BIO4102/BIO6102/MSB315

Evolutionary Ecology
(Varsha 2023)

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MODULE: PHENOTYPIC PLASTICITY

Photos: Erik Greene

Masquerade in *Nemoria arizonaria* (Emerald moth)

Source: moths.friendscentral.org

Spring morph

Summer morph

Spring larvae feed on, and resemble, oak catkins (flowers)

Summer larvae feed on oak leaves and resemble twigs.

Spring caterpillars fed on oak leaves or on artificial diet with high tannins develop into summer morphs. Greene (1989) *Science* 243:643-646

Phenotypic plasticity

Ability of the same genotype to produce different phenotypes under different environments.

Phenotypic traits:

- Morphology
- Physiology
- Behaviour, etc

Araschnia levana (Map butterfly)

Spring morph

Photo: Algirdas /Wikimedia Commons

Summer morph

Photo: Michael Apel / Wikimedia Commons

Larvae reared under short-day conditions become diapause pupae and emerge as spring-morph butterflies. Long-day larvae become non-diapause pupae, which emerge as summer morphs

Wet and Dry season morphs in tropical butterflies

Bicyclus anynana (Squinting bushbrown)

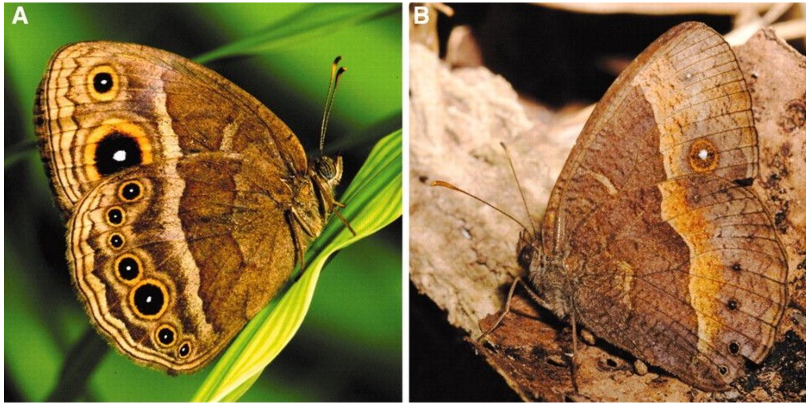
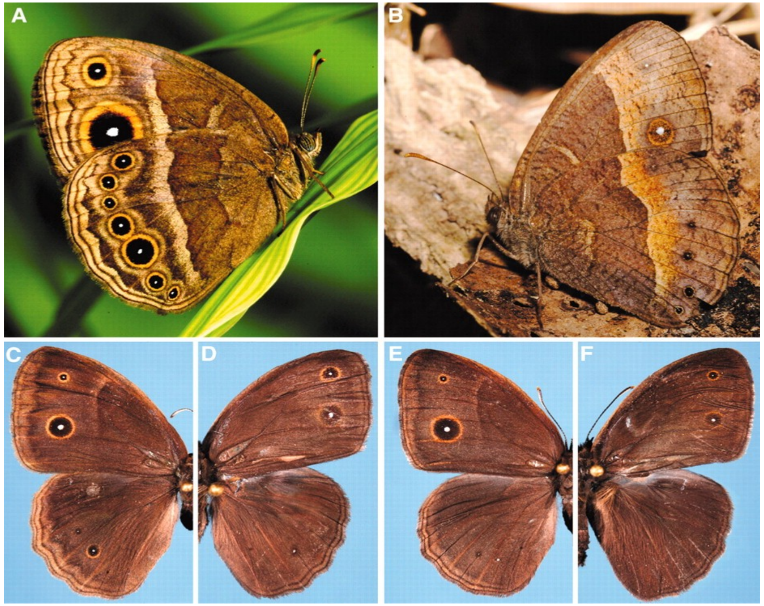


