How Pesticides Impact Bees

THE OHIO STATE UNIVERSITY

COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

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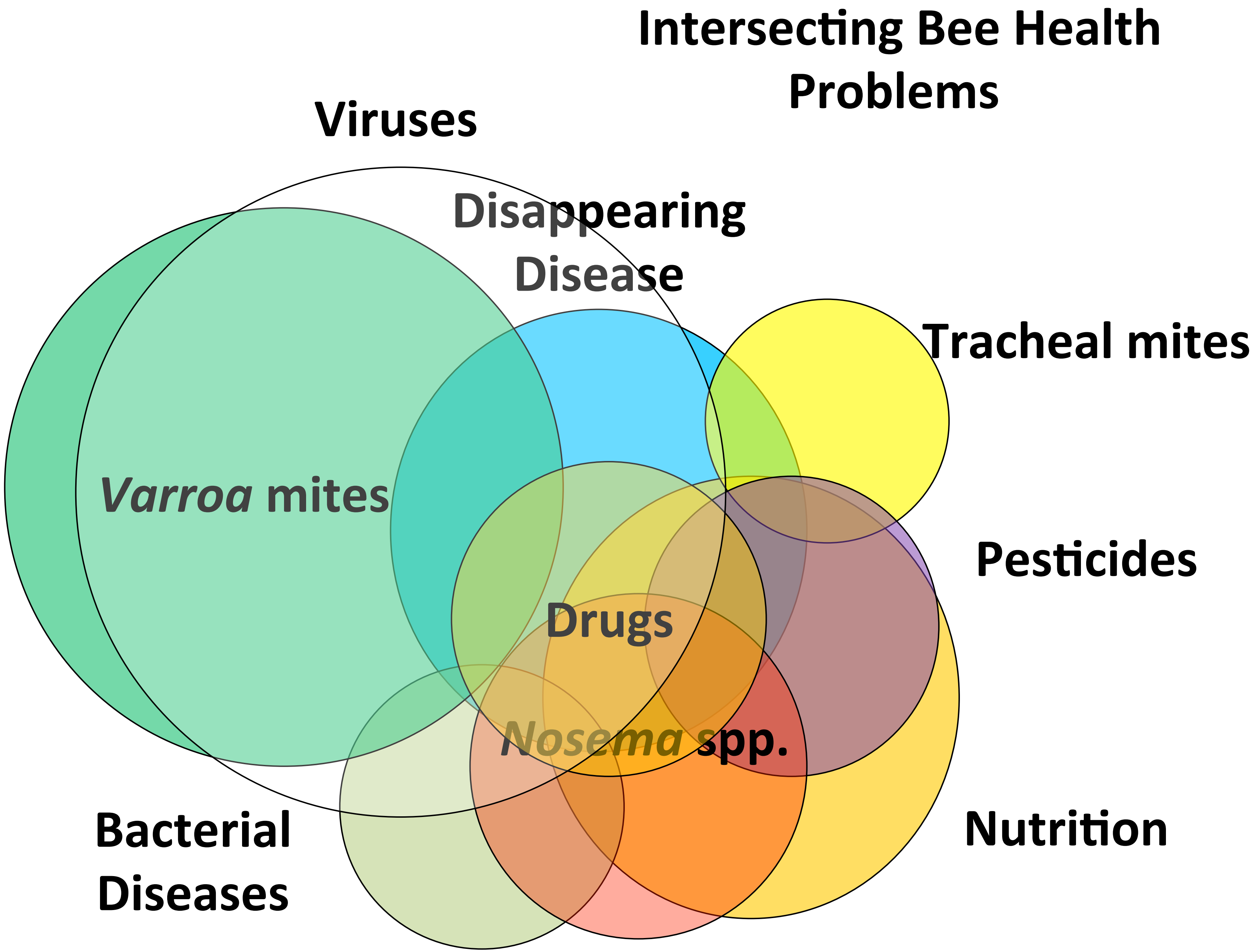
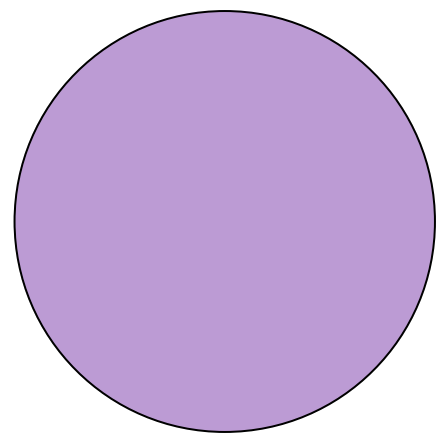

Intersecting Bee Health Problems
Viruses
Disappearing Disease
Tracheal mites
Varroa mites
Pesticides
Drugs
Nosema spp.
Bacterial Diseases
Nutrition

How much of a problem are pesticides?



Pesticides

What is a "pesticide"?

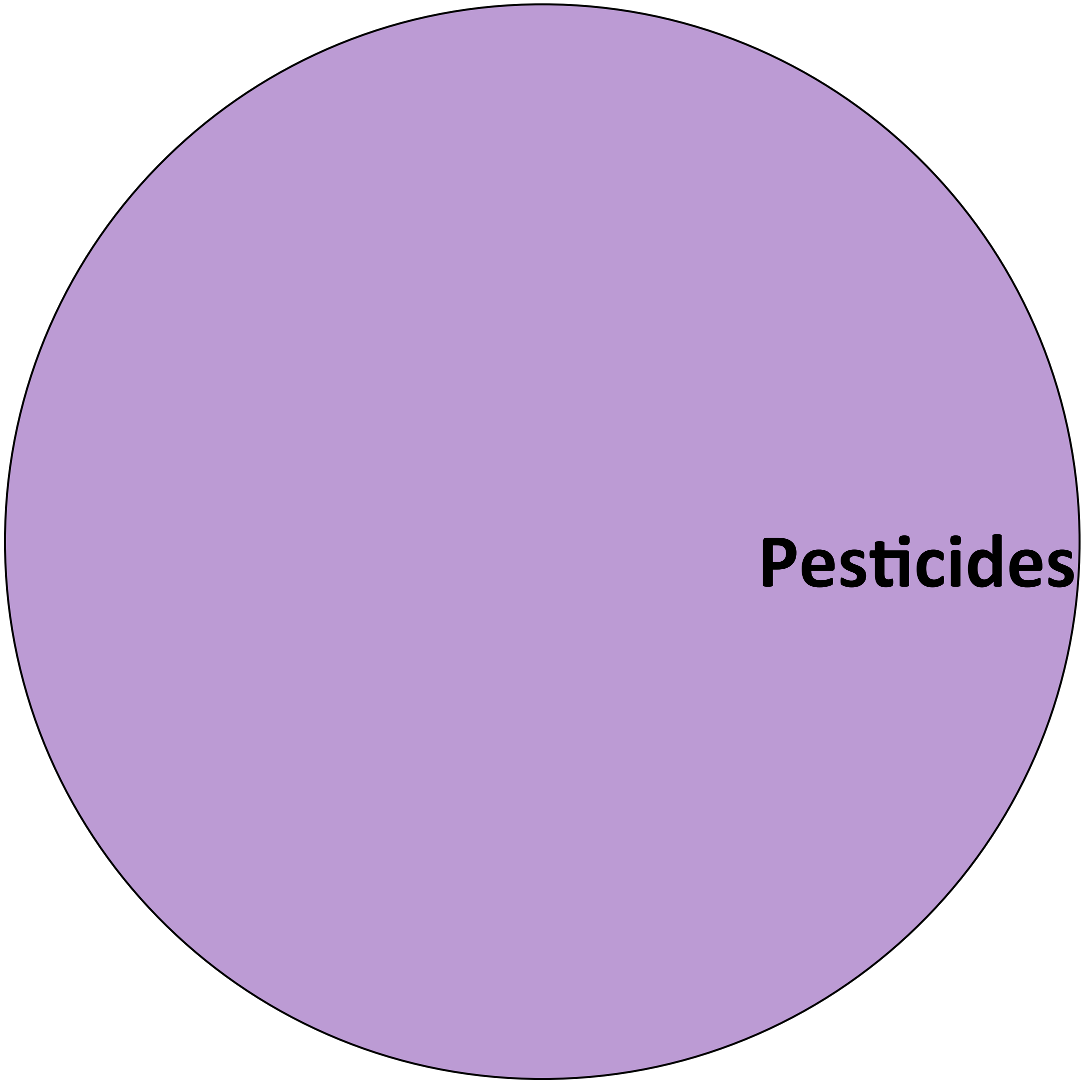
A pesticide is any substance or mixture of substances intended for:

- preventing,
- destroying,
- repelling, or
- mitigating any pest.

