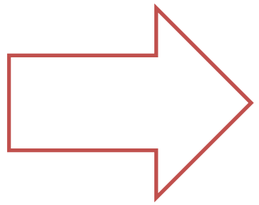
Model 1: results

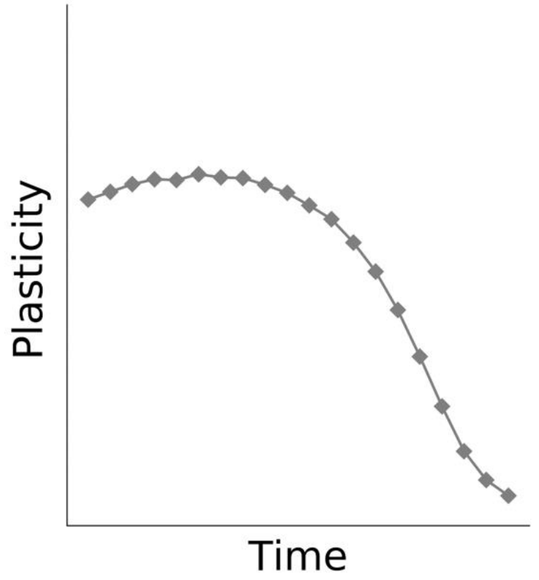
When the cue reliability increases …



… sensitive periods evolve …

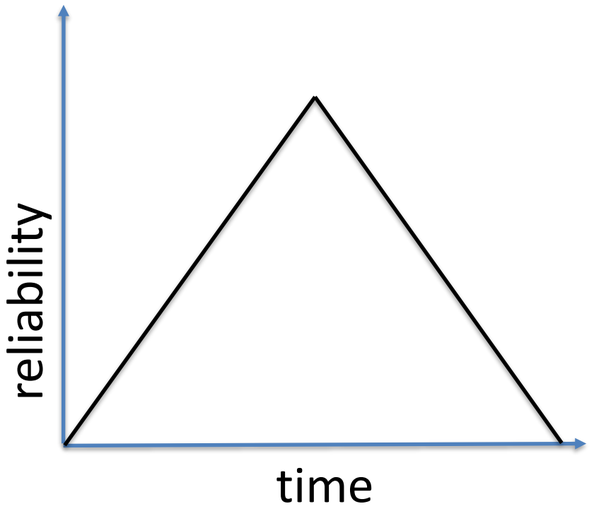




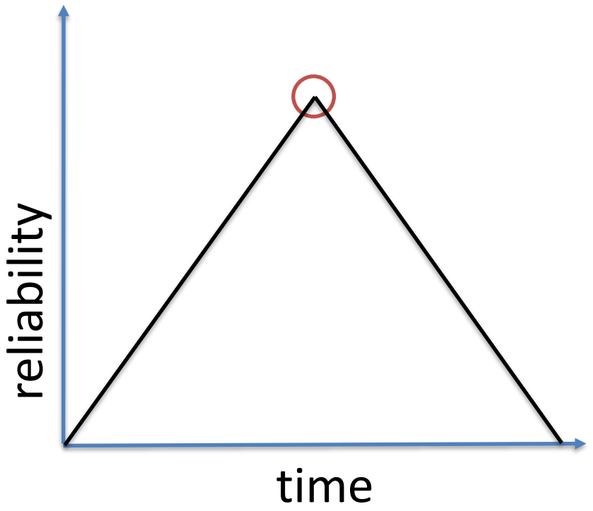


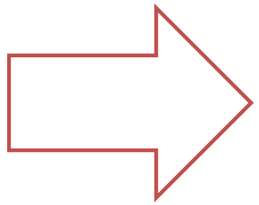
later in development

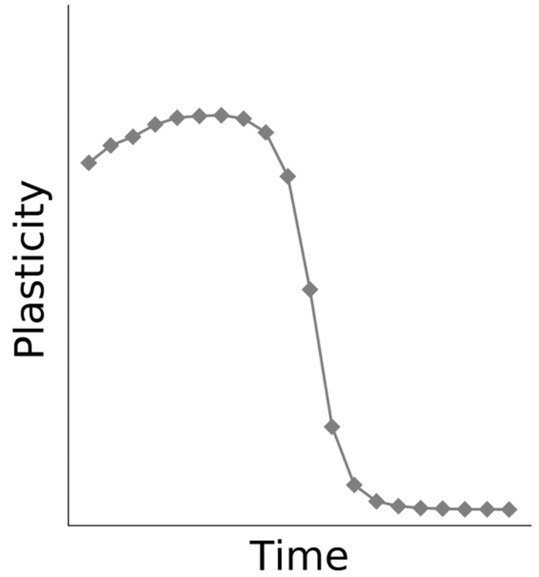
When the cue reliability first increases & then decreases …



