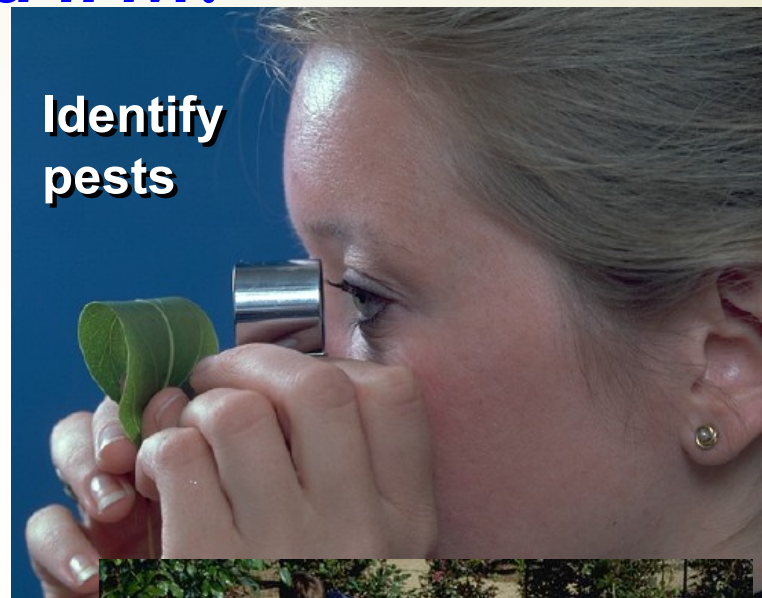


## *What is the idea behind IPM?*

### ➔ Prevents problems

- Based on knowledge of pest, biology, and habitat
- No spraying just because you see a pest
- Uses least-toxic methods to protect people and environment

Identify  
pests

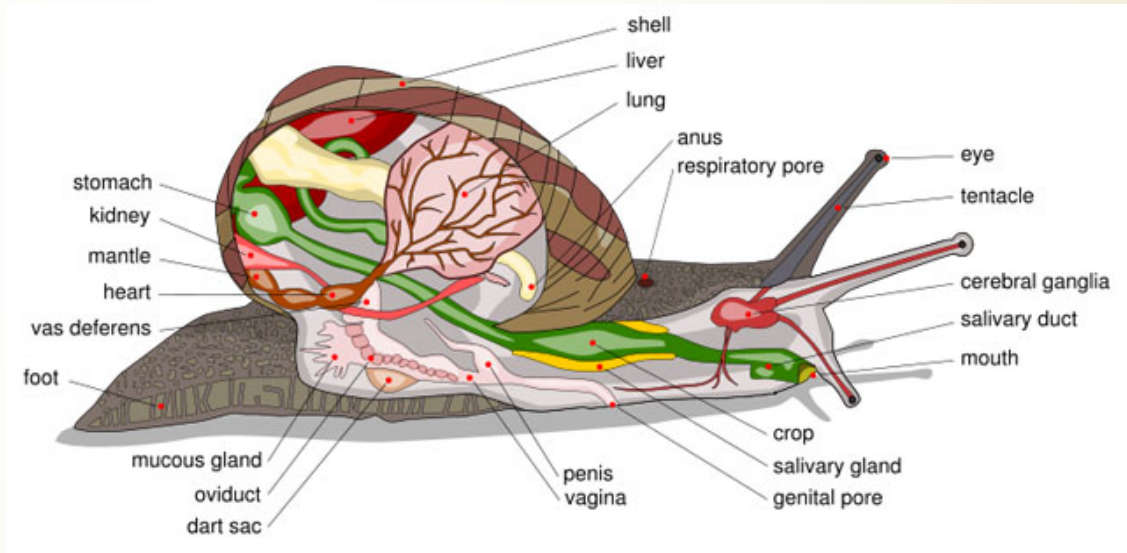
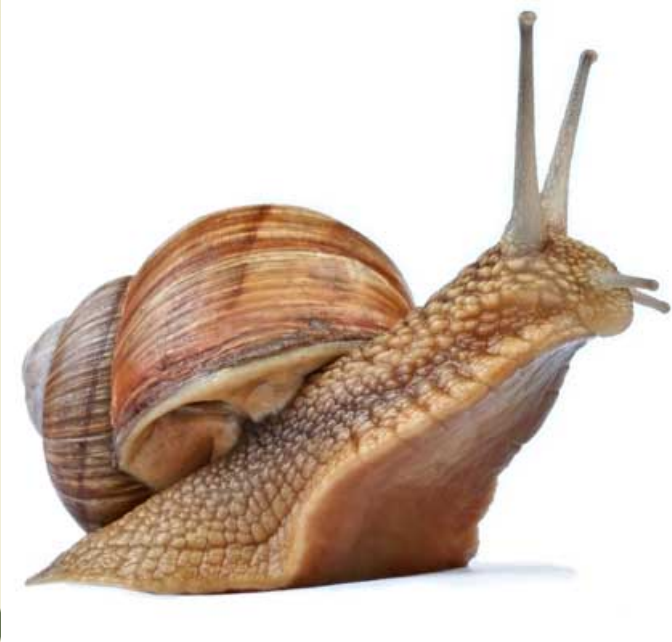