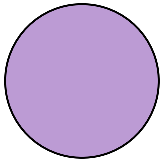
Though often misunderstood to refer only to insecticides, the term pesticide also applies to **herbicides**, **fungicides**, and **various other substances** used to control pests.

Federal Insecticide Fungicide and Rodenticide Act (1947)
http://www.epa.gov/pesticides/about/index.htm#what_pesticide

How much of a problem are pesticides?

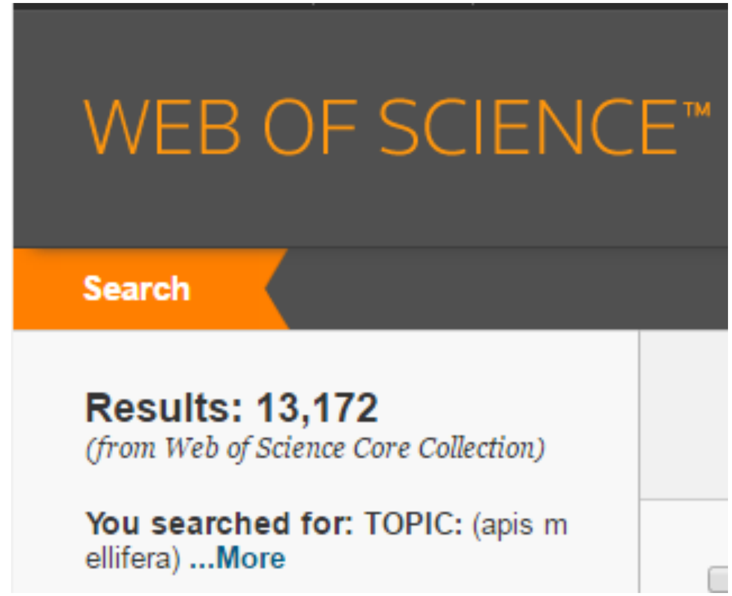


How much of a problem are pesticides?



Pesticides

The other 20,000 bees . . .
(3500 in North America)



Honey bees are an active area of research

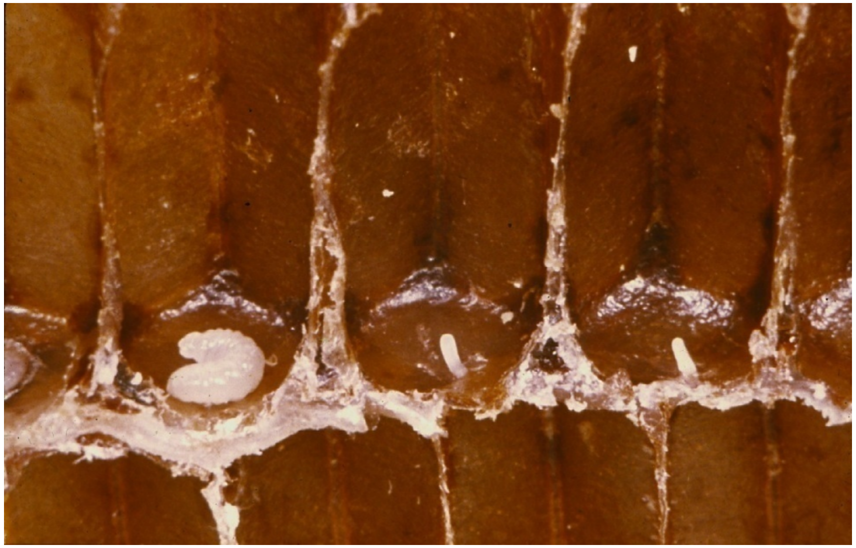
The honey bee was 3rd insect genome sequenced in 2006

Queen
1

Workers
3 - 100 thousand

Drones
0 - hundreds

Four Developmental Stages of Brood



egg (3 days)
larva (5 days)
pupa (12 days)
adult (weeks-months)

at 34°C

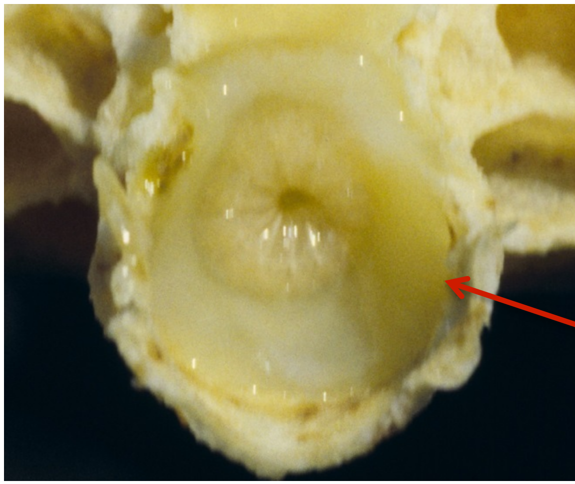
Age Related Division of Labor

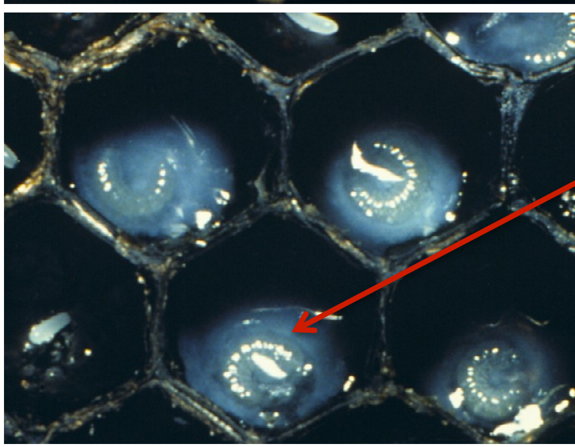
Younger

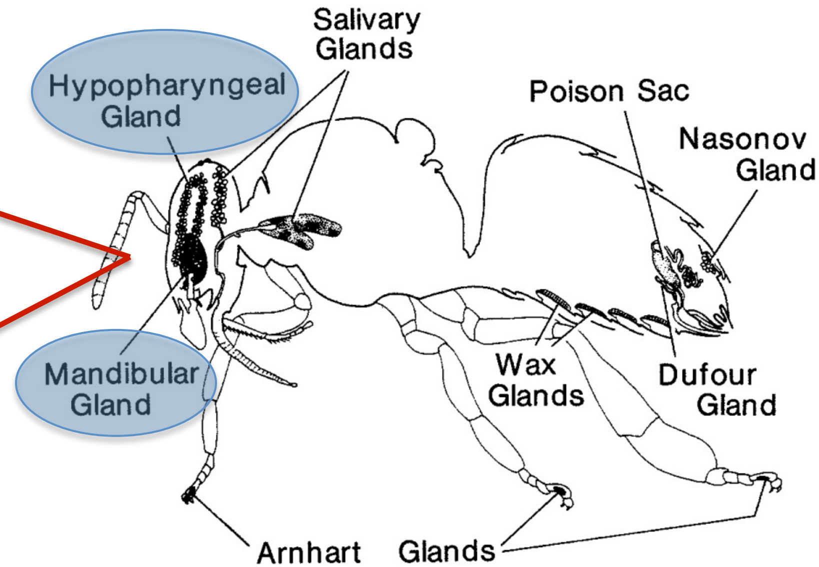
Older

- Cell cleaning
- Cell capping
- Brood tending
- Comb building
- Grooming
- Food handling
- Ventilating
- Guarding
- Foraging

