Ecosystem Services and Ground Nesting Bees

M. Rei Scampavia
PhD Candidate, UC Davis
Department of Entomology and Nematology

Presentation Goals

- How do insects shape and interact with soil environments?
- How do soil insects influence agriculture?
- How do can we protect soil-nesting bees for pollination services?

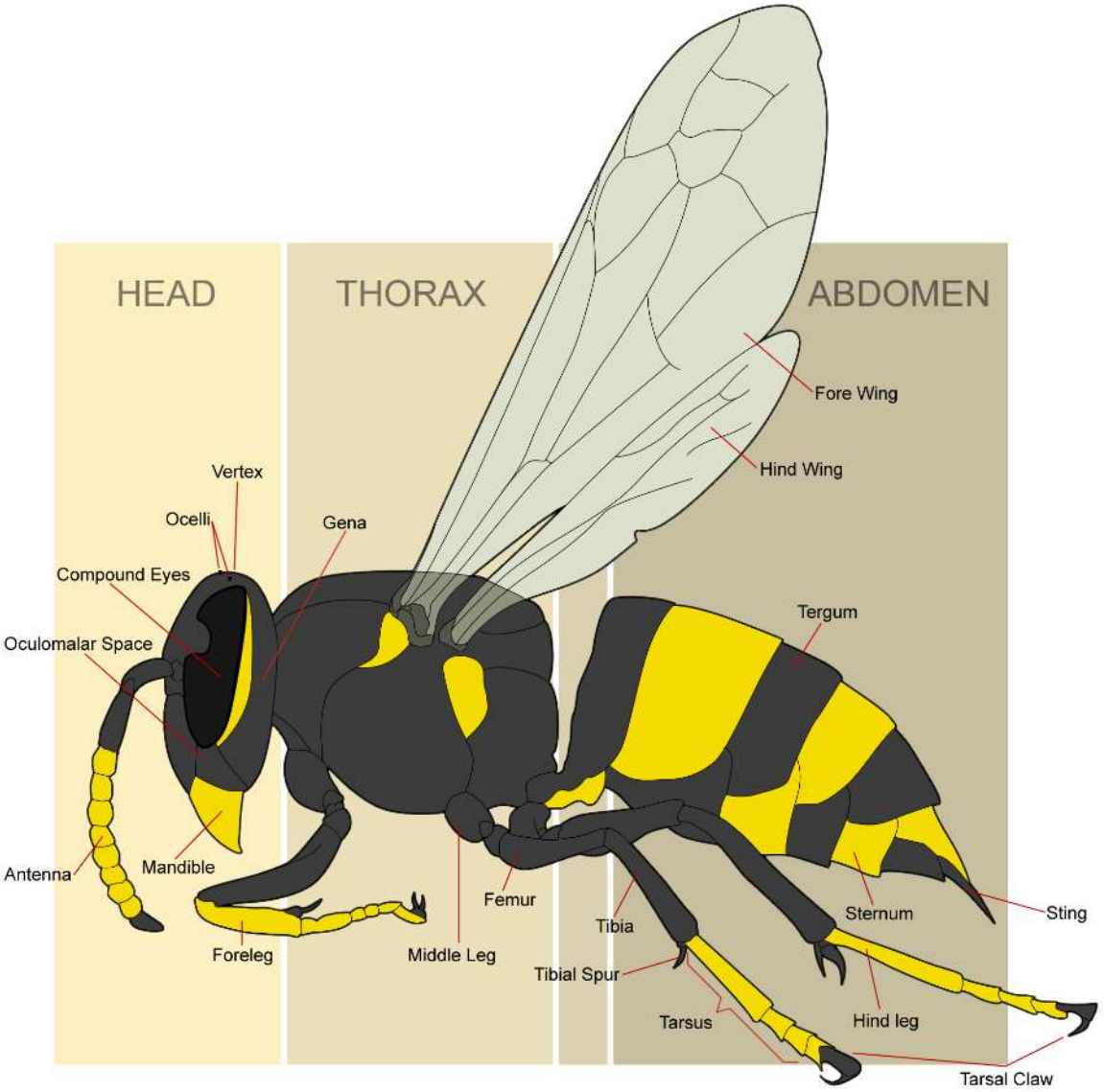
Outline

I. Insects and Our World: Primer Edition
II. Soil Insect Ecology
III. Insects and Agriculture
IV. Protecting Soil-Nesting Bees

I. Insects and Our World

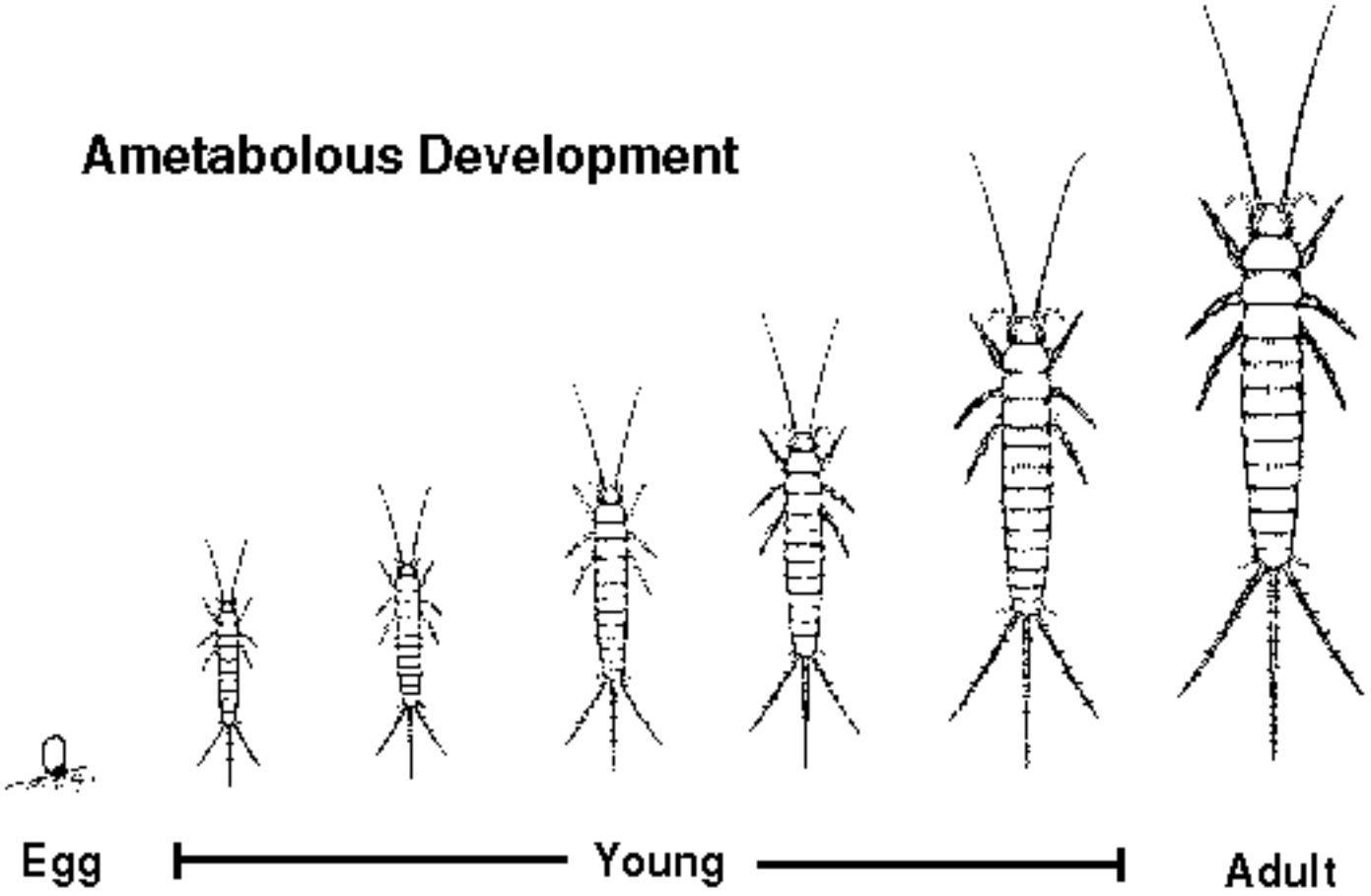
- Basic Body Plan & Life Cycle
- Insect Diversity & Distribution
- Insects shaping their environment

Insect Body Plan



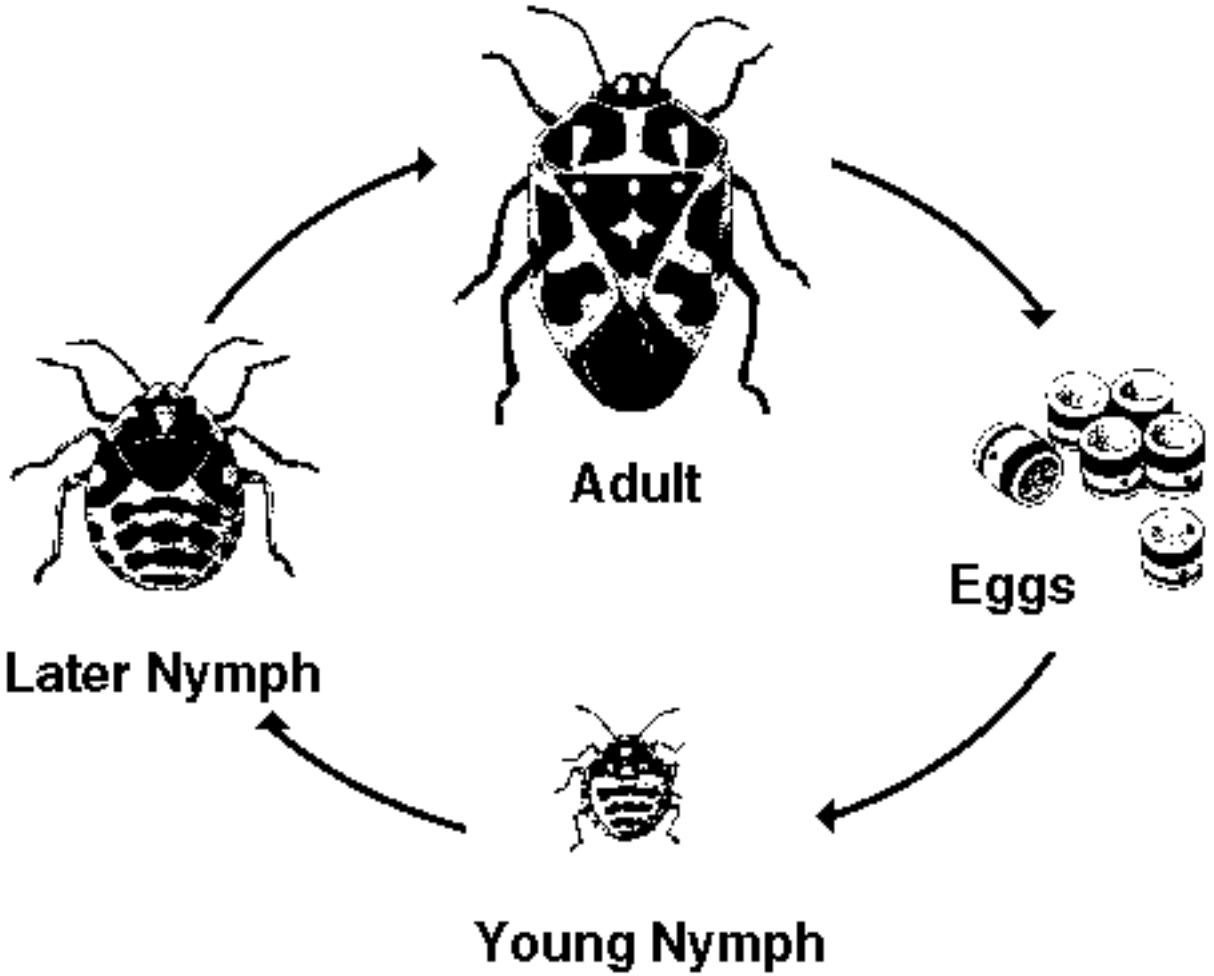
Insect Life Cycles

Ametabolous Life Cycle



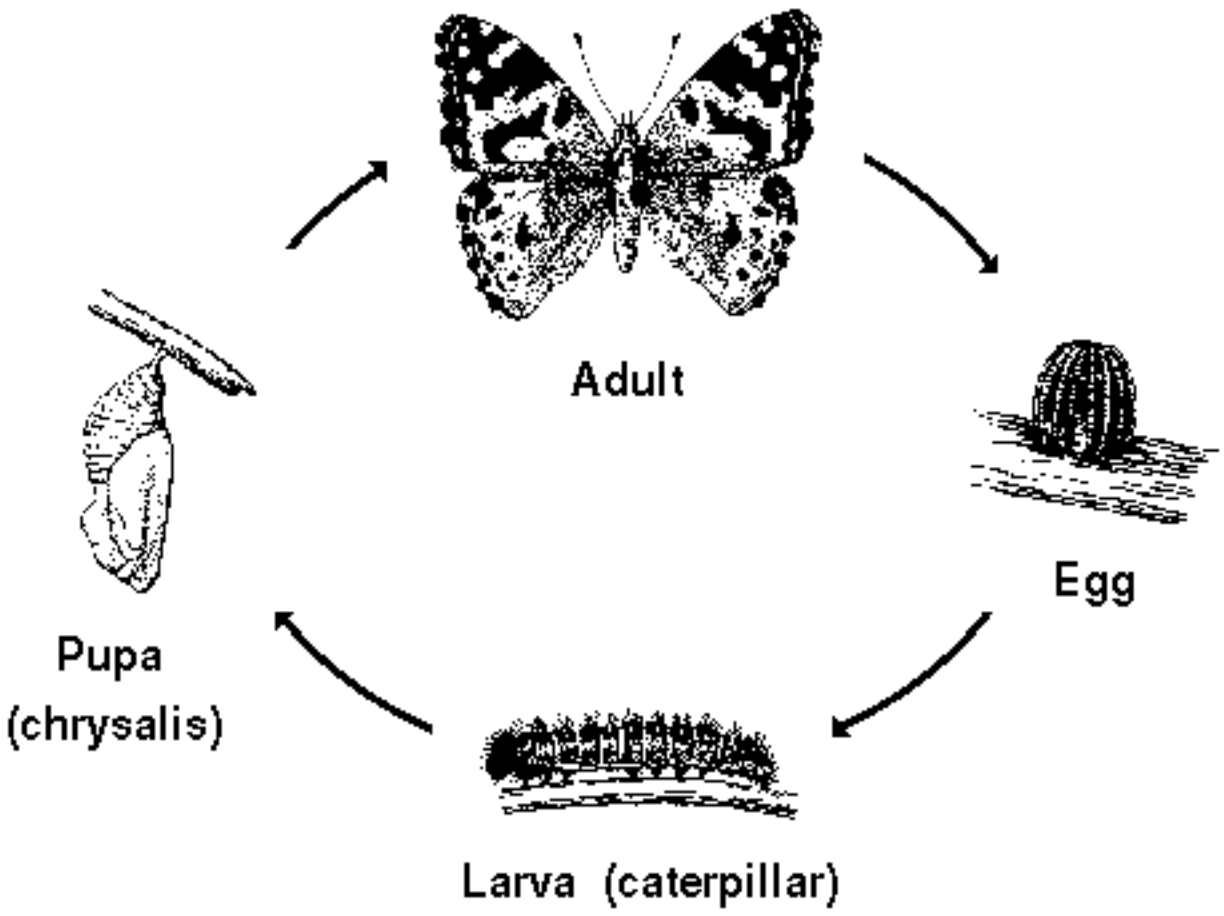
John R. Meyer- NC State Dept of Entomology

