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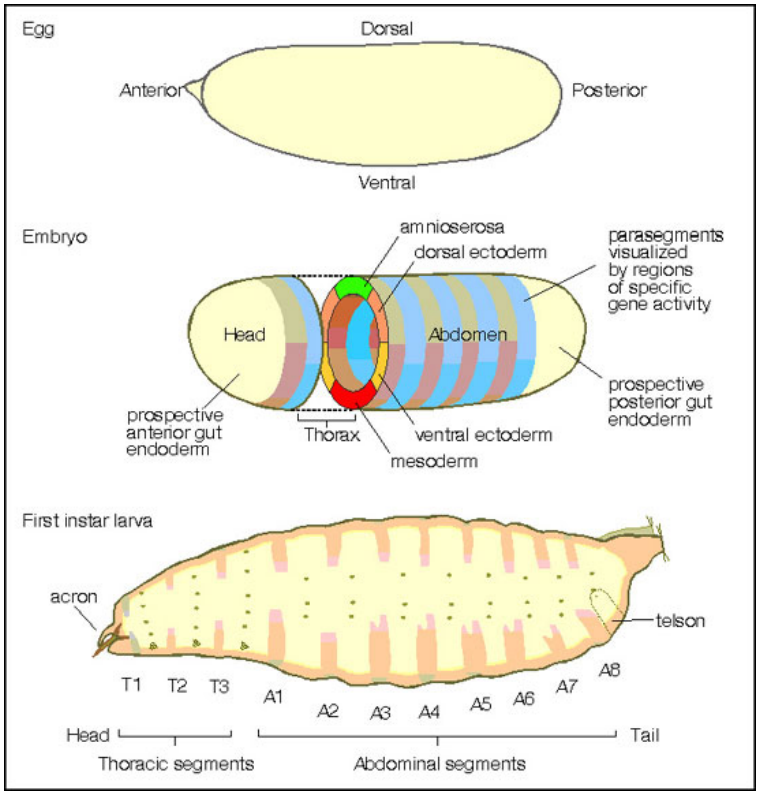
Ecological developmental biology

Integrative biology 2016, 5th lecture

Developmental biology

- We prefer clear cut cases of development: a well defined start and end point
- Development start from the zygote and ends with sexual maturity or with death
- Does genotype fully determine phenotype?



Development and environment

- The genotype is expressed during development and with the influence of the environment determine the phenotype
- Development is influenced by the environment
- This influence is mostly thought as noise, but it could also be a cue
- Is a different outcome of the developmental pathway an error or an adaptation?

Plasticity

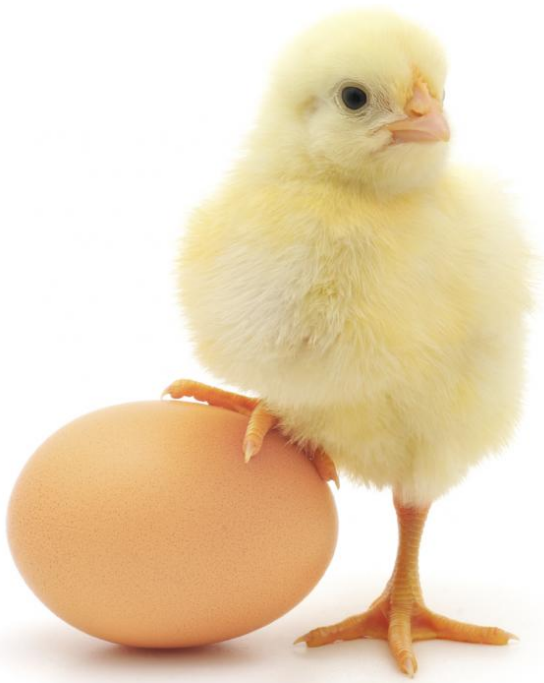
- The same genotype under different environment produces different phenotype
- The environmental cue influences the phenotype through the developmental pathway
- Is plastic behaviour a developmental plasticity?
- What is phenotype?

How to defend against environmental influence?

Because we do not want all environmental effect to influence development! On the contrary, we want a stable development.

How does the developing embryo defend against the environment?

