Title
Developmental Plasticity, Straight from the Worm's Mouth

Journal
Cell, 155(4)

ISSN
0092-8674

Authors
Hartenstein, Volker
Jacobs, David

Publication Date
2013-11-01

DOI
10.1016/j.cell.2013.10.038

Peer reviewed

Published in final edited form as:
Cell. 2013 November 7; 155(4): 742–743. doi:10.1016/j.cell.2013.10.038.

From the worm's mouth: the gene *eud-1* regulates teeth and diet in nematodes

Volker Hartenstein[*] and **David Jacobs**[**]

[*]Department of Molecular Cell and Developmental Biology, University of California Los Angeles, Los Angeles, CA 90095

[**]Department of Ecology and Evolutionary Biology, University of California Los Angeles, Los Angeles, CA 90095

Abstract

Developmental plasticity, defined as a frequent phenomenon whereby special environmental conditions trigger different programs of development within a single species (polyphenism), plays an important role in evolutionary theory. Investigating developmental plasticity in the nematode taxon Pristionchus, Ragsdale et al. (2013) demonstrate that the activity of a single gene, eud-1, constitutes the developmental switch deciding between two different types of feeding apparatus in these animals.

The presence of distinct discontinuous morphs within populations is often responsive to external cues associated with advantages in resources, recruitment, reproduction or matings. Winged dispersive forms of otherwise flightless insects such as locusts emerge following environmental stress or crowding, lagoonal sea-slugs with variable larvae produce dispersive planktonic larvae only in seasons when dispersal is advantgeous, predatory defenses such as spines in *Daphnia* appear following exposure of populations to predators, and different reproductive forms of males that engage in distinct mating strategies respond to the frequency of other mating types in the population (Beldade et al., 2011; Krug et al., 2013). The significance of these phenomena for sexual selection, adaptive evolution, and speciation is controversial and increasingly investigated (Pfennig et al., 2010). Understanding the mechanics of distinctive development from a common genome, inherent to polyphenism, provides an associated set of challenges in development (Moczek et al., 2011), and these environmentally induced examples of polyphenism are important in the broad integration of development, evolutionary mechanism and environmental or selective agent referred to as EcoEvoDevo (Beldade et al., 2011).

Nematodes, including the developmental model system, *C. elegans*, exhibit polyphenism as they produce a non-feeding dauer larva resistent to harsh conditions when subject to environmental stress. Diplogastrid nematodes have evolved a more extensive resource polyphenism related to the changing food available in their resource, dead scarab beetles (Kiontke et al., 2010; Fig.1). This group has many species and may constitute an example of an adaptive radiation associated with polyphenism and certainly constitutes an attractive model for EcoEvoDevo study. Different forms deploy distinct specialized cuticular teeth stenostomatous (St) and eurystomatous (Eu). The ratio of individuals with Eu and St teeth in

NIH-PA Author Manuscript

NIH-PA Author Manuscript

a given population depends on the species or strain, but is also influenced by environmental conditions, such as crowding and temperature. Low population densities favor the occurrence of St teeth, which are well suited to a bacterial diet. Crowding, presumably associated with an increasing scarcity of bacteria as a food source (Kiontke et al., 2010), induces dauer larvae which subsequently give rise to Eu adults. Eu teeth enable the worms to switch to a diet of fungi and other nematodes, which require different dentition to cut through cuticle.

Some elements of the pathway mediating the effect of crowding on tooth shape in the diplogastrid species *Pristionchus* (*P*.) *pacificus* have been elucidated in recent work; they include the hormone D7-dafachronic acid (DA) and the nuclear receptor DAF 12 (Bento et al., 2010). When activated, this pathway increases the ratio of Eu:St (Fig.1). The work by Ragsdale et al. (2013) published in this issue of Cell has identified the molecular mechanism underlying the developmental decision between Eu and St tooth structure. The authors show that the high level expression of a single gene, *eud-1*, accounts for the development of the Eu phenotype.

Eud-1 was identified in a genetic screen for mutations that suppressed the Eu phenotype in *P. pacificus*. The gene is located on the X chromosome and encodes a sulfatase homologous to the human aryl sulfatase A (ARSA). Injection of *eud-1* rescued mutant strains, yields 100% expressivity of the Eu tooth shape. The same effect could be achieved when adding *eud-1* to other strains of *P. pacificus*. Importantly, the dose of *eud-1* also promoted Eu tooth structure in a different species of *Pristionchus*, *P. expectatus*. An inbred strain of *P. expectatus* that displayed almost exclusively St teeth was found to express a lower dose of *eud-1*. When this strain was crossed to *P. pacificus* animals that carried extra copies of *eud-1* the resulting hybrid offspring exhibited a fully Eu tooth structure, consistent with the conclusion that *eud-1* represents a dosage dependant genetic switch controlling the Eu:St ratio, the authors also showed that wild type *P. pacificus* males (X0), which have a lower expression of *eud-1* and possess predominantly St teeth, could be converted to the Eu phenotype by extra copies of *eud-1*.

Further genetic experiments of Ragsdale et al. (2013) elucidate the position of *eud-1* within the pathway connecting the environment to tooth morphology. *Eud-1* acts as a sulfatase downstream of both DA and DAF 12 and is expressed in subsets of neurons. These findings position *eud-1* as the target of the DA/DAF 12 signaling cascade which processes an (as yet unknown) substrate activating the Eu developmental program in the network of genes ("realisators") that control tooth-formation in cells of the pharynx (Fig.1). The alternative interpretation, that Eud-1, as a sulfatase, acts directly on the pharynx during tooth morphogenesis, appears less likely in light of the fact that *eud-1* is expressed in neurons.