Monitor for  
problems

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## Brown Garden Snail (*Cornu aspersum*)





Calcium needed in snail diet

tongue has teeth on it  
tongue is called the radula





Most terrestrial snails and slugs are hermaphroditic

Garden snail lays eggs about 5x/year

# Estivation



epiphragm

# Management

Generally more active:  
at night  
cool mornings  
moist

Travel back and forth  
from daytime resting  
site to food



# Barriers and Traps



**Bordeaux mix**  
copper sulfate and hydrated lime mixture





# Baits



Iron phosphate  
Safer but slow

Sodium Ferric EDTA



Metaldehyde applied  
incorrectly

Very quick kill but  
pets can be  
poisoned

# Mesurol

Methiocarb

Ornamental Plants &  
Nonbearing Fruit and Nut  
Trees & Vines Growing in  
Nurseries and Greenhouses  
and Mature Ornamental  
Plantings

## **DANGER (RUP)**

Spray  
Fast acting  
Rescue treatment  
2 applications/year/crop  
max

## Natural enemies



decollate snail, *Rumina decollata*



**Adult devil's coach horse, *Ocyrops olens***

## Italian White Snail (*Theba pisana*)

- ▶ First recorded in CA (La Jolla) in 1914
- ▶ Considered eradicated through considerable effort ~1927
- ▶ Again found in San Diego in 1985, at 5 isolated locations in about a 10 square mile area
- ▶ It is established only in San Diego County, but reported in Los Angeles and Orange counties. No published records for North American populations outside of California
- ▶ B-rated pest in CA (shipping)
- ▶ Grapes, avocados, ornamentals, fruit trees, landscape plants



They are mainly active during damp weather, 60-75F

Mating usually takes place in mid autumn to mid winter. The eggs are laid into moist soil and cannot survive dry periods.

**Late Spring:** climb posts, plants and other vertical surfaces

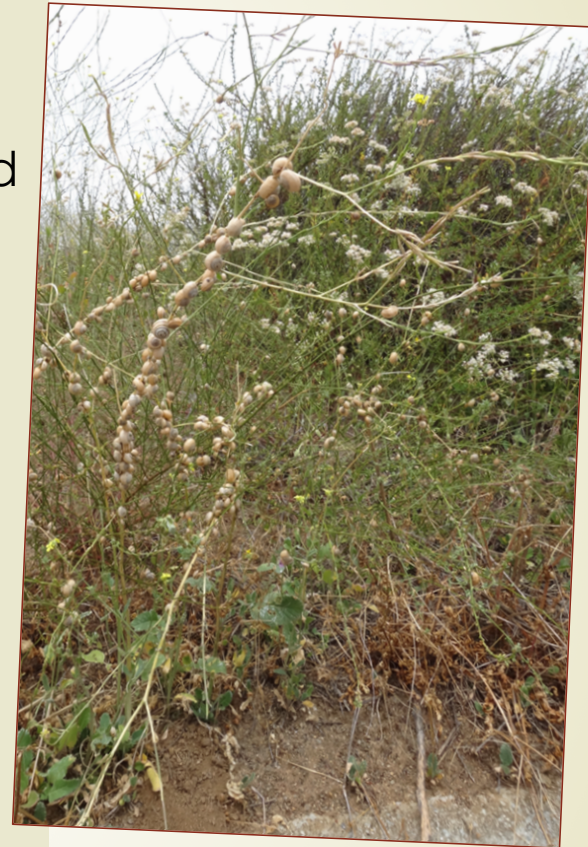
**Summer:** aestivate to **avoid the hot ground temperatures** and are often found on green summer weeds.

**Fall: become active again after rains. 1-2 mm of rain triggers feeding.**

- 1 (2) year old snails are sexually mature
- Mating occurs 2-3 weeks after fall rains and lower temperatures and egg laying starts soon after
- Egg clusters are laid in the top soil from fall to spring.
- Eggs hatch about 2 weeks after laying fall to spring.  
Mortality is high

**Winter:** juveniles feed in winter and spring

Egg laying occurs only after 1<sup>st</sup> year or sometimes 1<sup>st</sup> and 2<sup>nd</sup> year before snail dies (avg ~78 eggs/clutch, 5 times)



## Management and Control:

Baits - not effective on young snails that are less than 7 mm (1/4") diameter as they tend to eat decaying matter and don't consume the baits.