… sensitive periods evolve …



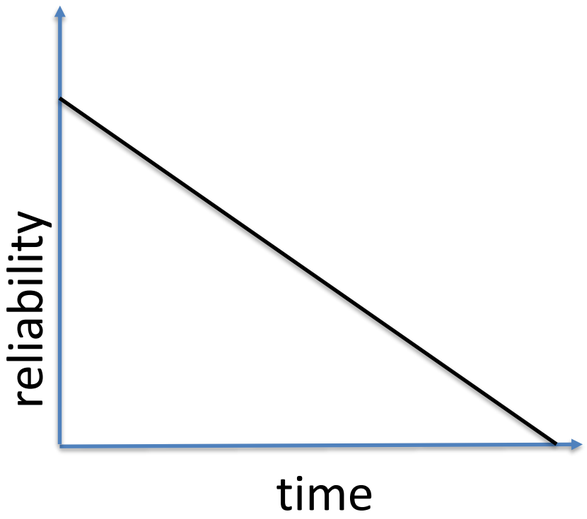




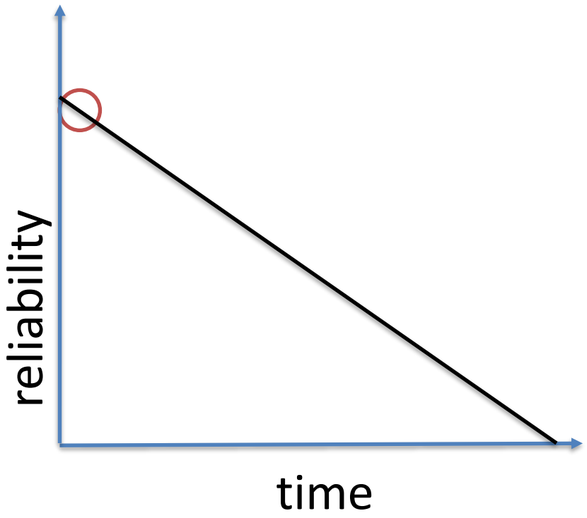
later in development &

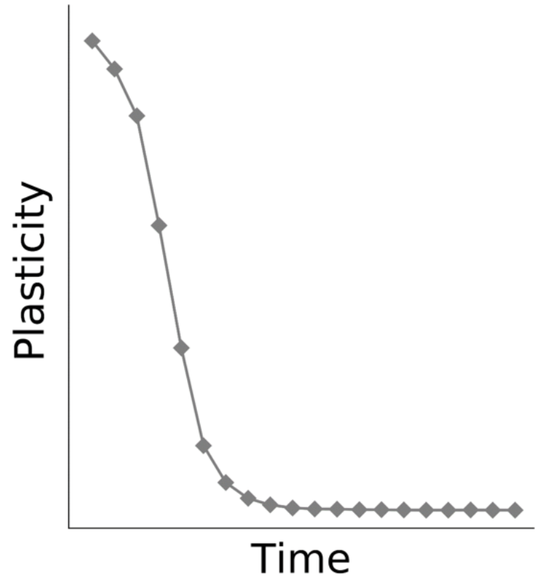
plasticity declines steeply

When the cue reliability decreases…



… sensitive periods evolve …

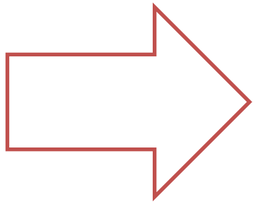


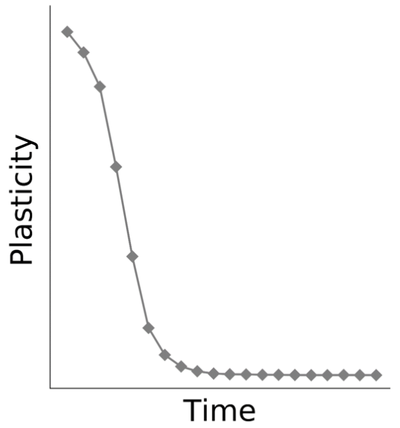


Only at the onset of development

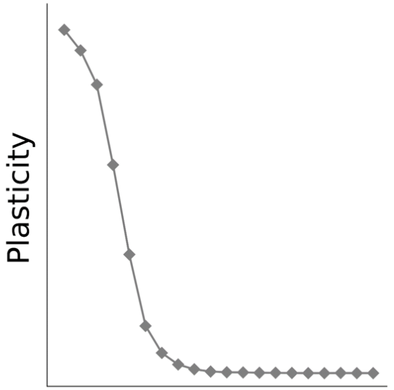
How do sensitive periods for song learning evolve?

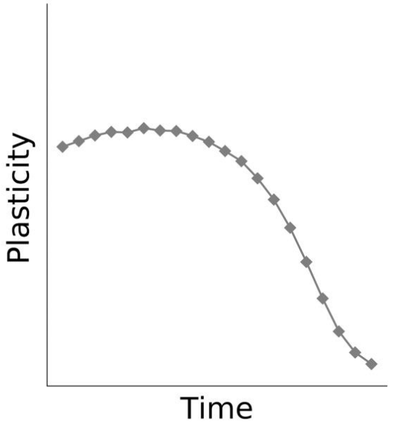
How do sensitive periods for song learning evolve?





How do sensitive periods for song learning evolve?

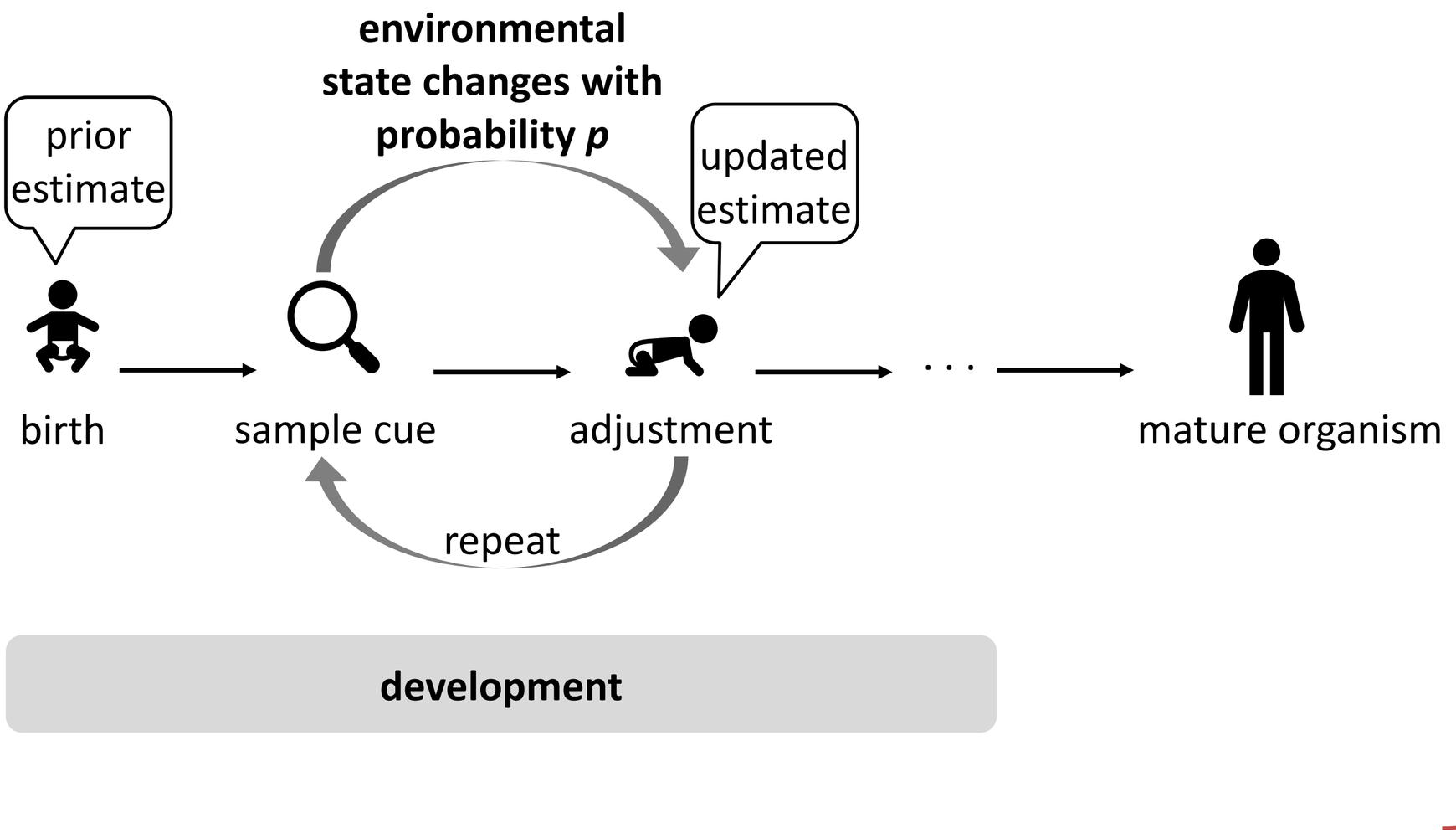


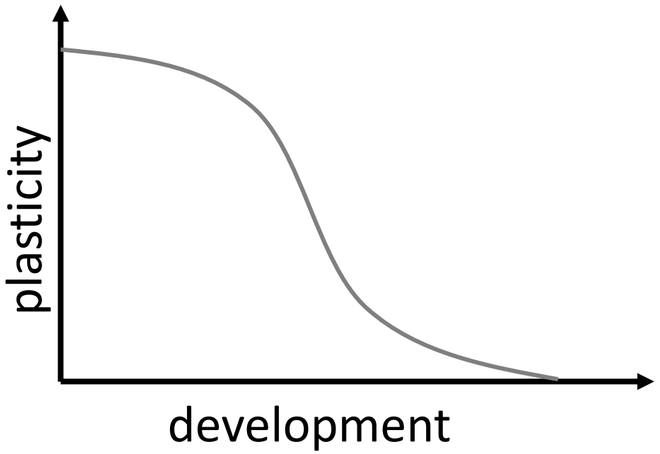


		Cue reliability	
		Constant	Varying
Environmental state	Constant	Sensitive periods at the onset of ontogeny 	Sensitive periods at the onset and midway through ontogeny 
	Varying	? 	

