

Offspring development and life-history variation in a water flea depends upon clone-specific integration of genetic, non-genetic and environmental cues

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The way that organisms develop their phenotype (their characteristic features or traits) is influenced by the genes that they possess and the environment that they experience, but also by the environments that their parents experienced. This is because the environment parents experience can be passed to their offspring by so-called parental effects (such as the yolk in a bird's egg). Specifically, maternal effects allow mothers to alter offspring development separately from genetic and environmental influences. Together, maternal effects, genetic factors and environmental variation can be thought of as 'cues' that provide information to a developing organism about the best way to develop.

How a developing organism perceives and 'integrates' these cues not only alters that individual's phenotype but also has consequences for our understanding of evolutionary processes. In stable environments, genetically adapted cues that evolve over long periods of time may be the most reliable source of information for a developing organism. But in unstable or rapidly changing environments, such as those disturbed by man or experiencing climate change, maternal and environmental cues may play a bigger role. To improve our understanding of cue integration, we measured several developmental traits in three different genetic variants (known as clones) of the water flea *Daphnia magna*. This small crustacean is ideal for investigating cue integration because it often reproduces asexually, allowing many genetically-identical individuals to



Mature female Daphnia magna. Photo credit: Stewart J. Plaistow

be grown in different environmental and maternal conditions.

We found that maternal cues were able to influence all the developmental traits we studied, but that the relative importance of genetic, maternal and environmental cues varied between clones and environments. Furthermore, different clones were able to develop similar phenotypes, using different patterns of cue integration and developmental response. We were able to observe this variation because we considered a number of different traits during the developmental process, and not just a single phenotype at the end of development. Variable cue integration during development appears to be a key driver of phenotypic variation, and can help us to understand how different phenotypes evolve.