Hemimetabolous Life Cycle



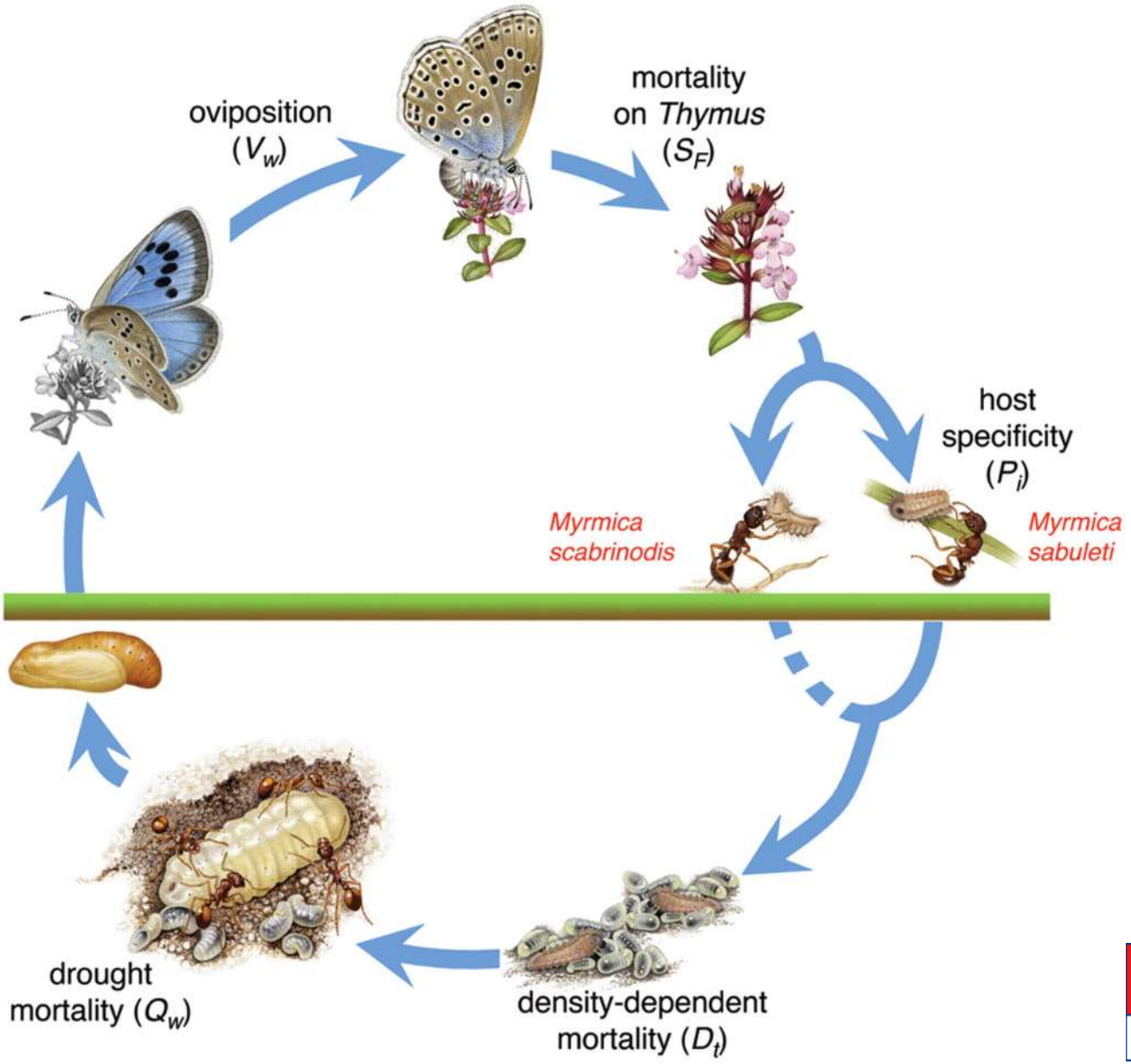
John R. Meyer- NC State Dept of Entomology

Holometabolous Life Cycle



John R. Meyer- NC State Dept of Entomology

Large Blue Butterfly Life Cycle



J. A. Thomas et al. Science 2009;325:80-83

Science
AAAS

There are > 1 million described insect species.

Assorted Coleoptera in the University of Texas Insect Collection

Arrangement by Julia Suits; Photograph by Alex Wild

Public Domain image produced by the "Insects Unlocked" project at the University of Texas at Austin.

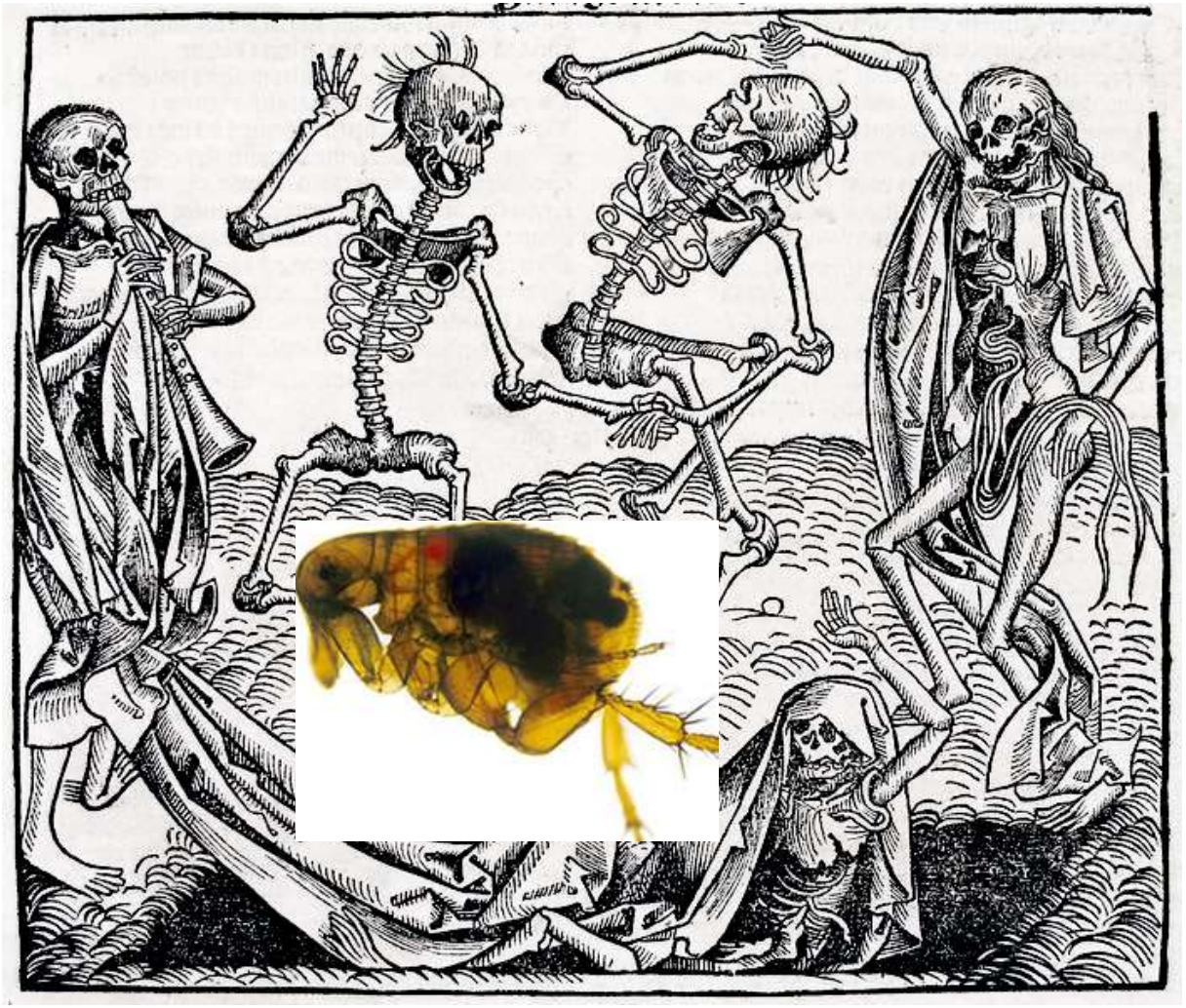
Insects have adapted to every environment on Earth (except the open ocean).

Jacopo Werther 2012

Insects play a key role in the functioning of nearly every terrestrial ecosystem.

- Food source
- Predators
- Nutrient Recycling and Decomposition
- Plant community Composition
  - Herbivory
  - Pollination
  - Biocontrol

Insects have a profound impact on human activities.



Human activities greatly affect insects, too.

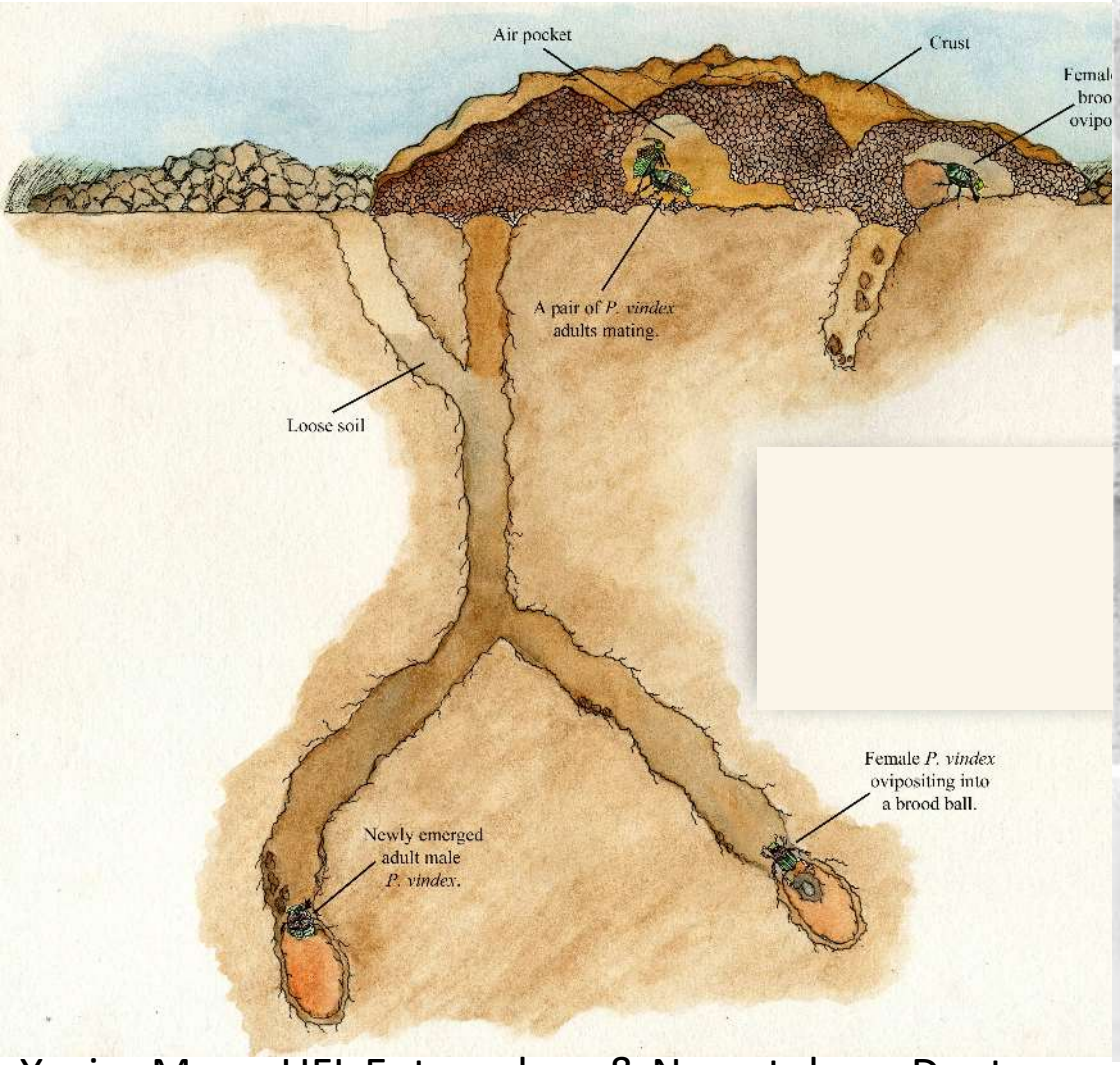
II. Soil Insect Ecology

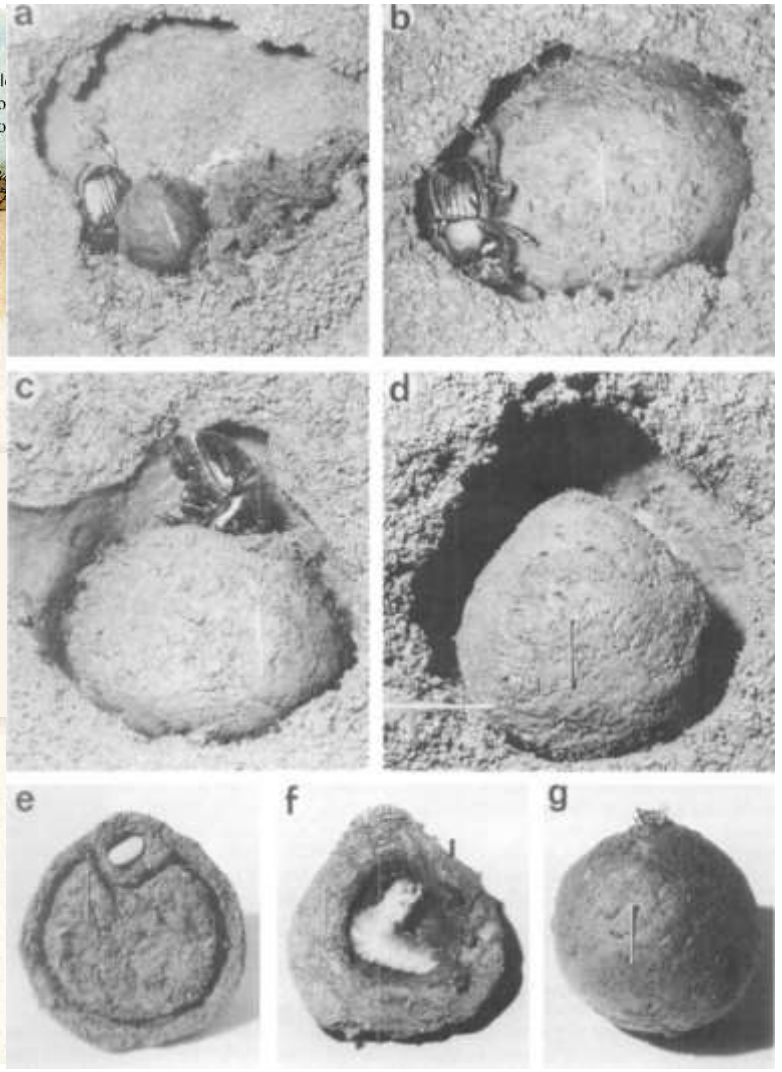
- Ecosystem Engineers
- Ecosystem Services
- The Above/Below Ground Connection

Ecosystem Engineers

- Make major alterations to environment
- Movement, burrowing activity of insects mixes soil layers, spreads microorganisms
- 3 Soil ecosystem engineers:
  - Dung Beetles
  - Ants
  - Termites