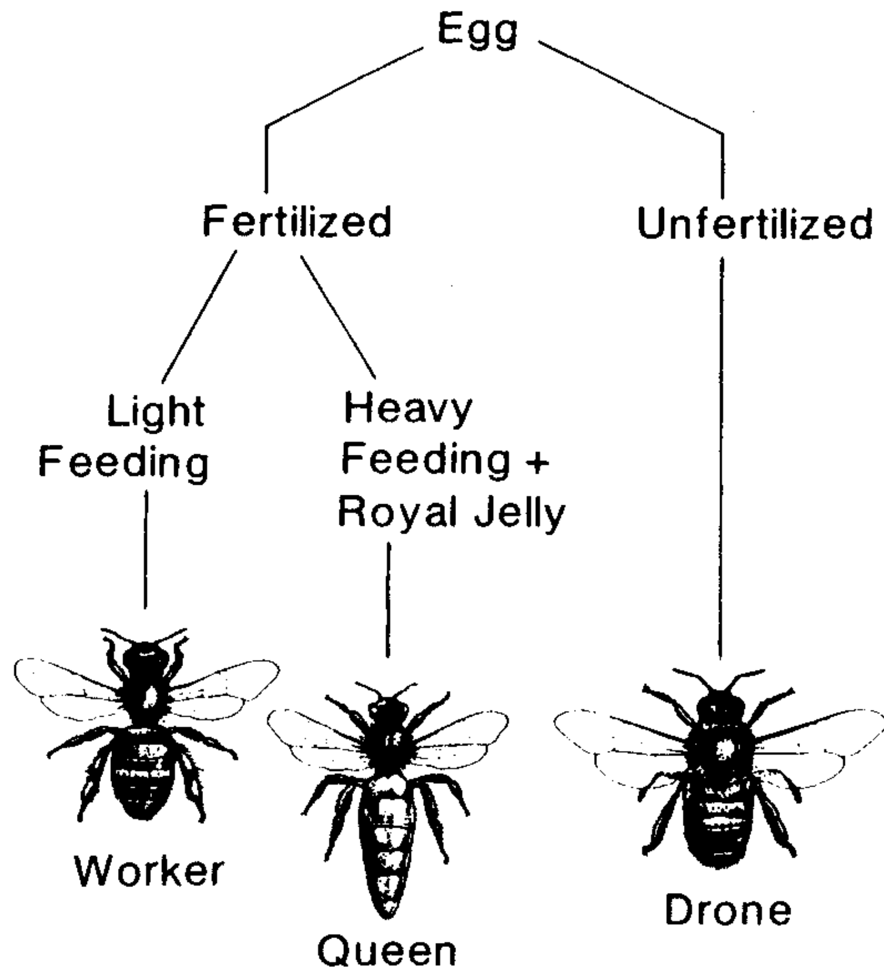
Larvae are progressively provisioned with "jelly" secretion from adults







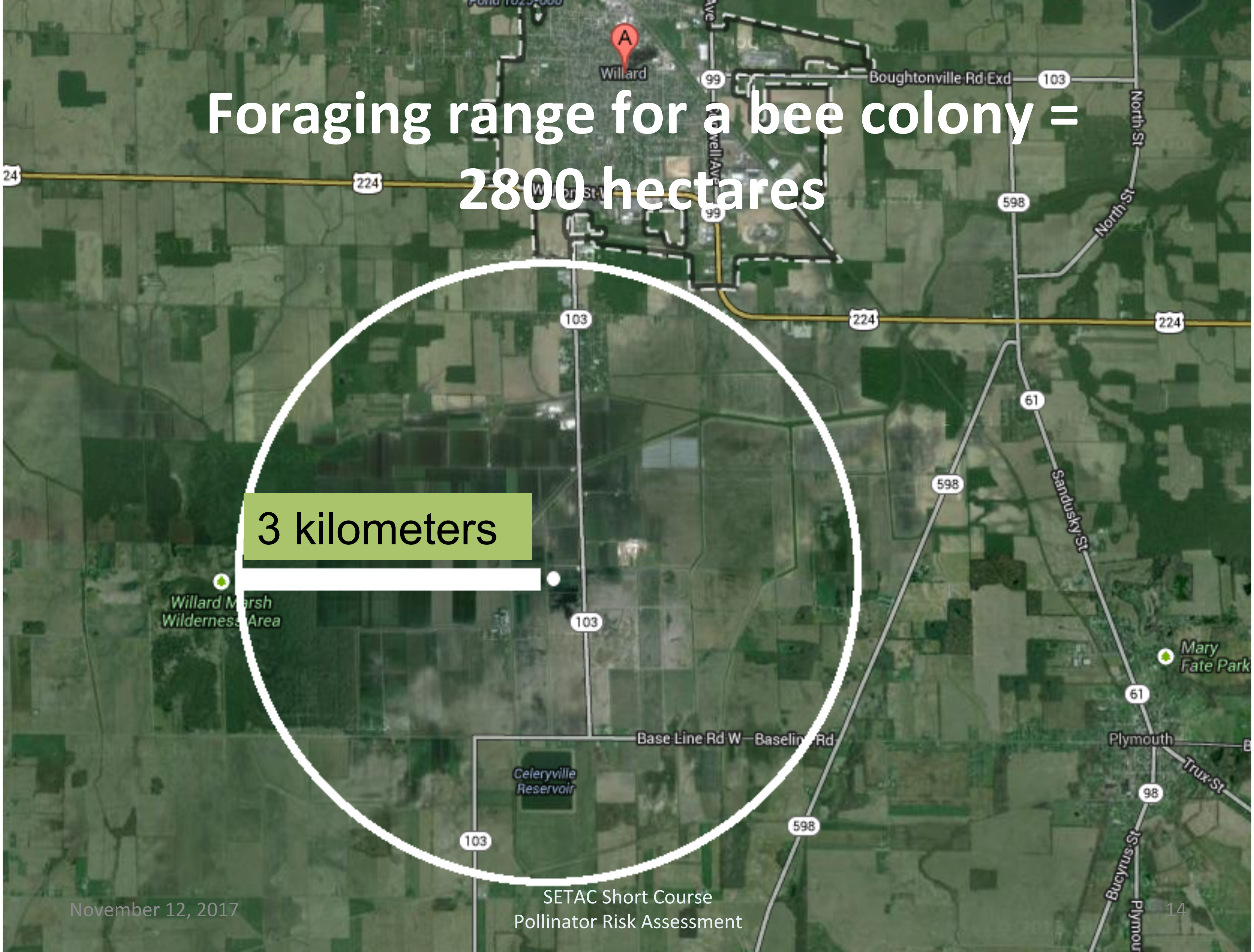
Nurse bees consume large quantities of protein-rich pollen to support jelly secretion



diploid **haploid**

Winston, 1987, “The Biology of the Honey Bee”

Foraging range for a bee colony = 2800 hectares



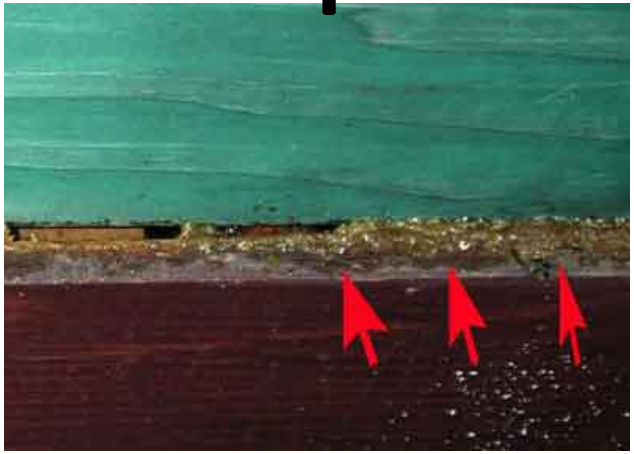
Forager bees collect:

Nectar

Water

Pollen

Propolis



Forager bees collect:

Nectar

300 kg
(65 kg honey)
7.5 million trips

Water

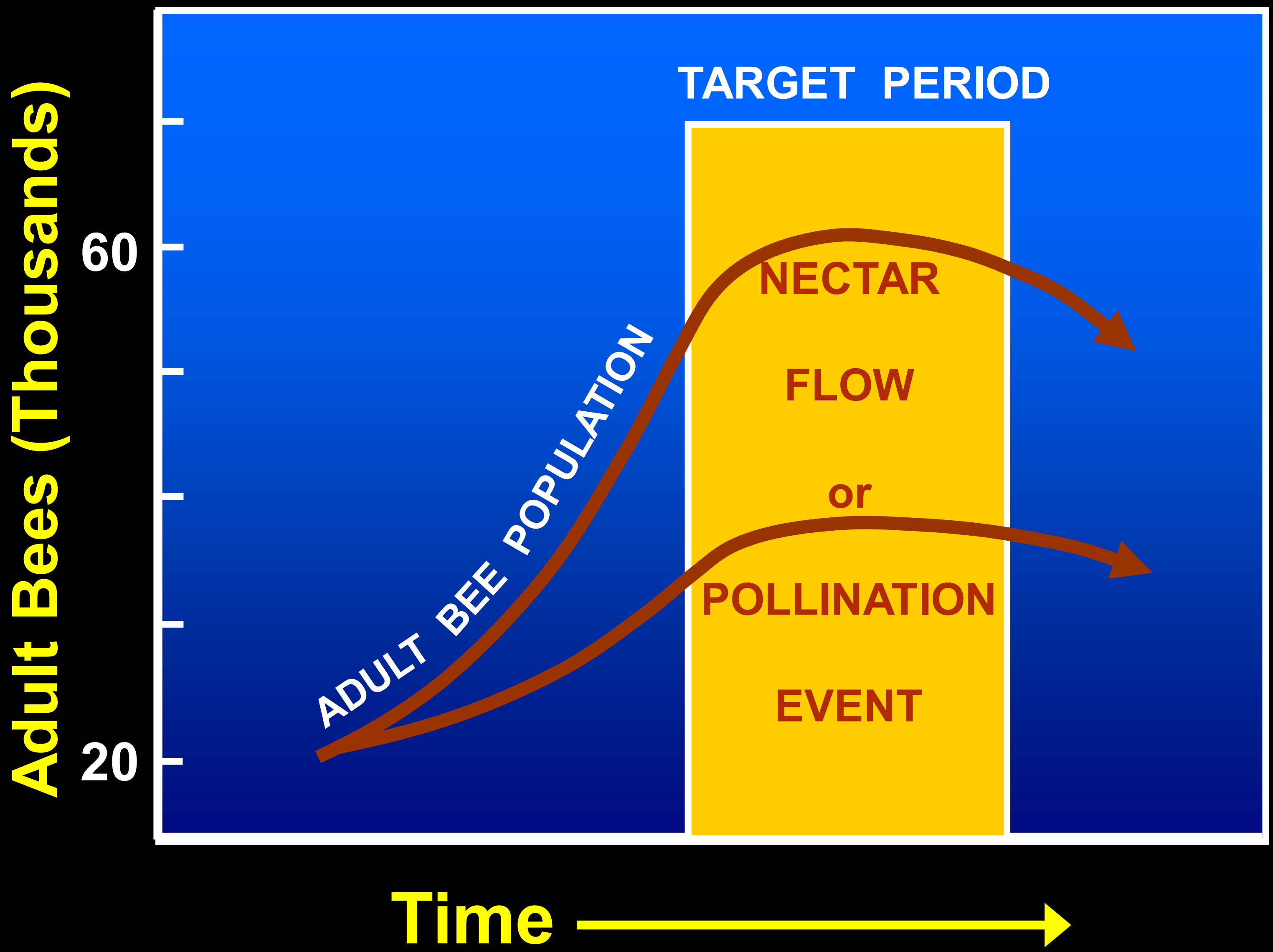
Pollen

20 kg
1 million trips

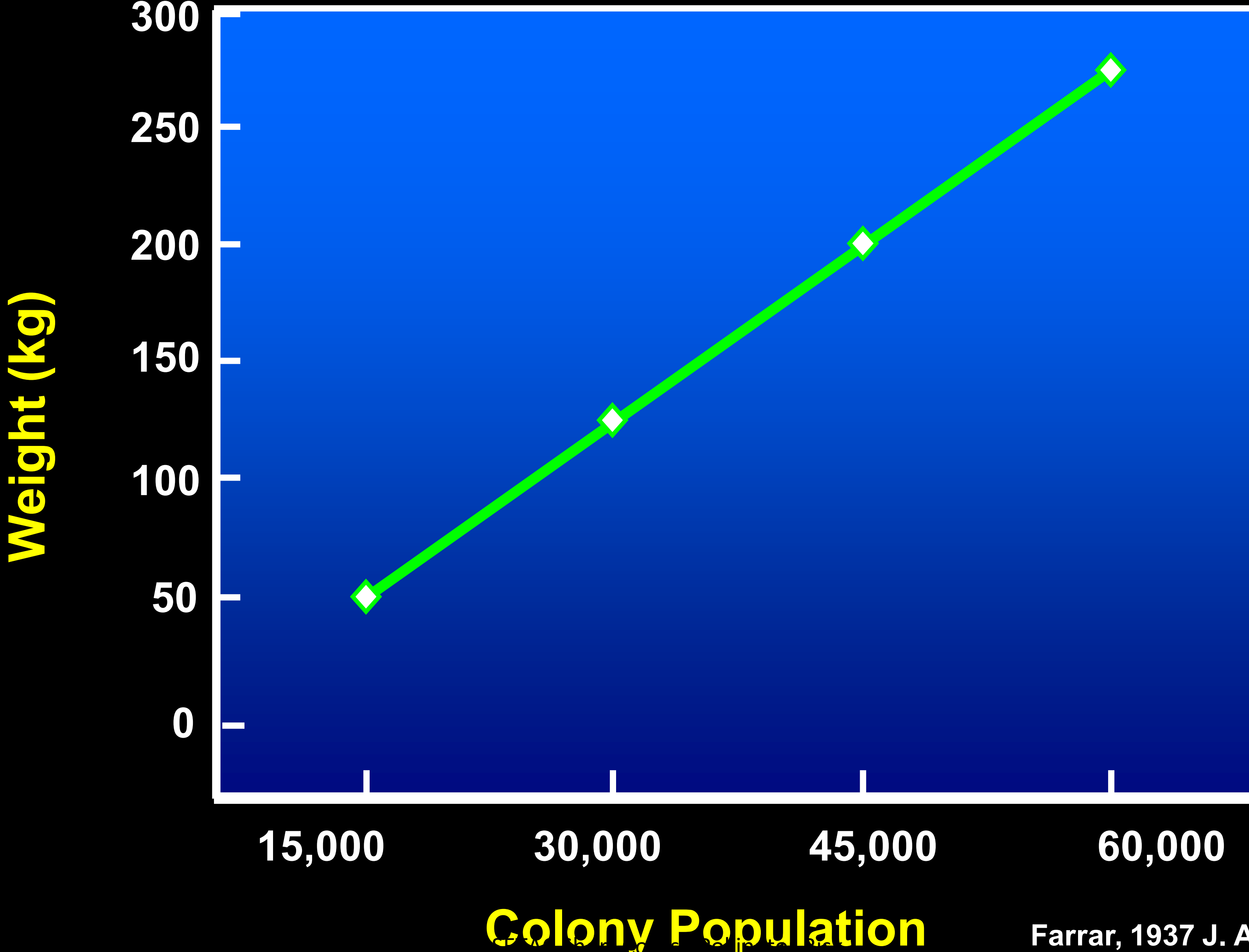
Propolis

Seeley, 1996, "The Wisdom of the Hive"