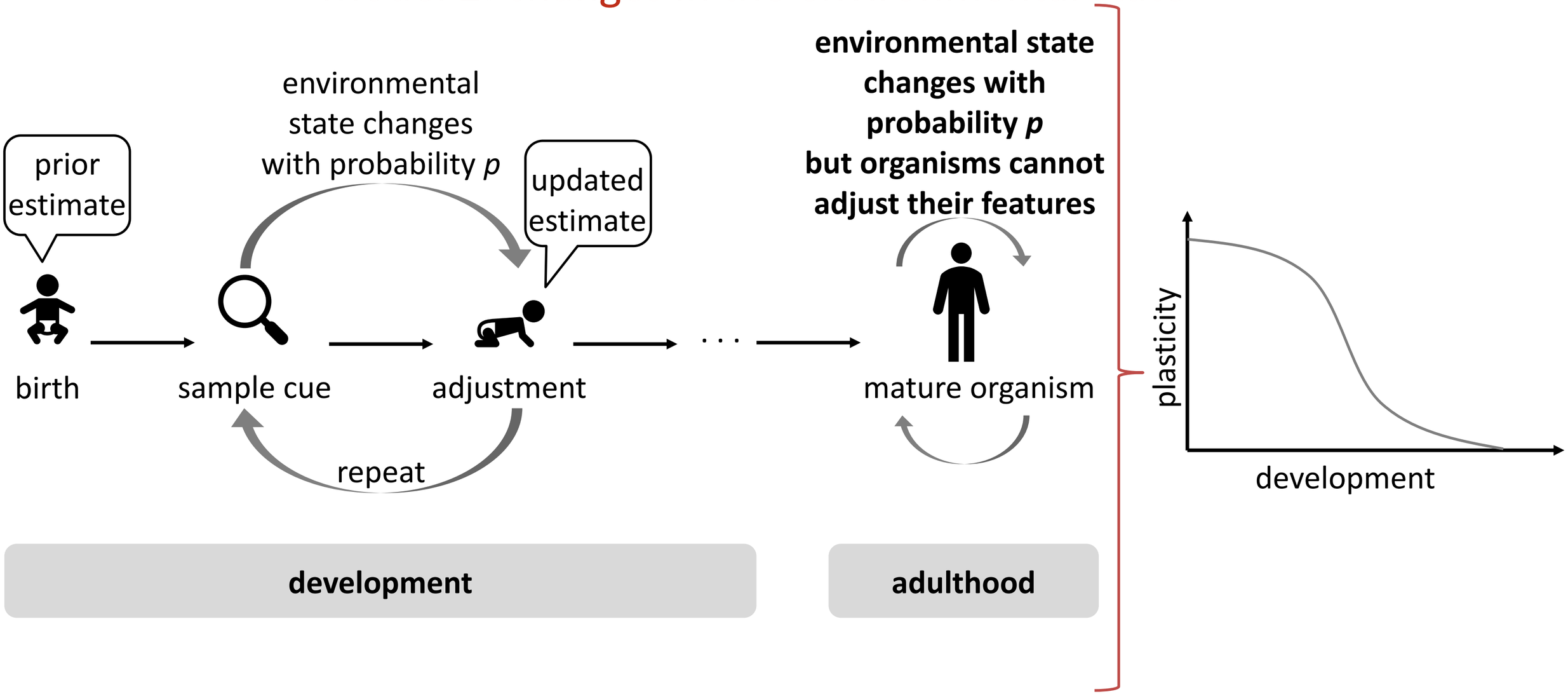
Model 2: changes in the environmental state