Ecosystem Engineers: Dung Beetles





Xavier Moss- UFL Entomology & Nematology Dept

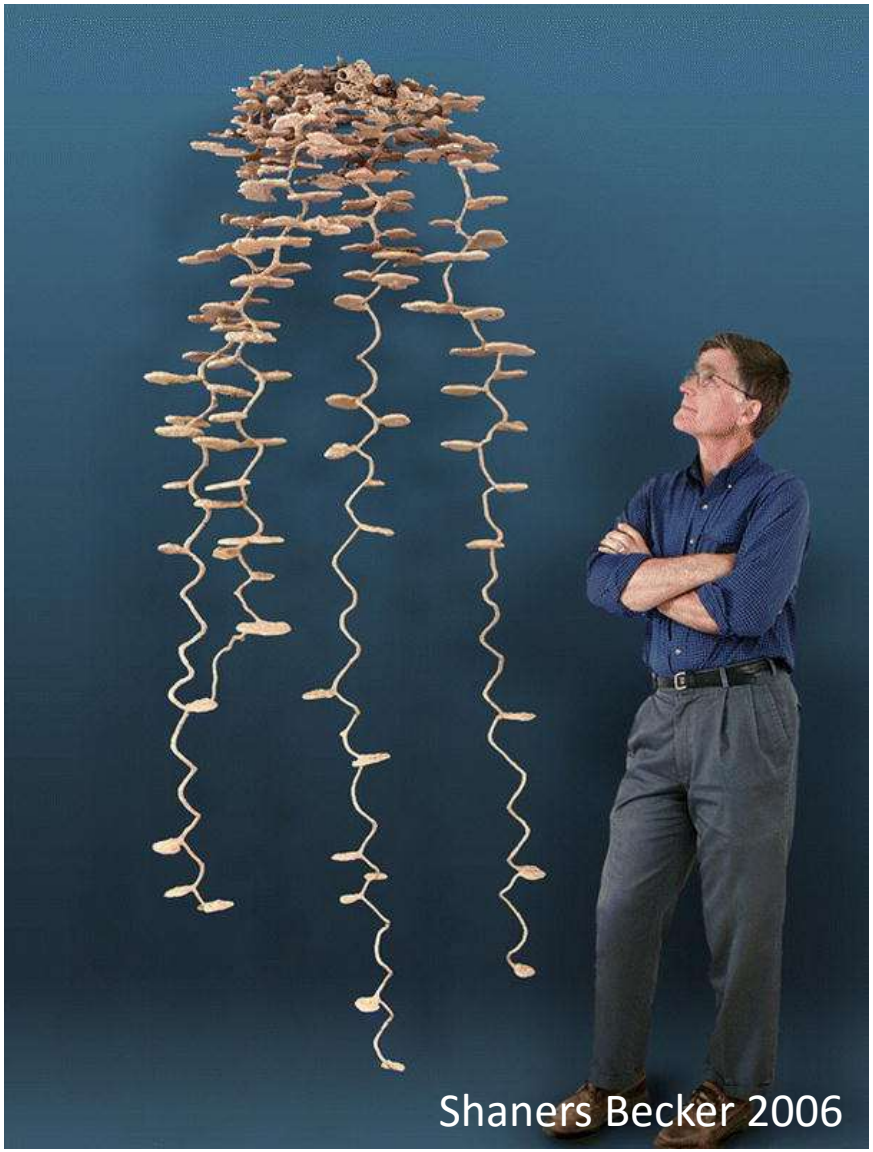
(Klemperer 1983)

Ecosystem Engineers: Ants

Important parts of the food chain

Ecosystem Engineers: Ants

- Nest building:
  - improves soil aeration
  - Increases water filtration
  - Modify soil pH
- Nests host unique communities of insects and microbes

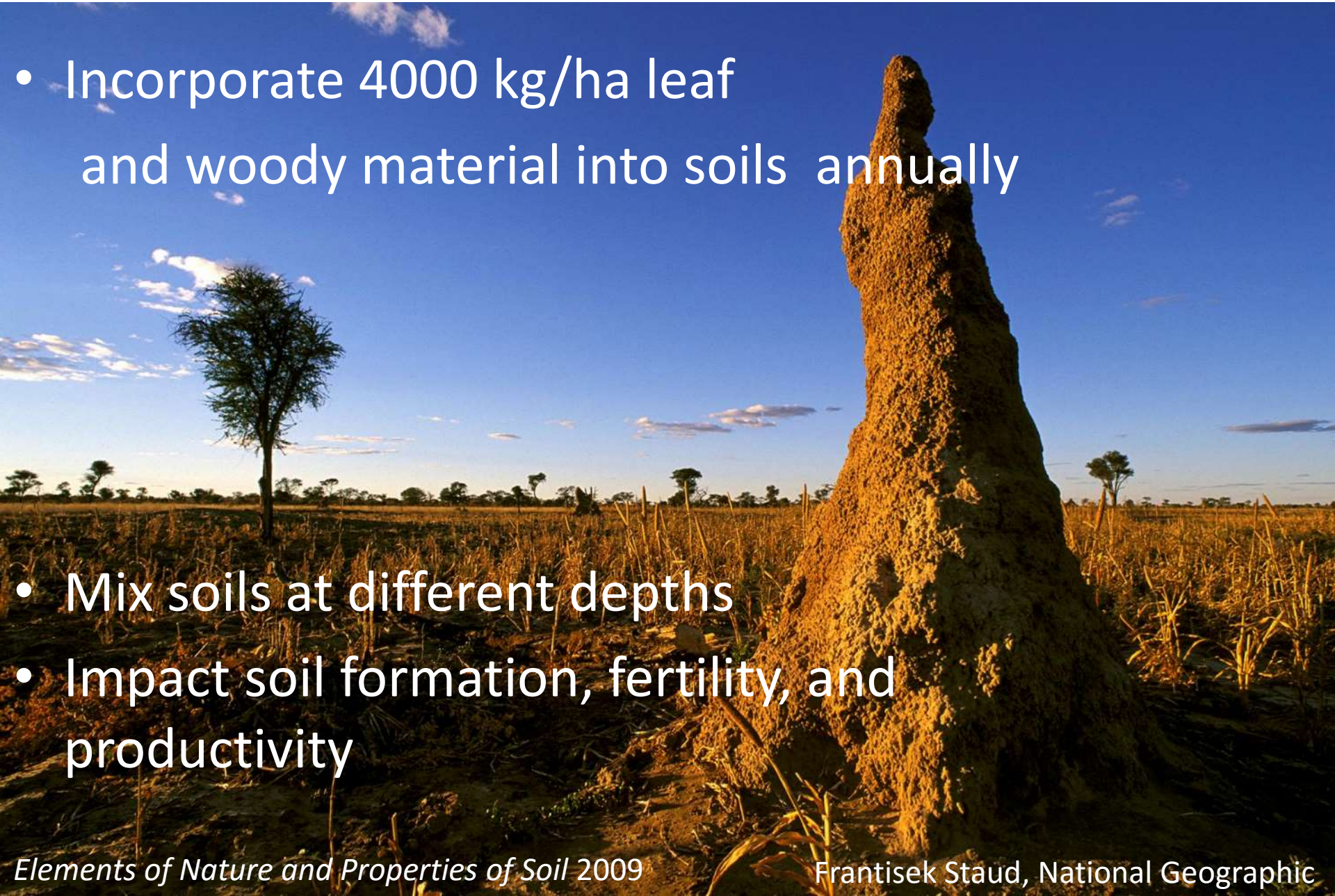


(Zimmerman et al. 1982)

Ecosystem Engineers: Termites

Region	Termites/square meter	% Biomass consumed	Methane produced (in 10^7 metric tons)
Temperate Forest	600	7	4.6
Dry Savannah	861	13	2.3
Tropical moist forest	2813	41	17.3
Wet Savannah	4402	51	39.9

Ecosystem Engineers: Mound Termites



- Incorporate 4000 kg/ha leaf and woody material into soils annually
- Mix soils at different depths
- Impact soil formation, fertility, and productivity

Elements of Nature and Properties of Soil 2009

Frantisek Staud, National Geographic

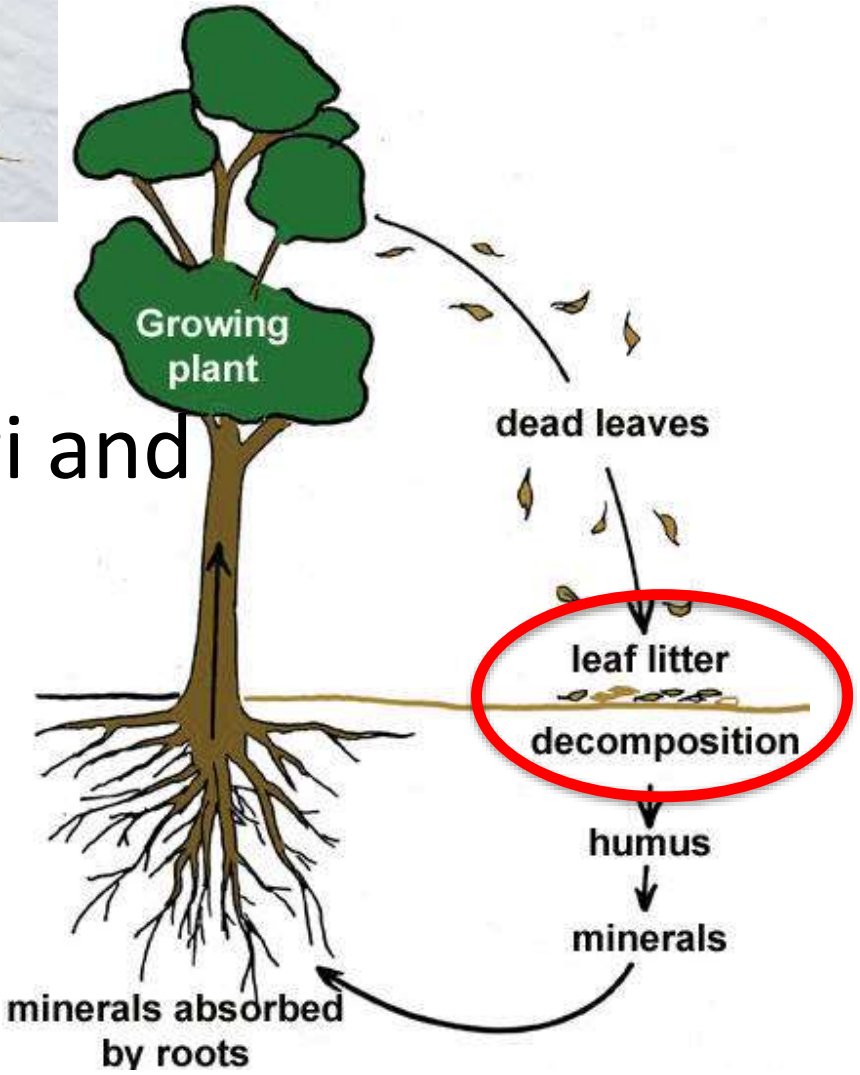
Ecosystem Services

Benefits humans derive from ecological processes

Ecosystem Services: Nutrient Cycling



- Increase surface area/accessibility to fungi and microbes
- Nutrients become bioavailable again



Ecosystem Services: Pollination

Animal pollination benefits:

- 90% of flowering plants --70% of major crops
- 1 of every three bites of food

(Ollerton et al. 2011, Klein et al. 2007)

Ecosystem Services: Pollination

Vast majority of animal pollination by bees

Ecosystem Services: Pollination

Vast majority of animal pollination by bees

- >20,000 spp.
- most nest underground

Solitary Bee Life Cycle

Foraging Habitat

Oviposition Habitat

Adult Bee
(above ground)

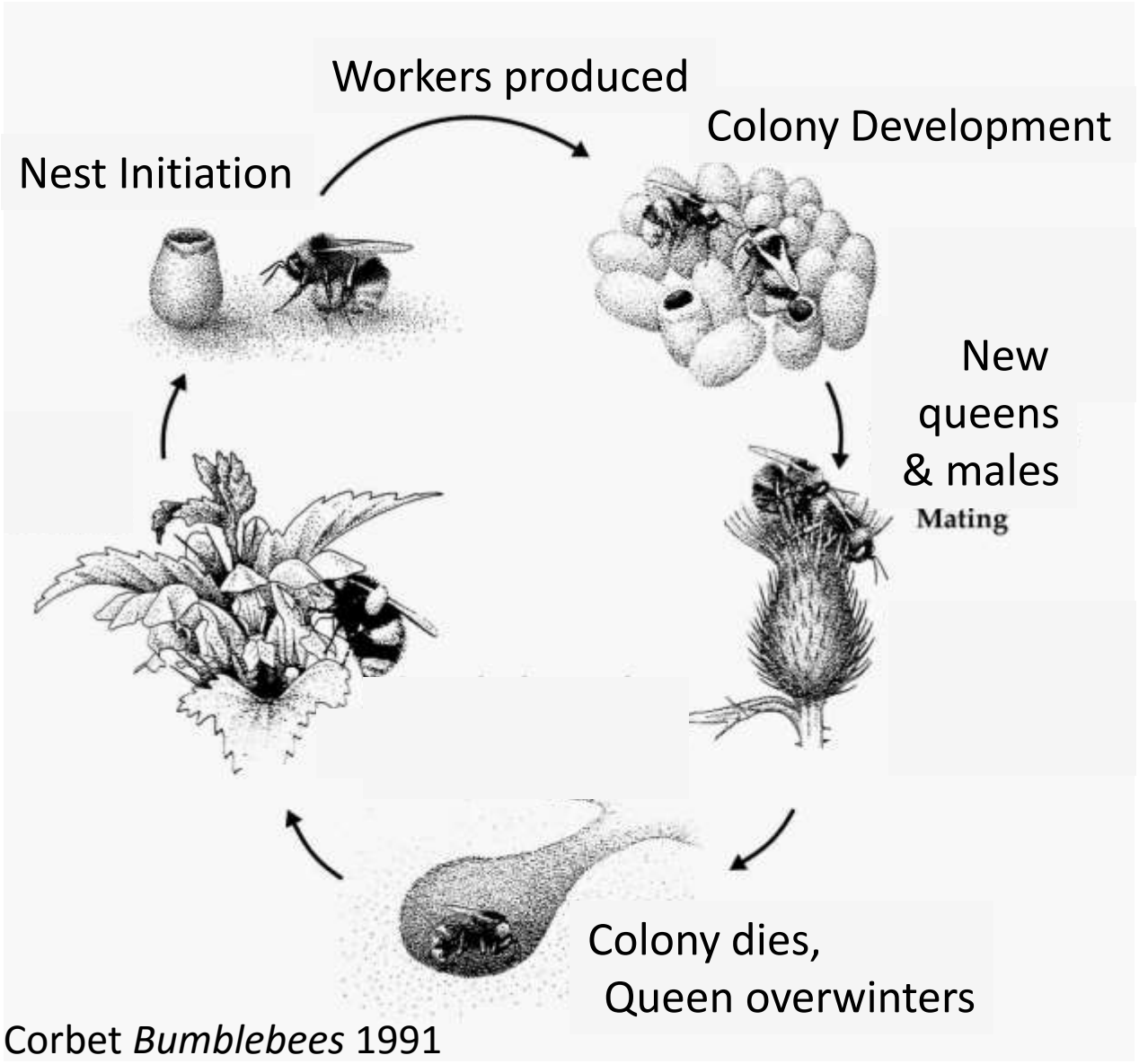
Developing Bee
(below ground)