- Dormancy
- By producing a hard shell
- By being less edible (bad taste)
- Biochemistry, parental care, symbiont can defend against pathogens



Environment's influence on phenotype through the genotype

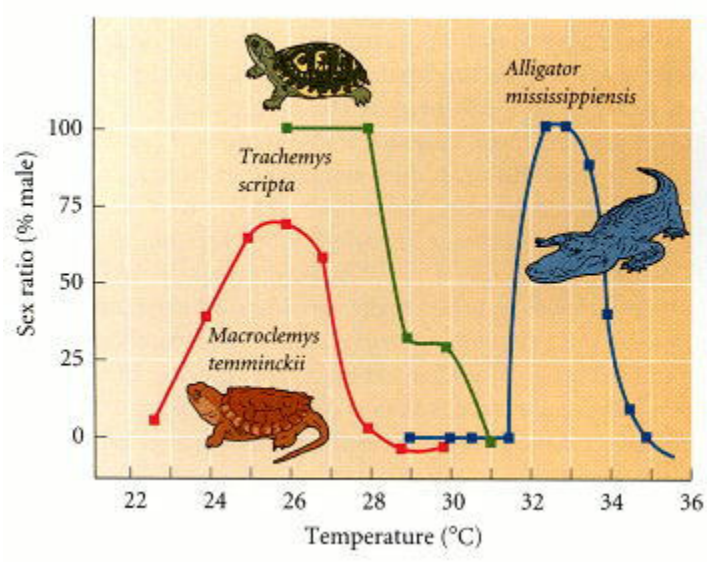
Sometimes one need to change fast, and the genome needs to prepare the individual for more than one environment

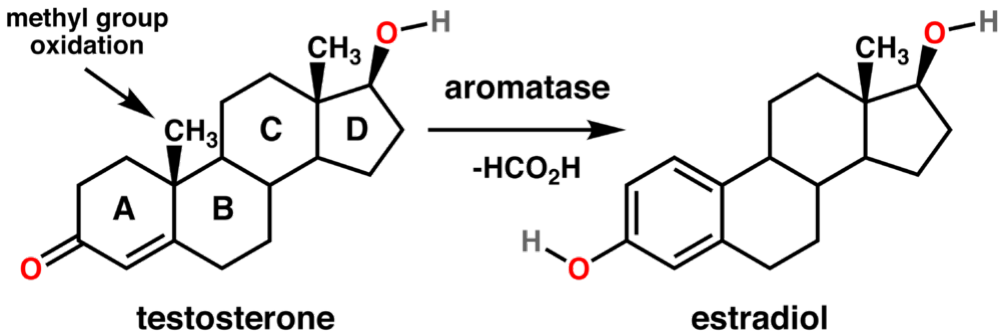
A list of topics covered

- Environmental sex determination
- Migratory forms of insects
- Influence of food on morphology
- Influence of predators on morphology

Temperature-dependent sex determination

- Aromatase transforms testosterone to estradiol
- Tuatara and crocodilians employ this exclusively
- Many other lizards and fish have temperature-dependent sex determination as well





Social sex determination among crustaceans

- The fish ectoparasite *Anilocra frontalis's* larvae has both sexes rudimentary organs.
- If it colonizes a fish alone, then it becomes a male at 7,5 mm and then at 14 mm turns into a female.
- If it the larvae colonizes a fish already having a female, then it stays male, even if growing larger than 20 mm (the normal size for females)

Social sex determination among crustaceans

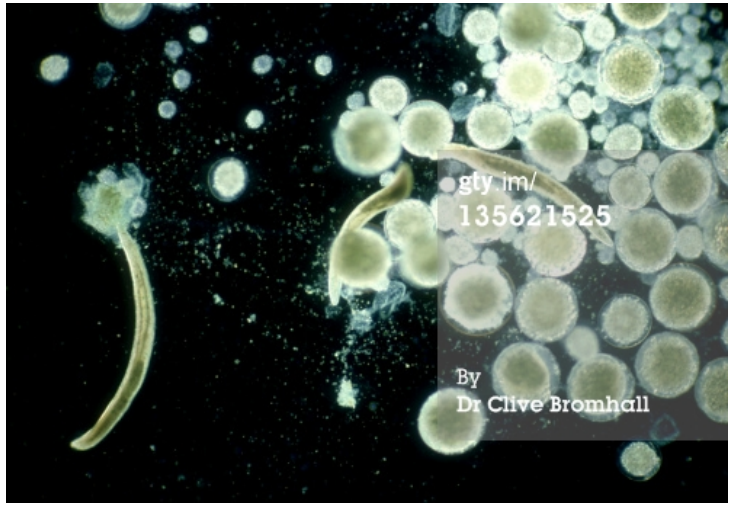
- In some parasitic isopods (*Callianassa laticaudata*, *Stegophrygus hyptius*) the first to colonize a host becomes a female. Subsequent colonizers become small males.
- The opposite happens in the copepod (*Pachypygus gibber*): the first parasite becomes a male, and subsequent ones females. If there are no females present for a while, the males can transform into females.