A combination of cultural, chemical and biological control are usually required to provide control.

### **Practices:**

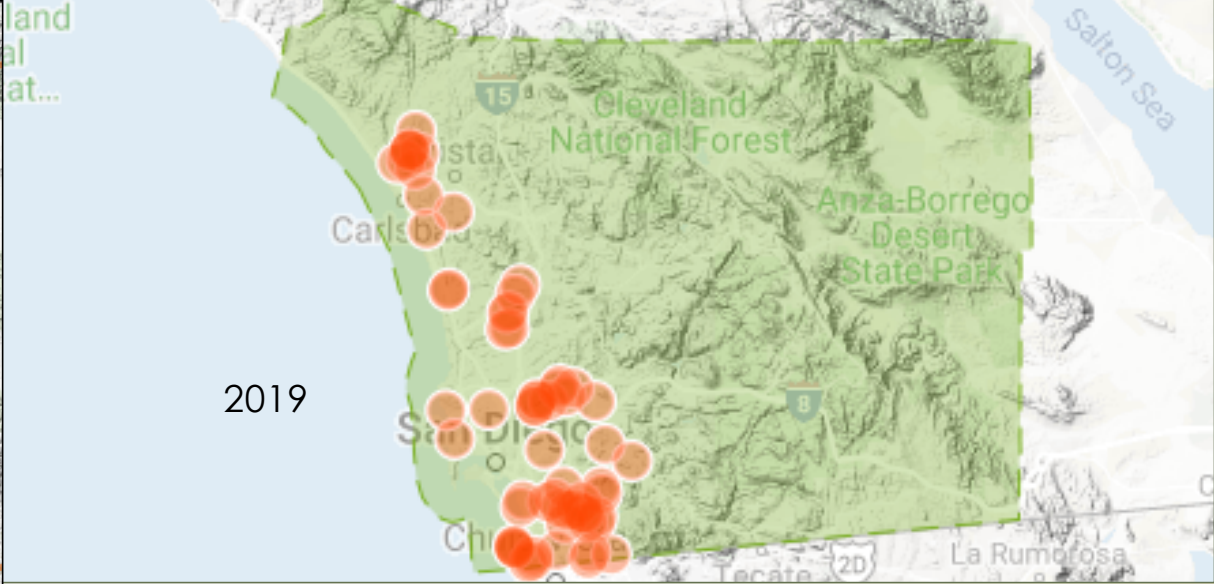
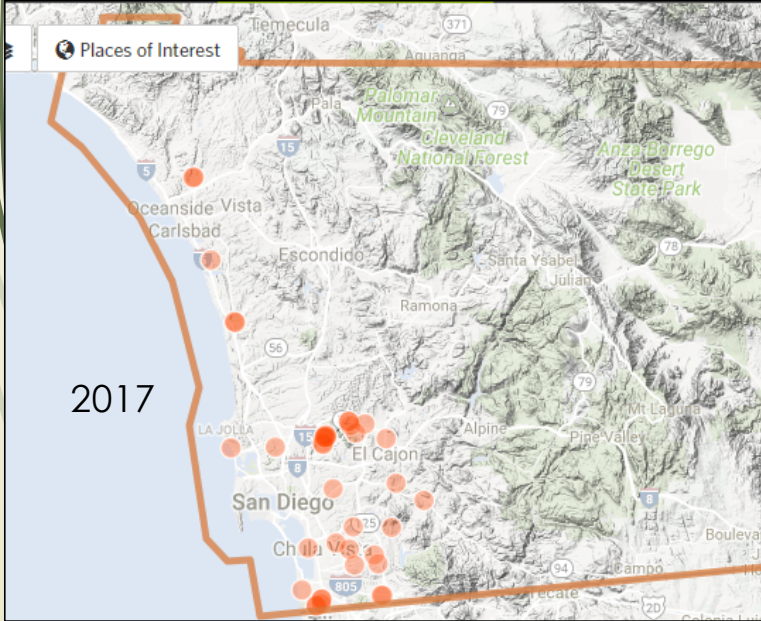
Kill summer and autumn weeds and plants along fence

Apply baits early before egg laying starts in autumn.

Concentrate baiting near refuge areas such as fence lines.