Developmental
Habitat

Dennis L. Briggs

Eusocial Bee Life Cycle

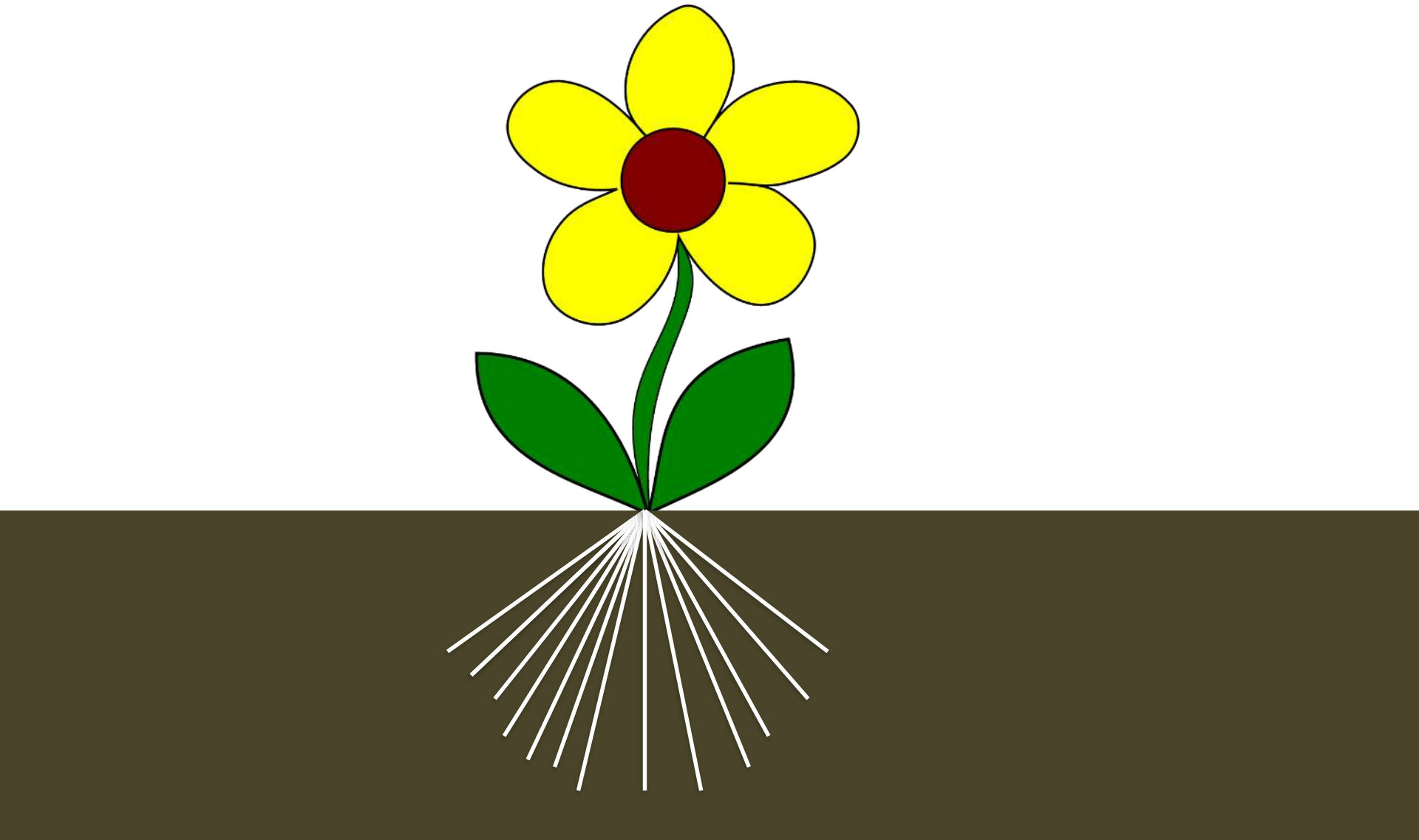
Early Spring



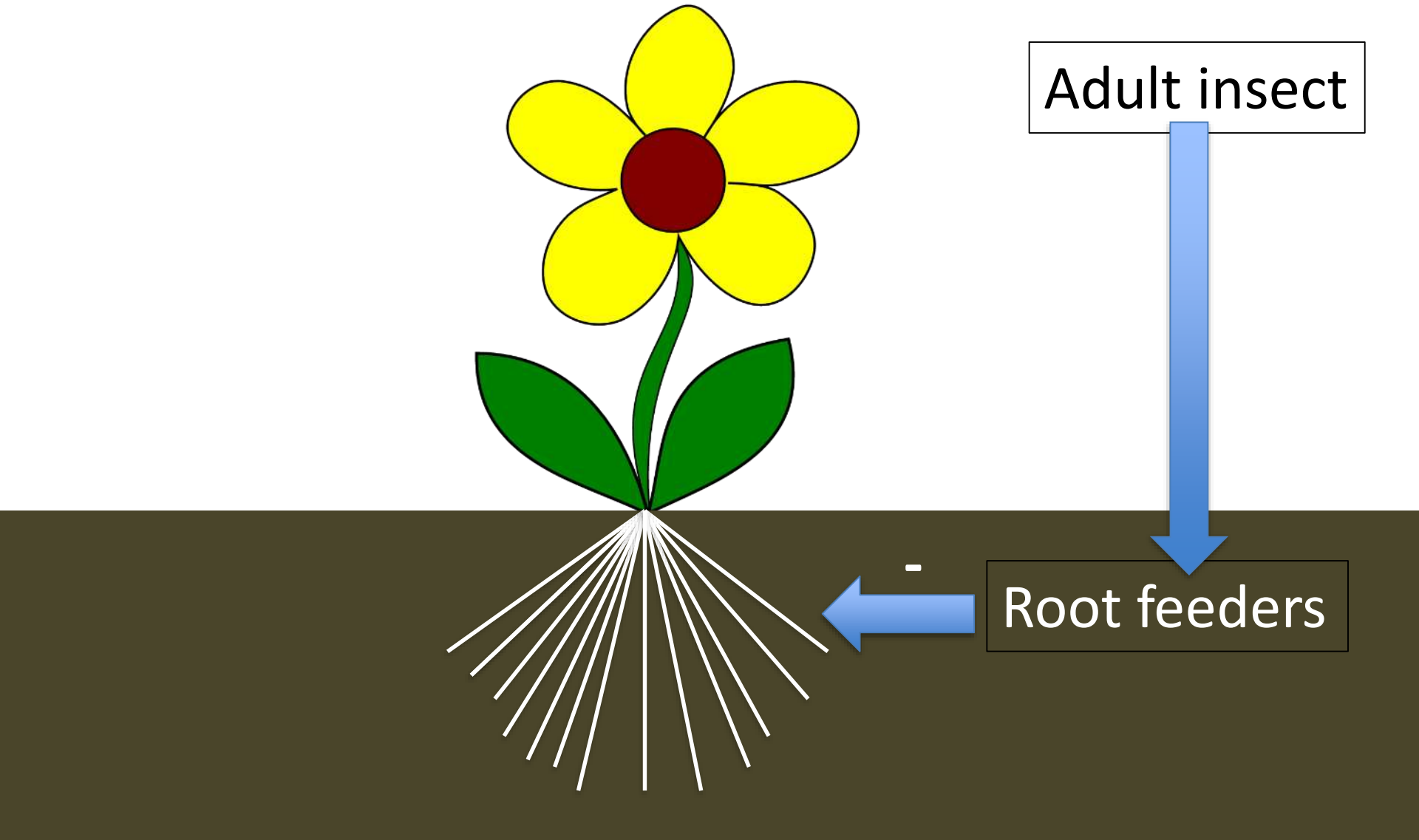
Late Summer

Prys-Jones and Corbet *Bumblebees* 1991

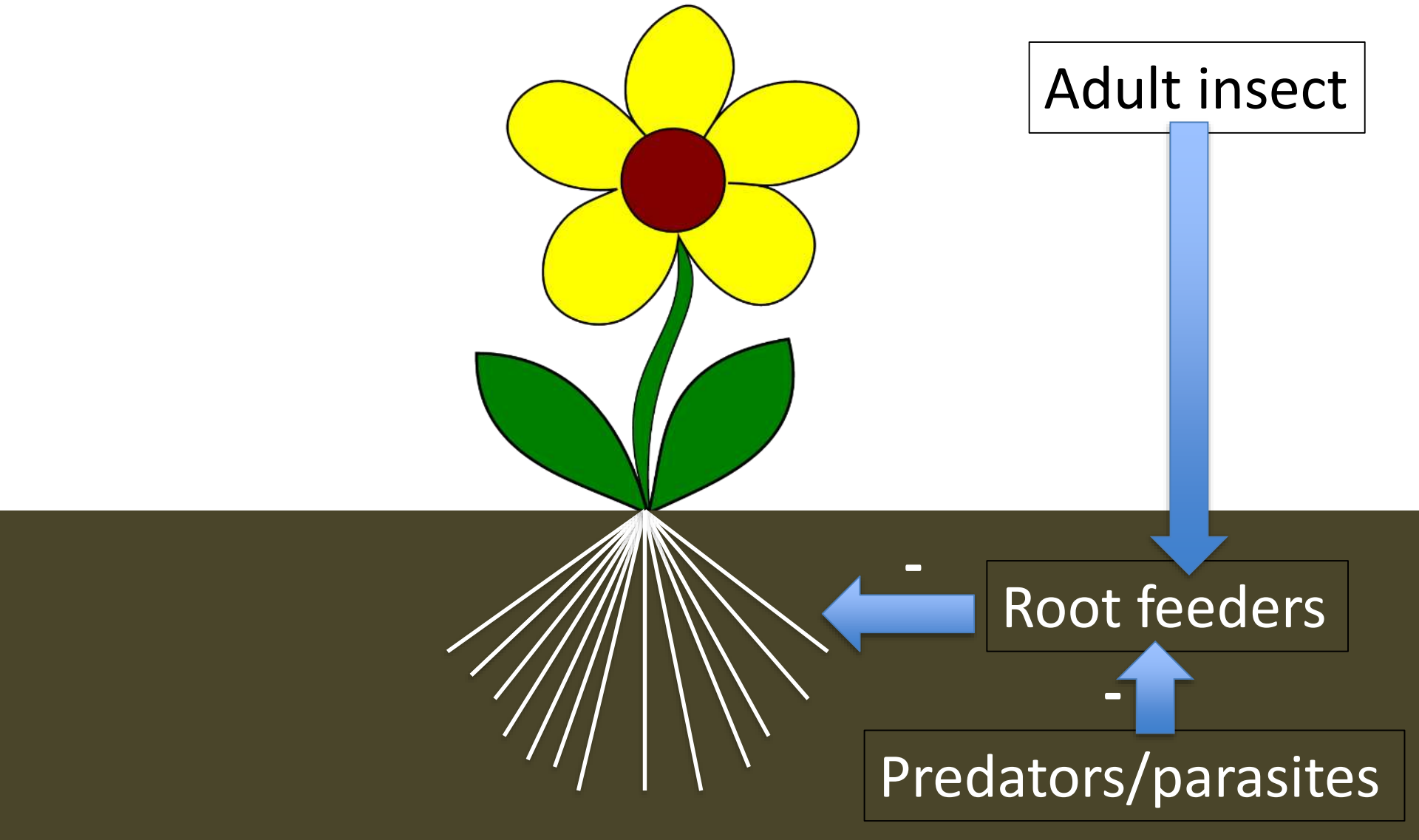
The Above/Below Ground Connection



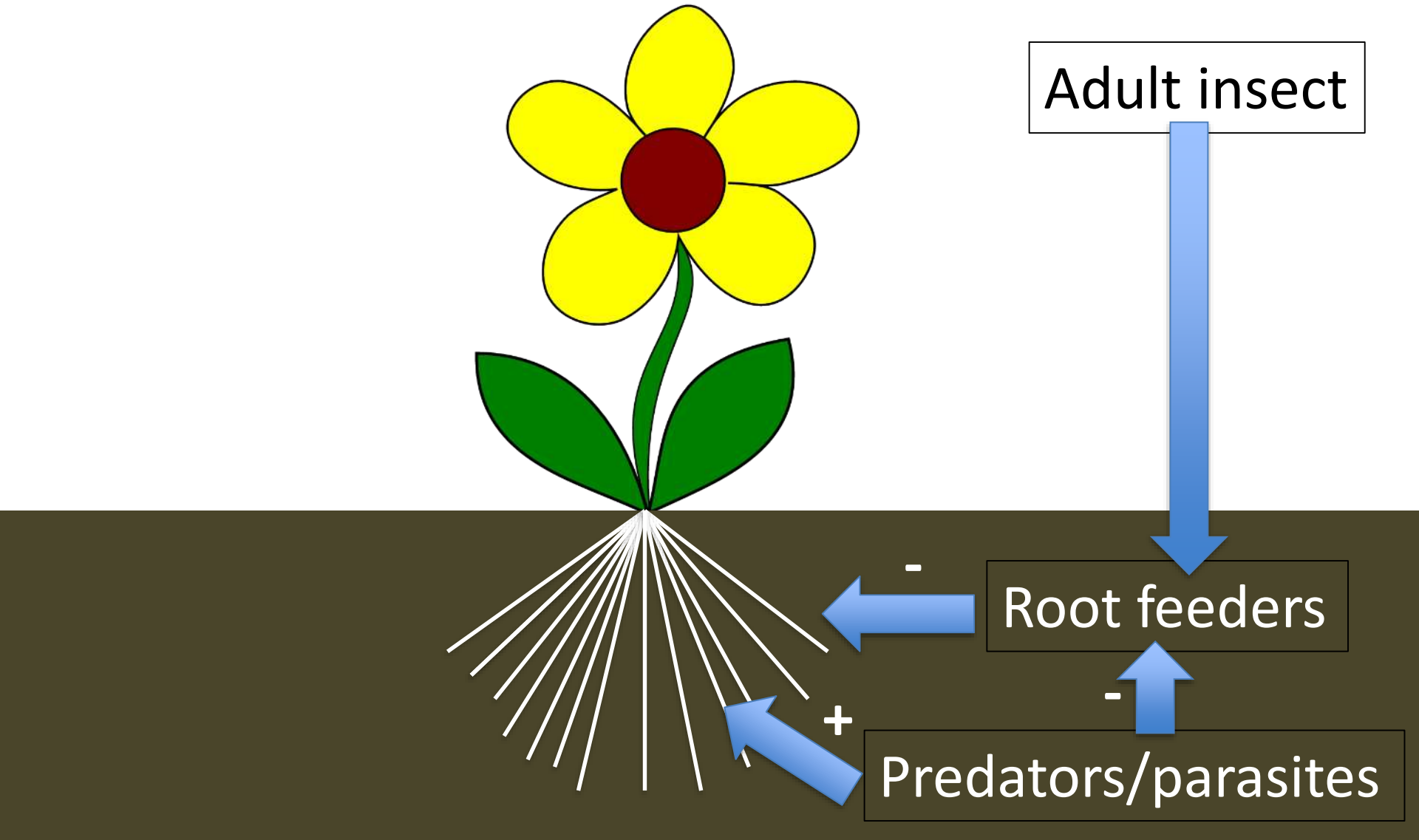
The Above/Below Ground Connection



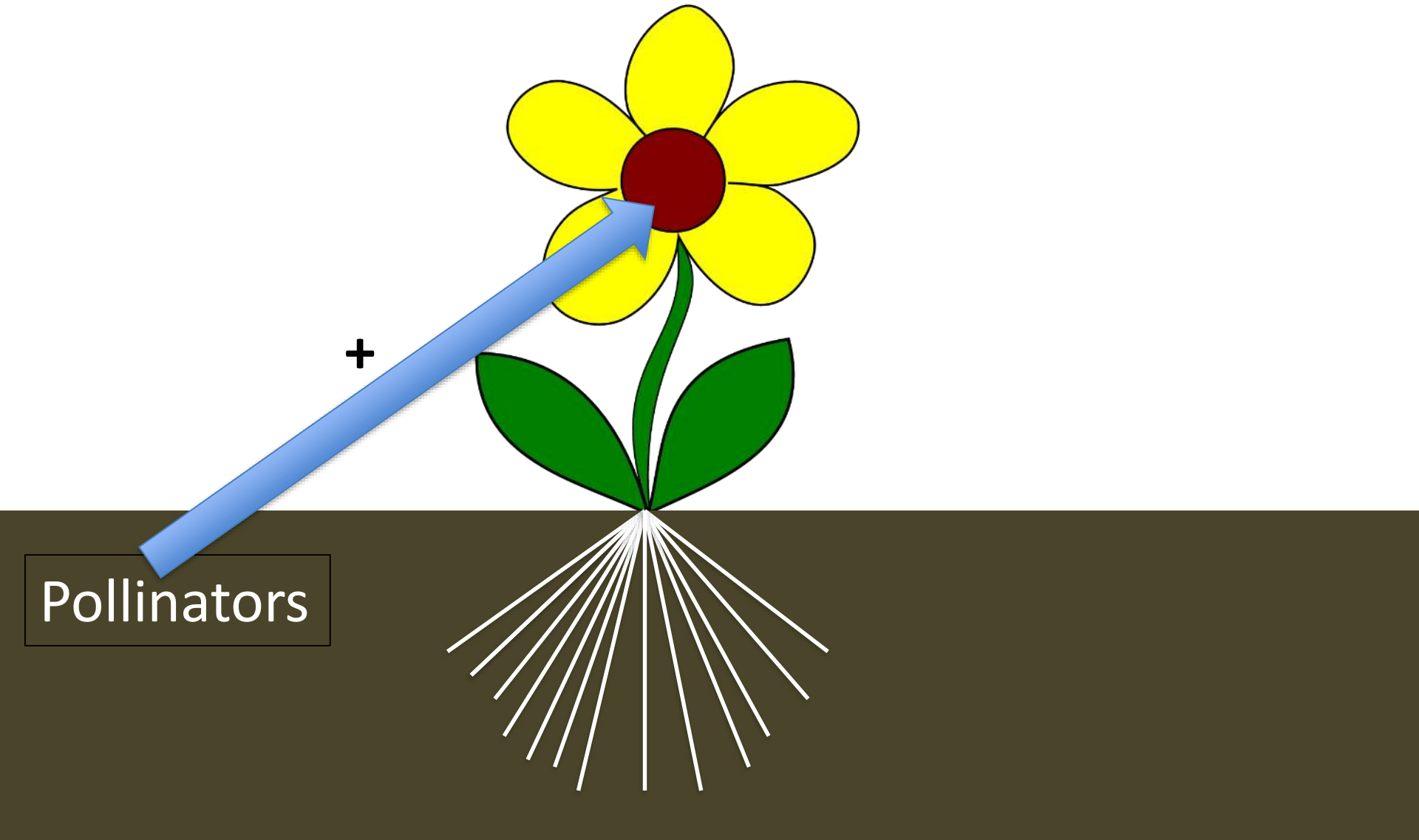
The Above/Below Ground Connection



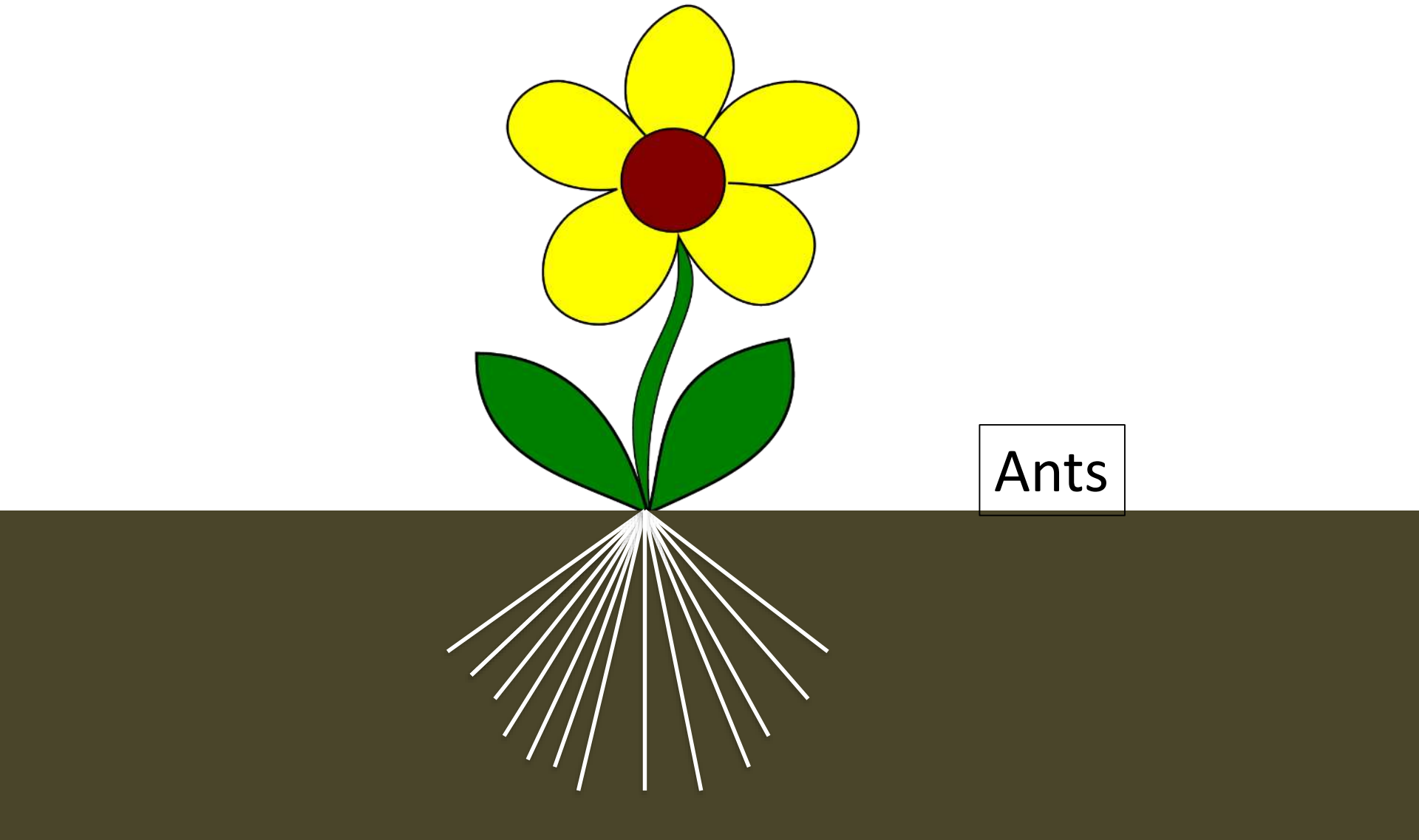