Gammarus duebeni

- In the amphipod crustacean *Gammarus duebeni* the eggs develop into a male in the very beginning of the reproductive season. Males can inseminate a female nearly any time, except when they moult.
- On the other hand females can only have sex during their moult. And thus there is very intense competition for females.
- Bigger males have a competitive advantage.
- Bigger size is better for both sexes, but relatively better for males

Sex-determination: landing site

- *Bonellia viridis* (annelid worm)
- If the larvae falls on the bottom of the sea, then it becomes a female
- The female then emits pheromones to attract other larvae.
- A new larvae then become a tiny male

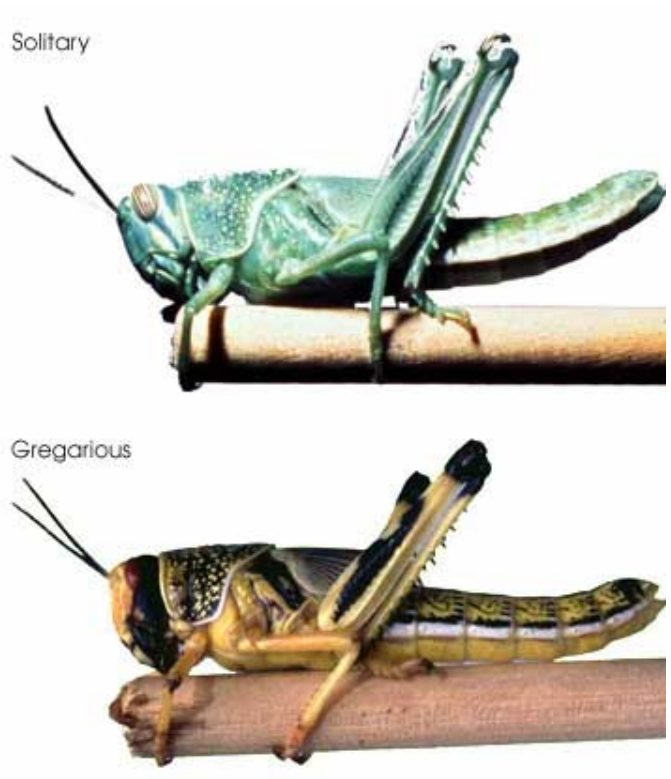


Social sex-determination

- *Thalassoma bifasciatum*
- If there is no male present, then the largest female transforms into one

Locust swarms

- *Schistocerca gregaria*
- When they feel the closeness of each other they shift to the gregarious, migratory form
- This form stays for some generations, and administering an L-dopa derivative to the eggs can induce this phenotype

