PEST CONTROL UNDER DIFFERENT LIGHT CONDITIONS

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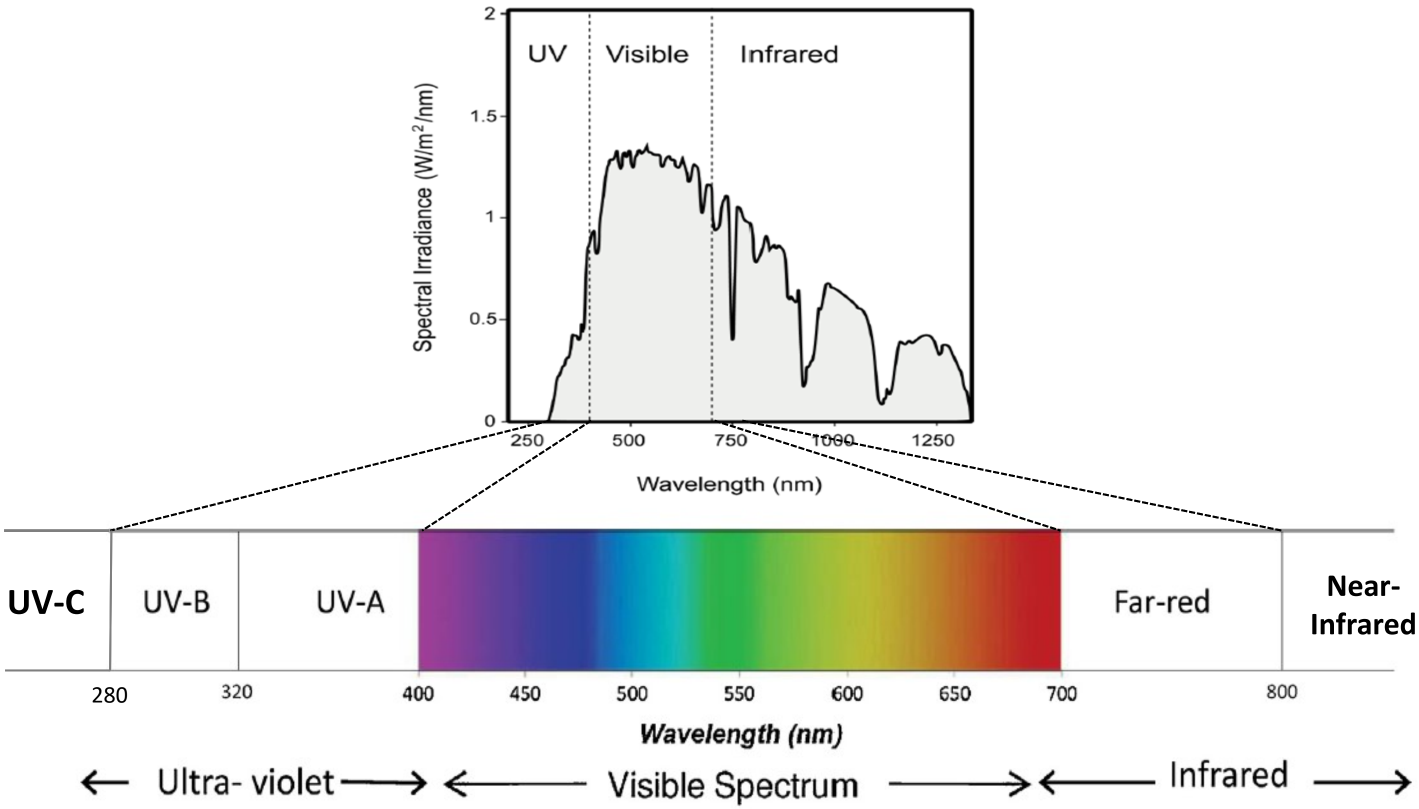
LIGHT CONDITIONS

- **What is light?**
  electromagnetic radiation within a certain portion of the electromagnetic spectrum

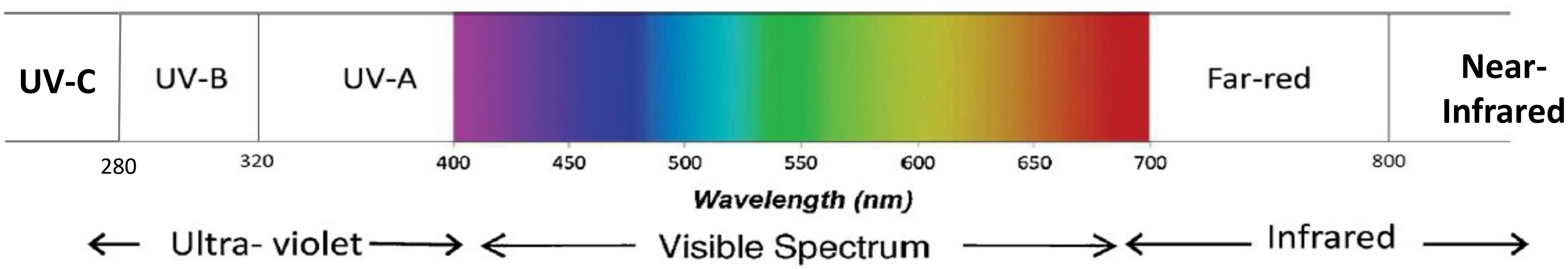


Huché-Thélier et al 2016, *Environ Exper Bot*, modified; Robert A. Rohde, Wikimedia Commons, modified)

LIGHT CONDITIONS

Greenhouse cladding changes the quality and quantity of the transmitted radiation, especially regarding:

- intensity (quantity)
- UV
- NIR
- blue wavelengths



Huché-Thélier et al 2016, *Environ Exper Bot*, modified

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PEST CONTROL

- **What is a pest?**

  Merriam-Webster dictionary: “a plant or animal detrimental to humans or human concerns (such as agriculture or livestock)“

→ *here:* focus on insect pests in agriculture; **food competitors to humans**

PEST CONTROL

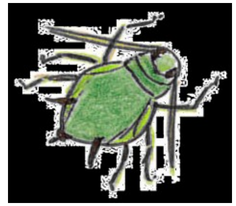
- Feeding on plant sap: aphids

PEST CONTROL

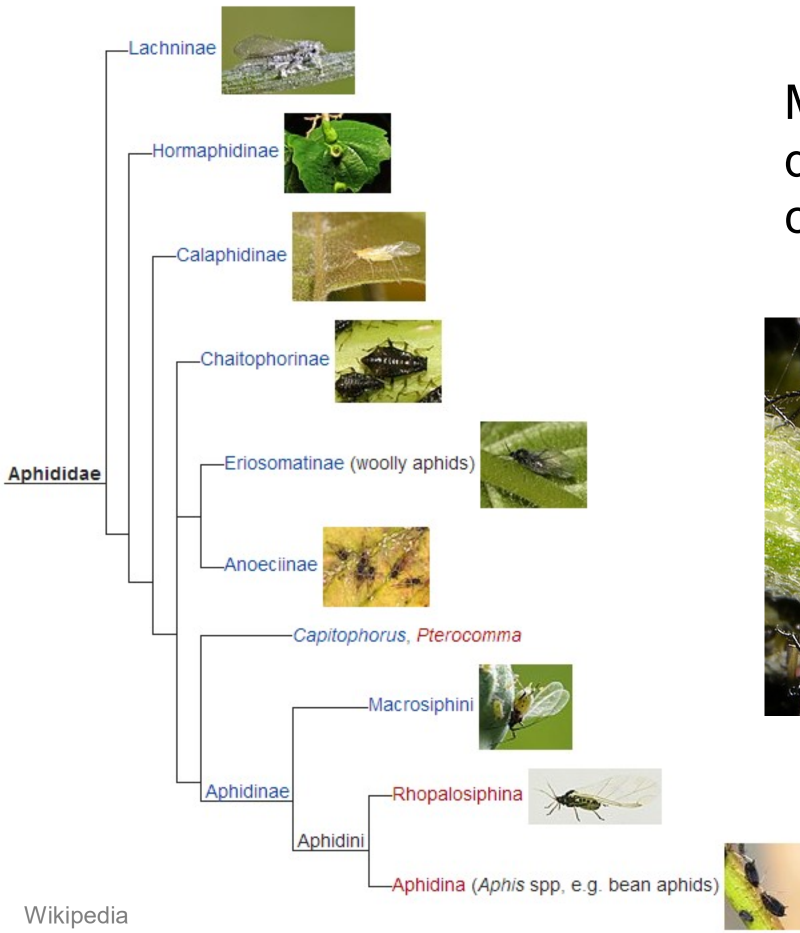
- Feeding on plant sap: aphids

Wikipedia, Jacopo Werther

PEST CONTROL



- aphids: high taxonomic diversity



Wikipedia

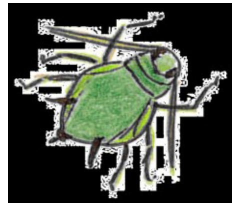
Many species with diverse shapes, colors and sizes!

Andreas Eichler

Sanjay Arachya

Alvesgaspar

PEST CONTROL



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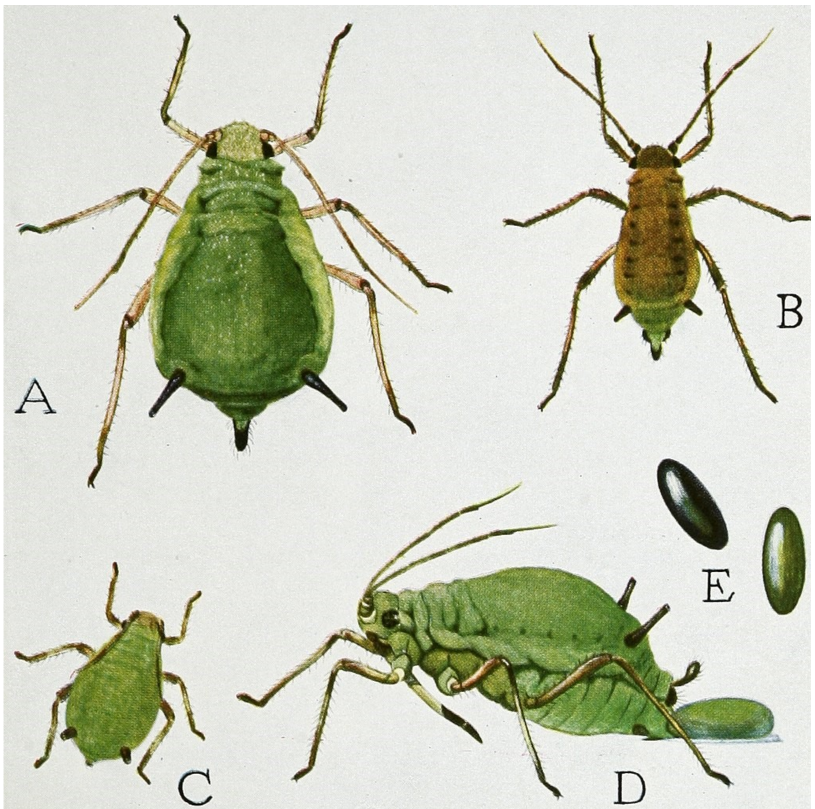
- aphid life cycle, reproduction

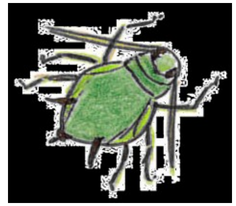


Green apple aphid (*Aphis pomi*)
(Robert Evans Snodgrass, 1930)

- Very diverse reproduction cycles!
- 1 common model:
  - beginning of the season: only females, asexual reproduction
  - declining food quality: winged females produced, to change host plant
  - end of the season: production of males, sexual reproduction

Yerpo

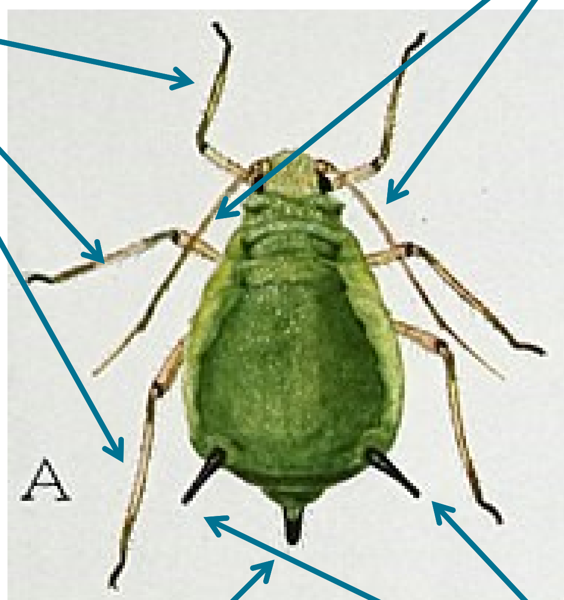
PEST CONTROL



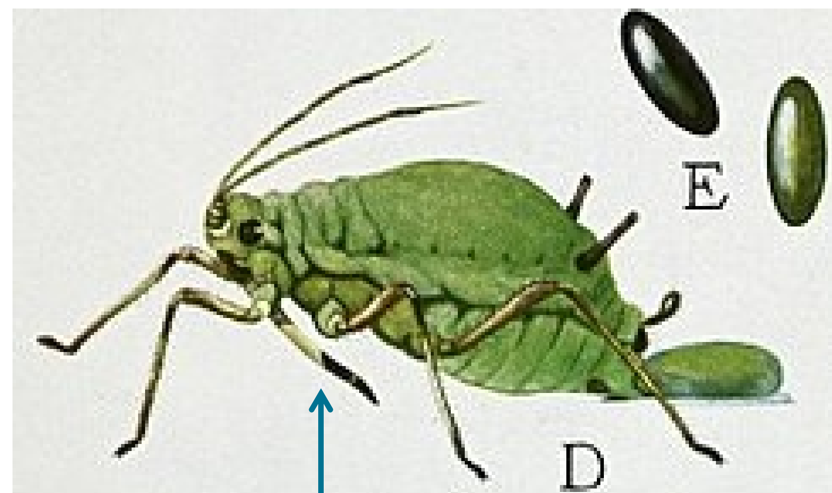
- aphid morphology

6 legs

antennae



Green apple aphid (*Aphis pomi*)
(Robert Evans Snodgrass, 1930)

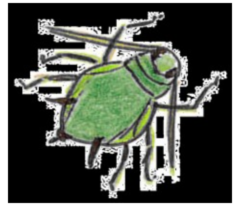


stylet in sheath ("rostrum")

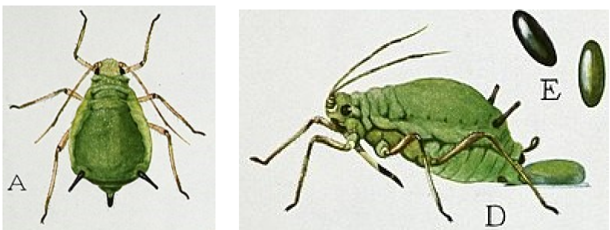
cornicles

the aphid's "behind"