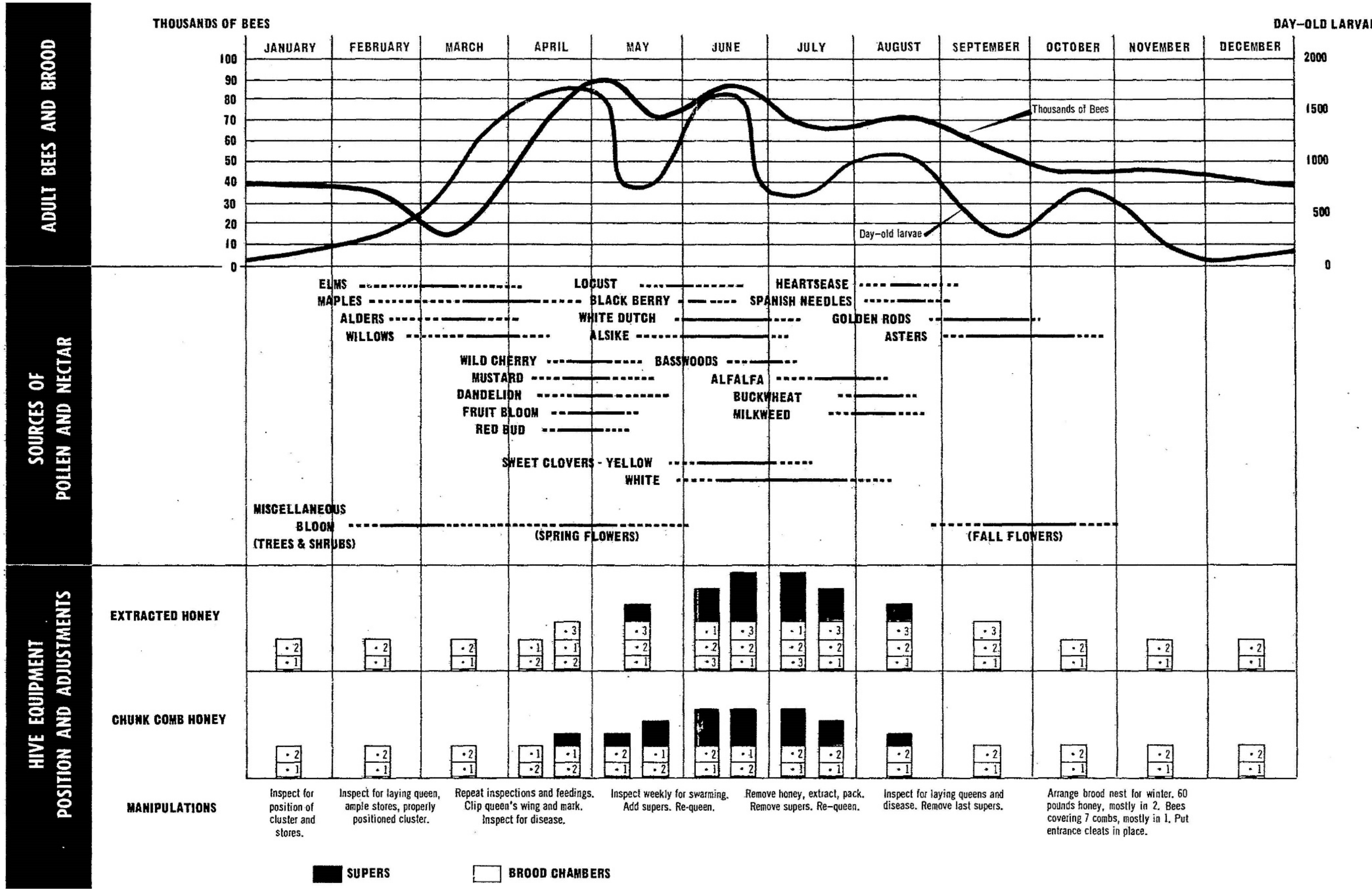
COLONY POPULATION



HONEY PRODUCTION



Farrar, 1937 J. Agric. Res.