Model 2: changes in the environmental state

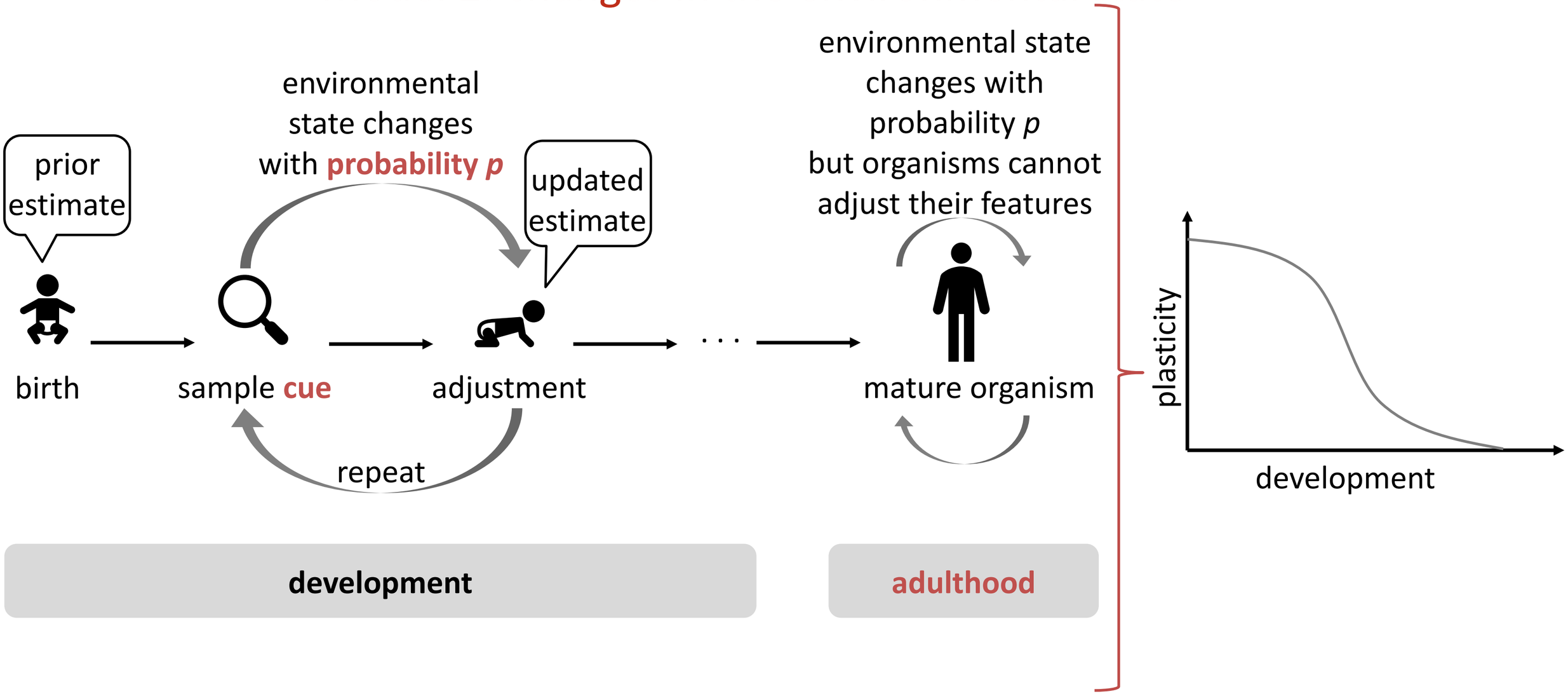




Model 2: changes in the environmental state

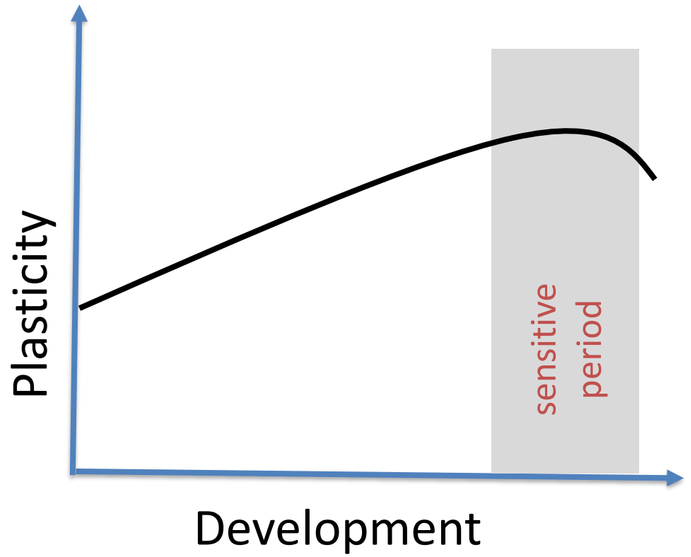


Model 2: changes in the environmental state



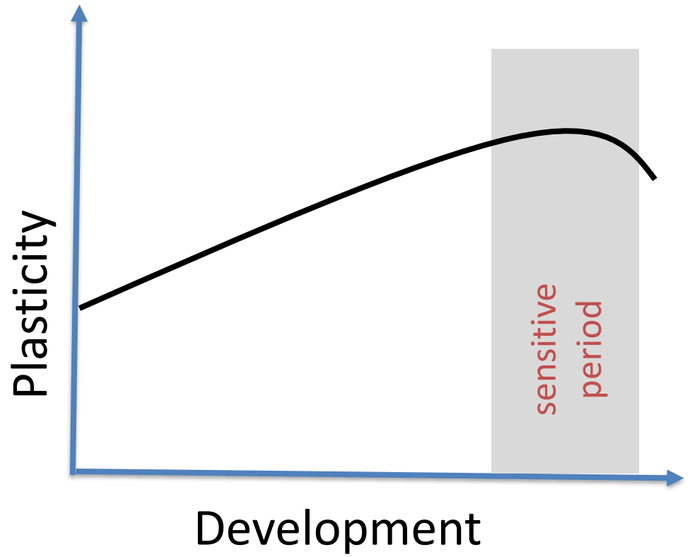
Model 2: results

Sensitive periods often evolve towards the end of development



Sensitive periods often evolve towards the end of development

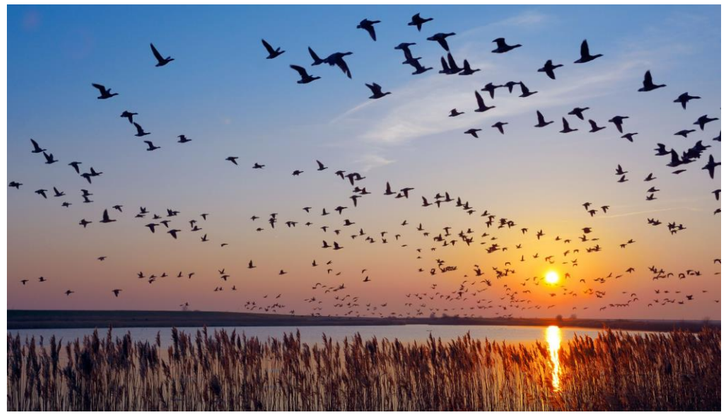
This finding contrasts results from models assuming stable environments



reviewed in:
Frankenhuis & Walasek (2020)
Frankenhuis & Fraley (2017)
Fawcett & Frankenhuis (2015)

Sensitive periods often evolve towards the end of development

This resonates with patterns of behavioural and phenotypic plasticity.



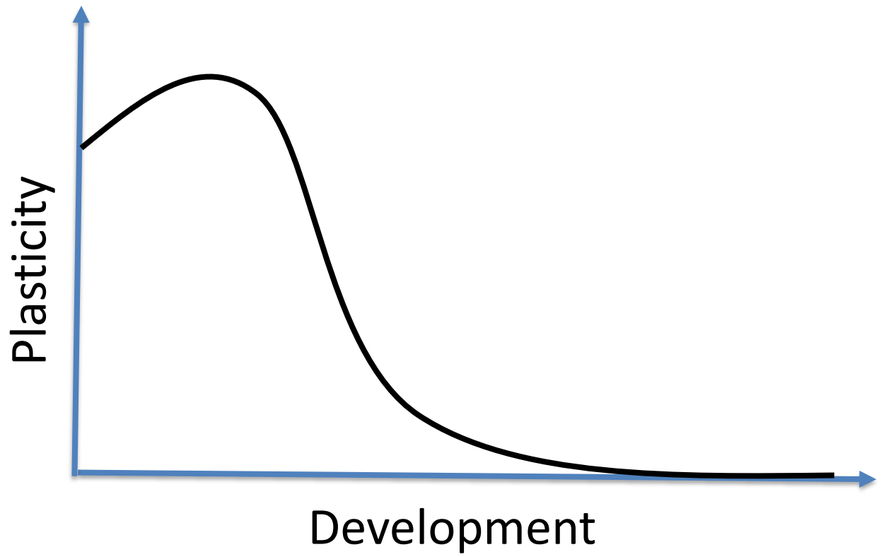
migratory bird species

Fighter *Scrambler*

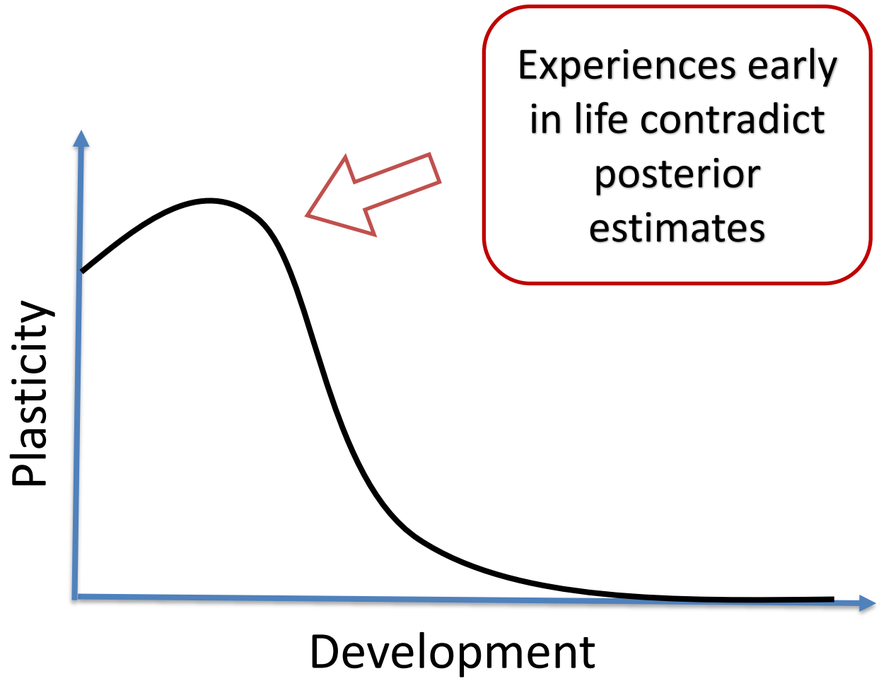
Bulb mites (Rhizoglyphus robini)

Winkler et al. (2014)
Smallegange (2011)