PEST CONTROL



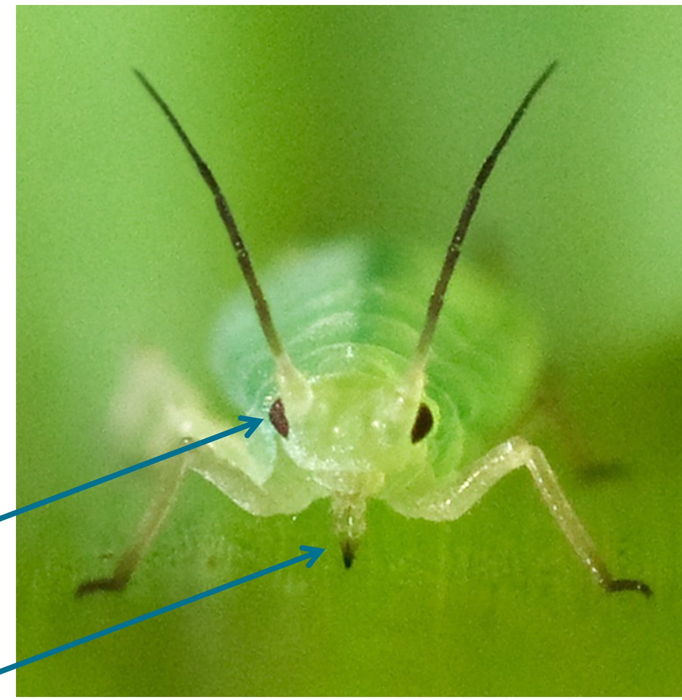
- aphid feeding



Green apple aphid (*Aphis pomi*)
(Robert Evans Snodgrass, 1930)

compound eye

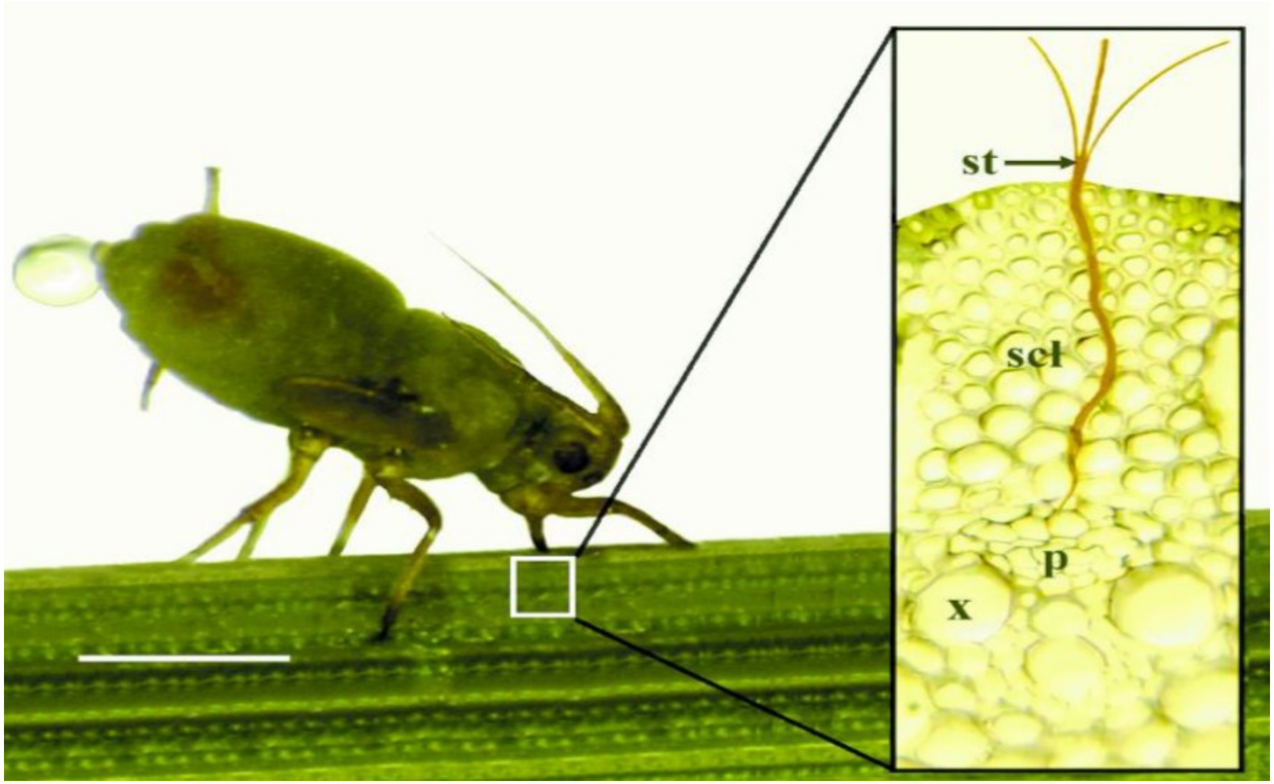
stylet in sheath (“rostrum“)



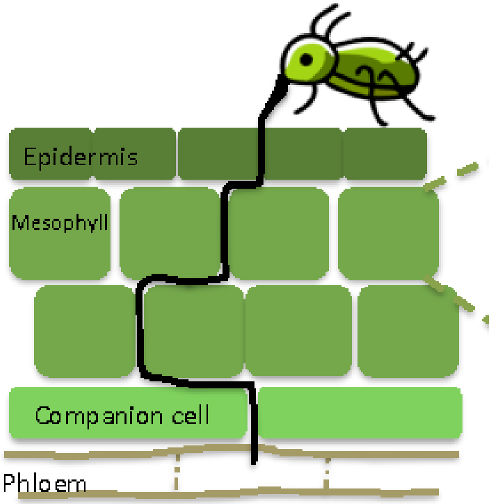
Front view of wheat aphid, *Schizaphis graminum*, showing the piercing-sucking mouthparts

PEST CONTROL

- Feeding on plant sap: aphids

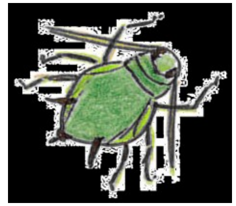


Aphid feeding on phloem sap.
st: stylet, scl: sclerenchyma, p: phloem, x: xylem. Scale bar = 1 mm.
("Plants in Action", Australian Society of Plant Scientists)



(Mehrabi 2016, modified)

PEST CONTROL



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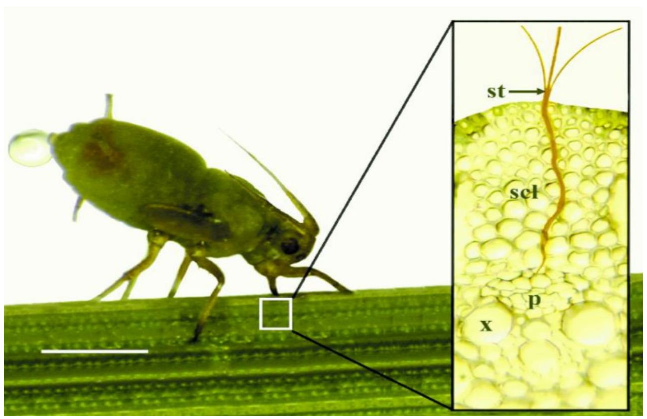
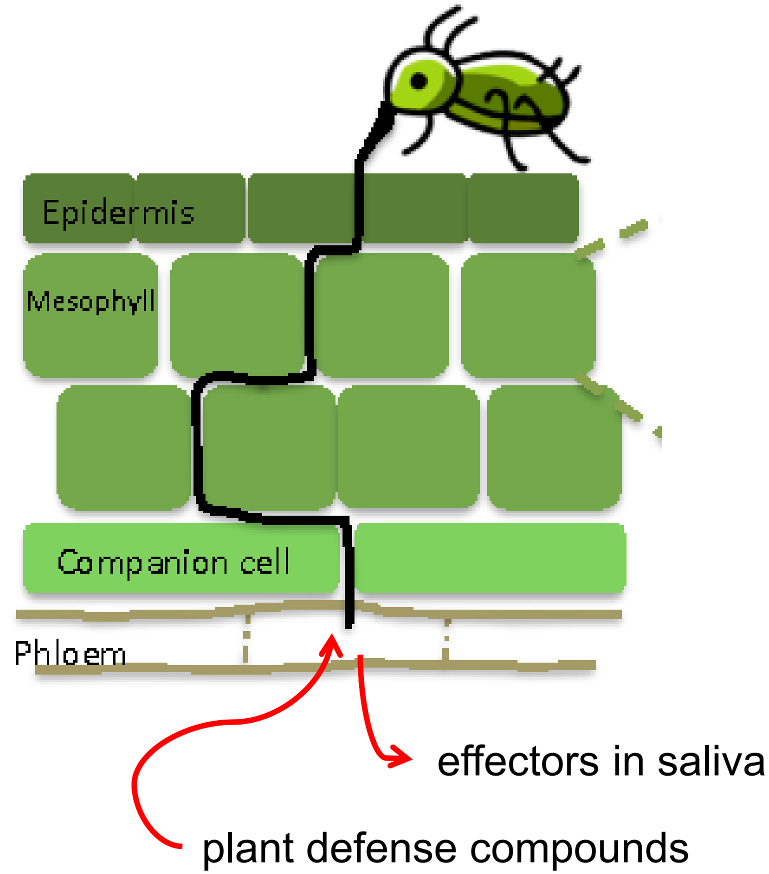
- Feeding on plant sap: aphids





(Mehrabi 2016, modified)

PEST CONTROL

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• aphids: feeding on plant sap, excreting fluids

Cornicles: excretion of **defense fluid**

Anus: excretion of **honeydew**

PEST CONTROL

- also feeding on plant sap: whitefly

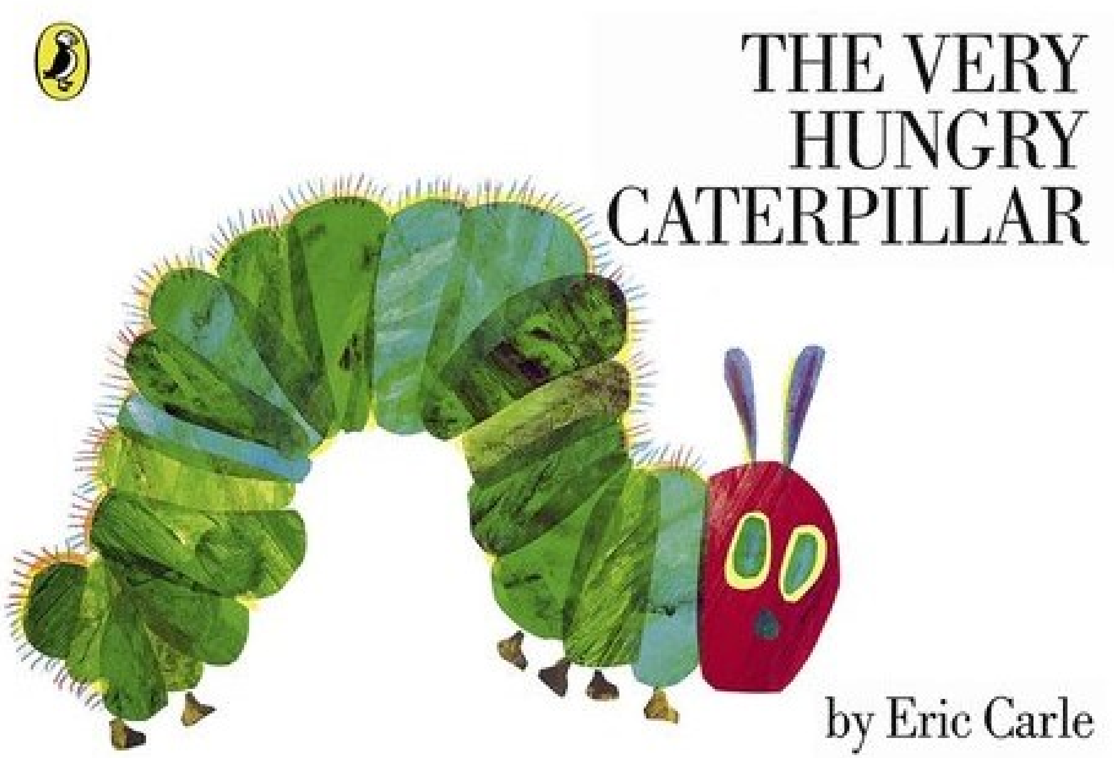
gaucho

Trialeurodes vaporariorum, Greenhouse Whitefly

- weaken plants through salivary toxins
- often spread virusus while feeding (like aphids)
- excrete honeydew that fosters mold (like aphids)
- Prominent pests:
  - *Bemisia tabaci*, Silverleaf whitefly
  - *Aleyrodes proletella*, Cabbage Whitefly
  - *Trialeurodes vaporariorum*, Greenhouse Whitefly

PEST CONTROL

- Eating whole leaves: caterpillars, larvae of Lepidoptera (butterflies and moths)



PEST CONTROL

- Eating whole leaves: caterpillars, larvae of Lepidoptera (butterflies and moths)

Bright-line brown-eye (*Lacanobia oleraceae*)

PEST CONTROL

- Eating whole leaves: caterpillars, larvae of Lepidoptera (butterflies and moths)

http://www.kreisblatt.de/lokales/main-taunus-kreis/Gespinstmotte-spinnt-ein
Fressfeinde;art676,2990551

Ermine moths, Yponomeutidae family

Blend5,6

PEST CONTROL

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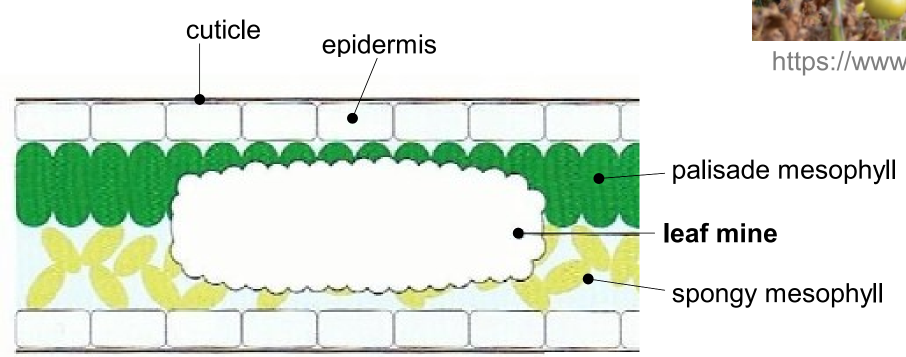
- Leaf mining caterpillars: feeding inside the leaf (e.g. *Tuta absoluta*)

http://www.nbair.res.in/insectpests/Tuta-absoluta.php

https://www.bursadelegume.ro/influenta-atacului-tutei-absolute-asupra-pretului-tomatelor/