Ohio State University Extension Beekeeping Almanac, 1981

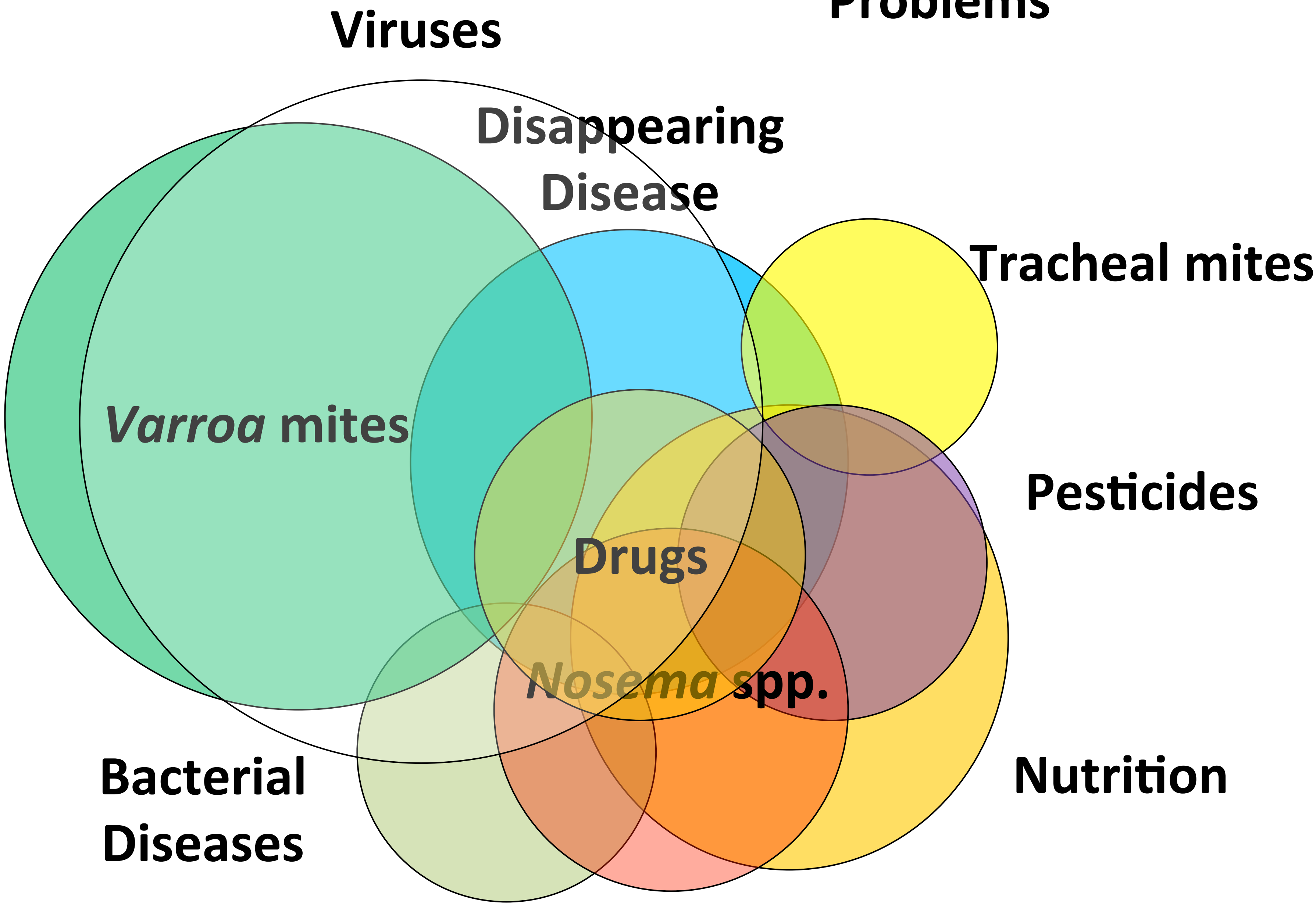
White dutch clover

Yellow sweet clover

Basswood / Linden

Tulip Poplar

Intersecting Bee Health Problems



Honey bee hives are repositories for many compounds

Bee Pesticide*	Class#	Detects	Samples	%	Detections (ppb)							
			Analyzed		High	Low	Median	90%tile	95%tile	Mean[§]	SEM[§]	LOD[†]
Fluvalinate	PYR	117	140	83.6	5860.0	1.1	53.0	610.8	1710.0	357.7	94.5	1.0
Coumaphos	OP	84	140	60.0	762.0	1.0	8.0	118.7	156.2	50.4	13.5	1.0
Chlorpyrifos	OP	12	140	8.6	10.7	1.0	2.2	8.5	9.7	3.4	0.9	0.1
Chlorothalonil	FUNG	10	140	7.1	878.0	1.5	7.2	121.1	499.5	100.2	86.5	1.0
Cypermethrin	PYR	9	140	6.4	25.8	2.0	3.5	22.0	23.9	10.1	3.2	1.0
Permethrin	PYR	8	140	5.7	19600.0	12.0	35.8	5919.2	12759.6	2478.1	2446.0	10.0
DMPF (amitraz)	FORM	8	125	6.4	9040.0	6.0	117.5	3015.8	6027.9	1249.1	1114.1	4.0
Esfenvalerate	PYR	8	140	5.7	9.3	1.0	3.5	8.5	8.9	4.3	1.2	0.5
Methidathion	OP	7	140	5.0	32.0	6.5	12.0	28.4	30.2	16.2	3.6	1.0
Deltamethrin	PYR	6	140	4.3	39.0	23.0	26.5	38.5	38.8	29.3	3.0	20.0
Pendimethalin	HERB	6	140	4.3	27.6	6.5	14.0	26.4	27.0	15.9	3.8	1.0
Cyfluthrin	PYR	5	140	3.6	14.0	2.0	10.0	13.2	13.6	8.2	2.4	1.0
Dicofol	OC	5	140	3.6	3.8	1.0	1.4	3.6	3.7	2.1	0.6	0.4
Fenpropathrin	PYR	4	140	2.9	37.0	2.8	14.2	32.8	34.9	17.1	8.0	0.4
Azinphos methyl	OP	4	140	2.9	22.0	4.8	13.1	20.5	21.3	13.3	3.9	3.0
Cyprodinil	S FUNG	4	140	2.9	19.0	9.2	11.0	16.6	17.8	12.6	2.2	5.0
THPI (captan)	PS FUNG	3	125	2.4	43.4	37.7	39.5	42.6	43.0	40.2	1.7	30.0
Allethrin	PYR	3	140	2.1	24.0	6.7	19.0	23.0	23.5	16.6	5.1	1.0
Tetramethrin	PYR	3	140	2.1	23.0	18.0	23.0	23.0	23.0	21.3	1.7	6.0
Methoxyfenozide	IGR	3	140	2.1	21.0	1.5	3.4	17.5	19.2	8.6	6.2	0.4
Endosulfan I	CYC	3	140	2.1	6.1	1.3	1.6	5.2	5.7	3.0	1.6	0.1
Endosulfan sulfate	CYC	3	140	2.1	3.0	1.6	2.7	2.9	3.0	2.4	0.4	0.1
Endosulfan II	CYC	3	140	2.1	2.4	1.4	1.9	2.3	2.4	1.9	0.3	0.1
Parathion methyl	OP	3	140	2.1	2.0	1.5	1.8	2.0	2.0	1.8	0.1	1.0
Cyhalothrin	PYR	3	140	2.1	1.8	1.1	1.7	1.8	1.8	1.5	0.2	0.1
DMA (amitraz)	FORM	2	125	1.6	4740.0	275.0	2507.5	4293.5	4516.8	2507.5	2232.5	50.0
Fipronil	INS	2	140	1.4	3060.0	9.9	1535.0	2755.0	2907.5	1535.0	1525.1	1.0
Bifenthrin	PYR	2	140	1.4	12.3	2.9	7.6	11.4	11.8	7.6	4.7	0.4
Dieldrin	CYC	2	140	1.4	12.0	10.0	11.0	11.8	11.9	11.0	1.0	4.0
Prallethrin	PYR	2	140	1.4	8.6	6.2	7.4	8.4	8.5	7.4	1.2	4.0
Coumaphos oxon	OP	2	140	1.4	6.8	2.1	4.5	6.3	6.6	4.5	2.4	5.0
Oxyfluorfen	HERB	2	140	1.4	4.8	3.8	4.3	4.7	4.8	4.3	0.5	0.5
Chlorfenapyr	PS MITI	2	140	1.4	2.7	1.8	2.3	2.6	2.7	2.3	0.5	1.0
Carbaryl	PS CARB	1	140	0.7	588.0	588.0	588.0	588.0	588.0	588.0	---	5.0
1-Naphthol (carbaryl)	S CARB	1	140	0.7	238.0	238.0	238.0	238.0	238.0	238.0	---	2.0
Dimethomorph	S FUNG	1	125	0.8	56.0	56.0	56.0	56.0	56.0	56.0	---	15.0
Tebuconazole	S FUNG	1	140	0.7	34.0	34.0	34.0	34.0	34.0	34.0	---	3.0
Chlorferone (coumaphos)	OP	1	125	0.8	25.0	25.0	25.0	25.0	25.0	25.0	---	25.0
Tebufenozide	IGR	1	140	0.7	23.0	23.0	23.0	23.0	23.0	23.0	---	2.0
Fenoxaprop-ethyl	S HERB	1	140	0.7	15.4	15.4	15.4	15.4	15.4	15.4	---	6.0
Atrazine	S HERB	1	140	0.7	15.0	15.0	15.0	15.0	15.0	15.0	---	1.0
Carbendazim	S FUNG	1	140	0.7	14.3	14.3	14.3	14.3	14.3	14.3	---	1.0
Pyraclostrobin	FUNG	1	140	0.7	8.6	8.6	8.6	8.6	8.6	8.6	---	1.0
DDE p,p′	OC	1	140	0.7	6.6	6.6	6.6	6.6	6.6	6.6	---	3.0
Fluridone	S HERB	1	140	0.7	6.5	6.5	6.5	6.5	6.5	6.5	---	5.0
Pronamide	S HERB	1	140	0.7	2.2	2.2	2.2	2.2	2.2	2.2	---	1.0

*Carbendazim is also a degradate of benomyl; Thiabendazole is a degradate of thiophanate methyl.
#Class: CAR = carbamate, CYC = cyclodiene, FORM = formamidine, FUNG = fungicide, HERB = herbicide, IGR = insect growth regulator, INS = misc. insecticide, MITI = miticide, NEO = neonicotinoid, OC = organochlorine, OP = organophosphate, PS = partial systemic, PYR = pyrethroid, S = systemic.
§Mean and SEM for detections > LOD.
†LOD = limit of detection (ppb).
doi:10.1371/journal.pone.0009754.t003

Pesticide	Maximum PHQ contact	Maximum PHQ oral	No. detections (of 313 samples)	
Phosmet	75,255	44,746[a]	103	32
Imidacloprid	1,595	17,949	38	12
Indoxacarb	5,957[a]	2,149[a]	4	1.
Chlorpyrifos	2,520	101	14	4.
Fipronil	590	839	2	0.
Thiamethoxam	171	820	3	1.
Azinphos-methyl	290	813	5	1.
Fenthion	640		16	5.
Dinotefuran	162	330	3	1.
Carbaryl	206		127	40
Fluvalinate	200		1	0.
Methomyl	150	83	12	3.
Diazinon	82	90	3	1.
Malathion	67	35	2	0.
Carbendazim	36		92	29
5-OH-Imidacloprid		35	1	0.
Acephate	33		6	1.
Dimethoate	26	75	4	1.
Dichlorvos	19		2	0.
Carbofuran	18		2	0.
Methamidophos	16		1	0.