Sensitive periods sometimes evolve midway through development

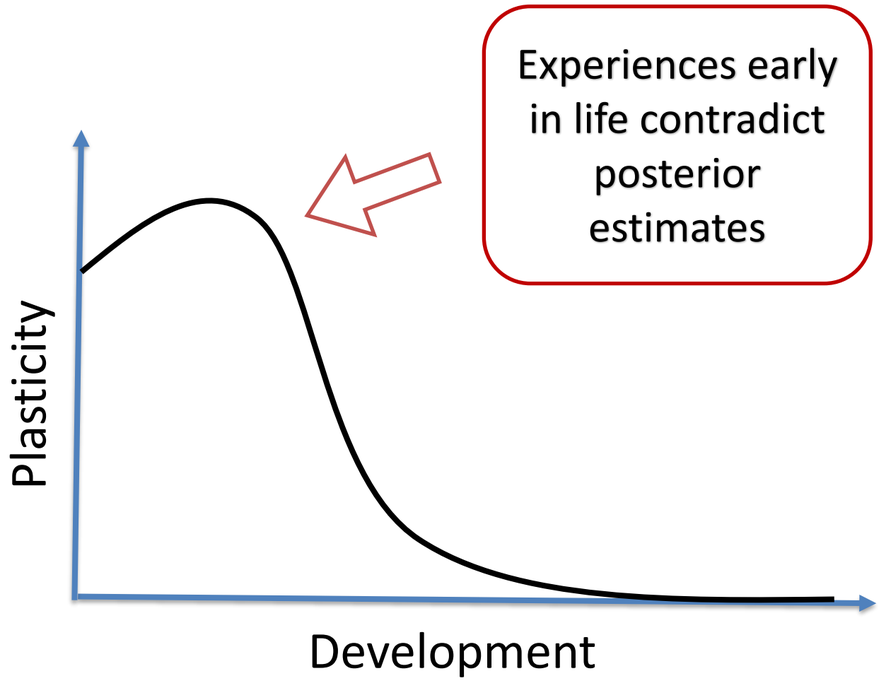


Sensitive periods sometimes evolve midway through development

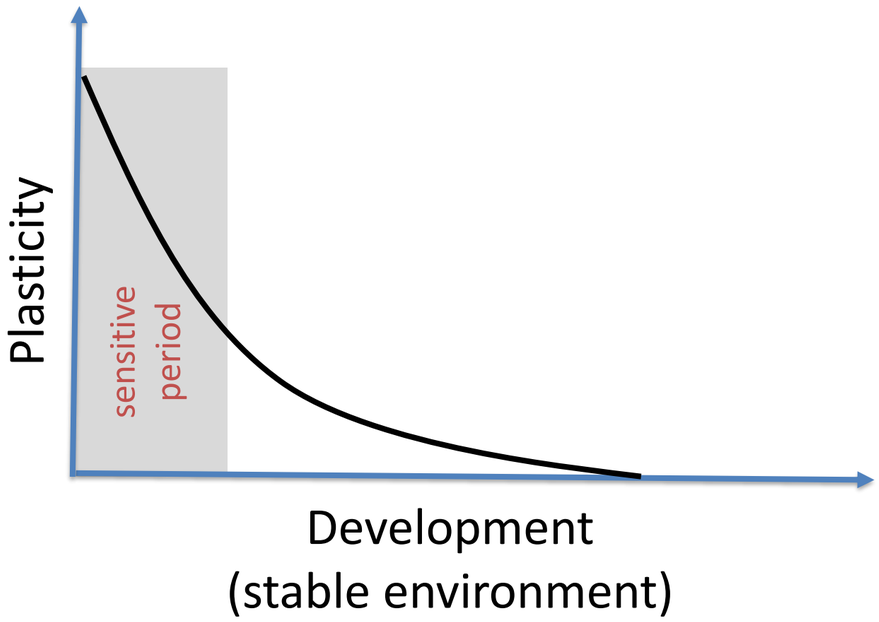


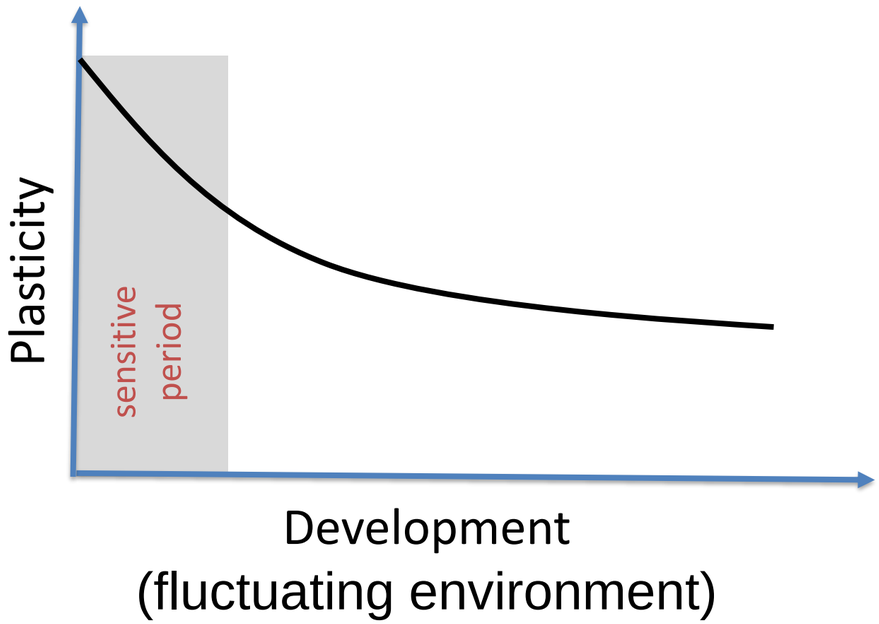
Sensitive periods sometimes evolve midway through development