The Above/Below Ground Connection



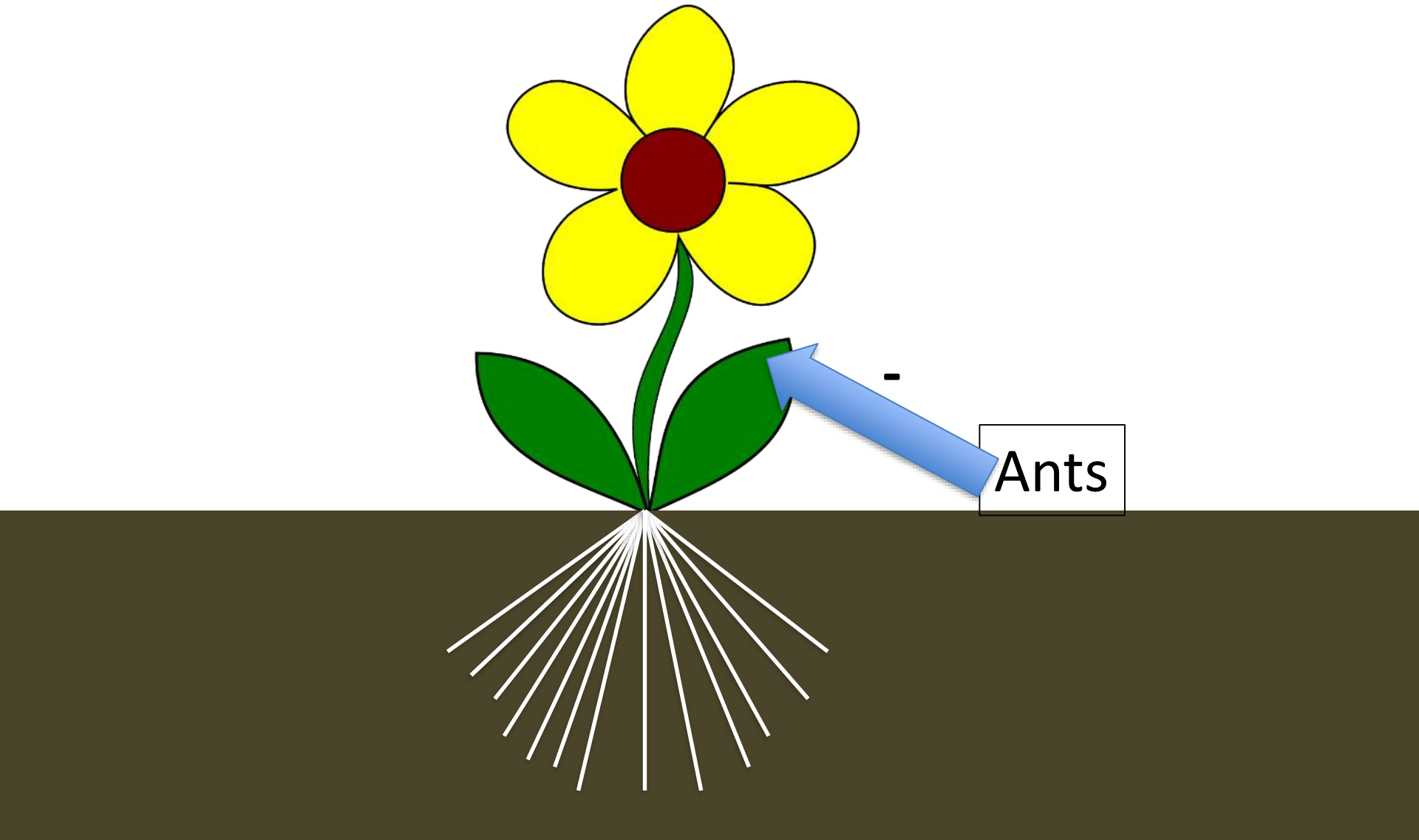
The Above/Below Ground Connection



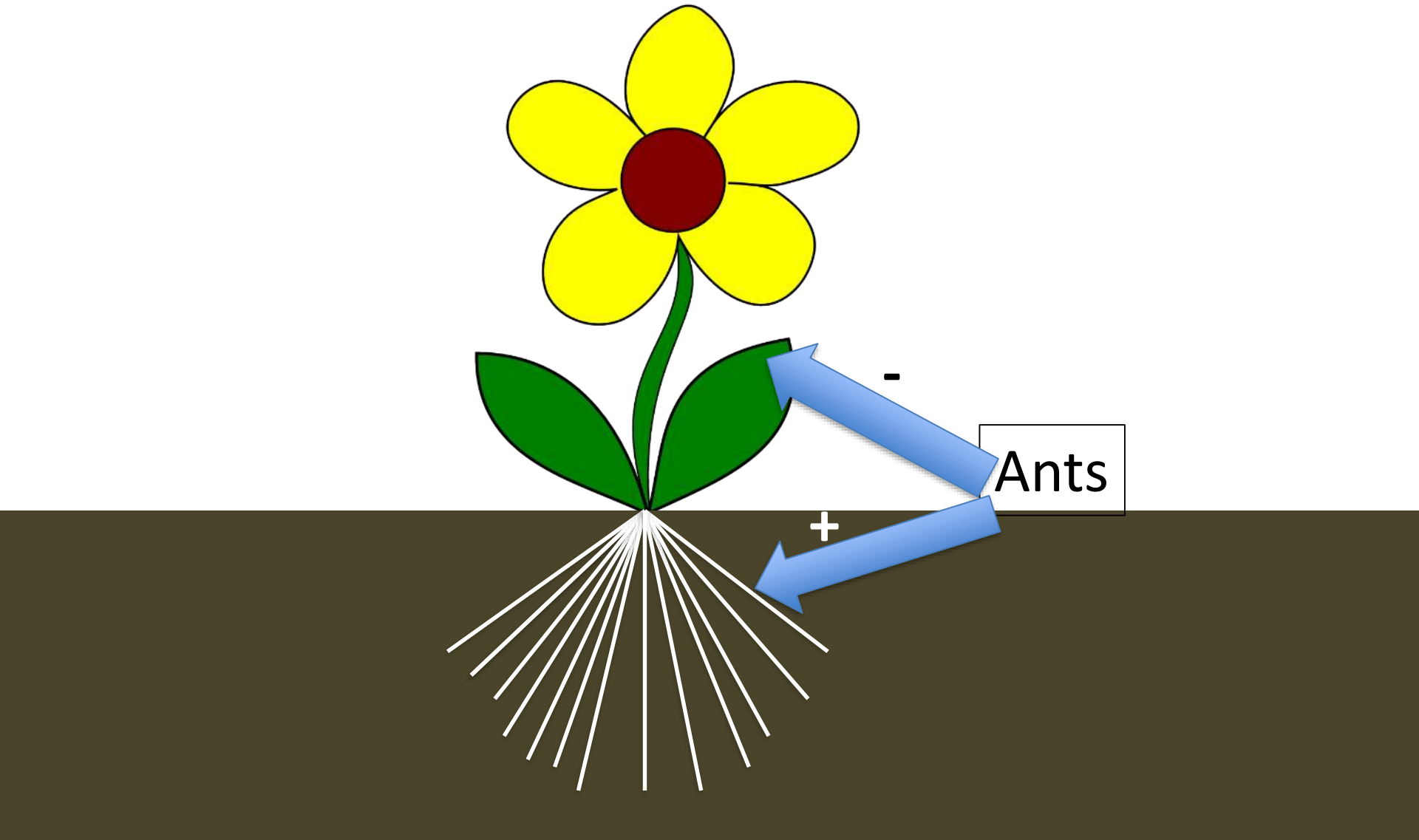
The Above/Below Ground Connection



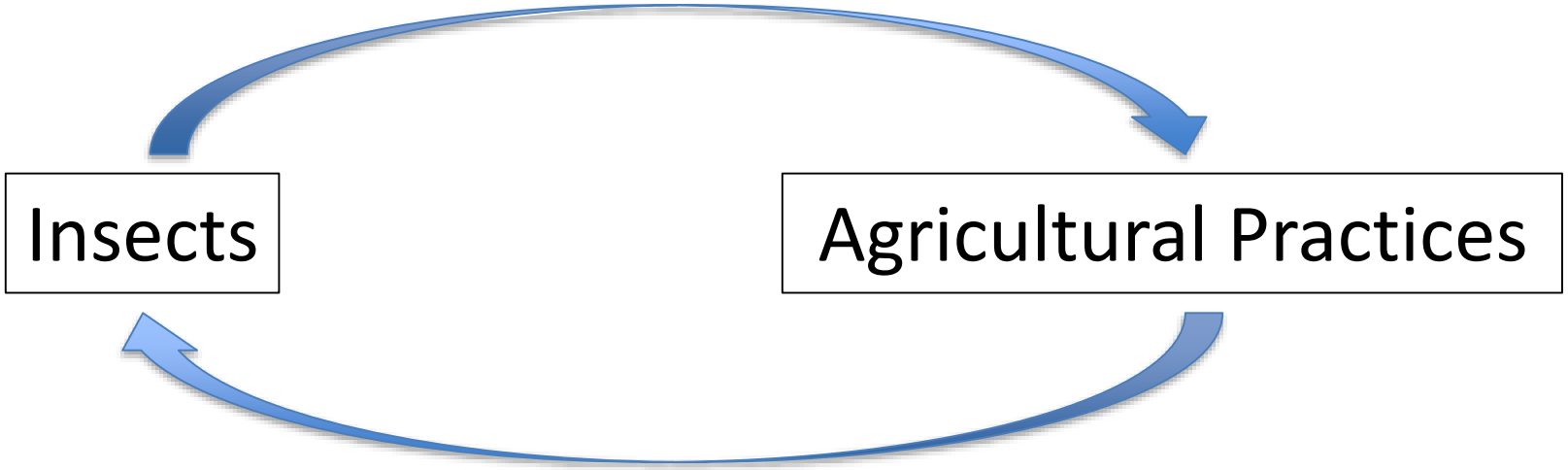
The Above/Below Ground Connection



The Above/Below Ground Connection



III. Soil Insects and Agriculture



Effects of Soil Insects on Agriculture

- Root pests

Root Pests

- Increased above-ground growth
- Loss of plant vigor
- Decreased yield
- Plant death