Eud-1 appears to be a relatively recent product of gene duplication that was subsequently co-opted as a regulatory switch at the downstream end of the regulatory hierarchy, suggesting additional aspects regarding the evolution or regulatory mechanisms. Ultimately, work of this sort on tractable experimental models will allow for a fuller causal understanding of the molecular substrate of evolutionary change. It is assumed that the stem species of the rapidly diversifying clade Diplogastridae possessed the Eu/St polyphenism

NIH-PA Author Manuscript

NIH-PA Author Manuscript

(Kiontke et al., 2010). While many descendants, among them the genus *Pristionchus*, have kept both tooth forms in their developmental repertoire, others have become exclusively eurystomatous or stenostomatous, a phylogeny that can be explained by genetic accommodation (Fig.1). The concept of phenotypic plasticity followed by genetic accomodation was initially assembled by Waddington in the middle of the last century, based on genetic experiments with *Drosophila* (Moczek et al. 2011). This concept has recently been resurrected and extended as a potentially important mechanism of evolutionary change (Pigliucci et al., 2006; Suzuki and Nijhout, 2006; Beldade et al. 2011). Future studies on the *Pristionchus* model will bring to light essential components of the molecular underpinnings of genetic accommodation.

References

Beldade P, Mateus ARA, Keller RA. Evolution and molecular mechanisms of adaptive developmental plasticity. Molecular Ecology. 2011; 20(7):1347–1363. [PubMed: 21342300]

Bento G, Ogawa A, Sommer RJ. Co-option of the hormone-signalling module dafachronic acid-DAF-12 in nematode evolution. Nature. 2010; 466 (7305):494–7. [PubMed: 20592728]

Kiontke K, Fitch DHA. Phenotypic plasticity: Different teeth for different feasts. Current Biology. 2010; 20 (17):R710–R712. [PubMed: 20833313]

Krug PJ, Gordon D, Romero MR. Seasonal Polyphenism in Larval Type: Rearing environment influences the development mode expressed by adults in the sea slug Alderia willowi. Integrative and Comparative Biology. 2012; 52 (1):161–172. [PubMed: 22576812]

Moczek AP, Sultan S, Foster S, Ledon-Rettig C, Dworkin I, Nijhout HF, Abouheif E, Pfennig DW. The role of developmental plasticity in evolutionary innovation. Proceedings of the Royal Society B-Biological Sciences. 2011; 278 (1719):2705–2013.

Pfennig DW, Wund MA, Snell-Rood EC, Cruickshank T, Schlichting CD, Moczek AP. Phenotypic plasticity's impacts on diversification and speciation. Trends in Ecology & Evolution. 2010; 25 (8): 459–467. [PubMed: 20557976]

Pigliucci M, Murren CJ, Schlichting CD. Phenotypic plasticity and evolution by genetic assimilation. The Journal of Experimental Biology. 2006; 209 (12):2362–2367. [PubMed: 16731812]

Ragsdale EJ, Müller MR, Rödelsperger C, Sommer RJ. A developmental switch coupled to the evolution of plasticity acts through a sulfatase. Cell. 2013

Suzuki Y, Nijhout HF. Evolution of a polyphenism by genetic accommodation. Science. 2006; 311(5761):650–652. [PubMed: 16456077]

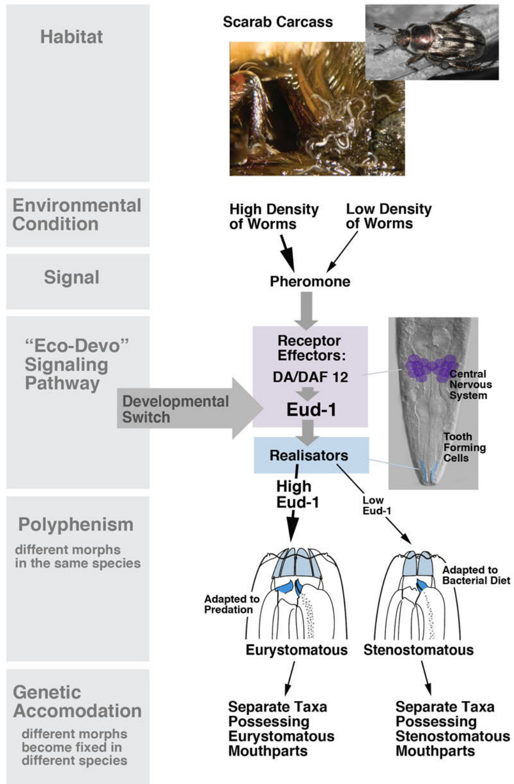

Fig 1.

The nematode *P.pacificus* feeds on dead scarab beetles. Pheromones reflecting population density of the worm activate a signaling pathway in the nervous system that regulates the expression of Eud-1 ("developmental switch"). In response to low Eud-1 expression levels (signifying low a population density) the pharynx produces stenostomatous teeth, adapted to a diet of bacteria which are plenty when few worms are around; at high Eud-1 levels eurystomatous teeth, permitting a diet of fungi and nematodes, prevail. These two morphs, coexisting in the species P. pacificus, can become genetically fixed through genetic accommodation in different species.

Photographs at the top: from Bento et al., 2010; schematic drawings at bottom: from Kiontke and Fitch, 2010