Other models have obtained similar results under different assumptions



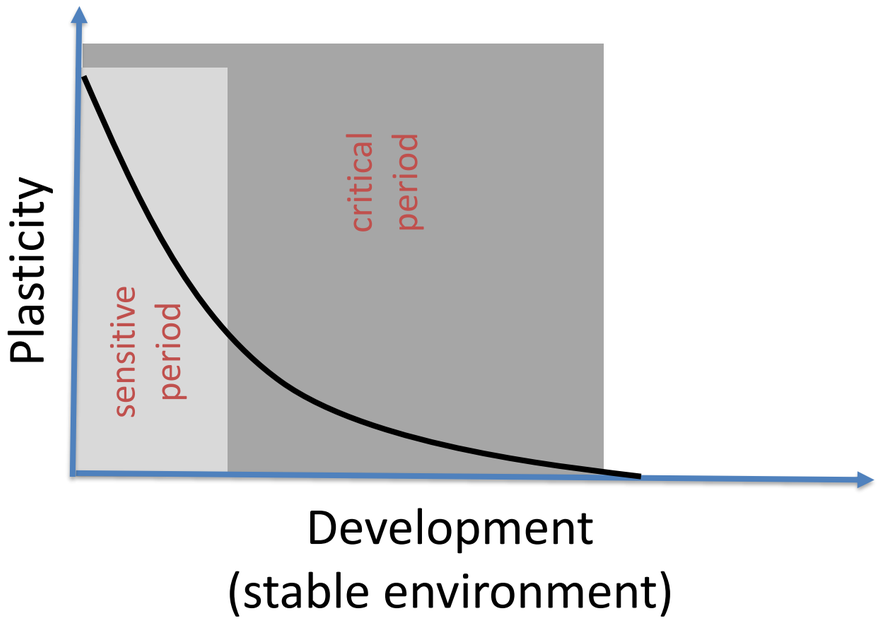
Critical periods are never favoured

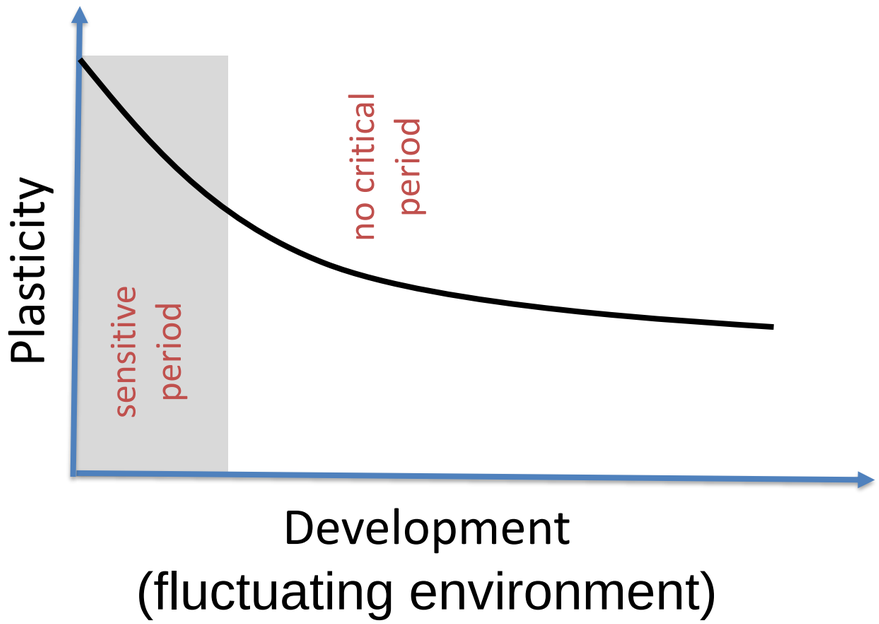




Critical periods are rarely favoured

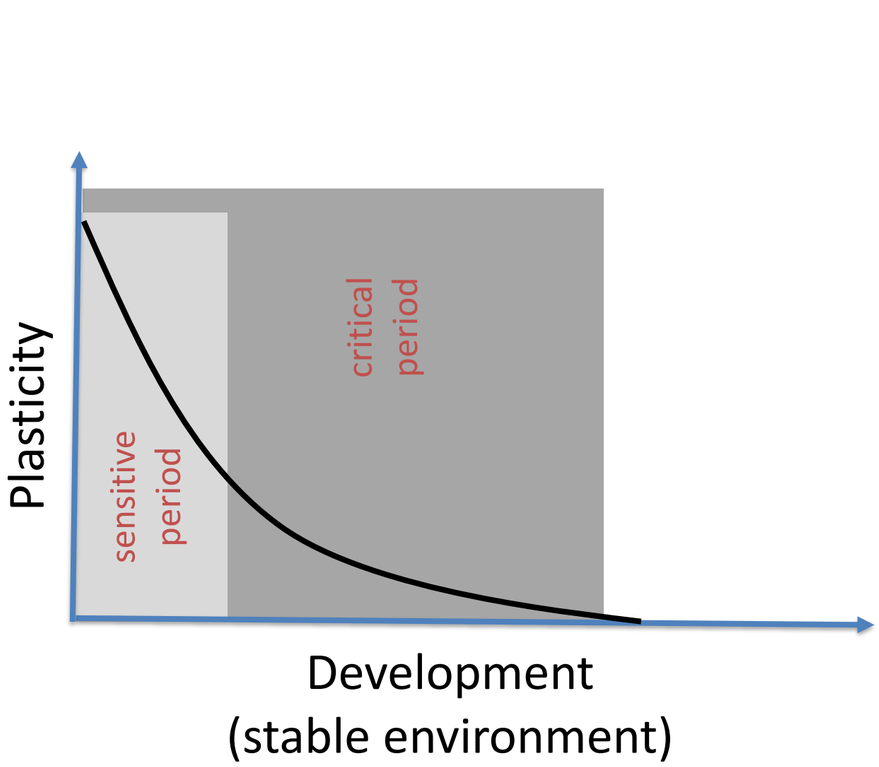
Critical periods are unlikely to evolve in environments that fluctuate across development

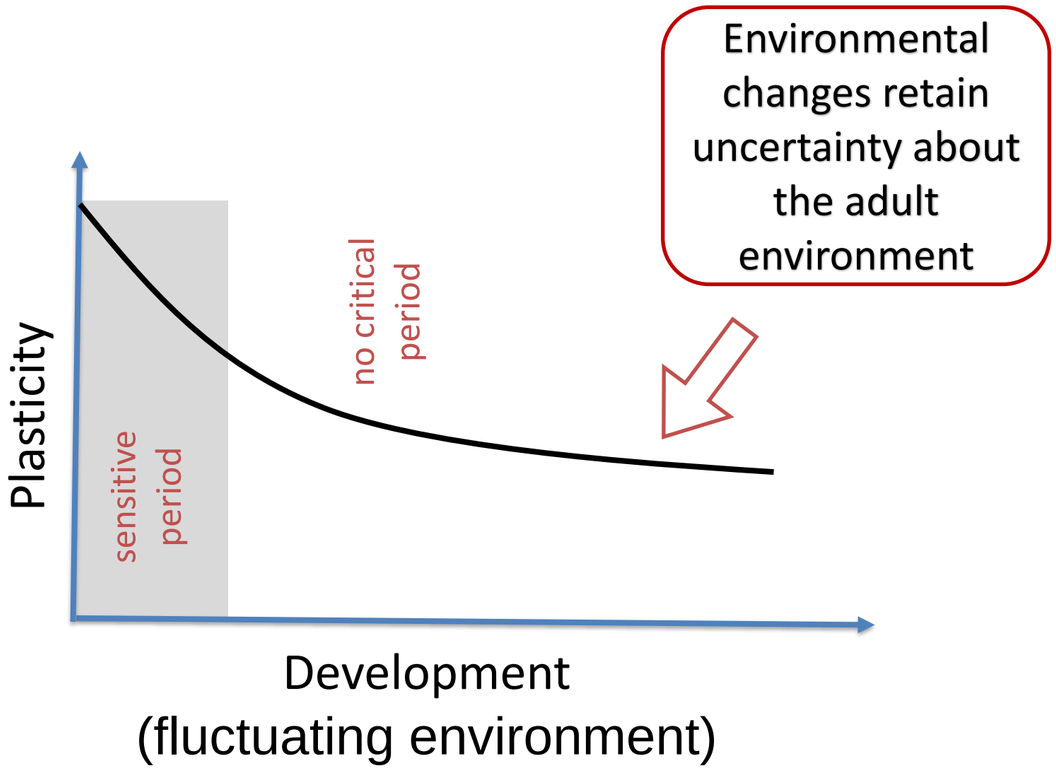




Critical periods are rarely favoured

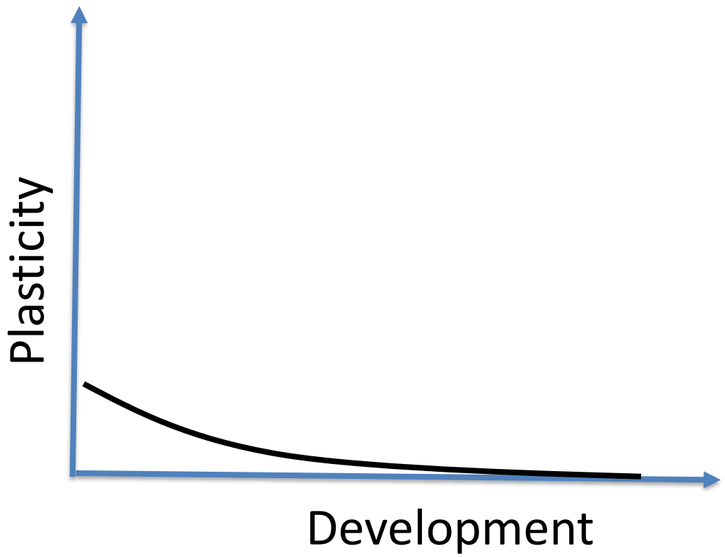
Critical periods are unlikely to evolve in environments that fluctuate across development