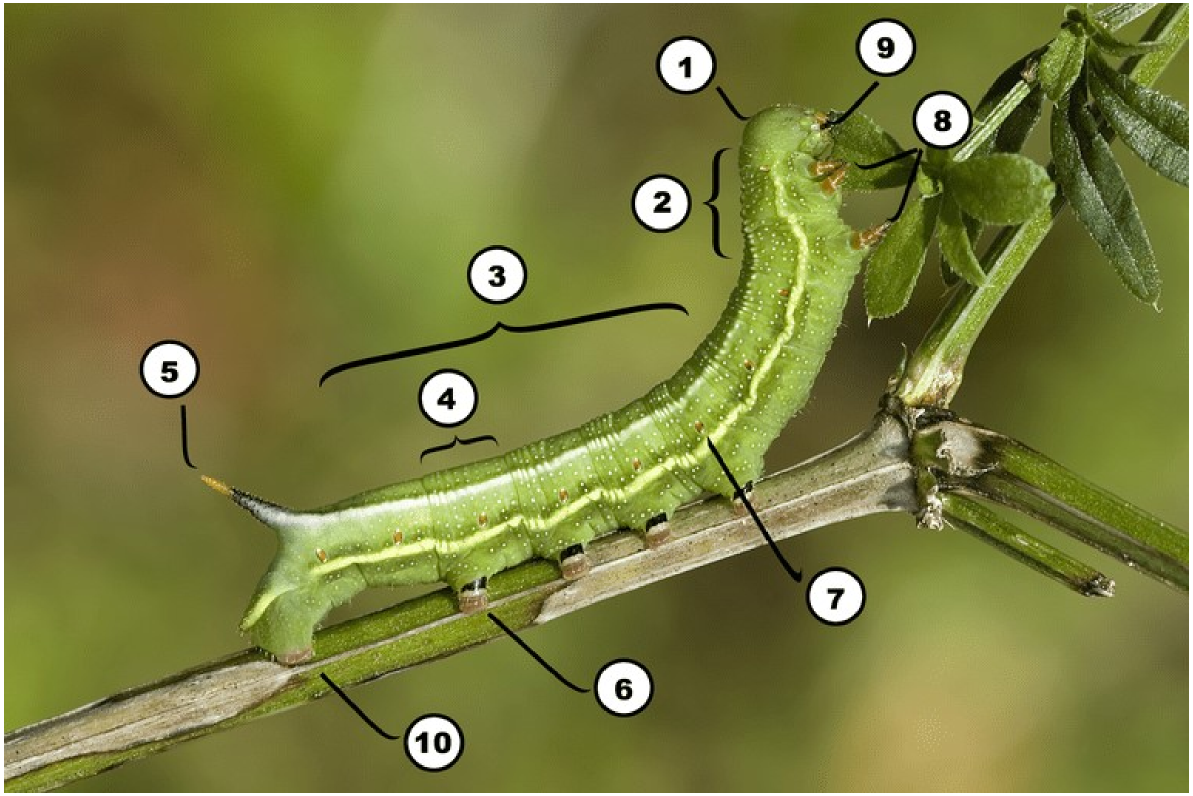


Double sided leaf mine (Jahrbücher des Nassauischen Vereins für Naturkunde, Band 130, Wiesbaden 2009)

Leaf miners feed inside the leaf, only minor damage to the epidermis.
They can be a devastating pest, sometimes causing complete yield losses.

PEST CONTROL

- Caterpillar anatomy

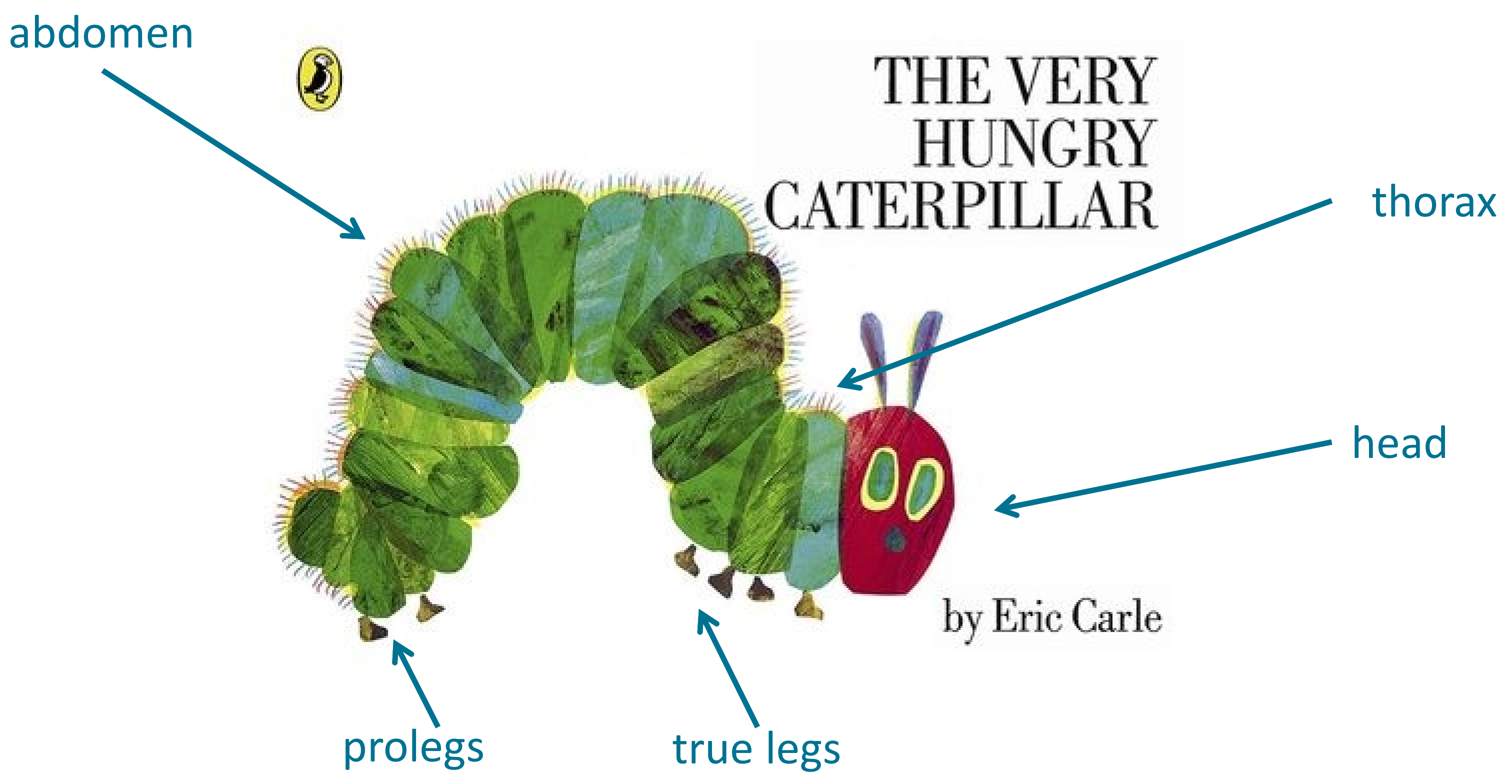


A. M. Liosi/Wikimedia Commons (CC by SA license), modified by Debbie Hadley, WILD Jersey

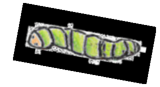
- **1**: Head
- **2**: Thorax with true legs (8)
- **3**: Abdomen with prolegs (6; fleshy, false legs used to cling on, like 10: anal prolegs)
- **4**: One segment
- **5**: Horn (not with all species)
- **7**: Spiracle: opening to respiratory system
- **9**: Mandibles: jaws for chewing

PEST CONTROL

- Caterpillar anatomy



PEST CONTROL



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- Caterpillar anatomy

AshLin

- **Mouth parts different from aphids**

  → different feeding mode, different kind of damage to the plant

- **Like aphids**: effectors in saliva; signal presence to plant (together with physical damage to leaves)

PEST CONTROL

- Caterpillars: not all of them are ugly!

Ceruna vinula, the Puss Moth

PEST CONTROL

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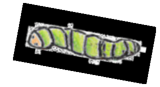
- Caterpillars: not all of them are ugly!

Waugsberg

Calliteara pudibunda, Pale Tussock

PEST CONTROL



- Caterpillars: not all of them are ugly!

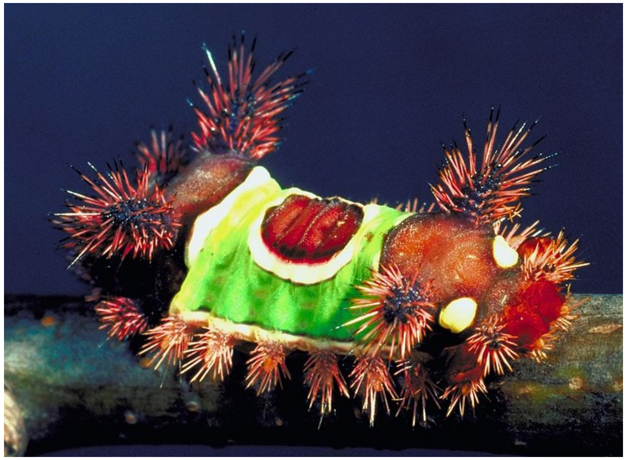
Mjh233

Deilephila elpenor, Elephant Hawk Moth

PEST CONTROL

- Caterpillars: not all of them are ugly!

Orgyia antiqua, the Rusty Tussock



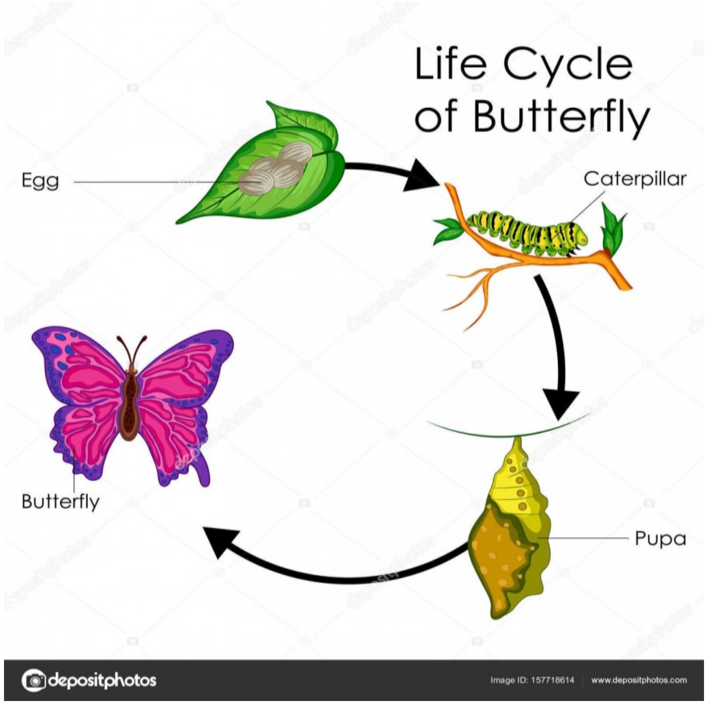
Acharia stimulea, the Saddleback caterpillar

Aglais io, European Peacock

Hypomecis roboraria, Great Oak Beauty

PEST CONTROL

- Life cycle of caterpillars



All developmental stages of the Monarch Butterfly (*Danaus plexippus*)

PEST CONTROL

- Life cycle of caterpillars: not all stages inflict damage on plants

Adult Lepidoptera usually don‘t feed or only nectar, but lay eggs…

PEST CONTROL

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- **How can we control pests?**

  - Toxins: chemical insecticides
  - Biological control: natural enemies

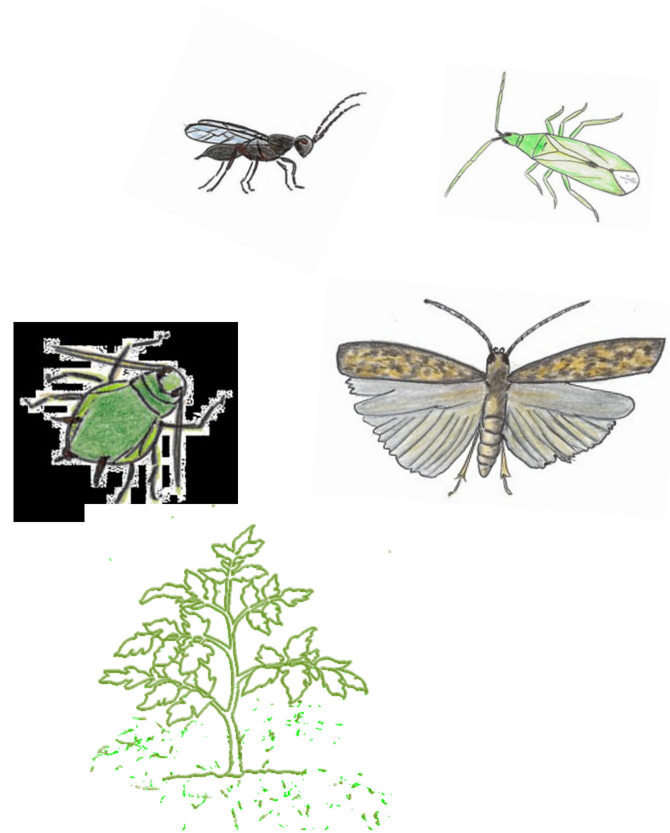
PEST CONTROL

- Natural enemies: **Parasitoids**

  → kill their hosts over time during own development

Alvesgaspar

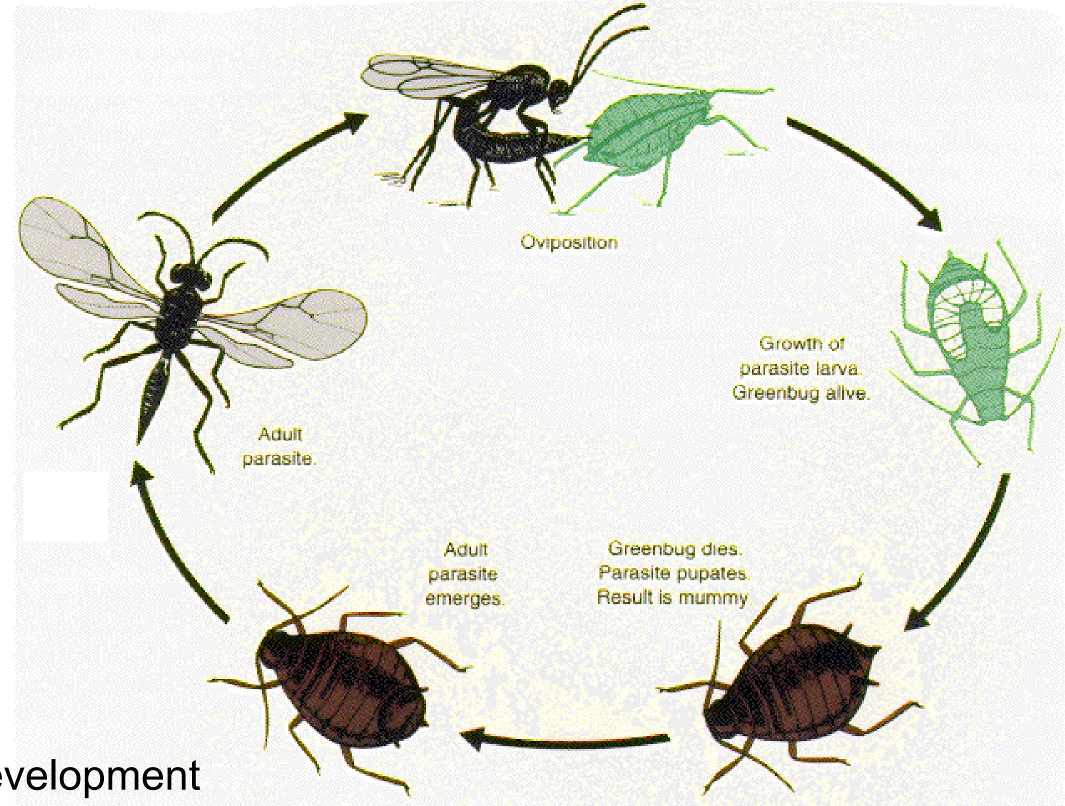
A small braconid wasp laying an egg inside a Black Bean Aphid (*Aphis fabae*). The aphid is about 1 mm long.