Spring baiting is often ineffective because many populations are relatively immobile juveniles and there is ample alternative feed





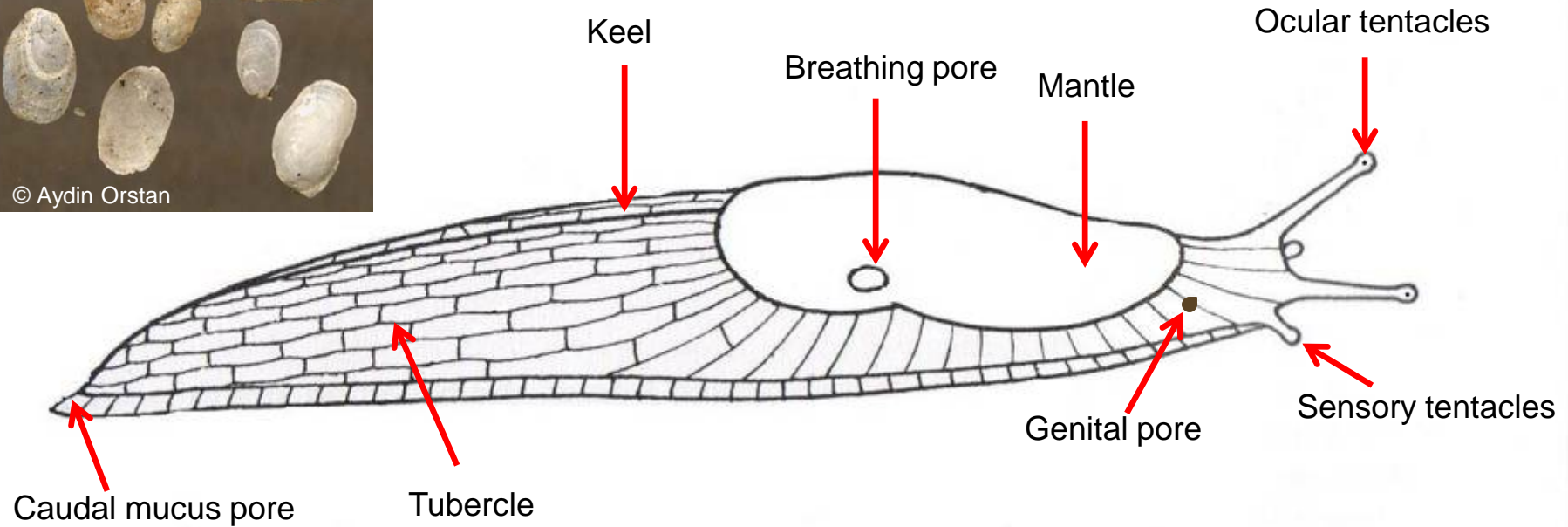
# Shell-less snails!

- ▶ Slug = snail minus an external shell!



- Advantages of no shell:
  - Squeeze through very tight spaces
  - Live in environments that snails cannot
  - Move more quickly i.e. top speed 14.4 mph!