Pesticide	Insecticide family	LD_{50} (ppm)[a]	Crops in which detected[c]	Detections	Quantity detected, mean±se (max) (ppb)	Relative risk (95% CI)
Fungicides						
Azoxystrobin		>1,562.5 [64]	Cr, Cu, Wa	10	60.3±25.6 (332)	0.75 (0.56, 1.02)
Captan		>78.13 [65]	Ap, Cr, Cu, Wa	9	976.9±734.4 (13,800)	0.59 (0.42, 0.81)†
Chlorothalonil		>1,414.06 [66]	Ap, Bl, Cr, Cu, Pu, Wa	17	4,491.2±2,130.7 (29,000)	2.31 (1.35, 3.94)†
Cyprodinil		>6,125 [67]	Ap	3	996.9±707.5 (12,700)	0.31 (0.15, 0.65)†
Difenoconazole		>781.25 [68]	Ap	3	171.4±119.4 (2,110)	0.31 (0.15, 0.65)†
Fenbuconazole		>2,282.65 [69]	Ap, Cr, Cu	10	227.3±89.2 (1,420)	0.33 (0.23, 0.48)†
Pyraclostrobin		573.44 [70]	Cr, Pu	4	2,787.1±1,890.1 (27,000)	2.85 (2.16, 3.75)†
Quintozene (PCNB)		>0.78 [71]	Cr	2	0.3±0.3 (4.7)	0.97 (0.59, 1.61)
THPI	Captan metabolite		Cr, Cu	3	832.1±531.8 (9,470)	0.42 (0.21, 0.82)†
Herbicides						
Carfentrazone ethyl		>217.97 [72]	Cr	1	0.1±0.08 (1.6)	1.05 (0.54, 2.05)
Pendimethalin		>388.28 [73]	Ap, Cr, Pu	5	5.1±3.7 (69.5)	1.47 (1.08, 1.99)†
Insecticides						
2,4 Dimethylphenyl formamide (DMPF)*	Amitraz (formamidine) metabolite		Bl, Cu, Pu, Wa	10	171.5±117.0 (2,060)	2.13 (1.56, 2.92)†
Acetamiprid	Neonicotinoid	55.47 [60]	Ap	3	59.1±32.2 (401)	0.31 (0.15, 0.65)†
Bifenthrin	Pyrethroid	0.11 [74]	Pu, Wa	3	6.6±3.8 (53.1)	2.08 (1.53, 2.83)†
Carbaryl	Carbamate	8.59 [75]	Ap, Cu, Wa	6	57.8±30.0 (403)	0.42 (0.27, 0.66)†
Chlorpyrifos	Organophosphate	0.86 [16]	Ap, Cr, Cu, Pu	7	3.1±1.1 (15.5)	0.89 (0.64, 1.23)
Coumaphos*	Organophosphate	35.94 [16]	Bl, Cr, Cu	6	2.2±1.0 (17.5)	0.62 (0.43, 0.91)†
Cyfluthrin	Pyrethroid	<0.31 [76]	Cr, Wa	2	0.6±0.4 (5.4)	1.31 (0.85, 2.02)
Cyhalothrin	Pyrethroid	0.30 [77]	Ap, Pu, Wa	7	14.6±7.9 (131)	0.94 (0.69, 1.29)
Cypermethrin	Pyrethroid	0.18–4.38 [78]	Cr	1	0.4±0.4 (6.9)	1.05 (0.54, 2.05)
Deltamethrin	Pyrethroid	0.39 [79]	Cr	1	4.5±4.5 (85.3)	1.05 (0.54, 2.04)
Diazinon	Organophosphate	1.72 [80]	Ap, Cr	3	1.4±1.0 (19.8)	0.56 (0.32, 0.97)†
Endosulfan I	Cyclodiene	54.69 [16]	Ap, Cr, Cu, Pu, Wa	8	1.5±0.7 (12.9)	1.60 (1.20, 2.14)†
Endosulfan II	Cyclodiene	54.69 [16]	Ap, Cr, Cu, Pu	6	0.8±0.3 (5.3)	1.41 (1.04, 1.91)†
Endosulfan sulfate	Endosulfan metabolite		Cr, Cu	4	0.3±0.2 (2.1)	0.79 (0.52, 1.19)
Esfenvalerate	Pyrethroid	0.13 [81]	Ap, Cr, Cu	7	16.9±12.0 (216)	0.51 (0.35, 0.75)†
Fluvalinate*	Pyrethroid	1.56 [82]	Bl, Cr, Cu, Pu, Wa	16	42.4±29.7 (570)	2.43 (1.49, 3.96)†
Heptachlor epoxide	Heptachlor[b] (cyclodiene) metabolite		Cr	1	0.6±0.6 (12)	1.05 (0.54, 2.04)
Imidacloprid	Neonicotinoid	0.23 [83]	Ap	3	2.8±2.0 (36.5)	0.31 (0.15, 0.65)†
Indoxacarb	Oxadiazine	1.41 [84]	Ap	2	0.5±0.5 (9)	0.28 (0.11, 0.73)†
Methidathion	Organophosphate	1.85 [85]	Cr	1	1.6±1.6 (31)	1.05 (0.54, 2.04)
Methomyl	Carbamate	<3.91 [86]	Wa	1	13.6±13.6 (259)	1.54 (0.91, 2.61)
Phosmet	Organophosphate	8.83 [85]	Ap, Cr, Cu	5	798.7±772.4 (14,700)	0.36 (0.21, 0.61)†
Pyrethrins	Pyrethroid	0.16 [16]	Cr	1	5.1±5.1 (97.4)	1.05 (0.54, 2.05)
Thiacloprid	Neonicotinoid	114.06 [60]	Ap	2	1.1±0.8 (12.4)	0.35 (0.15, 0.82)†
Control diets						
BRL	NA	NA	NA	NA	NA	0.58 (0.23, 1.48)
MegaBee	NA	NA	NA	NA	NA	0.74 (0.33, 1.67)

[a]We divided LD_{50} values given as µg/bee (g) by 0.128 (equivalent to multiplying by 7.8) to obtain ppm when necessary [85]. If multiple values have been published, we include only the smallest.
[b]Heptachlor has been banned for use on cranberries since 1978 [87], but can persist in the soil for extended periods of time.
[c]Ap = apple, Bl = blueberry, Cr = cranberry, Cu = cucumber, Pu = pumpkin, Wa = watermelon.
*Used by beekeepers within the hive for parasitic mite control.
†Relative risk different from 1 at the 95% confidence level.
NA indicates information that is not relevant to control diets.
doi:10.1371/journal.pone.0070182.t002

Mullin et al., 2010, PLoS ONE   Stoner and Eitzer, 2013, PLoS ONE   Pettis et al., 2013, PLoS ONE

Paracelsus
1493-1541

The Father
of
Toxicology

Portrait by Quentin Massys

poisons

"All things are poison and nothing is without poison, only the dose permits something not to be poisonous."

-Paracelsus 1493-1541

drugs

poisons

“The dose makes the poison"