PEST CONTROL

- Natural enemies: **aphid parasitoids**

Alvesgaspar



Rhonda Kappler, http://www.entomology.wisc.edu/mbcn/kyf209.html

Life cycle of an endoparasitoid:

- stings host, oviposits egg inside
- host still alive during offspring development
- offspring pupates, host dies
- adult parasitoid emerges

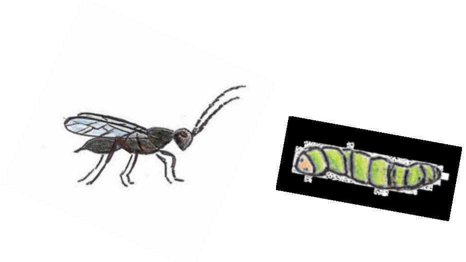
PEST CONTROL

- Natural enemies: **aphid parasitoids**

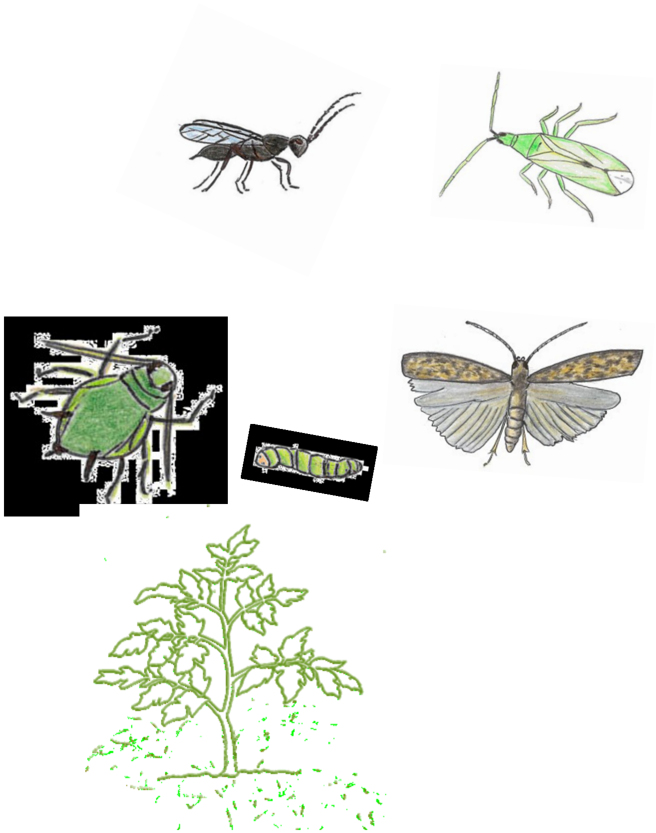
- for instance *Aphidius colemani, Aphidius ervi*
- one female lays 300-500 eggs in her lifetime
- wasp offspring develops from the egg to the adult inside the aphid
- parasitized aphids change color, become “mummies“, adult wasps emerge through round holes

PEST CONTROL



- Natural enemies: **caterpillar parasitoids**

Aleiodes indiscretus wasp parasitizing a gypsy moth caterpillar (*Lymantria dispar dispar*)



PEST CONTROL

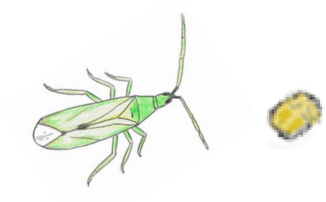
- Natural enemies: **caterpillar parasitoids**

Ektoparasitoids: oviposit eggs on outside of host

Larvae of parasitic wasp *Bracon* sp.

Larvae of parasitic wasp *Cotesia congregata*

PEST CONTROL



- Natural enemies: **predatory bugs**

https://www.entocare.nl/bestrijders/bestrijders-van-kevers/macrolophus-pygmaeus-feeding-on-pieris-brassicae-egg-1/

The predatory bug *Macrolophus pygmaeus* feeding on eggs of *Pieris brassicae*

PEST CONTROL

- Natural enemies: **humans?**

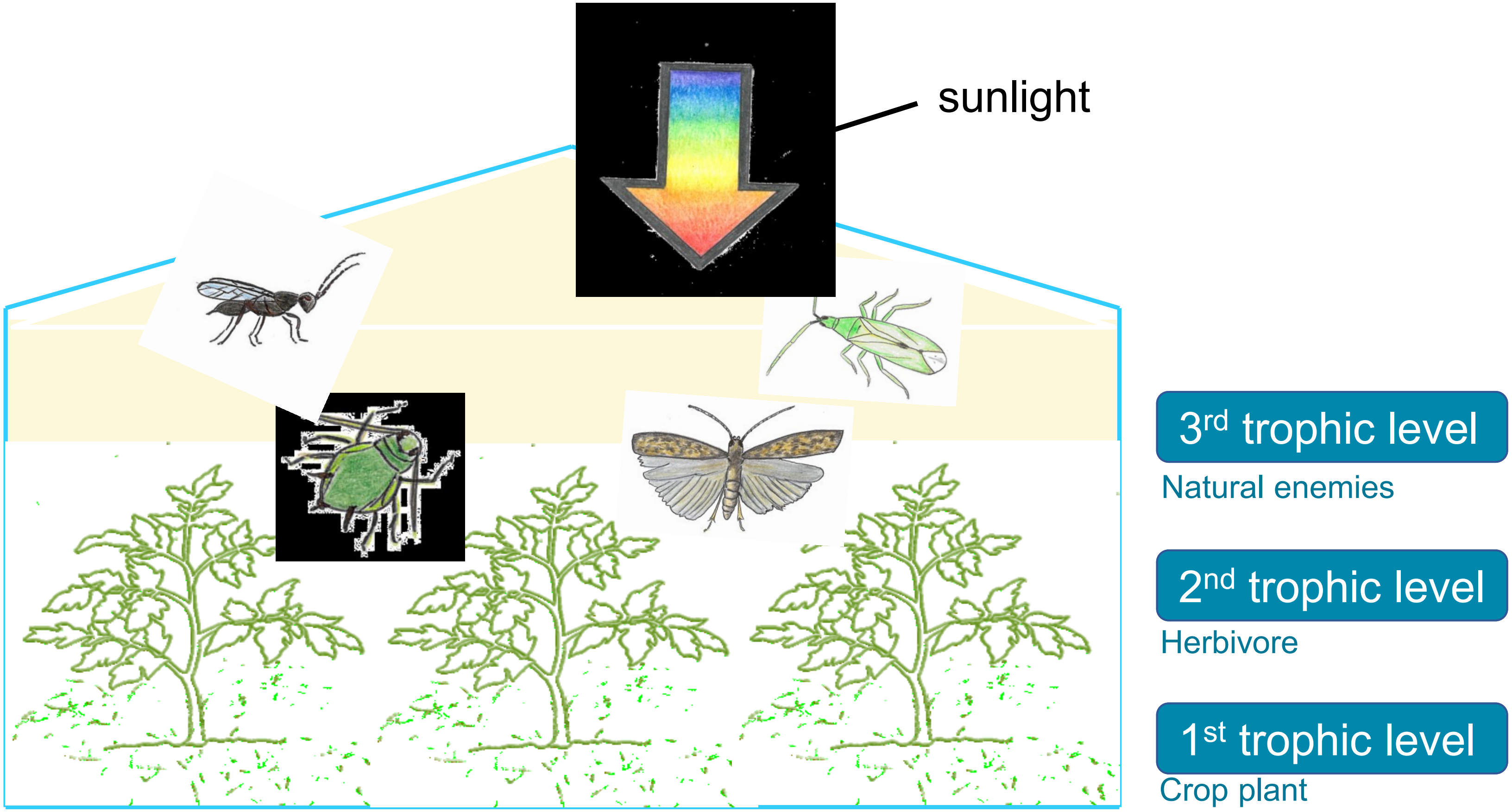
Pixabay

"Sago worm" satay

GREENHOUSES: AN ARTIFICIAL ECOSYSTEM

- Artificial ecosystem greenhouse: limited number of species

→ but: trophic networks ("food chain") exist, used for biological control



TROPHIC NETWORKS

Carnivores

3rd trophic level

Herbivores

2nd trophic level

Plants

1st trophic level

TROPHIC NETWORK IN THE GREENHOUSE

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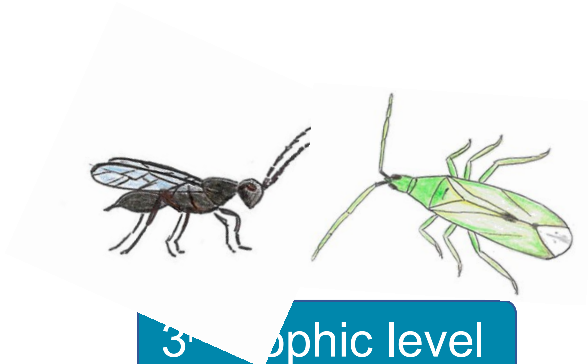
Carnivores



3 ophic level

- Natural enemies of pests: insect parasitoids and predators

Herbivores

2nd trophic level

- Herbivorous insects: leaf chewers like larvae of butterflies, and sap feeders like aphids and whiteflies

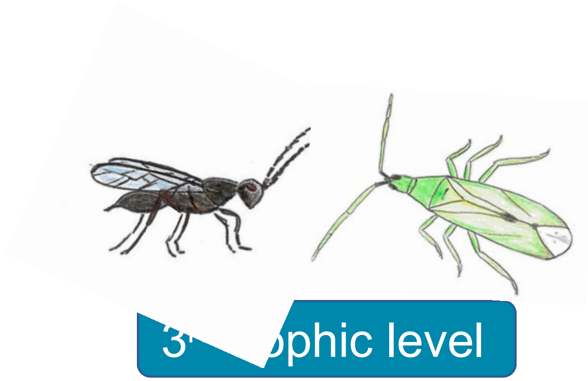
Plants

1st trophic level

- Crop plants

DIRECT EFFECTS OF LIGHT

Natural enemies

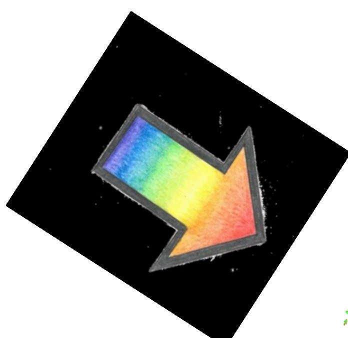


3 ophic level

Herbivores

2nd trophic level

Plants



1st trophic level

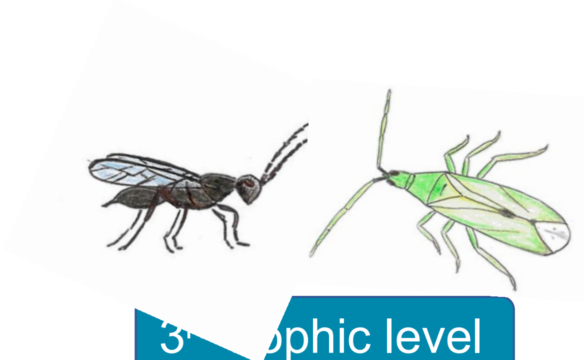
Direct effect:

on plant quality*

* nutritional value, defense compounds

EXCURSION: PLANT DEFENSE

Natural enemies



3 ophic level

Herbivores

2^{nd} trophic level

Plants

1^{st} trophic level

Direct defense:

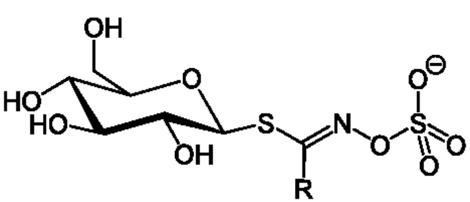
mophology and chemistry deter herbivores

DIRECT PLANT DEFENSE

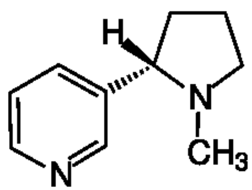
Direct defense:

- Morphology: trichomes, thorns and spines, cuticula and epicuticular waxes, tough epidermis…
- Chemical defense: glucosinolates, alkaloids, phenolics…

http://www.uva.nl/profiel/b/l/p.m.bleeker/p.m.bleeker.html



glucosinolate



nicotine
(alkaloid)

Howe & Jander 2008, *Annu Rev Plant Biol*

EXCURSION: PLANT DEFENSE

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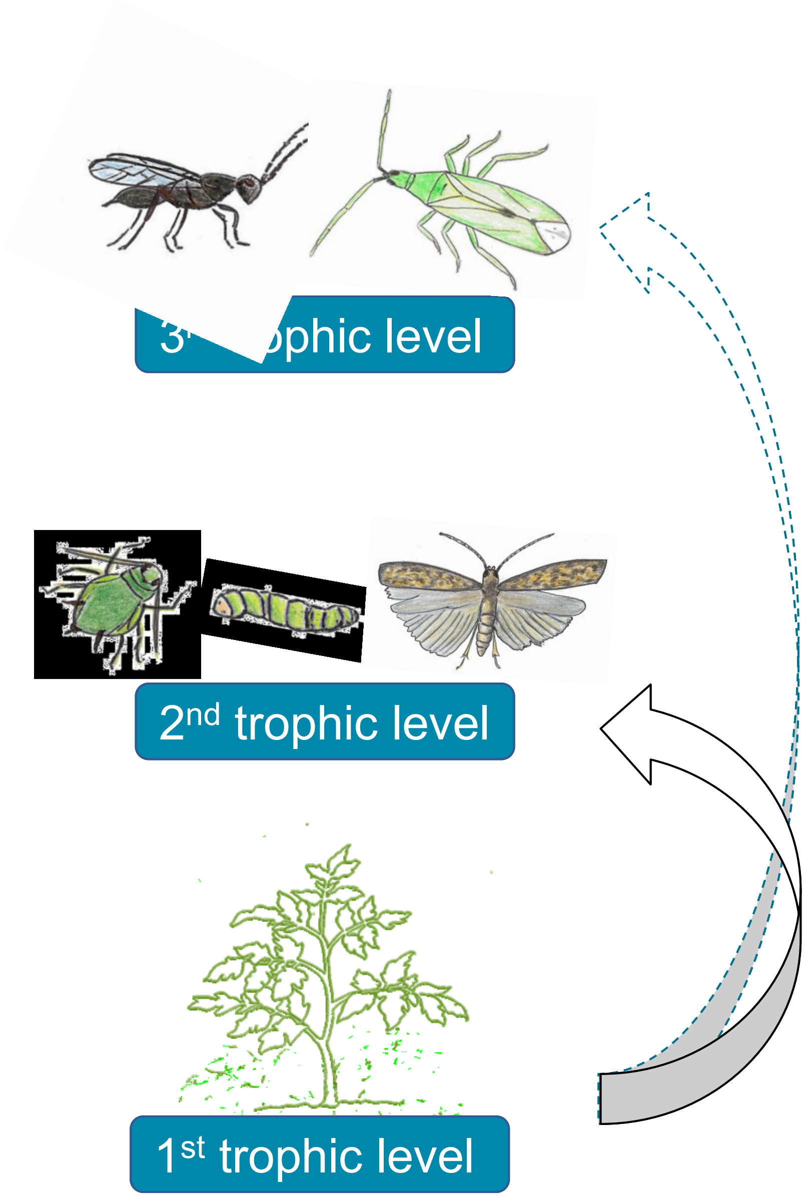
Natural enemies