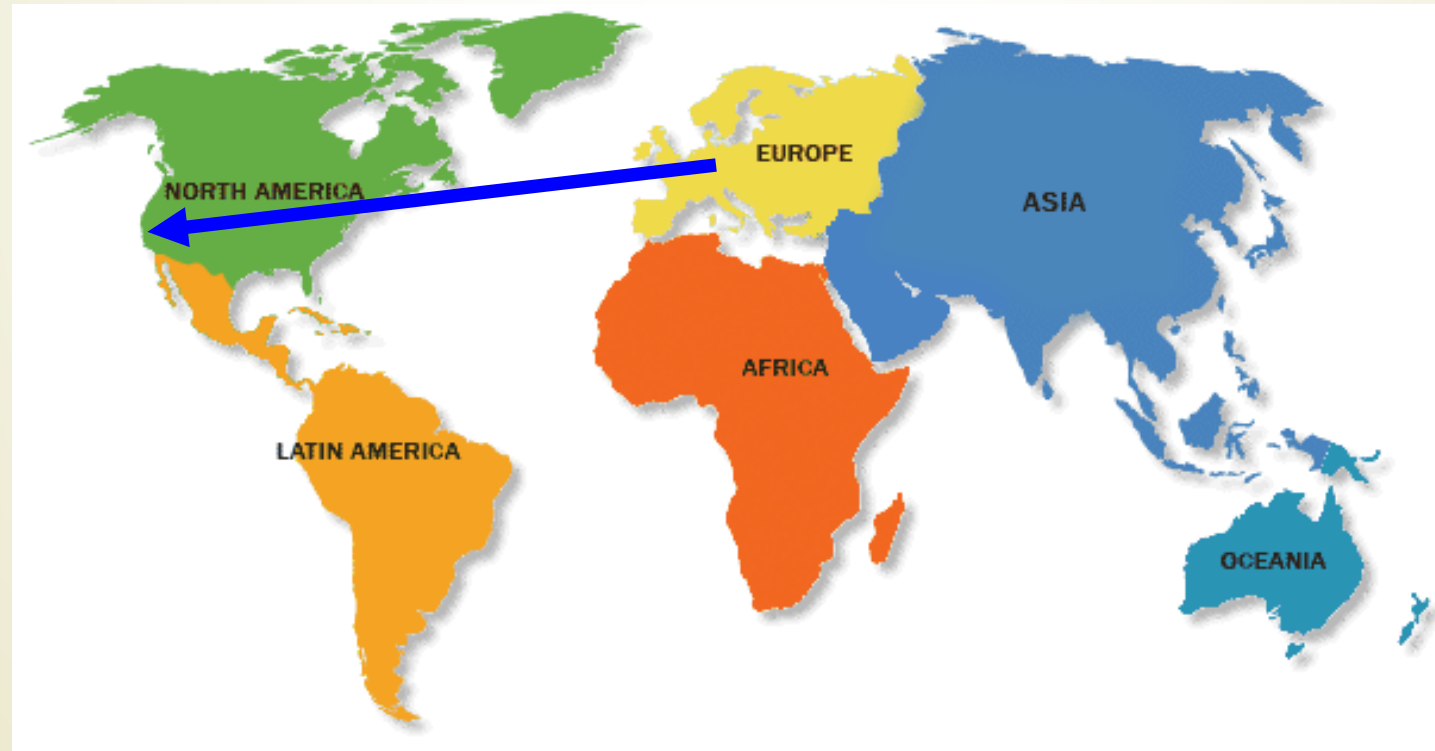
# Slug Body Plan





# Slugs on the west coast

- ▶ What species are causing the most damage?
- Invasive slugs
- Predominantly from Europe