Siga 2015

Corn Rootworm

- Injured roots increase susceptibility to disease and water stress
- Decreased yield → >$1 billion annually (USA)


Scott Bauer 2013 USDA ARS

Pioneer website

(Gullan and Cranston *The Insects* 2011)

Effects of Soil Insects on Agriculture

- Root pests

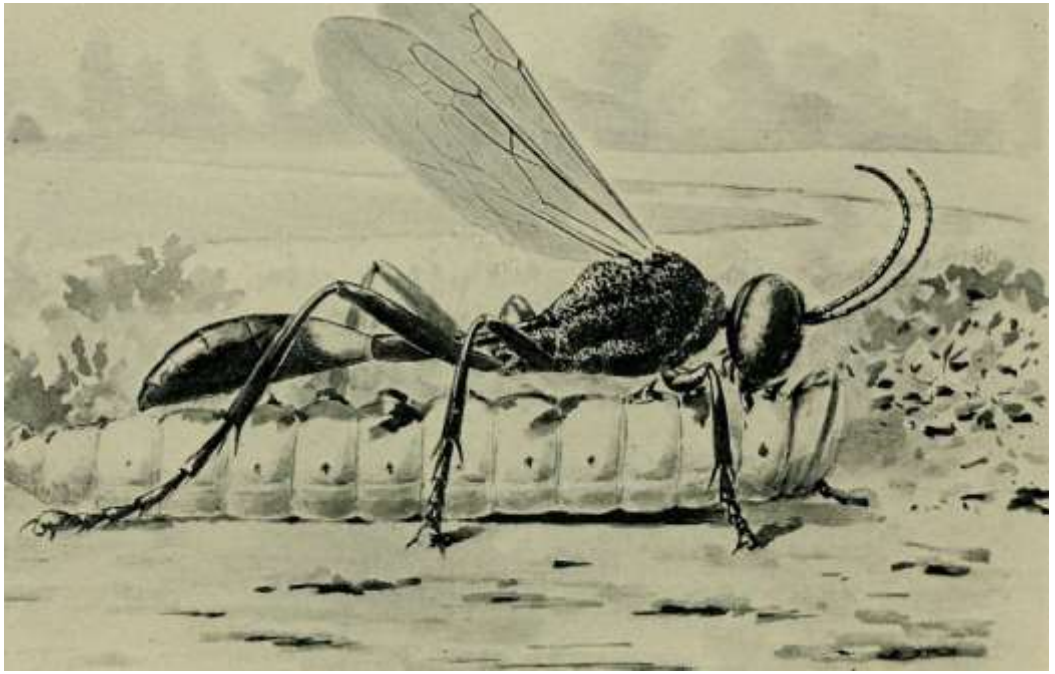
+ Pest predators

Rove Beetles (*Aleochara spp.*)

- Adults feed on small insects and mites that infest plants, root maggot eggs and larvae
- Larvae parasitize root maggot pupae

Digger Wasps

- Adults provision underground nests with aboveground pest insects (flies, caterpillars)
- Typically solitary, not aggressive like yellow jackets



Effects of Soil Insects on Agriculture

- Root pests

+ Pest predators

+ Ecosystem engineers

Ecosystem Engineers

- Facilitate soil nutrient cycling
- Improve soil hydrology
  - Drainage
  - Soil moisture
- Improve soil aeration
- Remove aboveground detritus

Dung Beetles and Livestock Health

Table 1. Total economic losses averted annually as a result of accelerated burial of livestock feces by dung beetles.

Billions of dollars

Cause of loss	Estimated losses: No dung beetle activity	Estimated losses: Current dung beetle activity	Losses averted
Forage fouling	0.65	0.53	0.12
Nitrogen volatilization	0.31	0.25	0.06
Parasitism	0.98	0.91	0.07
Pest flies	1.83	1.70	0.13
Total losses averted			0.38

(Losey and Vaughan 2006)

Effects of Soil Insects on Agriculture

- Root pests

+ Pest predators

+ Ecosystem engineers

+ Pollinators

(Gallai et al. 2009)

Economic Value of Pollinators

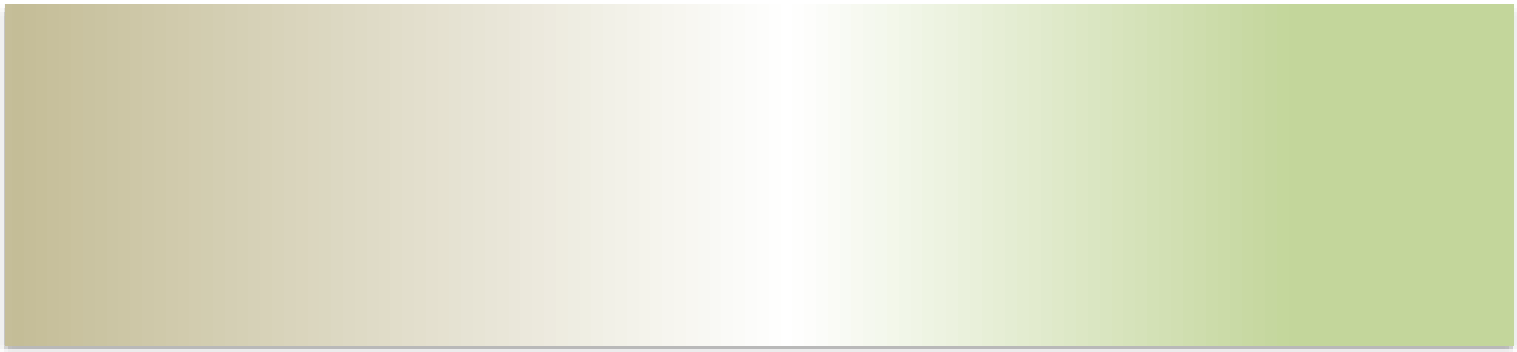
- ~$186 billion worldwide/year
- 9.5% of total food production

Effects of Agriculture on Soil-Nesting Bees

- Tillage
- Irrigation
- Pesticide Application

Effects of Disturbance on Bee Nesting

Potential Nesting Habitat

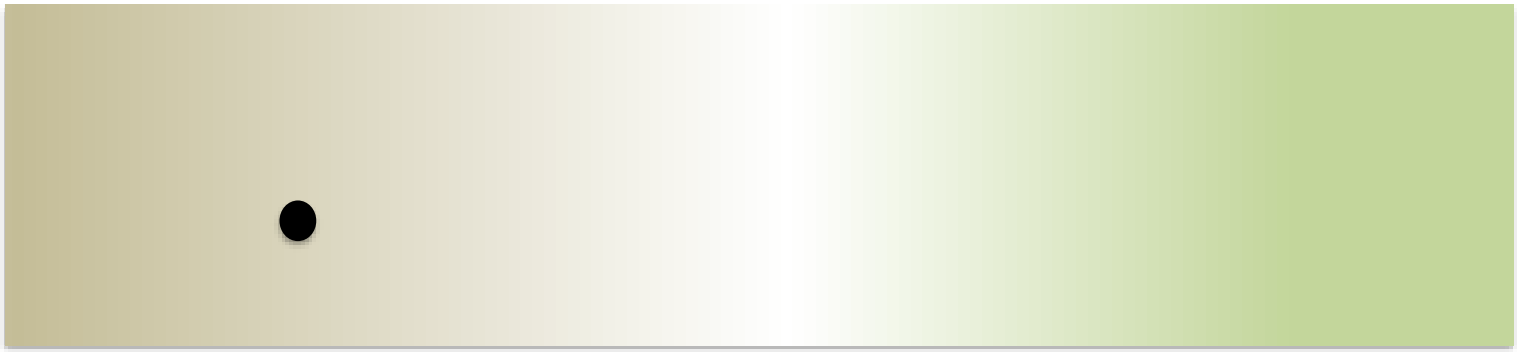


Cues

(habitat quality)

Steps to Reproductive Success

Potential Nesting Habitat



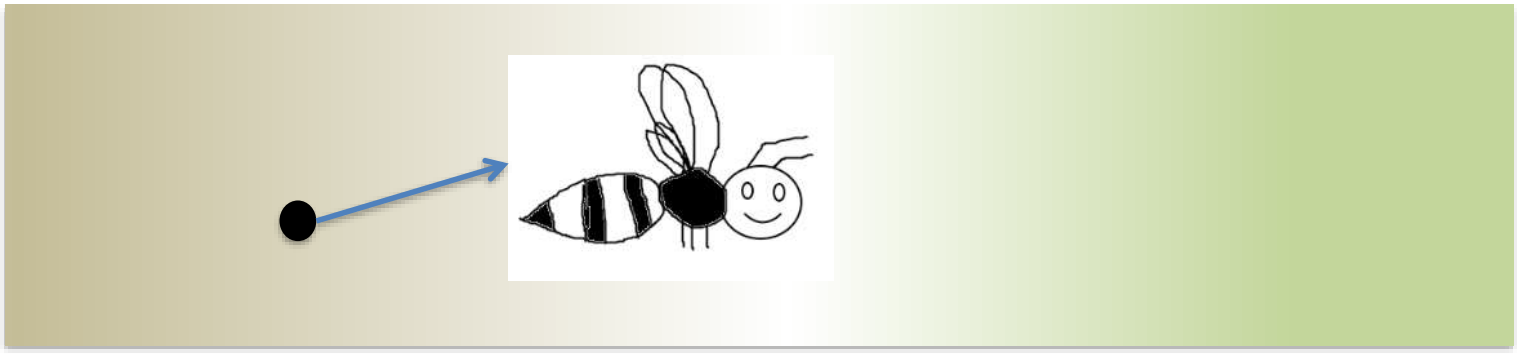
Cues → Nest Initiation

↕

(habitat quality)

Steps to Reproductive Success

Potential Nesting Habitat



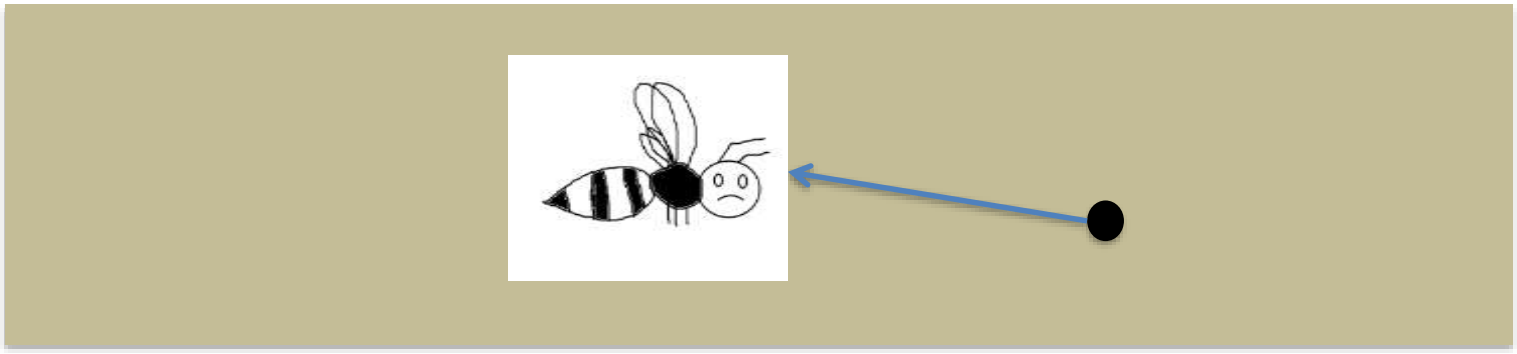
Cues → Nest Initiation → Reproductive output

↕

(habitat quality)

Nesting and Disturbance

Potential Nesting Habitat



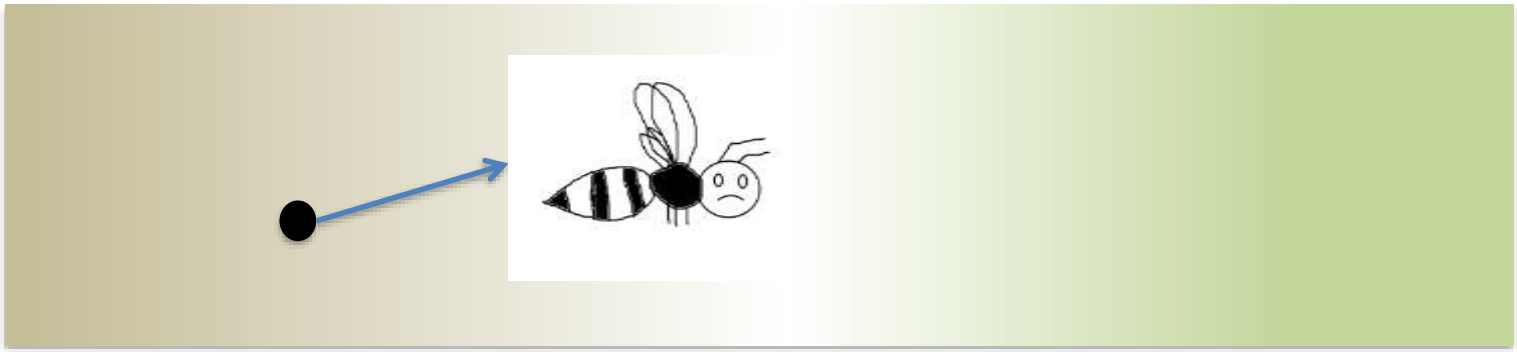
Cues → Nest Initiation → Reproductive output

Disturbance

(habitat quality)

Nesting and Disturbance

Potential Nesting Habitat



Cues → Nest Initiation → Reproductive output

(habitat quality)

Disturbance

(Scampavia, unpublished)

Tillage, Irrigation, and Bee Nesting

(Scampavia, unpublished)

Tillage, Irrigation, and Bee Nesting

- How do tillage and irrigation application affect a female bee's decision on where to nest?
- How does this affect the production of offspring?