Herbivores

Plants



Indirect defense:

e.g. VOC* attract natural enemies of herbivores

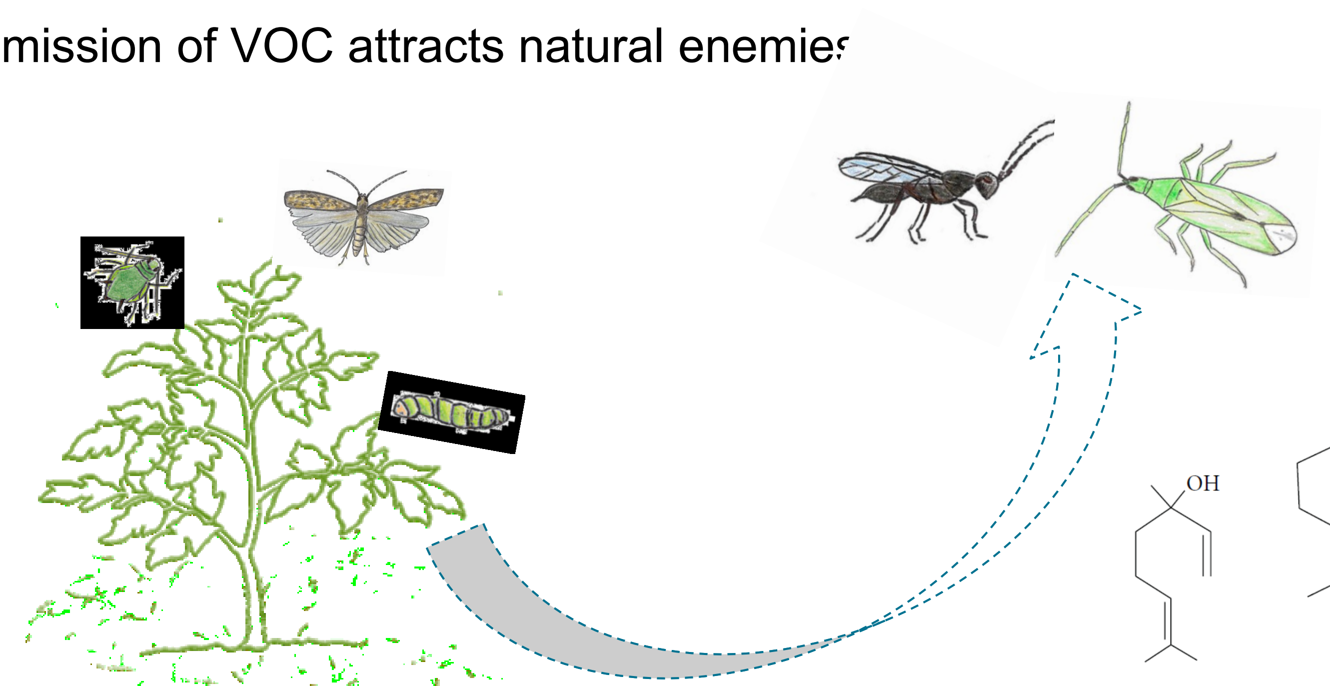
* volatile organic compounds

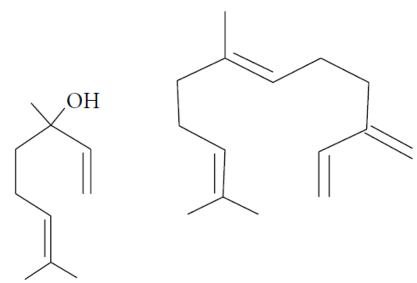
Direct defense:

mophology and chemistry deter herbivores

INDIRECT PLANT DEFENSE

- **Indirect defense:**
- cellular food bodies and extrafloral nectaries as nourishment, domatia as shelter
- emission of VOC attracts natural enemies





volatile organic compounds, like linalool and *E*-β-farnesene

LIGHT AND PLANT DEFENSE?

What is the connection between plant defense and light conditions?

Plants are phototroph organisms.

→ light is the prerequisite for energy and carbon resources,
i.e. for every process from growth to defense!

…and if resources are limited?

→ How to prioritize?

→ What is more important: growth or defense?

Well, that depends…

EFFECT OF LIGHT ON PLANT DEFENSE

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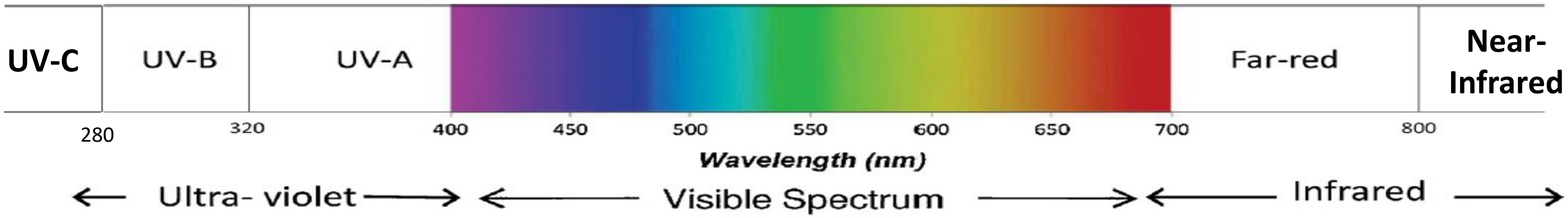

high UV-B

low R/FR

growth < defense

- High UV: plenty of light, no growth necessary, photosynthesis produces plenty of resources <u>that can be invested in defense</u>
- Can be a stress factor it self that warrants defense, dose dependency (interaction between biotic and abiotic stress when it comes to herbivory)

growth > defense

- shade avoidance-syndrome: high FR: competition or shading, plants invest majority of resources into growth to reach canopy top

  = foraging for light,
  i.e. resources

Huché-Thélier et al 2016, *Environ Exper Bot*, modified;
Ballaré et al 2009, *Plant, Cell Environ;* Ballaré & Perik 2017, *Plant Cell Environ*

EFFECT OF LIGHT ON PLANT DEFENSE

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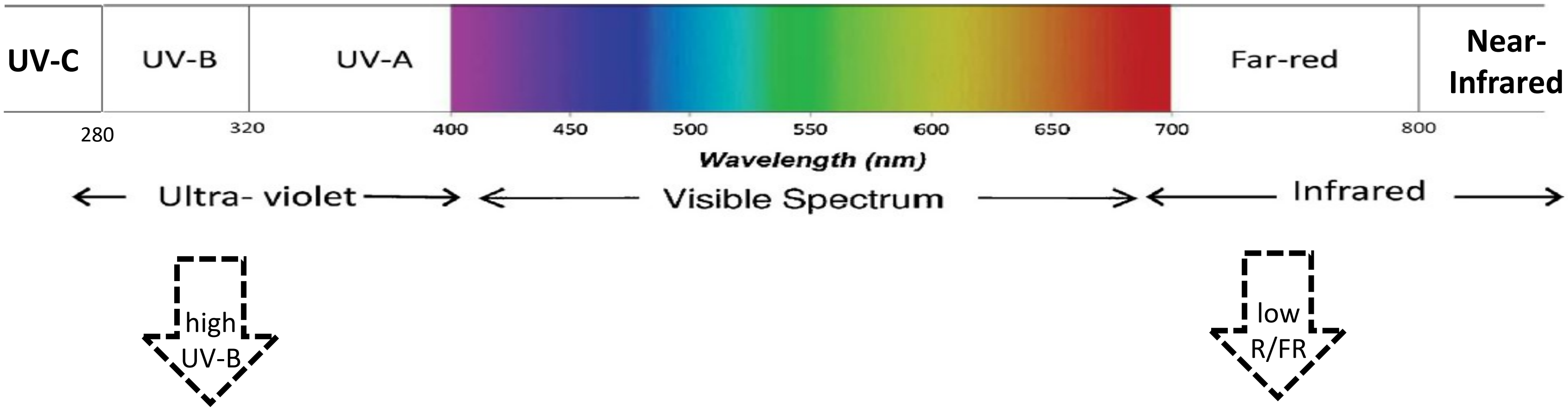


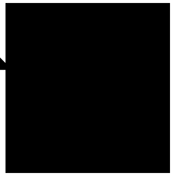
Probably well defended plants.

Probably weakly defended plants.

Huché-Thélier et al 2016, *Environ Exper Bot*, modified;
Ballaré et al 2009, *Plant, Cell Environ;* Ballaré & Perik 2017, *Plant Cell Environ*

EFFECTS OF LIGHT ON PLANT DEFENSE

- light quantity:

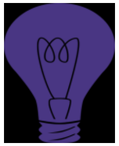


↑ trichome density and mechanical toughness of foliage,

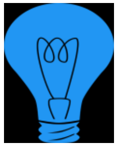
↑ chemical defense compounds (alkaloids, phenolics, terpenoids but not necessarily glucosinolates)

↑ nectar in extrafloral nectaries

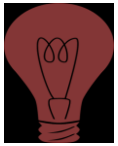
- light quality:



↑ UV-screening phenolic compounds, depending on intensity and frequency of exposure



↑ blue light profoundly affects plant metabolism, including defence compounds, induces pathogenesis related-genes



↓ far-red reduced plant direct defense by desensitizing against herbivory-signaling,

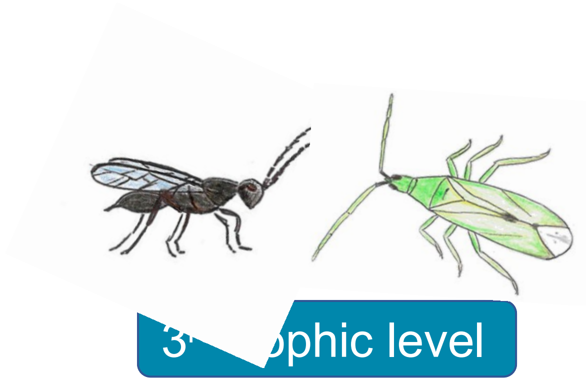
↓ decreased indirect defense (number of extrafloral nectaries)

↑ increased iindirect defense (manipulated VOC → more attractive to predators; *few studies so far!*)

DIRECT EFFECTS OF LIGHT

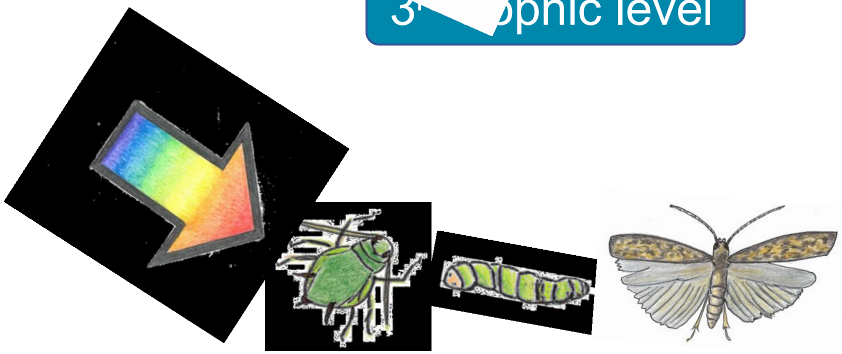
Hochschule Geisenheim University

Natural enemies



3 ophic level

Herbivores



2nd trophic level

Plants

1st trophic level

Direct effect:

on preference and performance*

* orientation, host choice, development

DIRECT EFFECTS ON PESTS

Light quantity and quality affects vision and orientation.

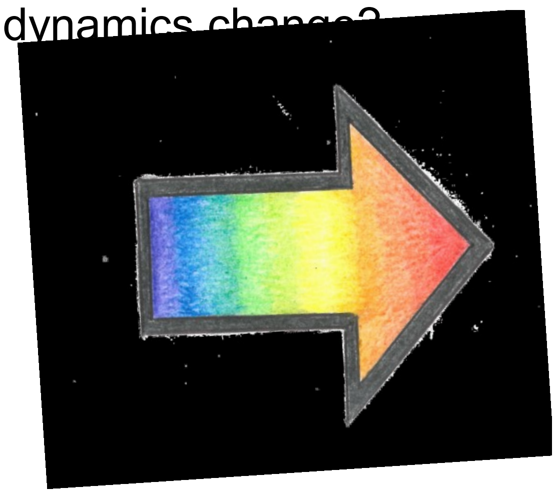
- Pest preference:

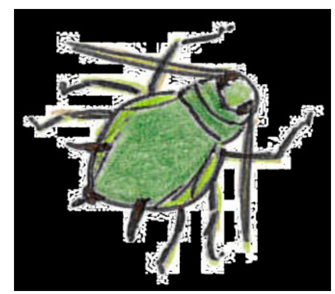
→ Can they find and recognize good host plants?

- Pest performance:

→ Can they find and recognize mates?

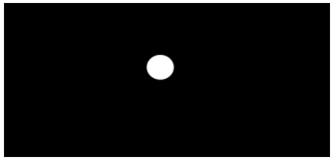
→ Do population dynamics change?





- What is necessary for a direct effect of radiation quality and quantity on herbivorous insects and their natural enemies?

PERCEPTION OF VISUAL CUES !