# Banded slug – *Ambigolimax valentianus*



# European red slug - *Arion rufus*



# Cellar Slug - *Limacus flavus*



© Rory Mc Donnell

# Shelled Slug - *Testacella haliotideae*



© Roy Anderson

# Gray field slug - *Deroceras reticulatum*



© Joshua Vlach, ODA



1 cm

© Rory Mc Donnell

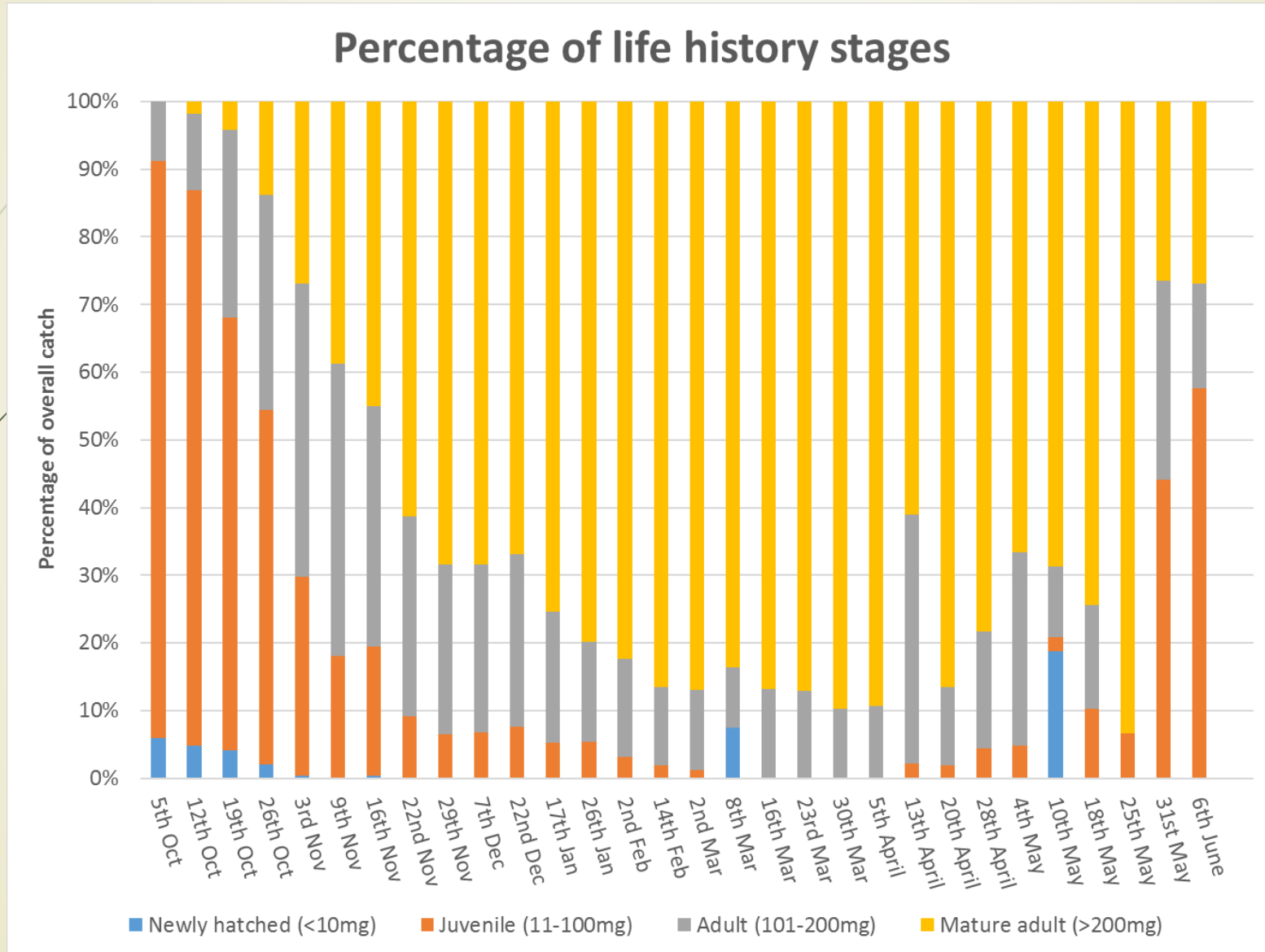
# Life history of gray field slug

- ▶ Knowing life history is critical for effective pest control
- ▶ Six fields of annual ryegrass grown for seed in the Willamette Valley
- ▶ 16 blanket traps per site positioned in a 4 x 4 grid





# Life history study



# Life history study

- Life history information can be used to guide slug management options



- Invertebrate natural enemies will be most effective when juvenile slugs dominate
- Killing adult slugs in spring before they lay their eggs will reduce Fall slug populations