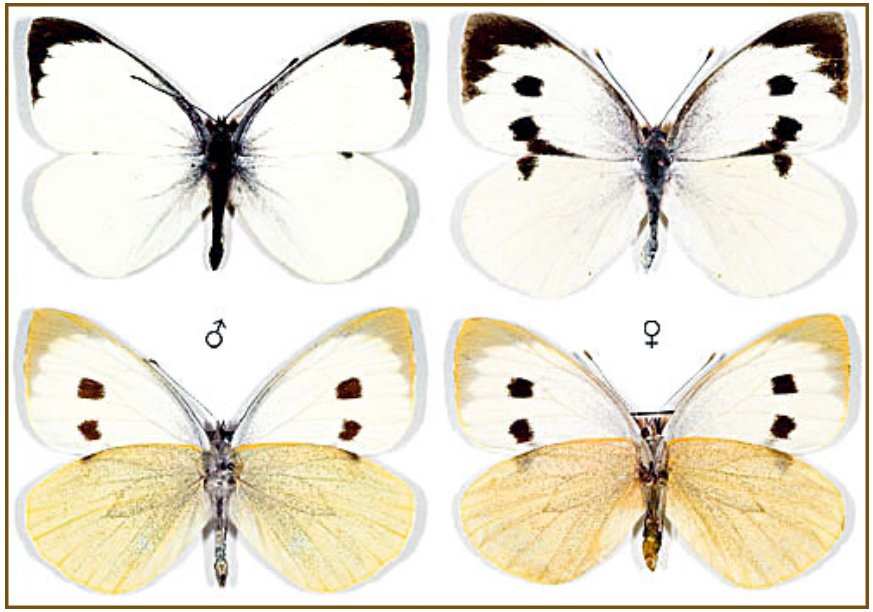


Temperature dependent enzyme activity

- A tyrosinase mutation makes it temperature dependent. The enzyme only takes its native conformation in colder environment. This enzyme is required for dark color.

Temperature and photoperiod

- In the northern hemisphere *Pieridae* butterflies have a darker spring morph
- This helps them to quicker absorption heat
- *Pontia* butterflies (above)
- Cabbage butterfly (*Pieris brassicae*) (below)



Season dependent camouflage

- *Nemoria arizonaria*

Nemoria arizonaria

(A)

Spring
Eat oak catkins (flower)
Looks like oak catkins
Feed oak leaves => summer morph

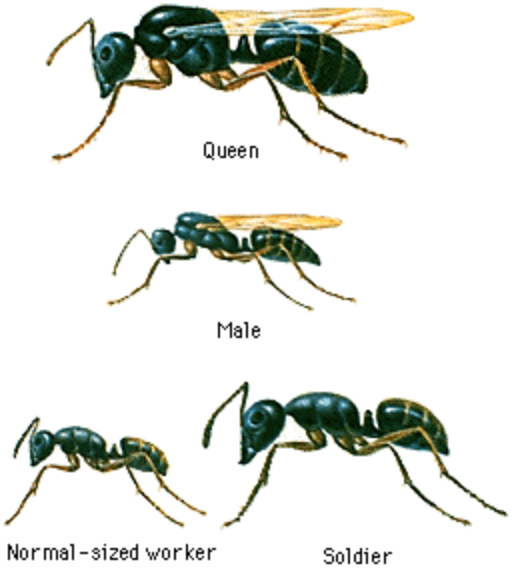
(B)

Summer
Eat oak leaves
Looks like oak twigs
Feed catkins => summer morph

spring form ==tanin in leaves?==> summer morph
(default state)

You become what you eat

- Bee fed with royal jelly becomes queen
- The corpora allata continues to produce juvenile hormone, and this the larvae can grow larger before metamorphosis
- This is crucial for becoming a queen



Gravity

- Frog and chicken embryo requires gravity
- Human also need gravity for bones and muscle

Mechanical pressure

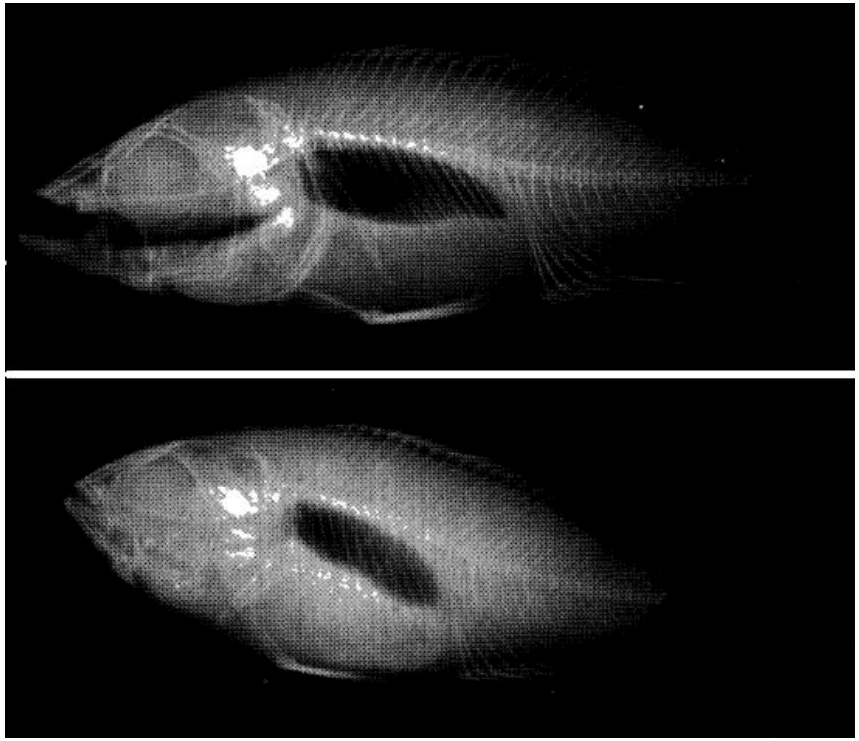
- For some bones, like the patella, pressure (usage) is required
- Mandible become more robust if we chew more