Image: Prudic *et al* (2011) *Science* 331:73-75

Eyespot size affected by larval development temperature. The dry season form benefits by crypsis (Lyytinen et al 2004 *Proc R Soc B* 271:279–283), whereas the wet season morph is thought to benefit by deflection (Prudic *et al* 2015 *Proc R Soc B* 282:20141531)

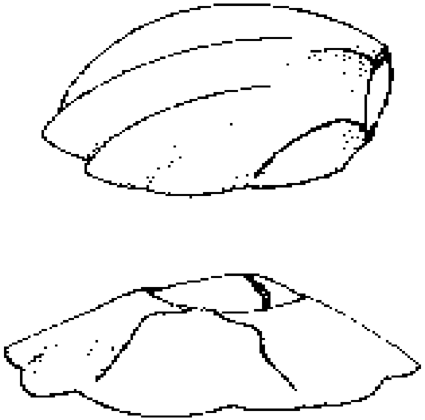
Plasticity in behaviour :: e.g. sexual selection in *Bicyclus anynana*. Dry season – choosy males

Wet season – choosy females



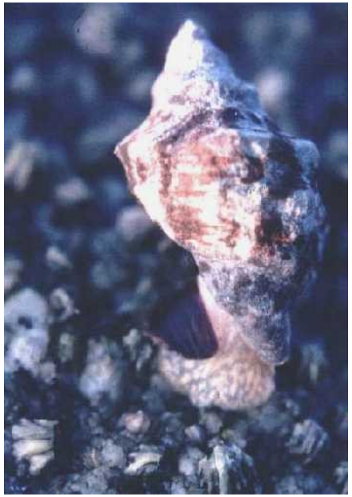
Prudic *et al* (2011) Science 331:73

In the barnacle *Chthalamus anisopoma*, presence of the predatory sea snail *Mexicanthina angelica* induces development of an attack resistant form where the aperture is in a plane that is perpendicular, rather than horizontal, to the rock surface. This orientation makes the barnacle more resistant to attack



Chthamalus anisopoma

Mexicanthina angelica



Images: Curt Lively

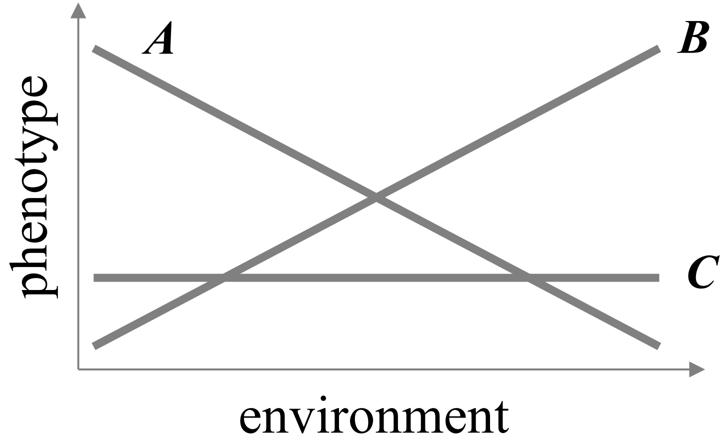
Lively CM (1986) *Evolution* 67:858-864

Reflection

- If one morph is better against predation by the snail, why not produce that morph always? What might be the advantage of having the ability to produce the less protected morph?

Reaction Norms

Reaction Norm: Range of phenotypes produced by a genotype when exposed to a range of values of a single environmental variable