(Scampavia, unpublished)

Treatment Groups

Treatment	TIE	TI	T	I	Ctrl
Tilled	X	X	X		
Irrigated	X	X		X	
Esfenvalerate	X				

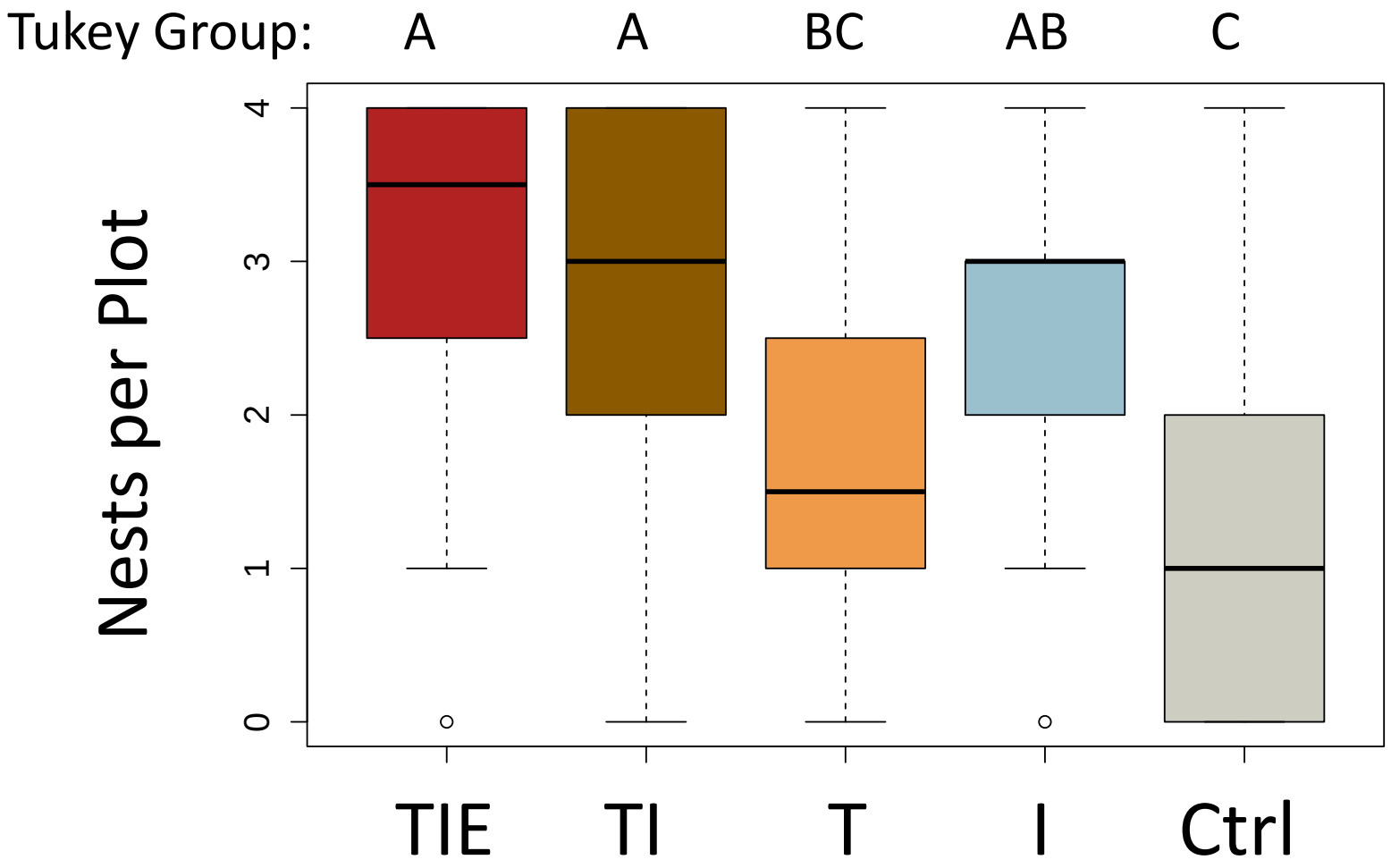
(Scampavia, unpublished)

Field Site

Sweat Bees- Social Nests

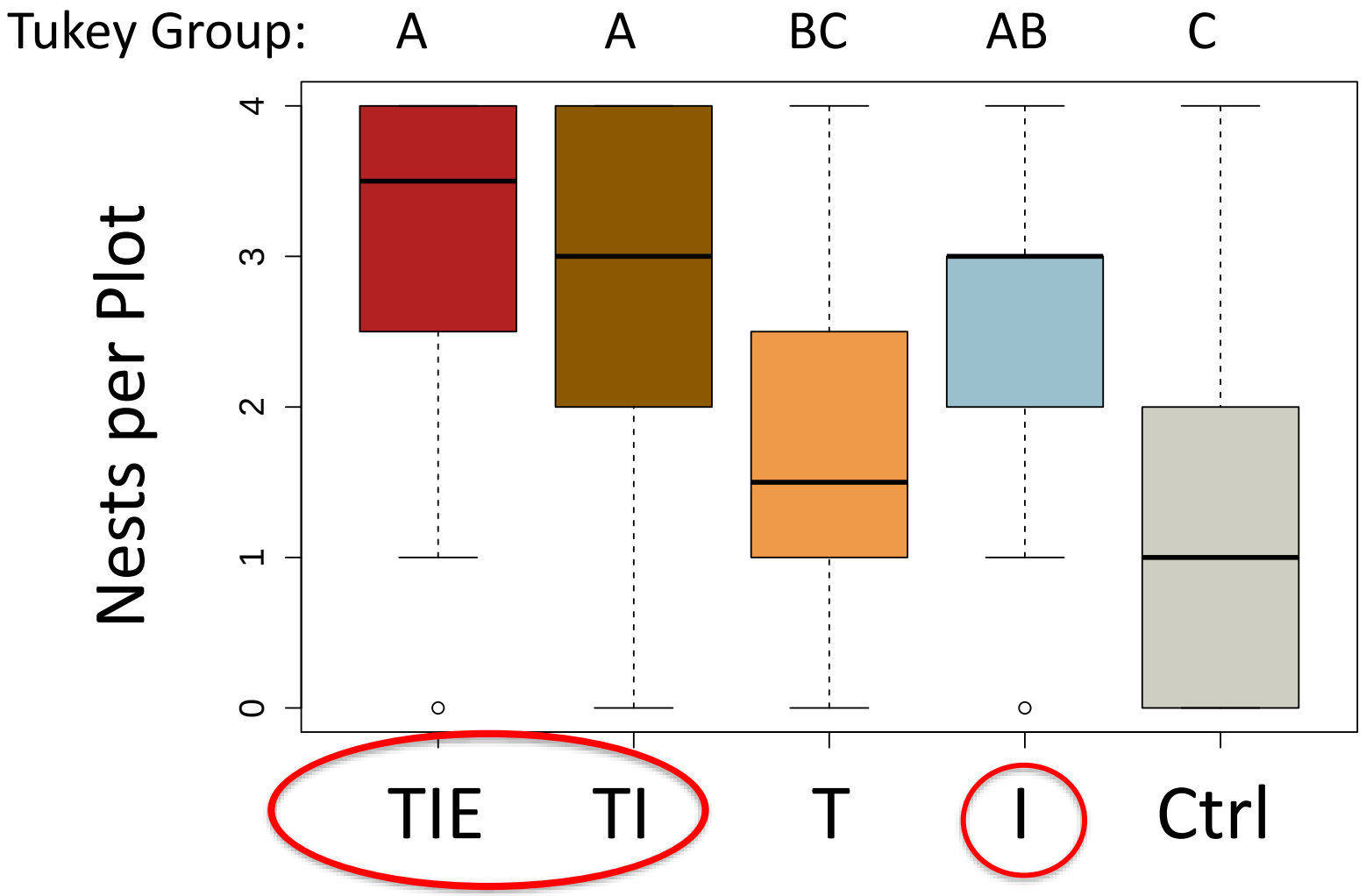
(Scampavia, unpublished)

Nest Initiation by Treatment



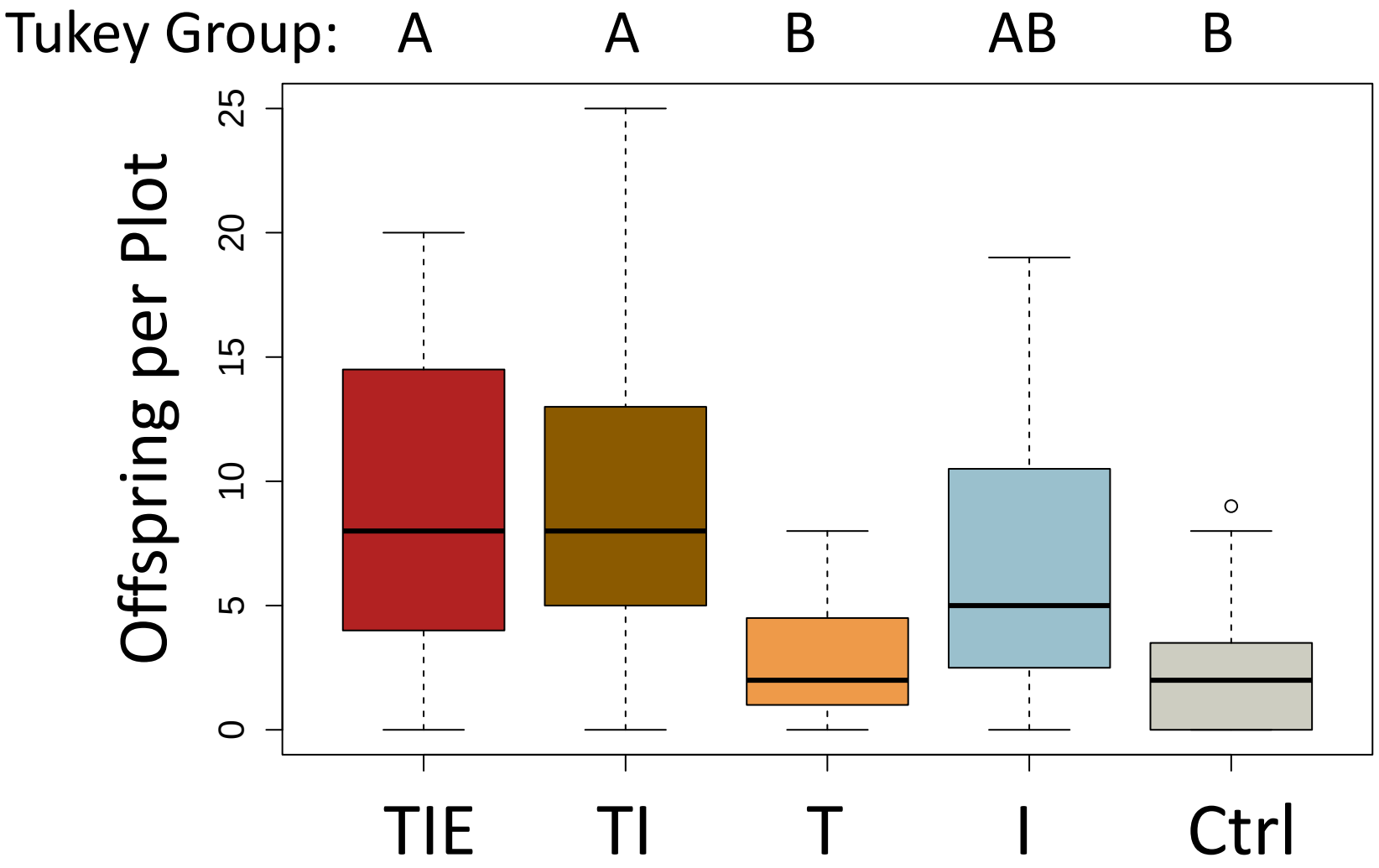
(Scampavia, unpublished)

Nest Initiation by Treatment



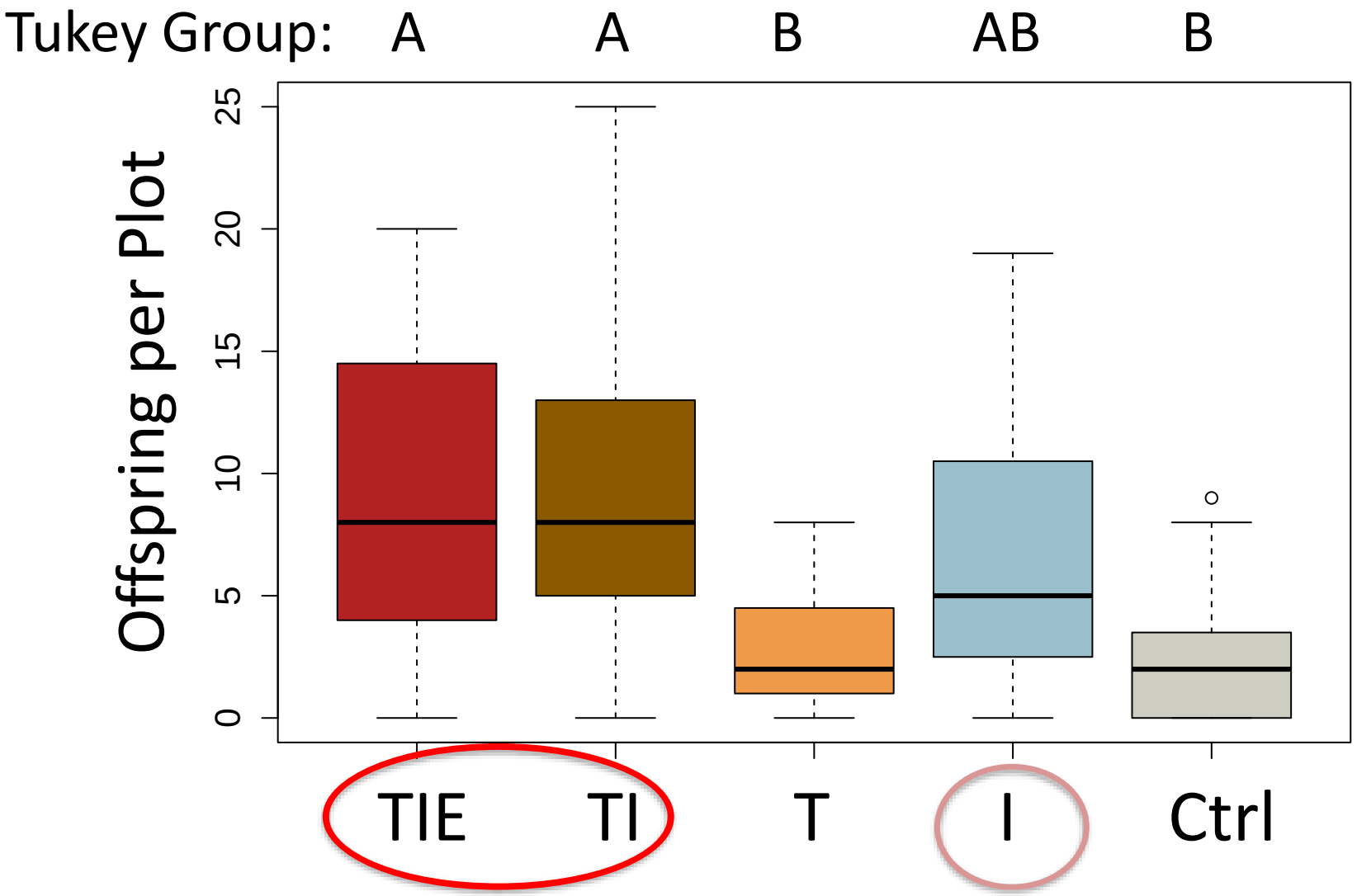
(Scampavia, unpublished)

Sweat Bee Productivity



(Scampavia, unpublished)

Sweat Bee Productivity



(Scampavia, unpublished)

Conclusions:

- Irrigation positively influenced nest initiation.
- Tillage and irrigation combined positively influenced sweat bee offspring production.

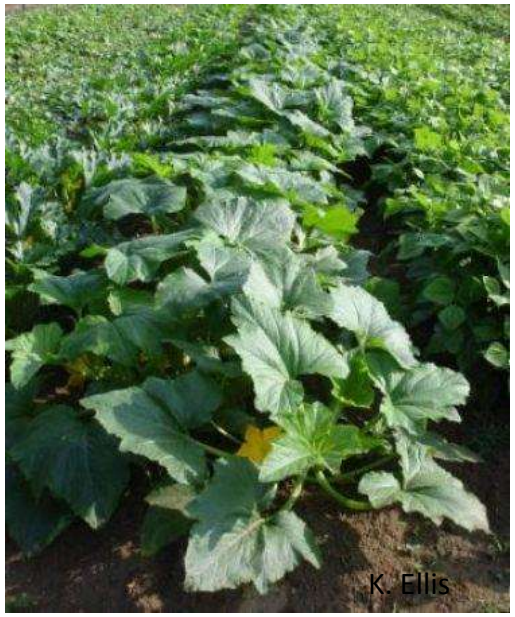
BUT…

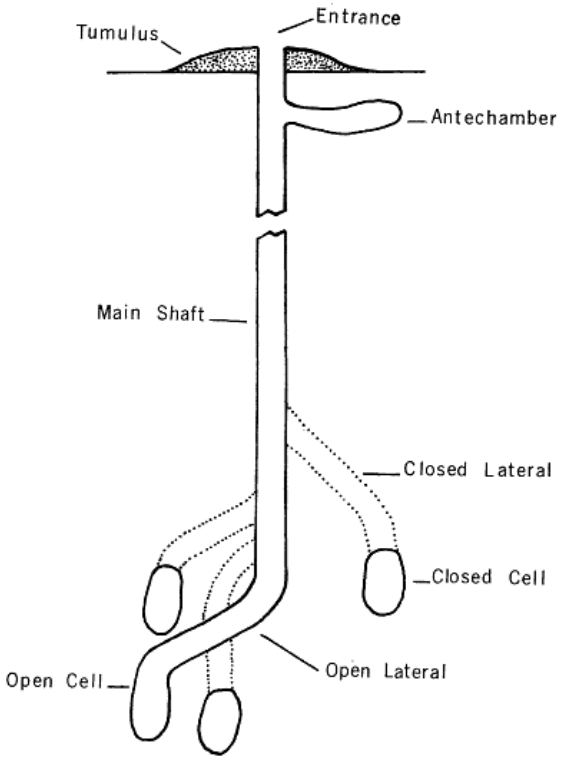
An ecological trap?