Longevity may select against plasticity

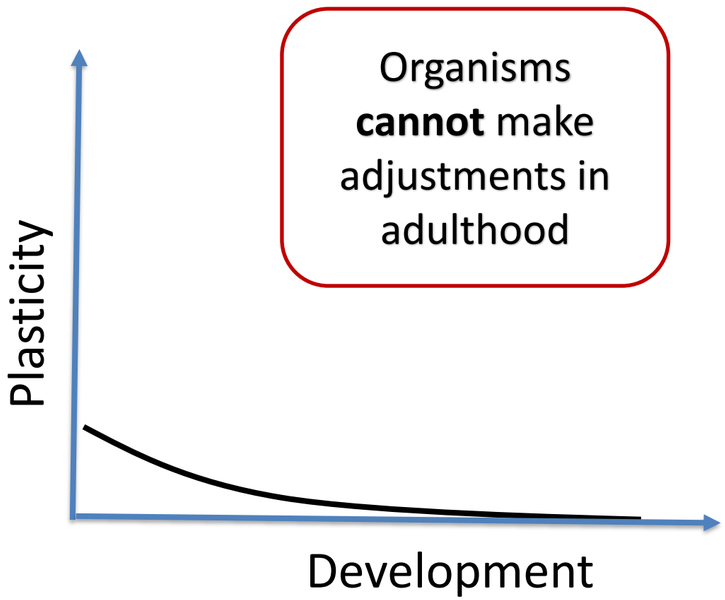
Plasticity is not adaptive when adulthood is long and organisms have prior information about their adult environment

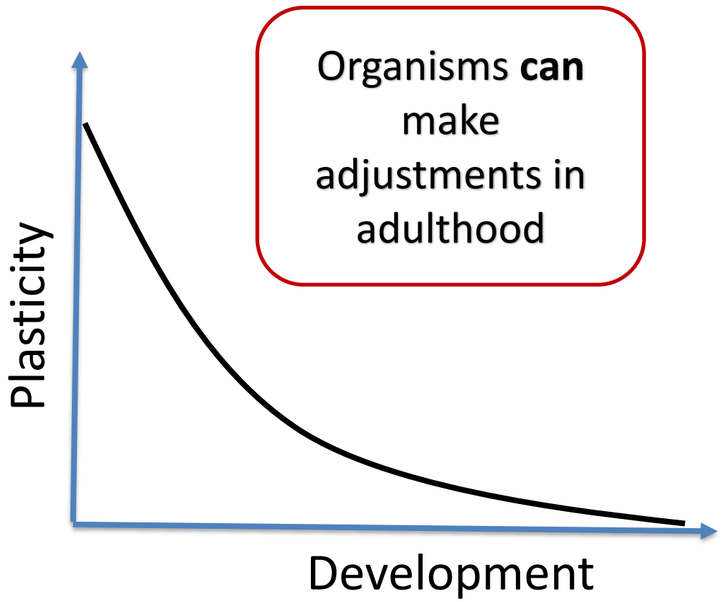


Ratikainen & Kokko (2019)

Longevity may select against plasticity

Plasticity is not adaptive when adulthood is long and organisms have prior information about their adult environment





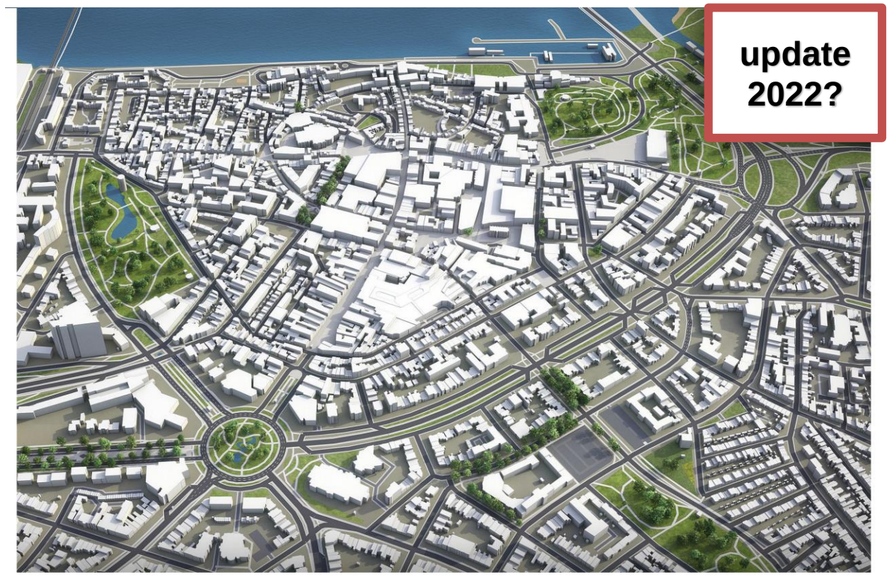
Ratikainen & Kokko (2019)

		Cue reliability	
		Constant	Varying
Environmental state	Constant	Sensitive periods at the onset of ontogeny  Often critical periods	Sensitive periods at the onset and midway through ontogeny  Only critical periods
	Varying	Sensitive periods the onset, midway through, and even towards the end of ontogeny  No critical periods	