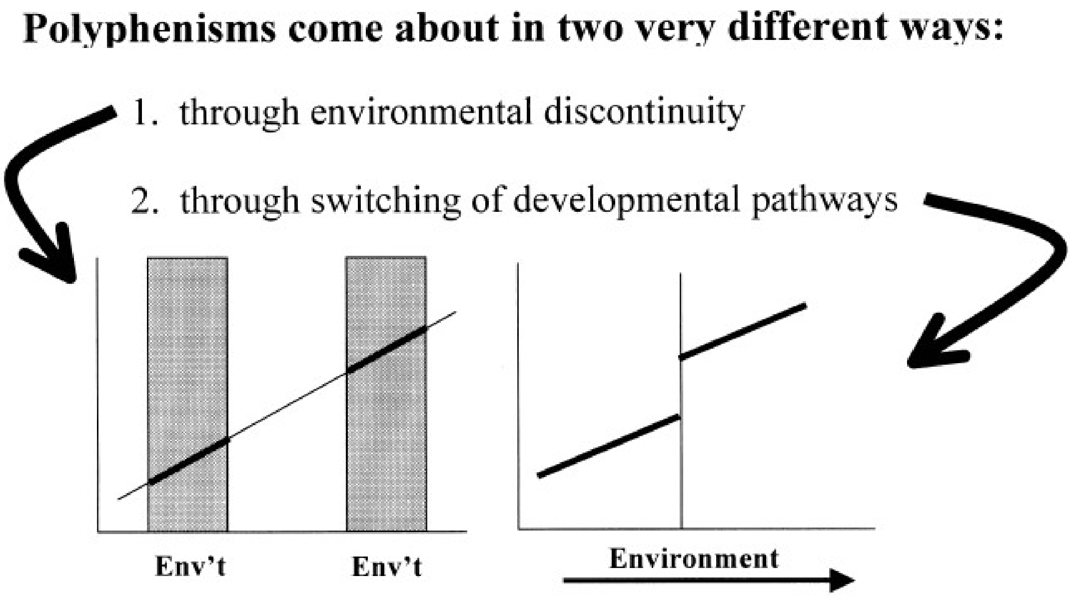
A & B exhibit phenotypic plasticity, whereas C does not

Polyphenism

Existence of discrete phenotypes due to phenotypic plasticity.

- Summer / Spring morphs in *Nemoria* & *Araschnia*
- Temperature dependent sex determination in many reptiles
- Caste in honeybees

Polyphenisms can come about in two ways *i)* when the environment is either discontinuous or is only sampled at discrete times or phases so that environment is effectively discontinuous; or *ii)* from switches in developmental pathways that produce a discontinuous reaction norm.
Nijhout (2003) *Evolution & Development* 5: 9–18



In nature *Araschnia levana* larvae develop into discrete summer or spring morphs. In the lab, intermediate forms can be induced by rearing under intermediate conditions. Nijhout (2003) *Evolution & Development* 5: 9–18

Most polyphenisms in nature appear to be due to discontinuous environments

Example for plasticity due to developmental switches: *Alternative developmental pathways* depending on whether a *hormone* is above or below a *threshold* value during a given period called the 'critical period' or the 'hormone sensitive period'.

Polyphenisms can also develop due to a combination of discrete environments and developmental switches. E.g. *Bicyclus anynana* eyespots

Reflection

- Find two studies that have shown the occurrence of polyphenism through developmental switches

Reversible versus irreversible plasticity

- Irreversible: E.g., larval morphs of *N. arizonaria*; wing patterns of *B. anynana* & *A. levana*

- Reversible: Sometimes called '*flexibility*'.