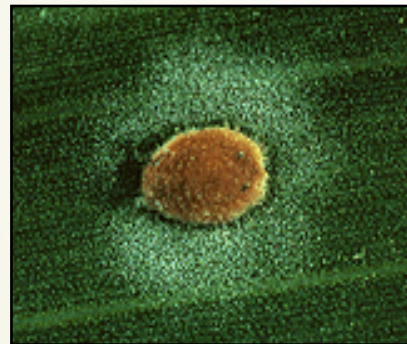


# Biological Control:

Use of natural enemies  
to manage pests and reduce their  
damage

*Agents:* Parasites, pathogens, parasitoids, and predators

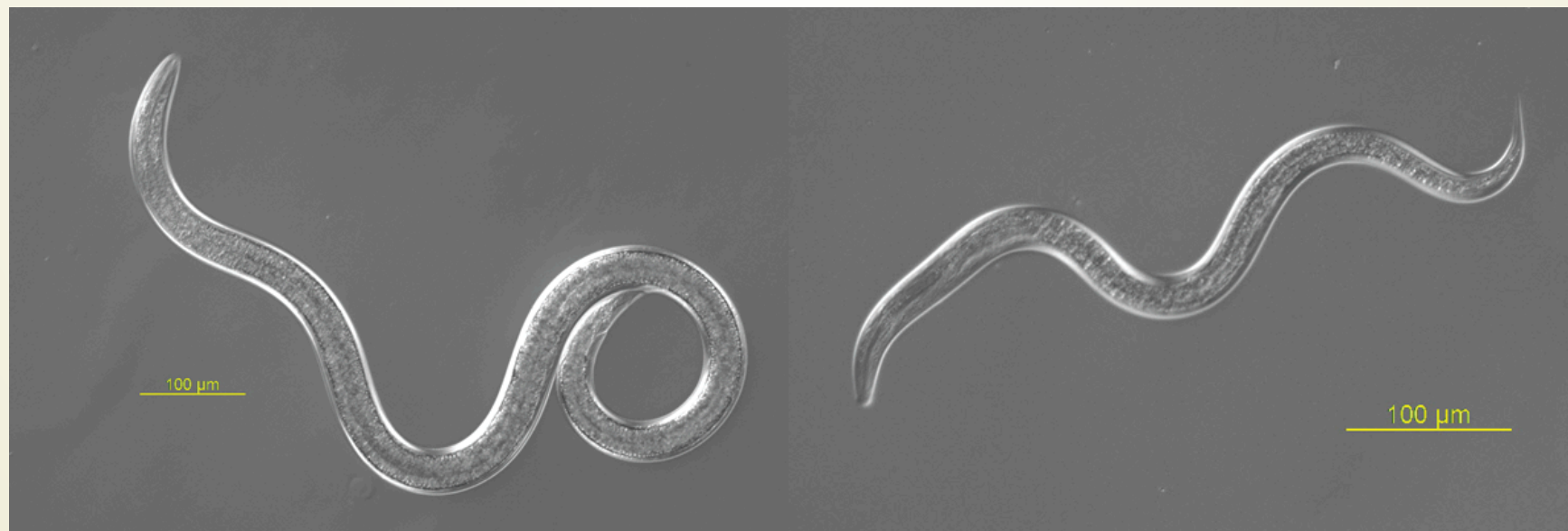
# Biological Control



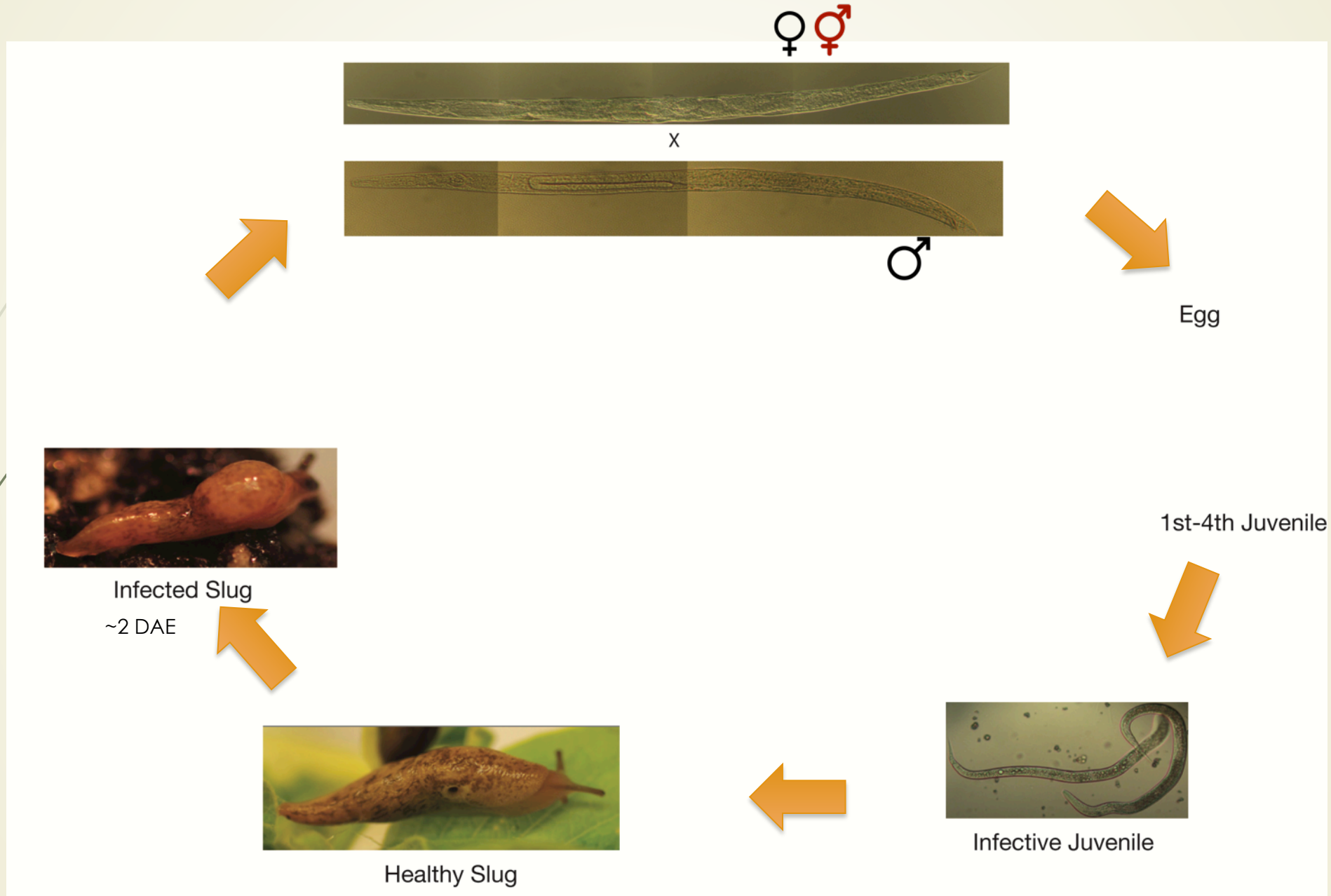
- Over 100 years of history
- Has advantages and disadvantages but safer than chemical means
- Demonstrated success in classical biocontrol
- Inadequacy of endemic enemies
- Lady bugs, praying mantis, EPN