Muscle mass increase with training

- Muscle mass can be induced quite well throughout our life

Feeding influence mouth shape

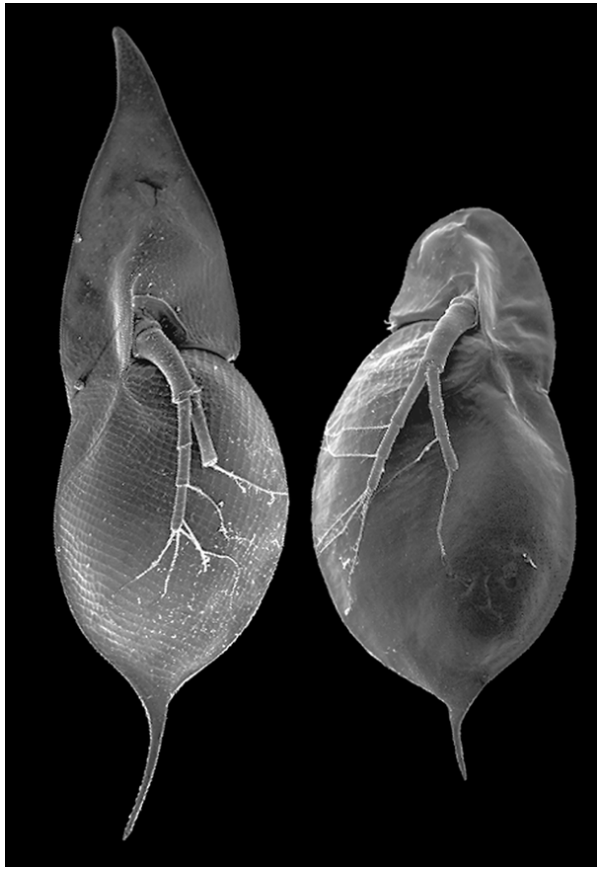
- *Cichlasoma managues* (ciclids)
- One (above) was fed with crustacean, while the other (bottom) with worms and fish feed



Meyer 1987 *Evolution* **41**: 1357

Daphnia

- In the presence of predators they develop a spine (hat)
- This is induced by the kairomone emitted by the predators
- The crested/spined form has lower fecundity



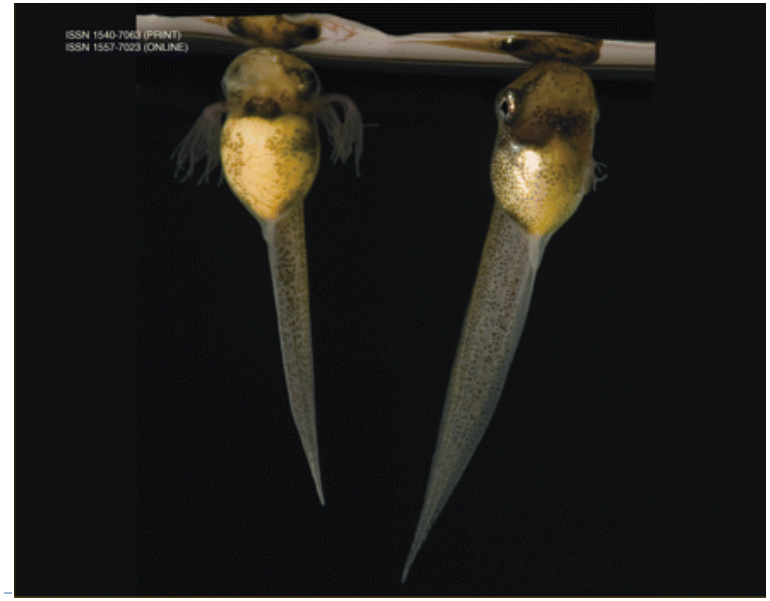
Crucian carp(*Carassius carassius*) morphs
(a) without predator
(b) with predator