Eyes! (or something similar…)

PERCEPTION OF VISUAL CUES

Hochschule Geisenheim University

- **Insects: several different organs to perceive light**

- Ocelli ("simple eyes")
- Compound eyes

Picture: Wikipedia

dorsal ocelli

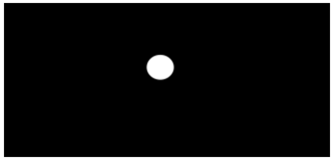
compound eyes

- **Ocelli:** “pigment pits“, simple eyes, one lense

dorsal ocelli of a wasp

dorsal ocelli of a hornet

Picture: Wikipedia



human eye: “pigment pit“ with one lense

PERCEPTION OF VISUAL CUES

Hochschule Geisenheim University

- **Compound eyes:**

Compound eyes of a fly

Compound eyes of a robber fly

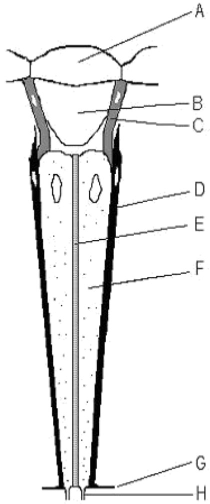
Picture: Wikipedia

PERCEPTION OF VISUAL CUES

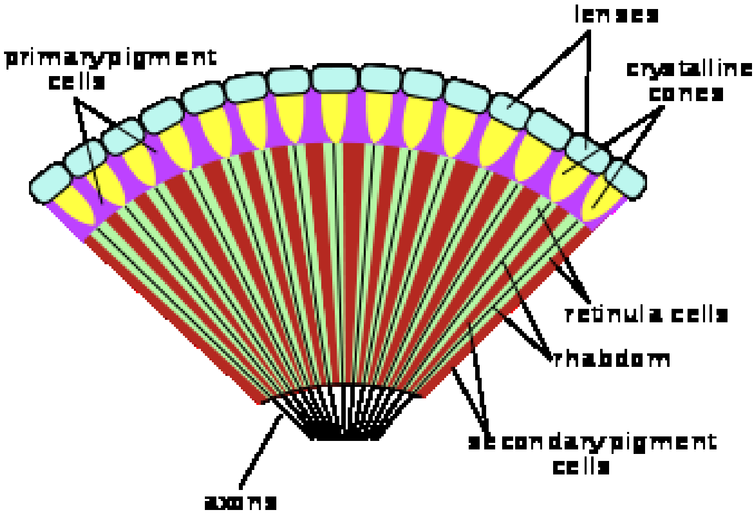
Hochschule Geisenheim University

Picture: Wikipedia

- **Compound eyes:**



- **Ommatidium: single eye**
  - cornea lense (A)
  - crystal cone (B)
  - pigment cells (C, D)
  - rhabdom (E), guides light to the
  - photoreceptor cells (F)
  - membrane (G)
  - optic nerve (H)



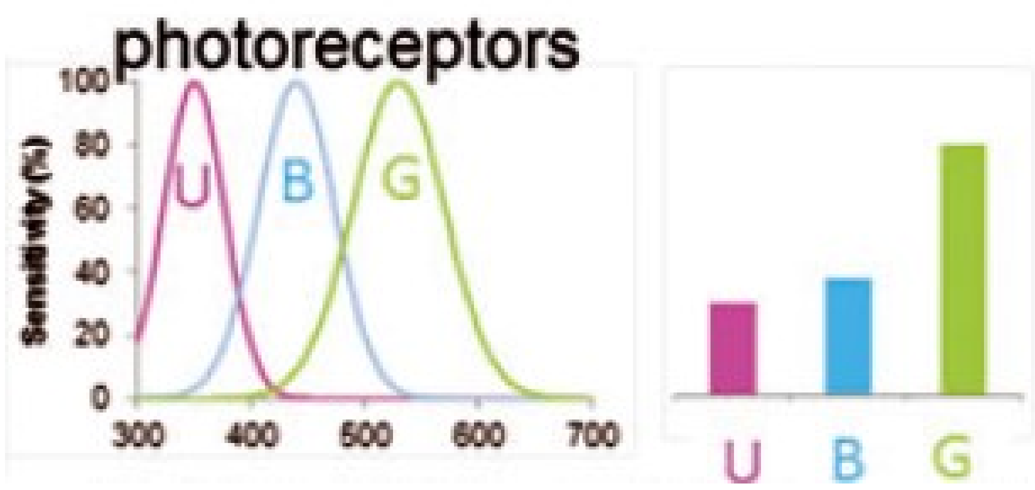
Wikipedia

- **Compound eye:** up to thousands of ommatidia

PERCEPTION OF VISUAL CUES

- The eyes contain photoreceptor cells located in the retina
- Photons are perceived if their wavelength is absorbed by the visual pigment:

  opsin protein + chromophore; λ_{max}= absorption maximum

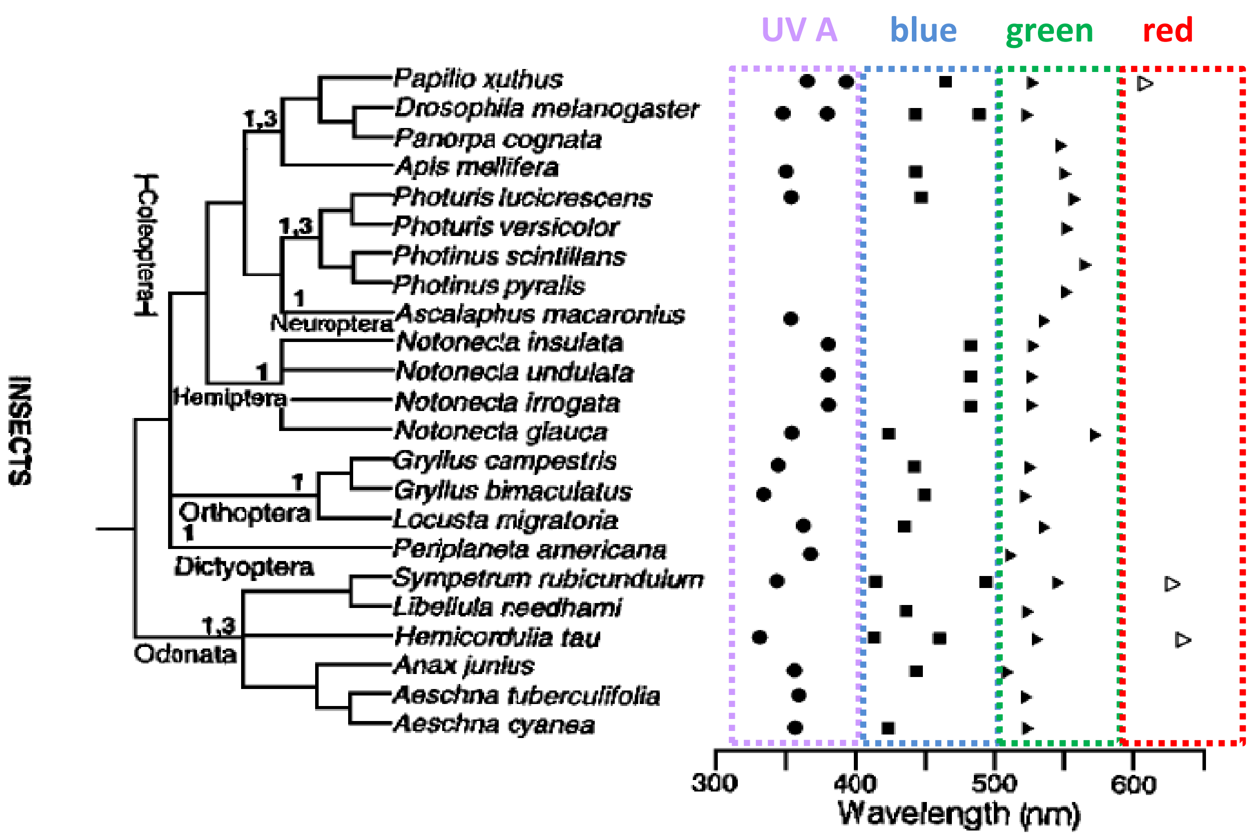


Döring 2014, *Ann Appl Biol*

Döring & Chittka 2007, *Arthropod-Plant Interactions*

PERCEPTION OF VISUAL CUES

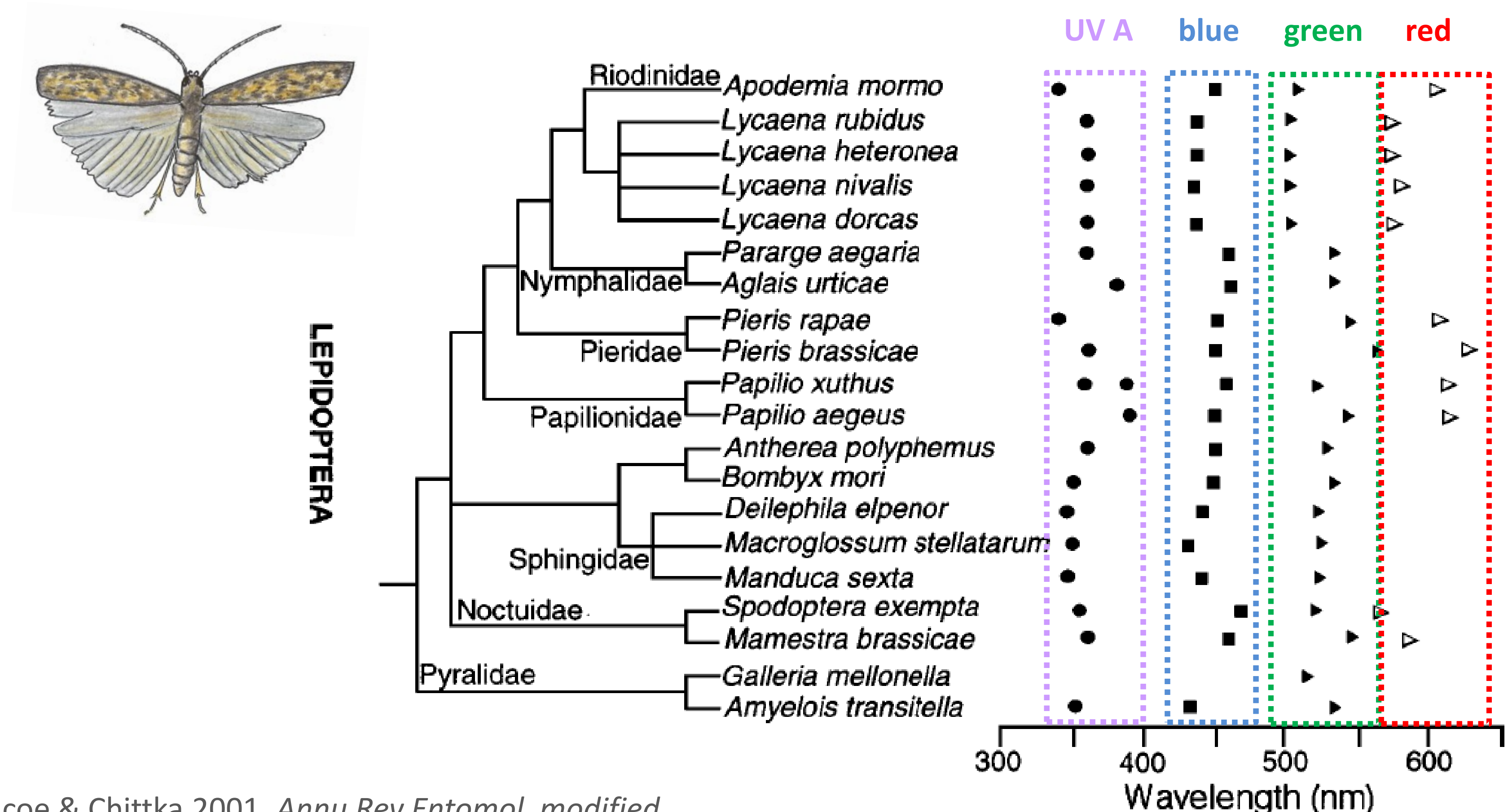
- Most insects perceive UV A (~350 nm) and green (~530 nm) wavelengths, many also blue (~440 nm), some also red (>565 nm)



Briscoe & Chittka 2001, *Annu Rev Entomol*

PERCEPTION OF VISUAL CUES

- Order of Lepidoptera: many well-studied and economically important herbivores



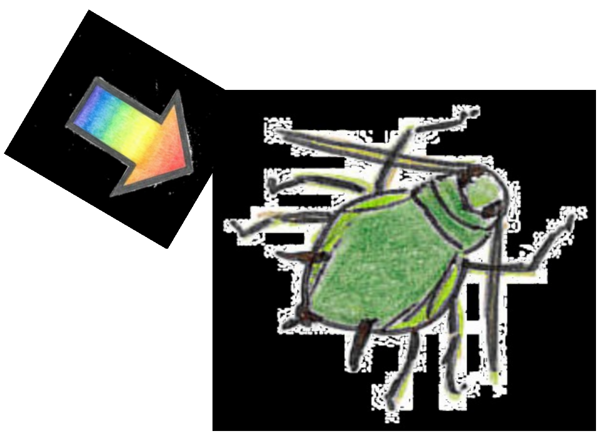
Briscoe & Chittka 2001, *Annu Rev Entomol, modified*

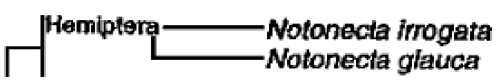
DIRECT EFFECT OF LIGHT ON PESTS

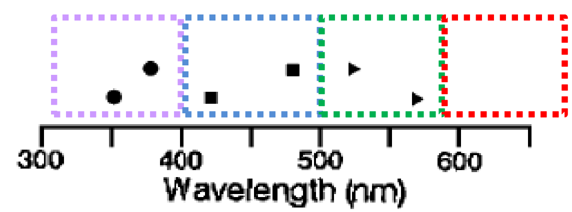
- Hemiptera*: mostly trichromatic as well (UV, blue, green)

- for instance: whitefly, *Bemisia tabaci* and most aphids BUT some also perceive red

- Difficult to study due to small size of organs!





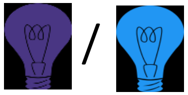


Briscoe & Chittka 2001, *Annu Rev Entomol, modified*

*Hemiptera: aphids, cicadas, planthoppers, leafhoppers, shield bugs

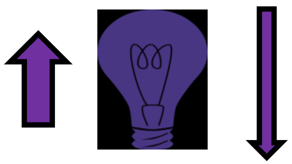
DIRECT EFFECT OF LIGHT ON PESTS

- **Light quality:**



orientation

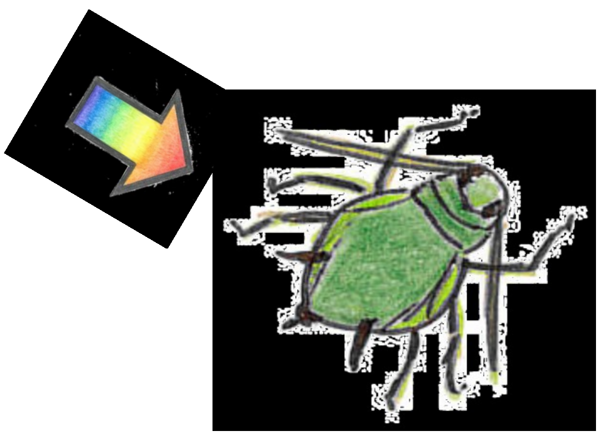
host plant location

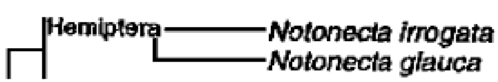


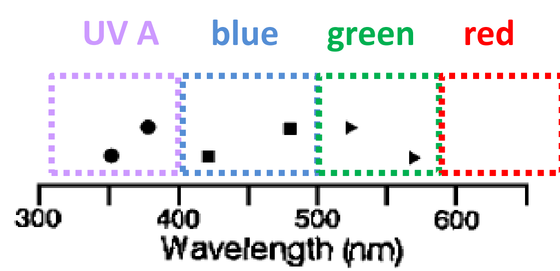
increased UV radiation reduced foraging and dispersal,

reduced survival of some pests

- **Response to wavelengths may differ with insect species & age!**





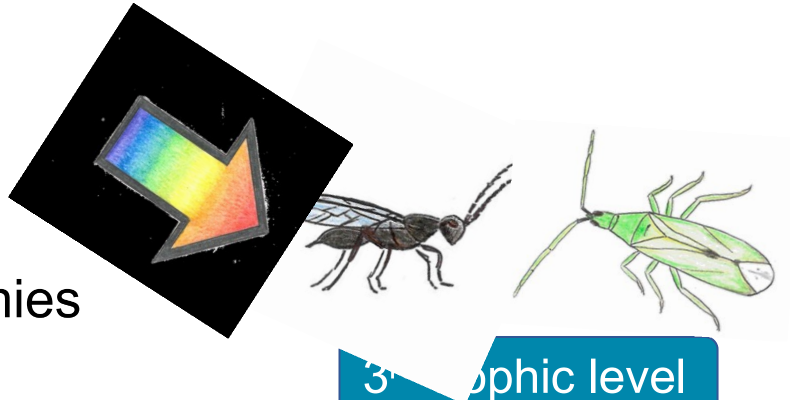


Briscoe & Chittka 2001, *Annu Rev Entomol, modified*

DIRECT EFFECTS OF LIGHT

Hochschule Geisenheim University

Natural enemies



3… ophic level

Direct effect:

on preference and performance*

* orientation, host choice, development

Herbivores

2nd trophic level

Plants

1st trophic level

DIRECT EFFECTS ON NATURAL ENEMIES

Light quantity and quality affects vision and orientation.