# What are Nematodes?

- The most abundant and genetically diverse multicellular organisms on earth
- Mostly microscopic organisms that undergo life stages from egg, 4 juvenile stages, to adults



# *Phasmarhabditis*: a gastropod-parasitic nematode



# Biocontrol as a better alternative: the *Phasmarhabditis* system



- Not a “quick kill”; safe to humans, animals, environment
- Useful in organic production system
- Recorded efficiency > 72% in Europe (agricultural & horticultural crops)
- Gastropod specific
- Not a threat to ecosystem diversity
- Resulting in stable, healthy crop environment & safer product

*Is this available for use?*

***Phasmarhabditis* is marketed as Nemaslug® in 14 European countries**

- UK, Ireland, France, Belgium, Italy, Switzerland, The Netherlands, Denmark, Germany, Norway, Poland, Spain, the Czech Republic



<http://www.nemasysinfo.com>



# Effective in greenhouse, field, miniplots in Europe

- **Vegetables** (Chinese cabbage, cabbage, lettuce, corguettes, asparagus, sugar beet, leaf beet, kale, Brussels sprouts)
  - **Ornamentals** (Hosta, orchid, lupines, Tagetes)
  - **Field crops** (maize, wheat, oilseed rapeseed)
  - **Fruit crops** (strawberries)
- Rec Rate: 1x= 300K IJs/m<sup>2</sup> soil

# Slugtech ® by Dudutech, sub-Saharan Africa

- SLUGTECH is a biological molluscicide containing infective juveniles of *Phasmarhabditis hermaphrodita* (isolate DDT M1) in an inert carrier
- control of agricultural and horticultural molluscs, e.g. *Deroceras reticulatum* and snails, e.g. *Monacha cantiana*
- Use in the field or greenhouse

# Will *Phasmarhabditis* be useful in the US?

- Discovery of multiple gastropod-killing *Phasmarhabditis* species (*P. hermaphrodita*, *P. californica* & *P. papillosa*)
- Distributed in CA and Oregon, more widely distributed than originally thought
- Growing demand for safe and effective tools for specialty/high value crops and organic farms
- Lab assays demonstrate gastropod-killing potential of *Phasmarhabditis* species



# Biocontrol potential of *Phasmarhabditis* US isolates

- Kills 4 invasive slugs and 4 snails
- Efficacy depends on *Phasmarhabditis* and gastropod species
- Safe to non-target organisms: Banana slugs and earthworms (gastropod-specific)



# Slug reaction to *Phasmarhabditis* US isolate

Nematode	Slugs	1 <sup>st</sup> mortality	% Mortality
<i>P. hermaphrodita</i>	Grey field slug	2 DAE	77%
<i>P. hermaphrodita</i>	Marsh slug	3 DAE	80%
<i>P. hermaphrodita</i>	Valencia slugs	5 DAE	40%
<i>P. hermaphrodita</i>	Black field slug	5 DAE	45%

# Snail reaction to *Phasmarhabditis* US isolate

Nematode	Slugs	1 <sup>st</sup> mortality	% Mortality 21DAE
<i>P. hermaphrodita</i>	Brown garden snail	5 DAE	80%
<i>P. hermaphrodita</i>	Giant African land snail	5 DAE	80%
<i>P. hermaphrodita</i>	Amber/water snails	5 DAE	100%
<i>P. papillosa</i> / <i>P. hermaphrodita</i> <i>P. californica</i>	Decollate snail	7 DAE	70% /<10%

# Non-target species reaction to *Phasmarhabditis* US isolate

Nematode	Slugs	1 <sup>st</sup> mortality	% Mortality 21DAE
<i>P. hermaphrodita</i>	Alabama jumper	none	none
<i>P. hermaphrodita</i>	Common earthworm	none	none
<i>P. hermaphrodita</i>	European nightcrawler	none	none
<i>P. hermaphrodita</i>	Red wigglers	none	none
<i>P. hermaphrodita</i>	Banana slug	none	none

# Symptoms on susceptible slugs



■ Grey field slug



■ Marsh slug



# Symptoms on less susceptible slugs



# *P. hermaphrodita* reduces leaf damage due to GFS

0 day

2 days

3 days



0 nema

(1x)

(5x)

0 nema

(1x)

(5x)

0 nema

(1x)

(5x)

# Snails



■ Brown garden snail



■ Amber snail



■ Giant African land snail

# ***Non-target species***



# Conclusion

- Gastropod biocontrol using *Phasmarhbaditis* is in its infancy in the US. Current funding allows us to:
- optimize *Phasmarhabditis* -bacteria partnership that is most virulent, has wide host range and safe to non-target organisms
- using species that are already widespread in Western US
- and are best suited to local conditions



*Thank you for your attention!*