Domenici P et al. Proc. R. Soc. B 2008;275:195-201

PROCEEDINGS OF THE ROYAL SOCIETY B

Predator induced early hatching

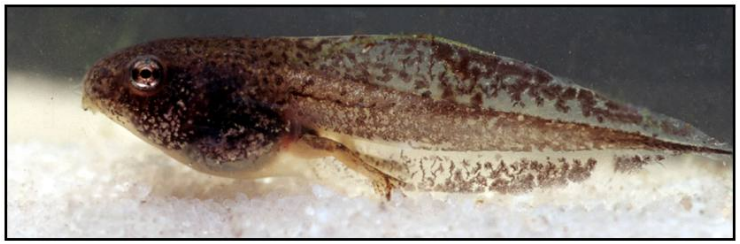
- Central American tree
- Frog (*Agalychnis callidryas*)
- http://sites.bu.edu/warkentinlab/video-library/
- They hatch earlier, at day 4-5 instead of 6-7, if attacked.
- Early hatched tadpoles are less robust



- Warkentin, K. M. 2011 Plasticity of hatching in amphibians: Evolution, trade-offs, cues and mechanisms. *Integrative and Comparative Biology* ***51, 111-127.***

The presence of predators

- Tadpole (têtard / girino) of *Hyla chrysoscelis*
- The morphological change affect swimming speed, and thus the tadpole can escape the predator



McCollum, S. A., & J. D. Leimberger. (1997). Predator-Induced Morphological Changes in an Amphibian: Predation by Dragonflies Affects Tadpole Shape and Color. *Oecologia*, *109*(4), 615–621.

Cannibalistic tadpoles

- *Scaphiopus couchii*
- They live in ephemeral, desert lakes
- Available water determines if they can finish their metamorphosis
- Some will become cannibals and thus finish metamorphosis earlier

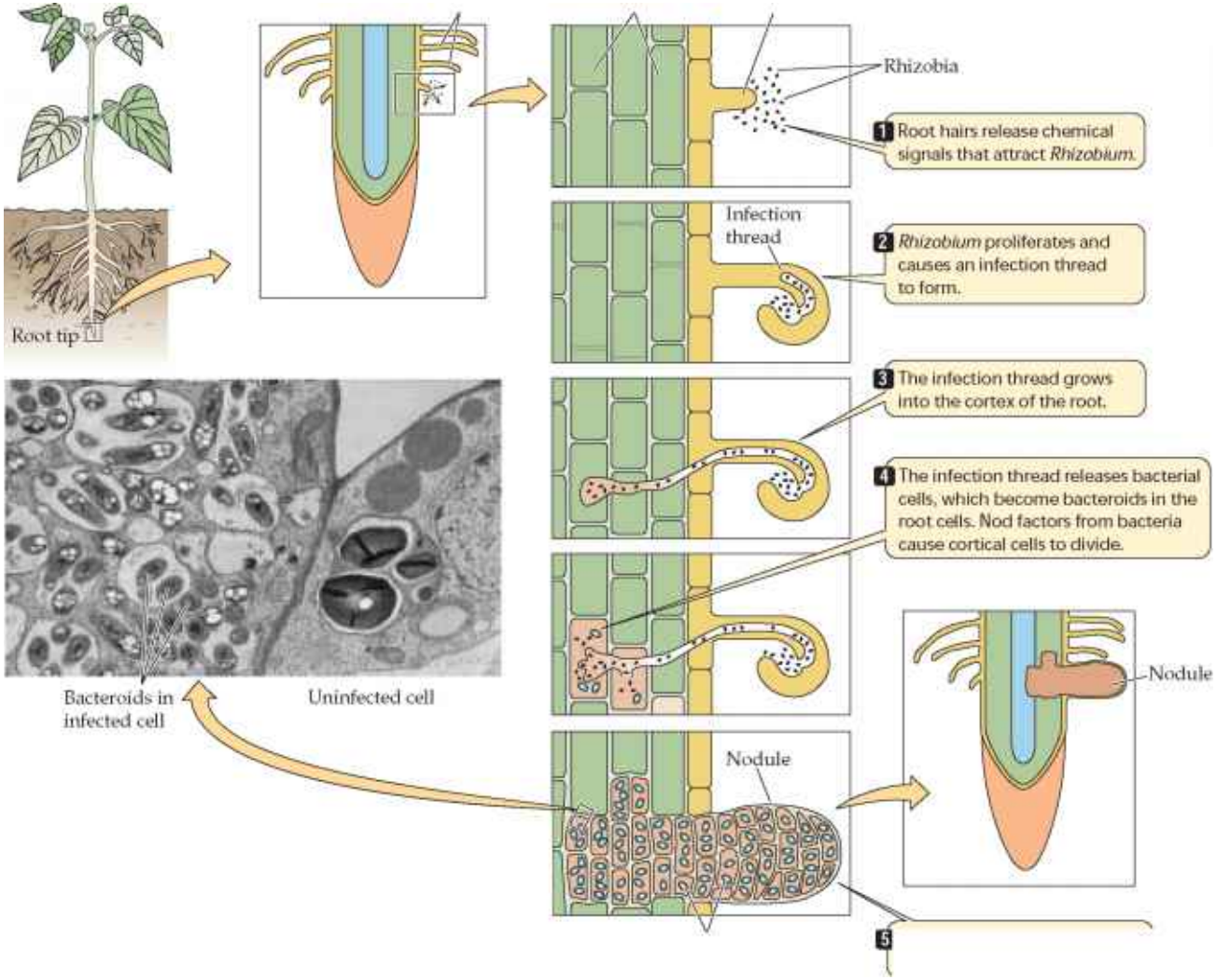
- The cannibalistic individuals are bigger, but will become small adults