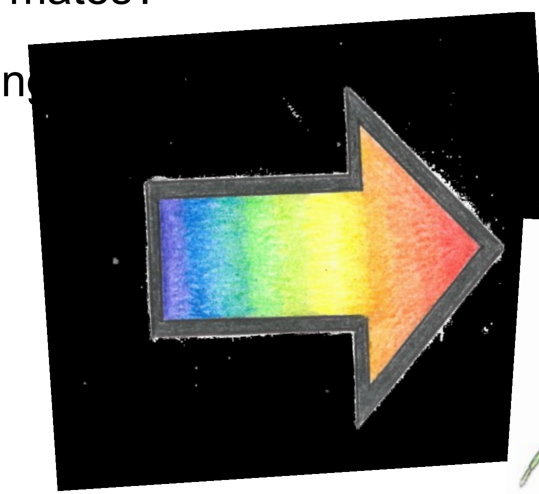
- Parasaitoid preference:

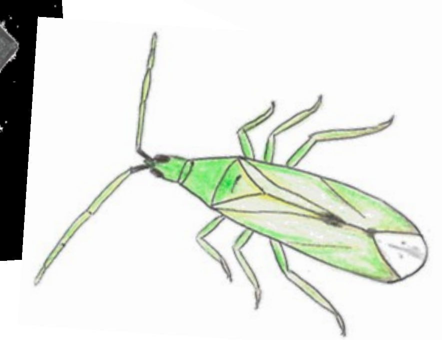
→ Can they find and recognize good hosts?

- Parasitoid performance:

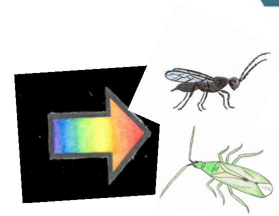
→ Can they find and recognize mates?

→ Do population dynamics chan



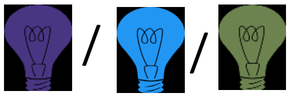


DIRECT EFFECTS OF LIGHT ON NATURAL ENEMIES



- **<u>Vision of parasitoids:</u>** similar to other insects; not as many studies…
- perceive mainly UV, blue, and green-yellow

- Parasitoid wasp, *Aphidius gifuensis*: UV, blue, green



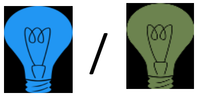
- Parasitoid wasp, *Encarsia formosa*: UV, blue, green-yellow, red

- **<u>Phototaxis observed:</u>**

- Tachinid parasitoid fly, *Exorista japonica*: towards UV-A

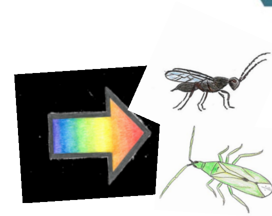
- *E. formosa*: towards UV-A, blue and green, but also active in UV-blocked environment

- Parasitoid wasp, *Scleroderma guani:* towards blue, green



- **Response to wavelengths may differ with insect sex, age, and experience!**

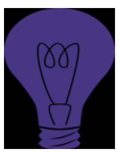
DIRECT EFFECTS OF LIGHT ON NATURAL ENEMIES



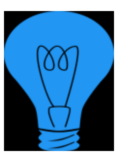
- **light quantity:**

⇧ orientation, activity (parasitoids and predators)

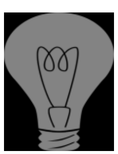
- **light quality:**



⇧ increased activity and improved host location by some parasitic wasps



⇩ developmental rate (found in predatory bug *Orius sauteri*)



⇧ diffusion of light promoted host finding by *E. formosa* in 1 study*

*Doukas & Payne 2007, *Horticultural Entomology*

TROPHIC NETWORK IN THE GREENHOUSE

Hochschule Geisenheim University

Natural enemies

3rd trophic level

Herbivores

2nd trophic level

Plants

1st trophic level

Each trophic level can be impacted directly

***But:* trophic levels depend on and interact with each other!**

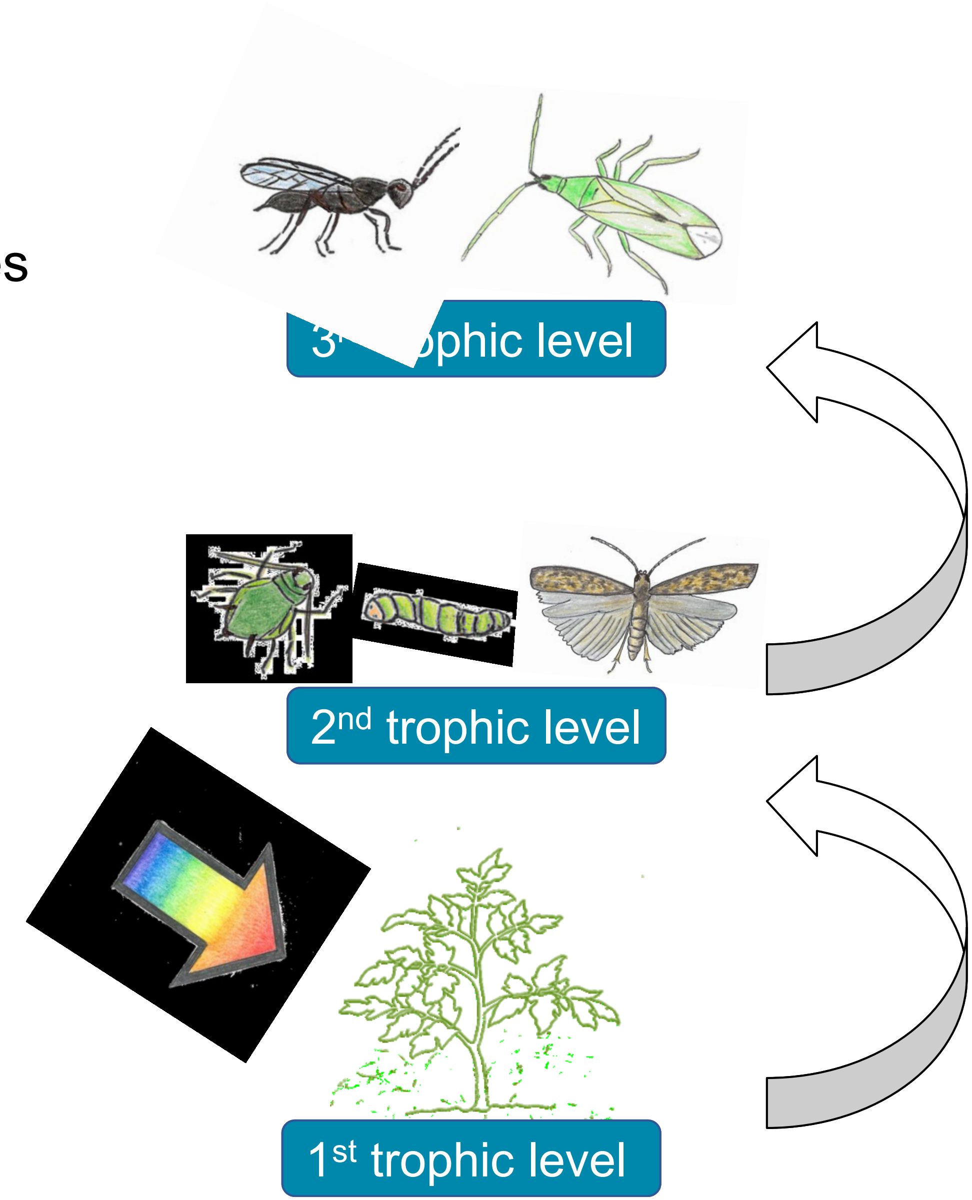
INDIRECT EFFECTS OF LIGHT: BOTTOM-UP

Hochschule Geisenheim University

Natural enemies

Herbivores

Plants



Bottom-up effect:

changes* induced on 1st affect higher levels

* nutritional value, defense compounds

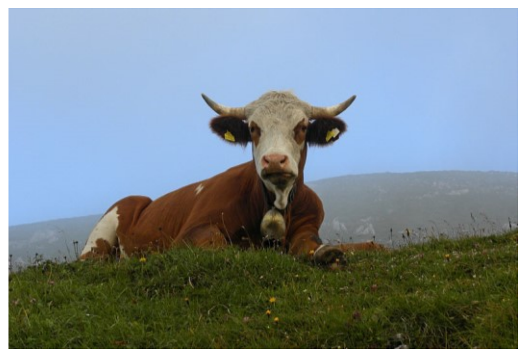
BOTTOM-UP EFFECTS

Carnivores

3rd trophic level

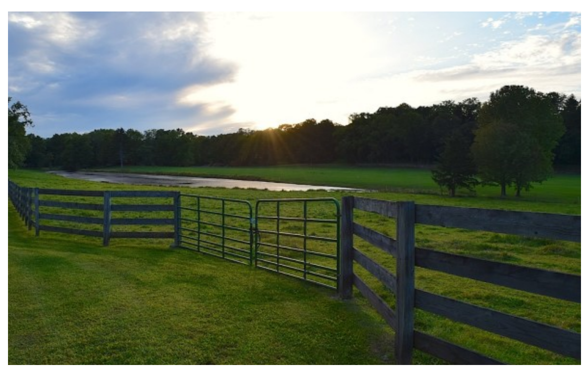
Herbivores

2nd trophic level



Plants

1st trophic level



INDIRECT EFFECTS ON PESTS: BOTTOM-UP

Light conditions affect plant quality. Pests consume/develop in/on plant tissue.

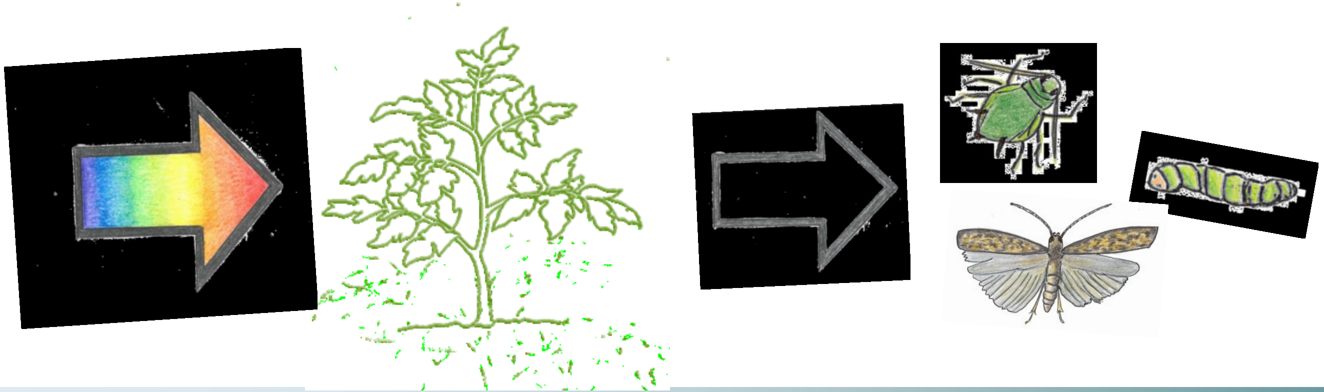
- Pest preference:

→ Can they find and recognize good host plants?

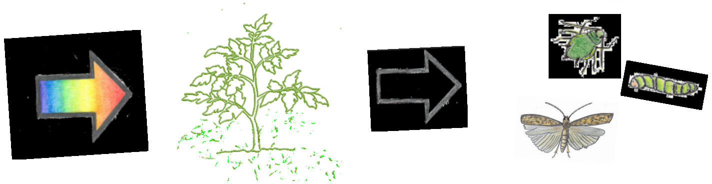
- Pest performance:

→ Does the plant offer enough nutrients for good development?

→ Has the plant accumulated toxic defense compounds?



INDIRECT EFFECTS OF LIGHT ON PESTS



- **light quantity:**

⇧

⇩ decreased palatability of leaves due to enhanced toughness and defense chemicals (phenolics, terpenes, alkaloids)

⇧ increased plant nutritional value, benefit for herbivores that can cope with also elevated defense compounds

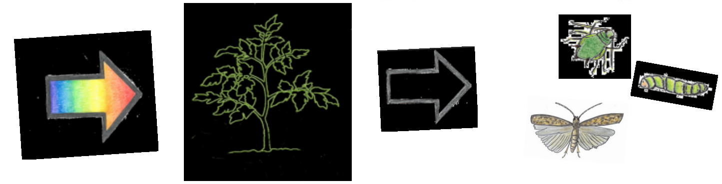
⇧ increased trichome density can trap more small arthropod pests (e.g. mites)

⇧ increased VOC-emission; increased “chemical visibility“ to insects

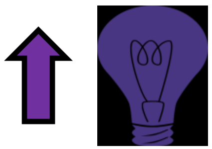
→ In summary: probably lower infestation rates with higher light intensity

→ (But it‘s complicated: species, sex, development, experience…)

INDIRECT EFFECTS OF LIGHT ON PESTS



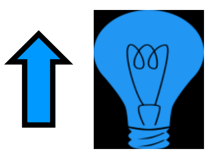
- **light quality:**



reduces plant digestibility and attractivity for herbivores due to increased phenolics concentration → probably decreased herbivore performance

flavonoid-rich larval diet enhances attractivity of adult females of *Polyommatus icarus* butterfly

especially in the field, herbivores may benefit from UV-effect on entomopathogenic pathogens, and nematodes *



increases preference of cabbage aphid (*Brevicoryne brassicae*) on broccoli **

→ In summary: probably higher infestation rates with lower UV radiation intensity.

→ But **it‘s complicated!** Herbivore and plant species, feeding mode and degree of dietary specialization are as important as experimental design…

* Roberts & Paul 2006, *New Phytol* **Rechner et al 2017, *Plos ONE*

INDIRECT EFFECTS OF LIGHT ON NATURAL ENEMIES

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Light quantity and quality affect plant quality and therefore affect pests.