- Ground nesting bees preferentially nest and perform best in soil types found in actively farmed fields
- Subject to other practices
  - Late season tillage
  - Pesticide application
  - Fertilizer Application

(Ullmann et al. 2016)

Tillage and Squash Bee Survival

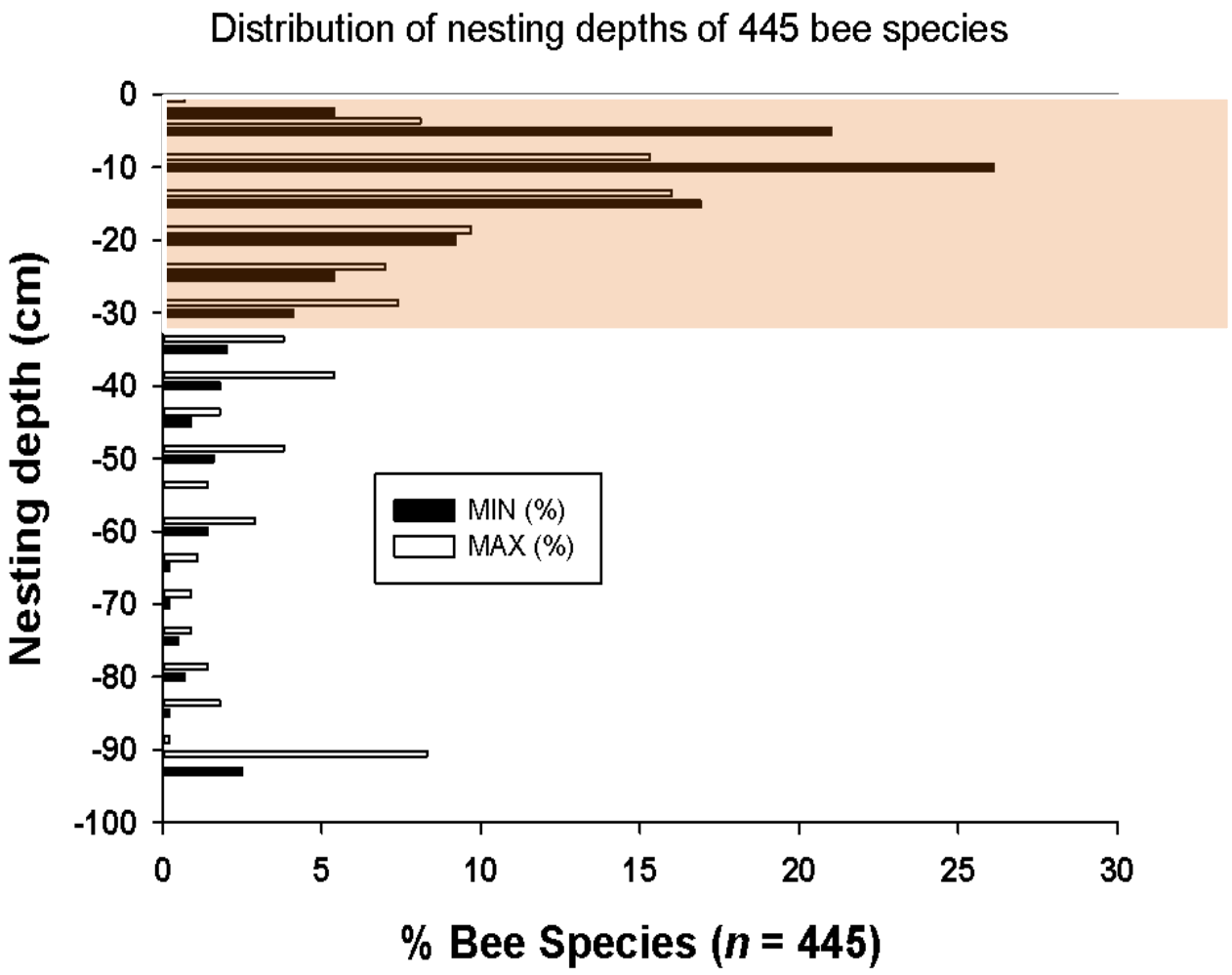




Hurd *et al.* 1974, Matthewson 1968

(Ullmann 2016)

Many Bees Nest in Tillage Zone



Tilling Zone

(Cane and Neff 2011)

(Ullmann et al. 2016)

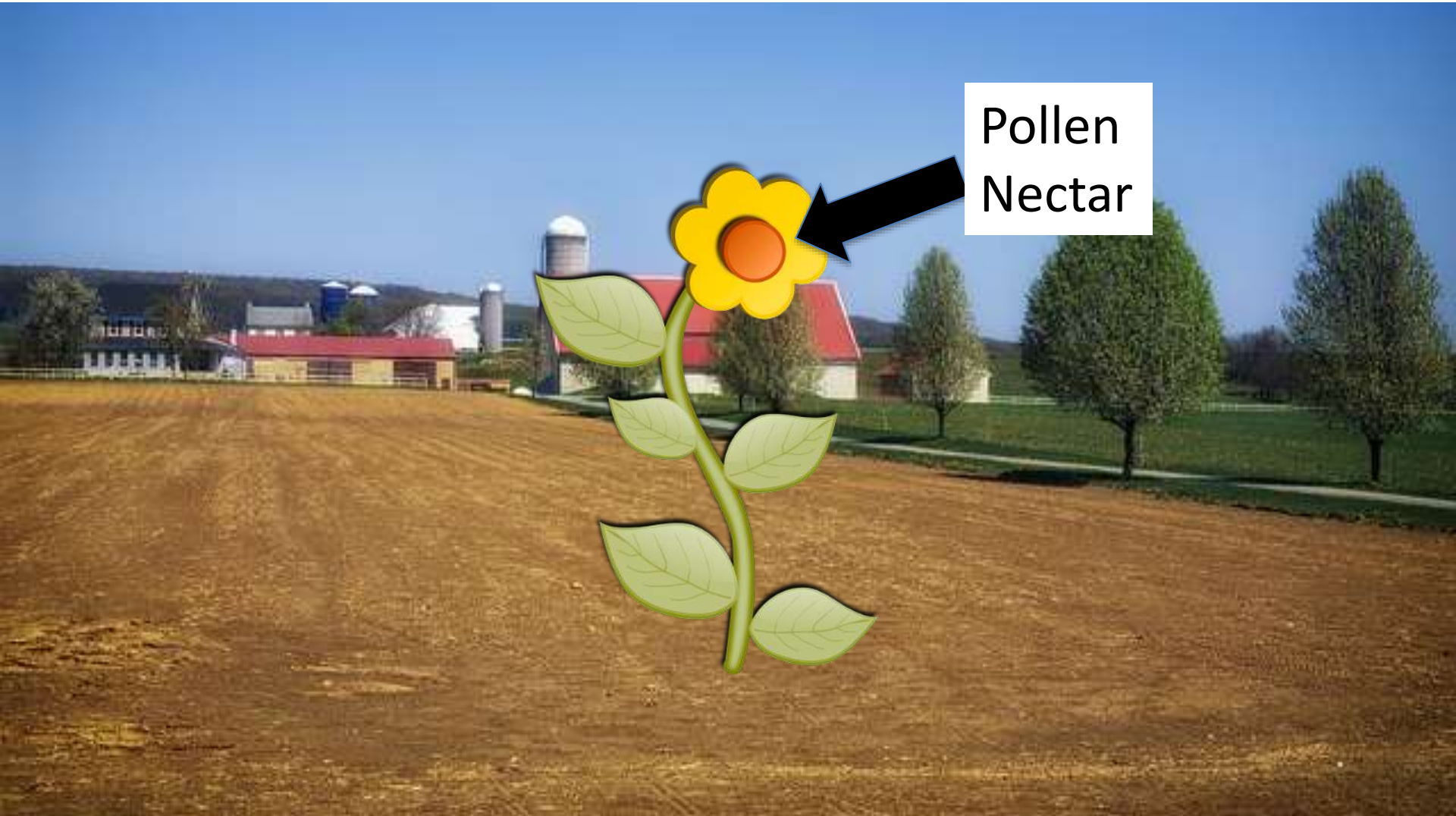
Study Site

(Ullmann et al. 2016)

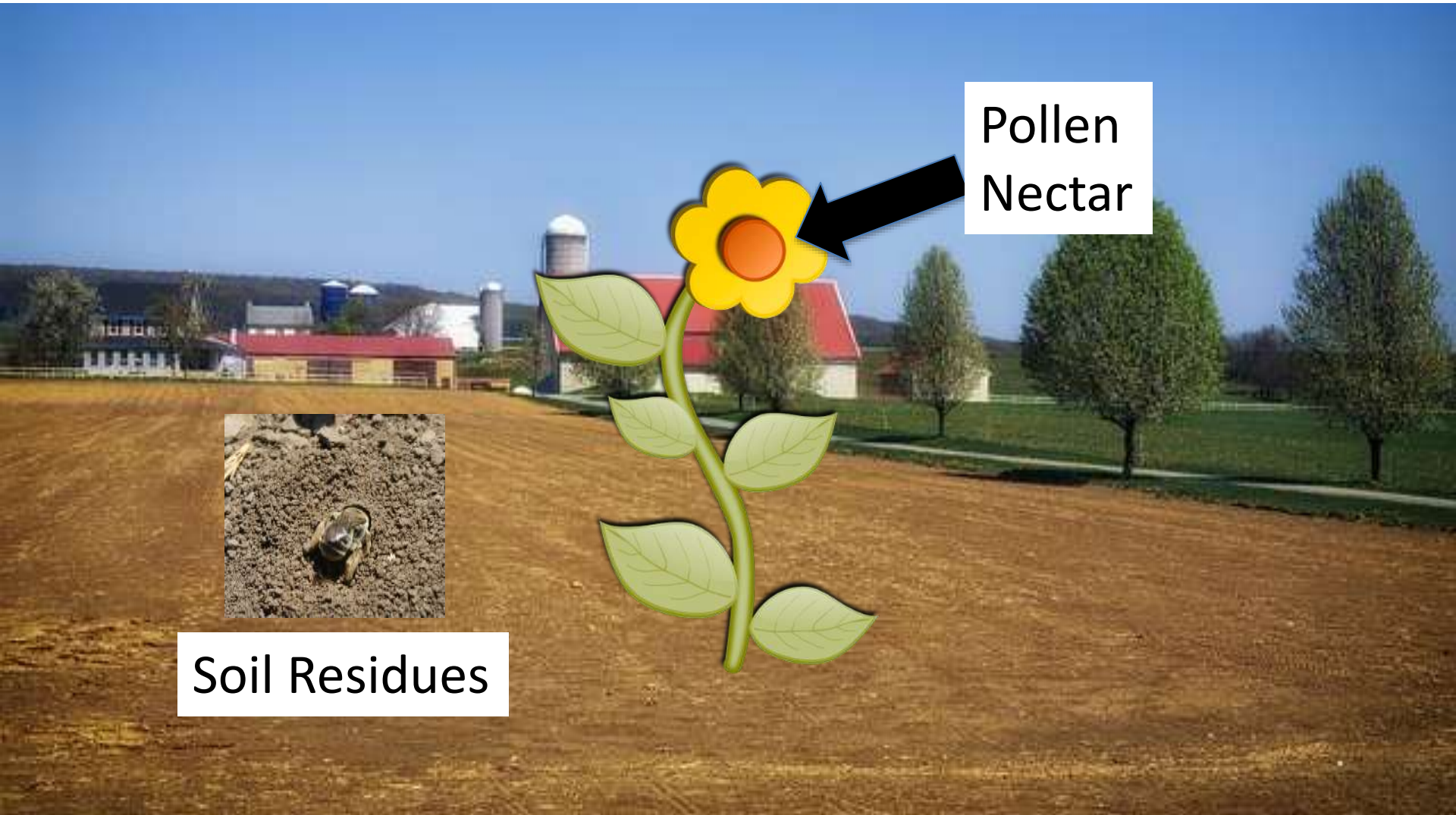
Conclusions

- Some evidence negative effect on survival (still some bees survive)
- Strong evidence tilling → delayed emergence subsequent year

Bees and Pesticides in the Soil



Bees and Pesticides in the Soil



(Goulson 2013)
(Rundlof et al. 2015)

Neonicotinoid Seed Treatments

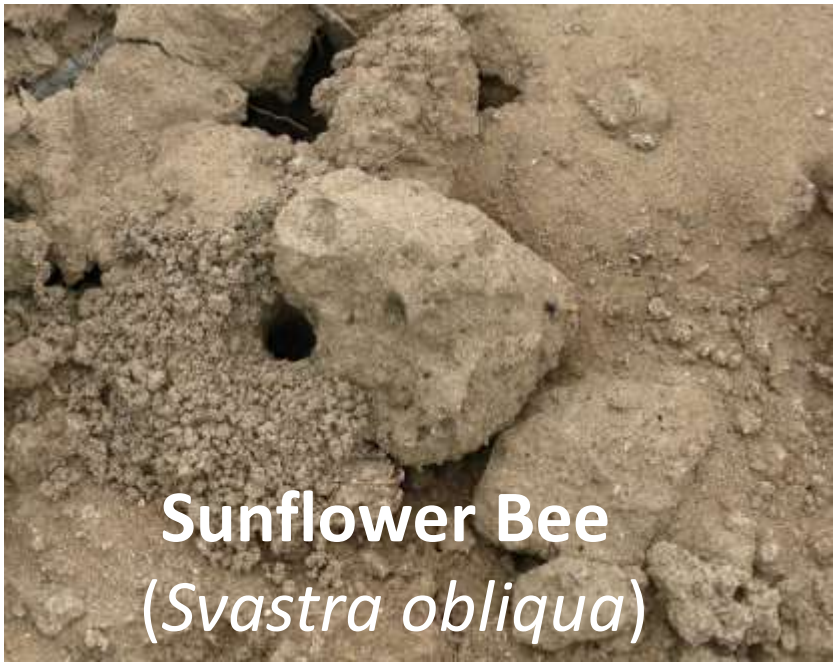
- >90% active ingredient in soil
- Soil half life 200 - >1000 days
- Neonicotinoid + pyrethroid seed treatment in oilseed rape reduced wild bee density, solitary bee nesting

IV. Protecting Soil Nesting Bees

(Ullmann et al. unpublished)
(Scampavia unpublished)

Identify and protect existing bee nests

Identify and Protect Existing Nests



Roger Ruston 2016

Identifying Nest Aggregations

Minimize soil disturbance

- Frequent tilling
- Deep tilling
- Hot fires
- Heavy grazing

Avoid tilling during bee development

Bee Species	J	F	M	A	M	J	J	A	S	O	N	D
Colletes inaequalis												
Andrena spp												
Augochlora pura												
Halictus spp												
Lasioglosum spp												

= Flight period- tilling ok

= Developmental period- avoid tilling

(Adapted from Javorek, Agriculture Canada)

Keep soils moist, but avoid pooling water

Abhiriksh 2016

Create Nesting Habitat

- Protect natural areas with minimal disturbance (hedgerows)
- Create patches of open, bare ground for bees to nest
- Set aside and protect small patches of ground representing different soil types

Create Nesting Habitat

Create Nesting Habitat

Some bees need bare vertical soil banks or berms

Thanks!

mrscampavia@ucdavis.edu
diadasia.wordpress.com