Robert Hormonal Correlates of Environmentally Induced Metamorphosis in the Western Spadefoot Toad, *Scaphiopus hammondii* Denver. General and Comparative Endocrinology **110, 326–336 (1998)**

Symbioses

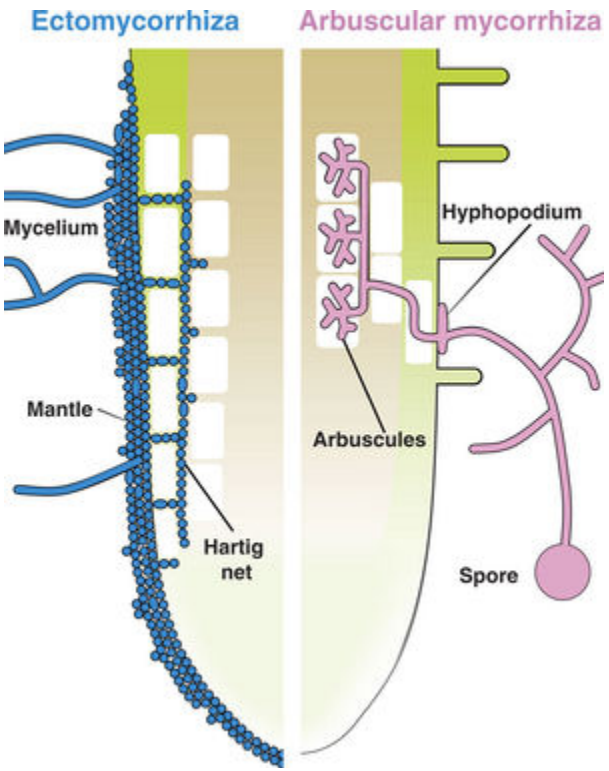
The species influence each other's development

Nitrogen fixation (*Rhizobium*)



Mycorrhiza

- Mycorrhiza is required for the germination of orchids



Light emitting squid

- The belly of the squid *Euprymna scolopes* emit light so it resemble moonshine
- This requires the bacterium, *Vibrio fischeri,* which is taken up from the environment
- It takes up many Gram-negative bacteria, but all except *V. fischeri* is killed
- The light organ finishes its development in the presence of the bacterium

Wolbachia

- Infecting insects
- Transferred via the egg
- It can transform a male into female

- Can cause the change of sex determination in some species

Maternal influence

- What will happen if we cross these two breeds?
- The offspring will resemble the mother

Handedness of snails

- The genotype of the mother determines the form of the shell
- D/D and D/d genotype will result in right handed shell, while homozygote recessive (d/d) will be left handed
- The segregation numbers are quite strange at first sight