Natural enemies consume/develop in/on pest.

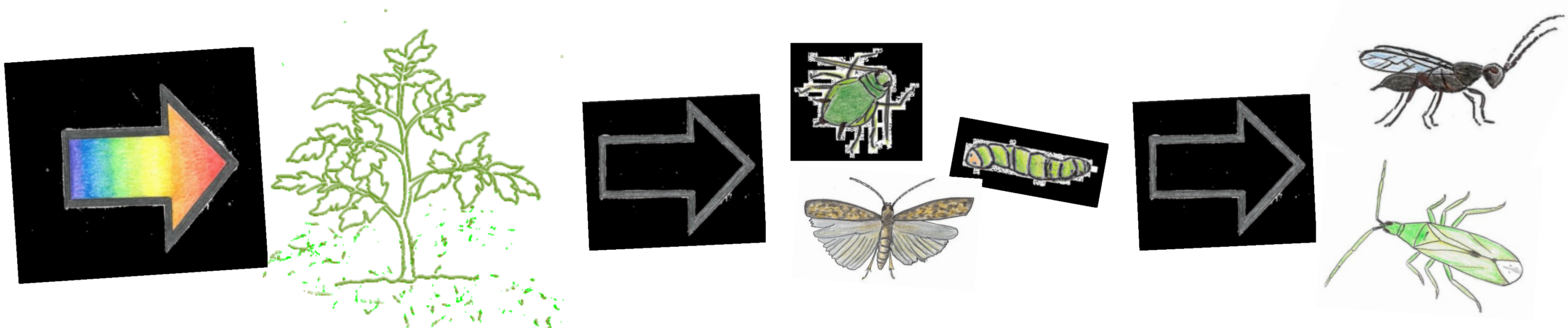
- Natural enemy preference:

→ Can they find and recognize good insect hosts/ prey ?

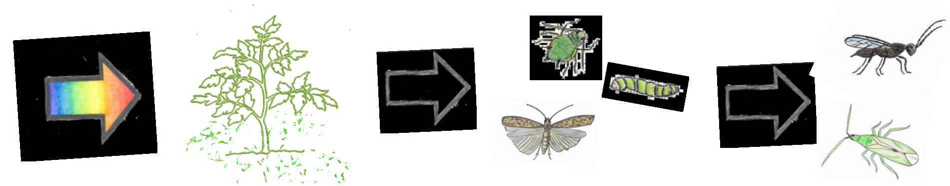
- Natural enemy performance:

→ Does the insect host offer enough nutrients for good development and longevity?

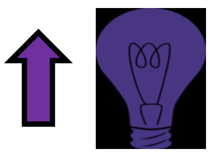
→ Has the insect host taken up toxic plant defense compounds?



INDIRECT EFFECTS OF LIGHT ON NATURAL ENEMIES

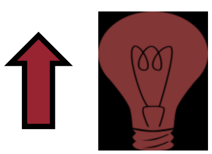


- **light quality:**



↑ parasitic wasp *Cotesia plutellae* prefered diamondback moth larvae (*Plutellae xylostella*) that had fed on UV-B-exposed plants*

0 No effect of elevated UV-B on *Cotesia marginiventris* and it's host *Spodoptera frugiperda* **



↑ increased indirect defense (manipulated VOC → more attractive to predators; *few studies so far!*)

→ In summary: it depends on the involved species and experimental design. (More studies needed.)

*Foggo et al 2007, *Oecologia* **Winter & Rostàs 2008, *Environ Pollut*

Photochemistry and Photobiology, 2004, 79(3): 219–226

Hochschule Geisenheim University

Invited Review

UV Radiation Effects on Pathogens and Insect Pests of Greenhouse-Grown Crops

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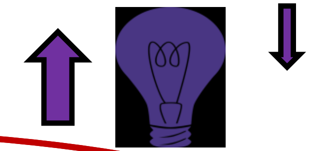
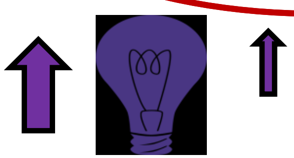
[2]Department of Virology, Volcani Center, Agricultural Research Organization, Bet Dagan, Israel

Received 6 June 2003; accepted 2 January 2004



ABSTRACT

Production of high-value crops is often performed u protected cultivation. In recent years various spectral ifications have been made in greenhouse covers. Two o main reasons to modify the spectral characteristic greenhouse covers have been to suppress the prolifera several foliar diseases and to protect crops from insects insect-borne virus diseases of greenhouse-grown crops. T goals were achieved by complete or partial absorption of UV radiation, which interrupts the life cycle of several fu pathogens and alters the visual behavior of many in Examples of these management strategies are described in article.



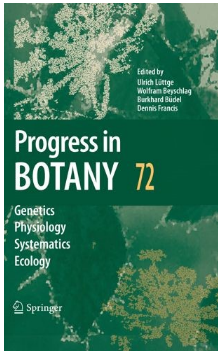
Evidence from field studies. More than 80% of the studies that have evaluated the effects of ambient UVB on insect herbivory reported that plant damage or insect growth increased in response to attenuation of UVB radiation (10). Insect-feeding experiments with plants pretreated with either ambient or attenuated UVB radiation have clearly demonstrated that at least part of the effect of solar UVB reducing herbivory is indirect (i.e., mediated by changes in the quality

Ballaré 2014, *Annu Rev Plant Biol*

Contradiction?

et al. 2001; Kuhlmann and Müller 2009a). The species-specific and life-history trait-specific responses of herbivores to visual cues are probably driven by adaptations to different habitats. Under applied aspects, UV-absorbing filters can be used in integrated pest management programs at least against certain herbivorous insects (Antignus et al. 1996; Raviv and Antignus 2004).

Kuhlmann & Müller 2011, *Progress in Botany 72*



UV RADIATION

Hochschule Geisenheim University

Table 1. Overview of ultraviolet (UV) radiation and its biological effects

Waveband	Response to ozone depletion[a–c]	Physical and biological properties[a–c]	Role in animals[d–j]	Role in plants[d–j]
UV-C (200–280 nm)	None	Short wavelength, therefore highly energetic	None	None
	Absorbed in atmosphere; does not penetrate to biosphere	Strongly absorbed by nucleic acids	Artificial UV-C causes severe amage to skin and eyes	Artificial UV-C sources cause severe damage to exposed tissues
UV-B (280–315 nm)	Strongly affected by variation in the ozone column	The most energetic UV radiation to reach biosphere	Possible acute and chronic damage to skin and eyes	Rarely damaging in the field but induces many morphological, physiological and biochemical changes in plants leading to many ecological effects
		Absorbed by many biological molecules, including nucleic acids	Compromises immune system	
			Possible factor in decline of many amphibian populations	
			Acute exposure causes sunburn in humans; chronic exposure is a cause of skin cancers	
UV-A (315–400 nm)	Not affected	Less energetic than UV-B but present at much higher intensity in sunlight	Increasingly recognized as an important factor in development of skin cancers in humans	Influences plant morphology, plus some specific effects (e.g. stomatal opening and induction of 4pigment formation)
		Absorbed by many proteins, including important photoreceptors	Widely used in vision of many invertebrates and vertebrates	

Paul & Gwynn-Jones 2003, *Trends in Ecology and Evolution*

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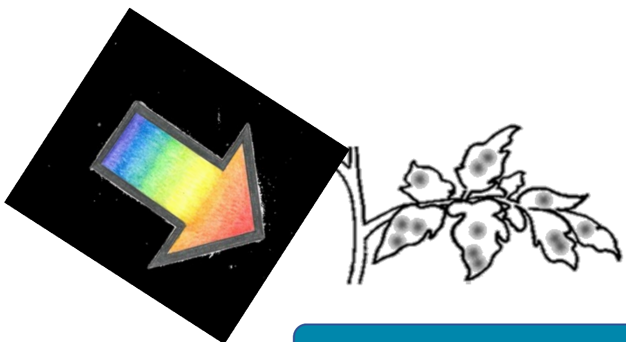
…AND WHAT ABOUT PATHOGENS?

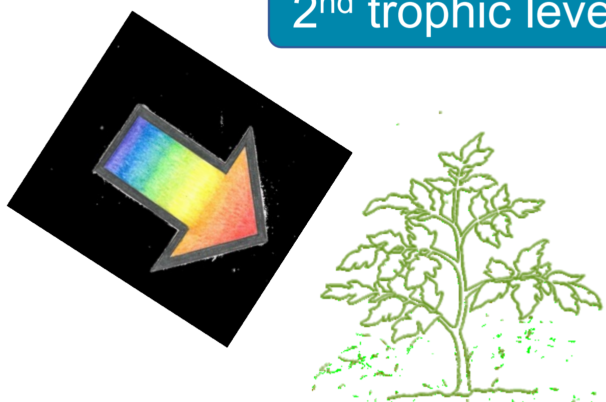
EFFECTS OF LIGHT ON PATHOGENS

Pathogens



2nd trophic level

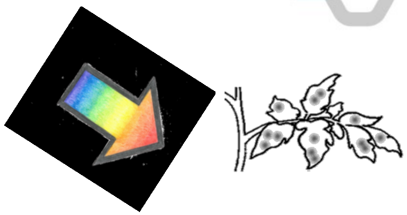
Plants



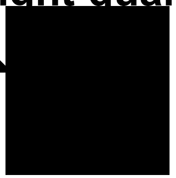
1st trophic level

Direct and indirect effects of light quality and quantity

DIRECT EFFECTS OF LIGHT ON PATHOGENS

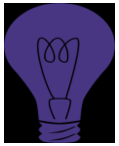


- **light quantity:**



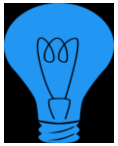
⇩ reduced infestation in many species

- **light quality:**



⇩ reduced sporulation, infection and/or dispersal in many species

⇧ increased sporulation in some species



⇩ development suppressed under blue light

⇧ increased sporulation in some species

→In summary: It depends on the involved species and their developmental stages

INDIRECT EFFECTS OF LIGHT ON PATHOGENS

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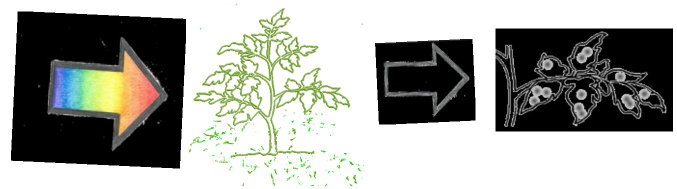
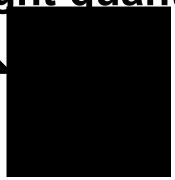
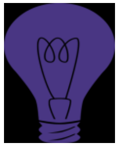


- **light quantity:**

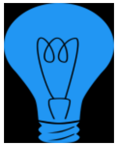


can reduce the susceptibility gainst Turnip mosaic virus

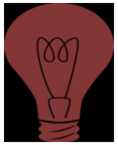
- **light quality:**



can reduced infection of many pathogen species due to increased plant chemical defense and strengthened cell walls which reduce penetration by fungal hyphae



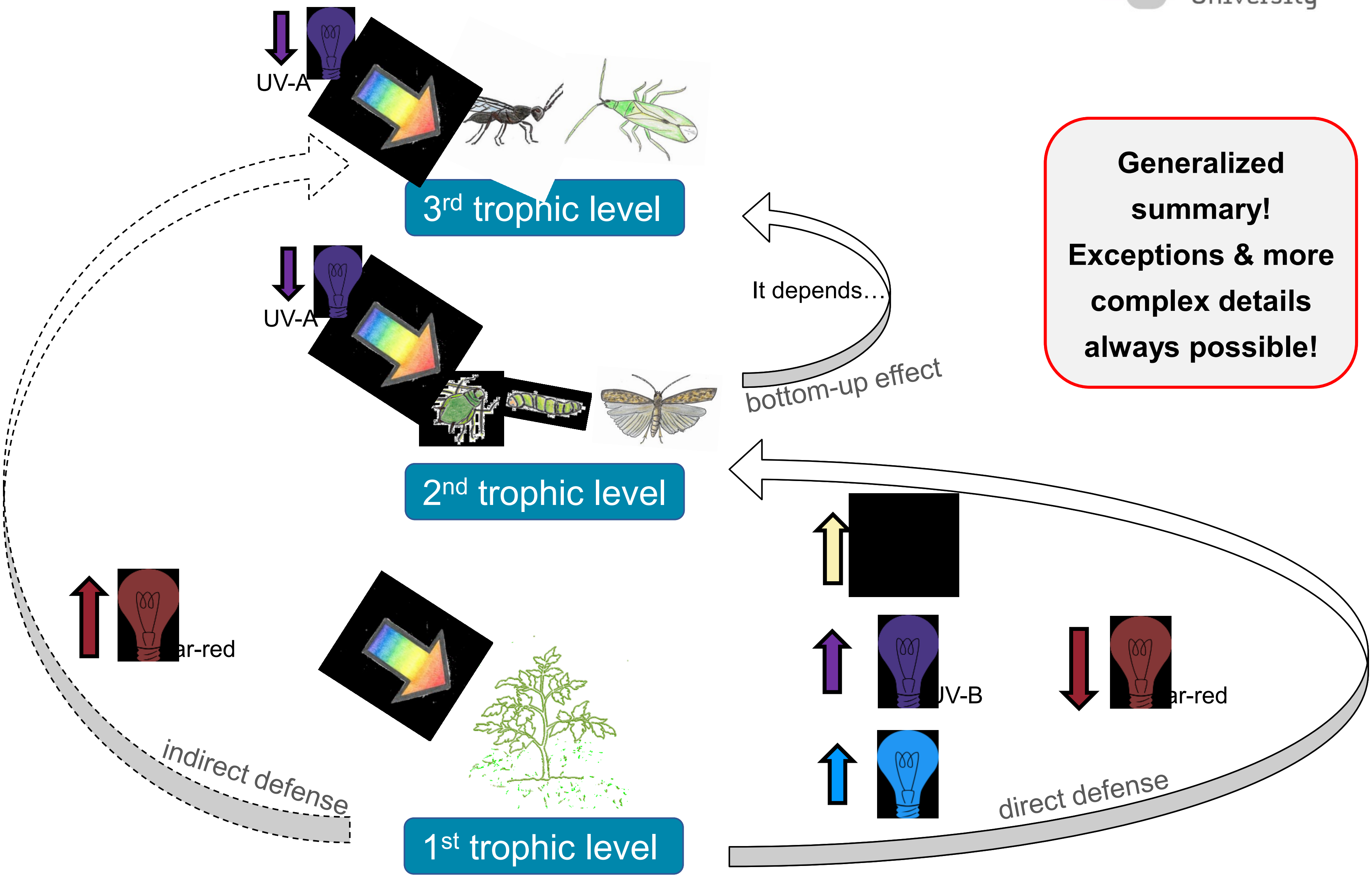
can reduce *Pseudomonas syringae, Pseudoperonospora cubensis,* Turnip Crinkle virus, and Cucumber mosaic virus infection due to increased plant defense



can reduced resistance to pathogens

→In summary: It depends on the involved species and their developmental stages

SUMMARY



Generalized summary!
Exceptions & more complex details always possible!

THANK YOU FOR YOUR ATTENTION

Any questions?

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