  e.g. Acclimatization

  Learning

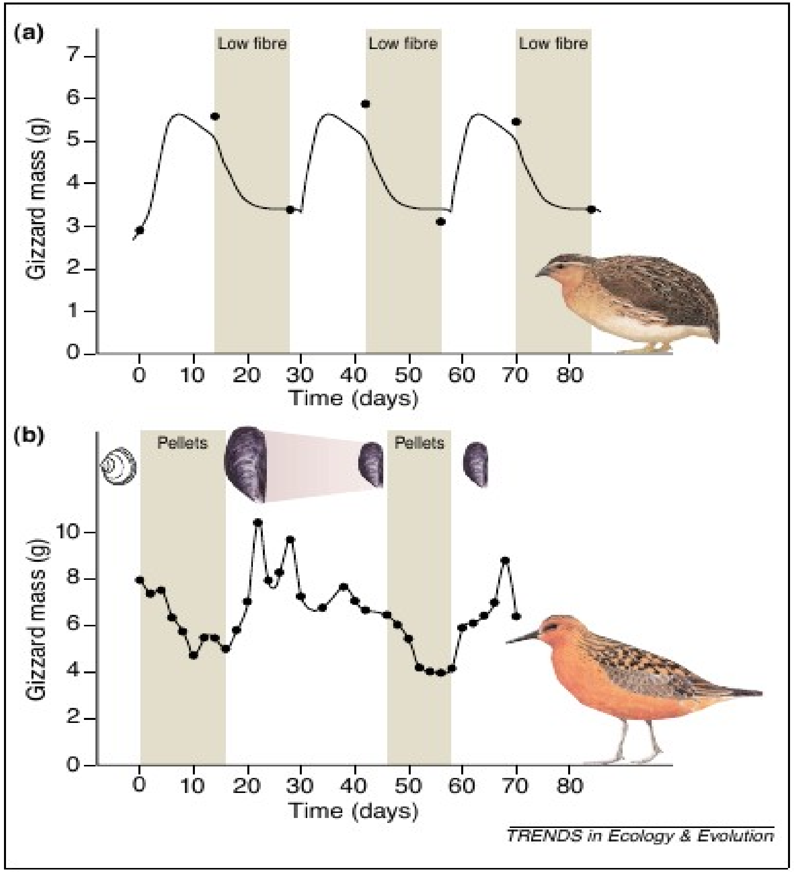
  Chameleon colour change

Reflection

- One might assume that reversible plasticity is always better than irreversible plasticity. Yet, there are innumerable examples of irreversible plasticity in nature, suggesting that irreversible plasticity has its advantages.
- What might be conditions under which irreversible plasticity provides higher fitness compared to reversible plasticity?

Piersma & Drent (2003) *TREE* 18: 228-233

Reversible size changes in the gizzards of adult Japanese quail *Coturnix japonica* (a) and red knots *Calidris canutus* (b) The quail were given a diet of alternately low or high non-digestible fibre content (3% and 45%, respectively). Gizzard size doubled in 14 days. Red knots are specialized molluscivore shorebirds with strong muscular gizzards, which they use to crush ingested hard-shelled prey. With a change in diet from medium–small mussels *Mytilus edulis* ingested whole (the smallest size classes are easiest to crush) to a diet of soft food-pellets, gizzard mass halved within the first eight days following the diet shift. Shifts from a pellet to a mussel diet induced doublings of gizzard mass within even shorter time periods.



Phenotypic plasticity is extremely common

Phenotype:: Genotype+*Environment+Genotype* x *Environment interactions*

This is because developmental, physiological, and metabolic processes are usually sensitive to environmental variables.

Adaptive phenotypic plasticity

- Resulting phenotypes have higher fitness in their respective environments compared to a single phenotype
- Some conditions for phenotypic plasticity to be ***adaptive***, assuming it is irreversible

1) Heterogenous environment

2) No single phenotype is optimal in all environments

3) Environmental cue during development is correlated with future environmental conditions

How does adaptive plasticity evolve?

- Genes/allele that regulate plasticity are selected for

Genetic assimilation

- Phenotypic plasticity involves alternate developmental pathways.
- Developmental pathways consist of genetic components that may be able to respond to selection

Genetic assimilation: Wherein, a phenotype, which initially is produced only in response to some environment, evolves through selection such that it is produced without the influence of the environment

Waddington (1956) *Evolution* 10: 1-13

- Found the 'bithorax' (two thoraces) phenotype in some *Drosophila* individuals in response to ether vapor
- Artificial selection experiment: selected for developmental capacity to produce 'bithorax'
- After many generations, found that some individuals exhibited 'bithorax' even without ether

Fig 21. Campbell Biology