Future work

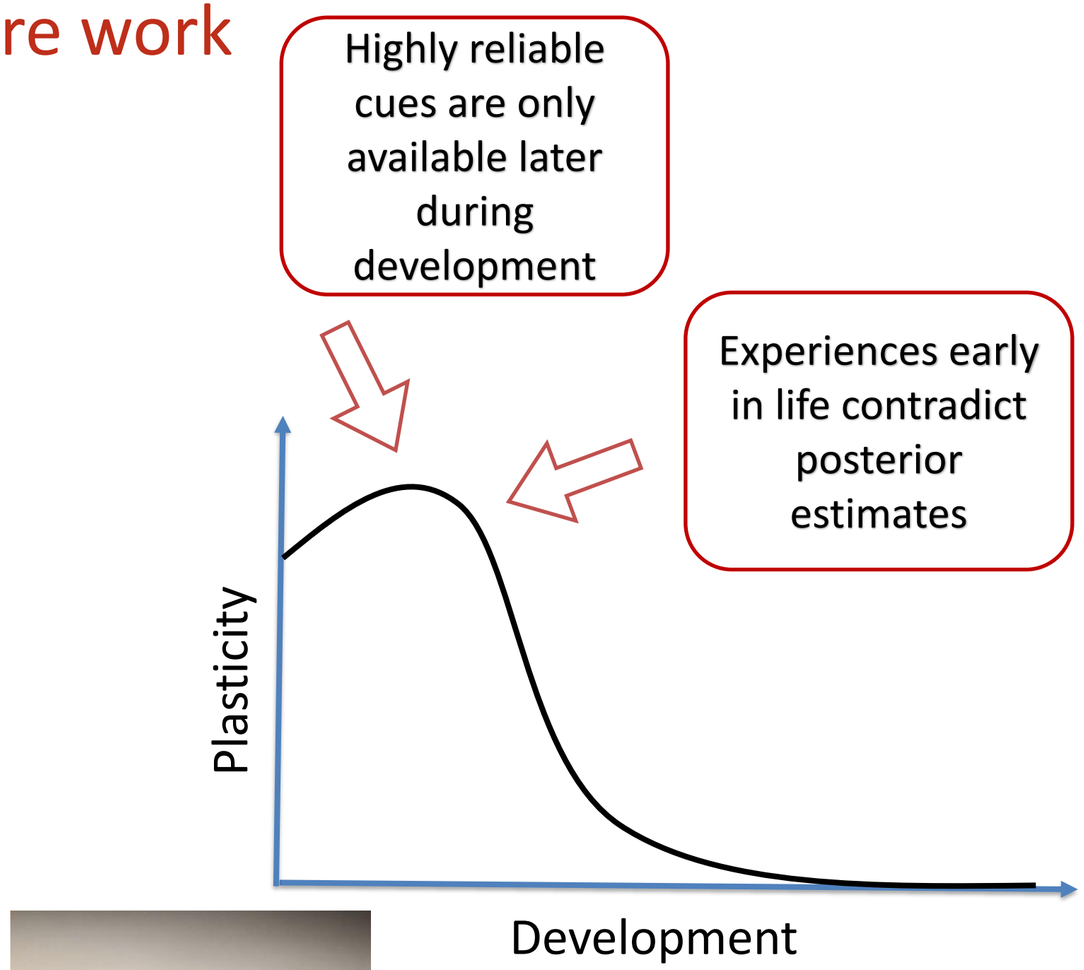
Future work

Incrementally relax more assumptions



Future work

Test predictions derived from existing models



Dunlap & Stephens (2014)
English & Barreaux (2020)

Future work

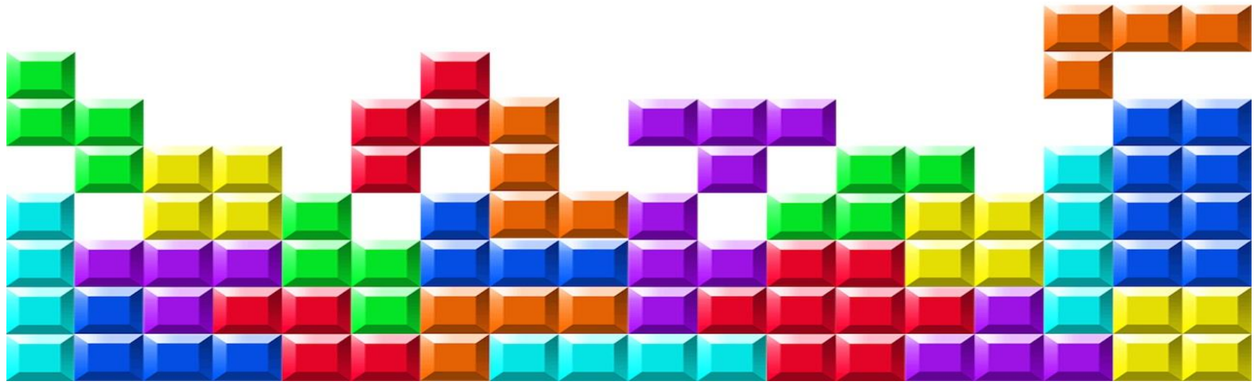
Quantify statistics of real environments

data repository of environmental statistics

Frankenhuis et al. (2019)

The value of models for theory

Some of our most interesting findings emerged only in direct comparison with other, existing models



Thank you!

✉

nicole.walasek@ru.nl

References

Agrawal, A. A., Laforsch, C., & Tollrian, R. (1999). Transgenerational induction of defences in animals and plants. *Nature*, *401*(6748), 60–63. https://doi.org/10.1038/43425

Beecher, M. D., & Brenowitz, E. A. (2005). Functional aspects of song learning in songbirds. *Trends in Ecology and Evolution*, *20*(3), 143–149. https://doi.org/10.1016/j.tree.2005.01.004

Chen, A. N., & Daniel Meliza, C. (2020). Experience- And sex-dependent intrinsic plasticity in the zebra finch auditory cortex during song memorization. *Journal of Neuroscience*, *40*(10), 2047–2055. https://doi.org/10.1523/JNEUROSCI.2137-19.2019

Dunlap, A. S., & Stephens, D. W. (2014). *Experimental evolution of prepared learning*. *111*(32), 11750–11755. https://doi.org/10.1073/pnas.1404176111

Fawcett, T. W., & Frankenhuis, W. E. (2015). Adaptive explanations for sensitive windows in development. *Frontiers in Zoology*, *12*(Suppl 1), S3. https://doi.org/10.1186/1742-9994-12-S1-S3

Fischer, B., van Doorn, G. S., Dieckmann, U., & Taborsky, B. (2014). The Evolution of Age-Dependent Plasticity. *The American Naturalist*, *183*(1), 108–125. https://doi.org/10.1086/674008

Frankenhuis, W. E., & Fraley, R. C. (2017). What do evolutionary models teach us about sensitive periods in psychological development? *European Psychologist*, *22*(3), 141–150. https://doi.org/10.1027/1016-9040/a000265

References

Frankenhuis, W. E., Nettle, D., Dall, S. R. X. X., Nettle, D., & Frankenhuis, W. E. (2019). A case for environmental statistics of early-life effects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *374*(1770). https://doi.org/10.1098/rstb.2018.0110

Frankenhuis, W. E., & Walasek, N. (2020). Modeling the evolution of sensitive periods. *Developmental Cognitive Neuroscience*, *41*(April 2019), 100715. https://doi.org/10.1016/j.dcn.2019.100715

Freund, J., Brandmaier, A. M., Lewejohann, L., Kirste, I., Kritzler, M., Krüger, A., Sachser, N., Lindenberger, U., & Kempermann, G. (2013). Emergence of individuality in genetically identical mice. *Science*, *340*(6133), 756–759. https://doi.org/10.1126/science.1235294

Gabard-Durnam, L. J., & McLaughlin, K. A. (2019). Do Sensitive Periods Exist for Exposure to Adversity? In *Biological Psychiatry* (Vol. 85, Issue 10, pp. 789–791). Society of Biological Psychiatry. https://doi.org/10.1016/j.biopsych.2019.03.975

Gobes, S. M. H. H., Jennings, R. B., & Maeda, R. K. (2019). The sensitive period for auditory-vocal learning in the zebra finch: Consequences of limited-model availability and multiple-tutor paradigms on song imitation. *Behavioural Processes*, *163*(April 2017), 5–12. https://doi.org/10.1016/j.beproc.2017.07.007

Hansen, S. N., Schou-Pedersen, A. M. V., Lykkesfeldt, J., & Tveden-Nyborg, P. (2018). Spatial memory dysfunction induced by Vitamin C deficiency is associated with changes in monoaminergic neurotransmitters and aberrant synapse formation. *Antioxidants*, *7*(7). https://doi.org/10.3390/antiox7070082

References

Larsen, B., & Luna, B. (2018). Adolescence as a neurobiological critical period for the development of higher-order cognition. *Neuroscience & Biobehavioral Reviews*, *94*(March), 179–195. https://doi.org/10.1016/J.NEUBIOREV.2018.09.005

Maugarny-Calès, A., & Laufs, P. (2018). Getting leaves into shape: A molecular, cellular, environmental and evolutionary view. *Development (Cambridge)*, *145*(13). https://doi.org/10.1242/dev.161646

Ratikainen, I. I., & Kokko, H. (2019). The coevolution of lifespan and reversible plasticity. *Nature Communications*, *10*(1), 1–7. https://doi.org/10.1038/s41467-019-08502-9

Sachser, N., Hennessy, M. B., & Kaiser, S. (2018). The adaptive shaping of social behavioural phenotypes during adolescence. *Biology Letters*, *14*(11). https://doi.org/10.1098/rsbl.2018.0536

Tooley, U. A., Bassett, D. S., & Mackey, A. P. (2021). Environmental influences on the pace of brain development. *Nature Reviews Neuroscience*, 1-13.