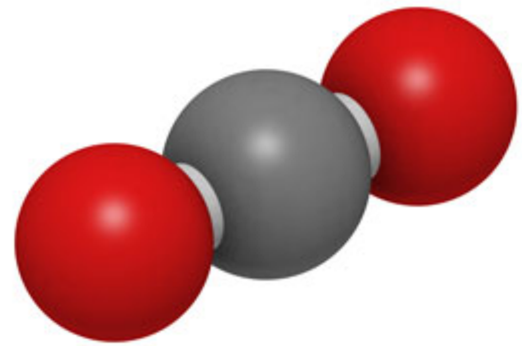
-Paracelsus 1493-1541

drugs

Risk = Hazard x Exposure

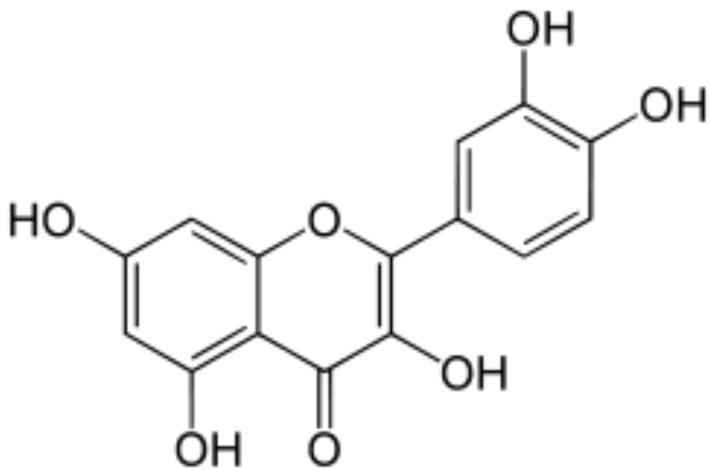
Toxic Gasses

Carbon dioxide

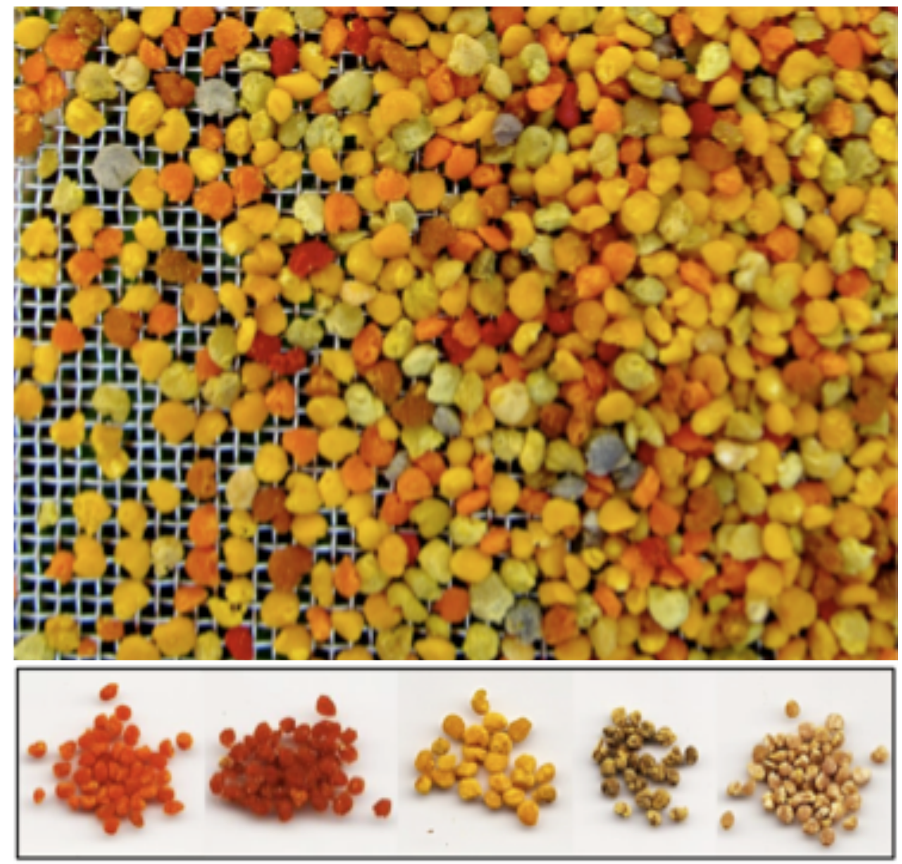


- Induces queens to begin laying eggs
- Reduces longevity of workers

Toxic Pollen



quercetin



Toxic Nectar

Caffeine

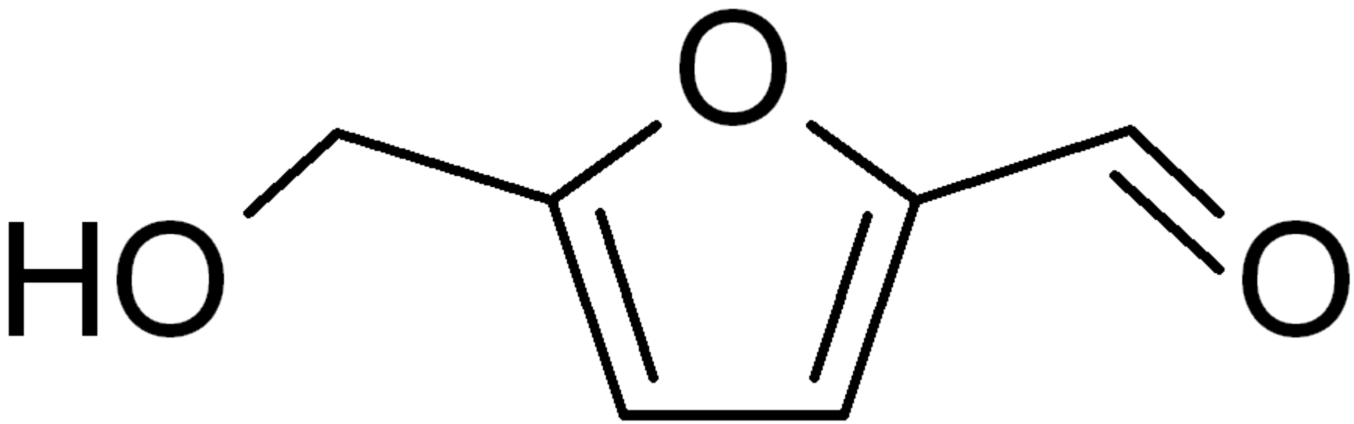
Nicotine

Amygdalin

Bees may prefer nectar that is toxic

Learn to avoid high concentrations

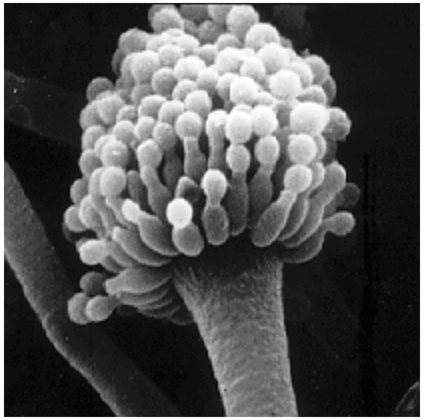
Toxic Honey

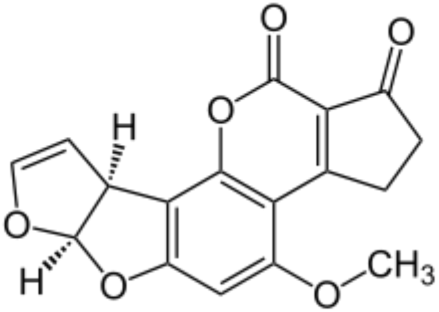


Hydroxymethylfurfural (HMF)

Fructose is naturally converted to toxic HMF over time

Toxins produced by microorganisms





Aflatoxin B1

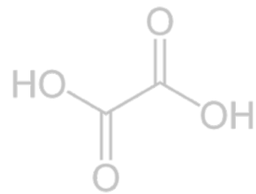
Aflatoxins are produced by *Aspergillus* fungi growing on pollen and bee bread

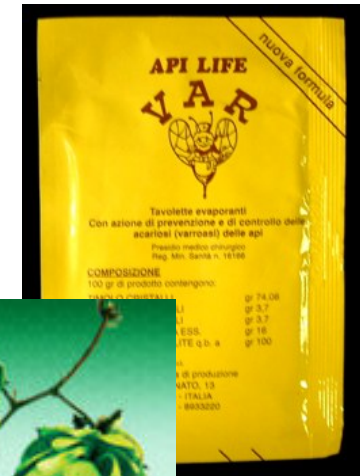
Bees have ways of dealing with exposure to natural toxins

- Detoxification
- Avoidance
- Dilution

Do these same processes work for modern pesticides?

Varroa destructor





coumaphos
(organophosphate)
tau-fluvalinate
(pyrethroid)
amitraz
(formamadine)
thymol
(monoterpenoid)
hops beta acids
oxalic acid
(organic acid)
formic acids
(organic acids)
fenpyroximate
(pyrazole)

Apivar

Hivastan™

49 g mono-terpenoids

1.4 g pyrethroid

0.7g phenyl-pyrazole

1.0 g formamadine

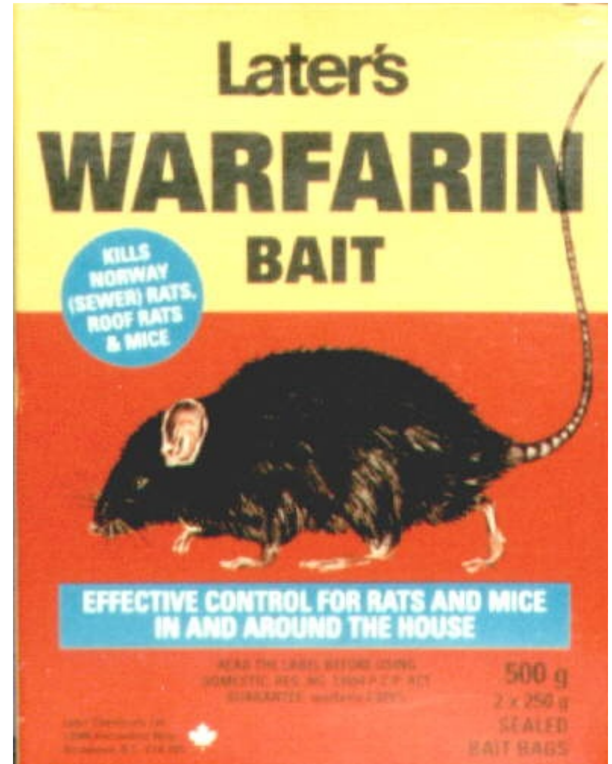
1.8 g organic acid

2.8 g organophosphate

“The dose makes the poison"

-Paracelsus 1493-1541

Quentin Massys

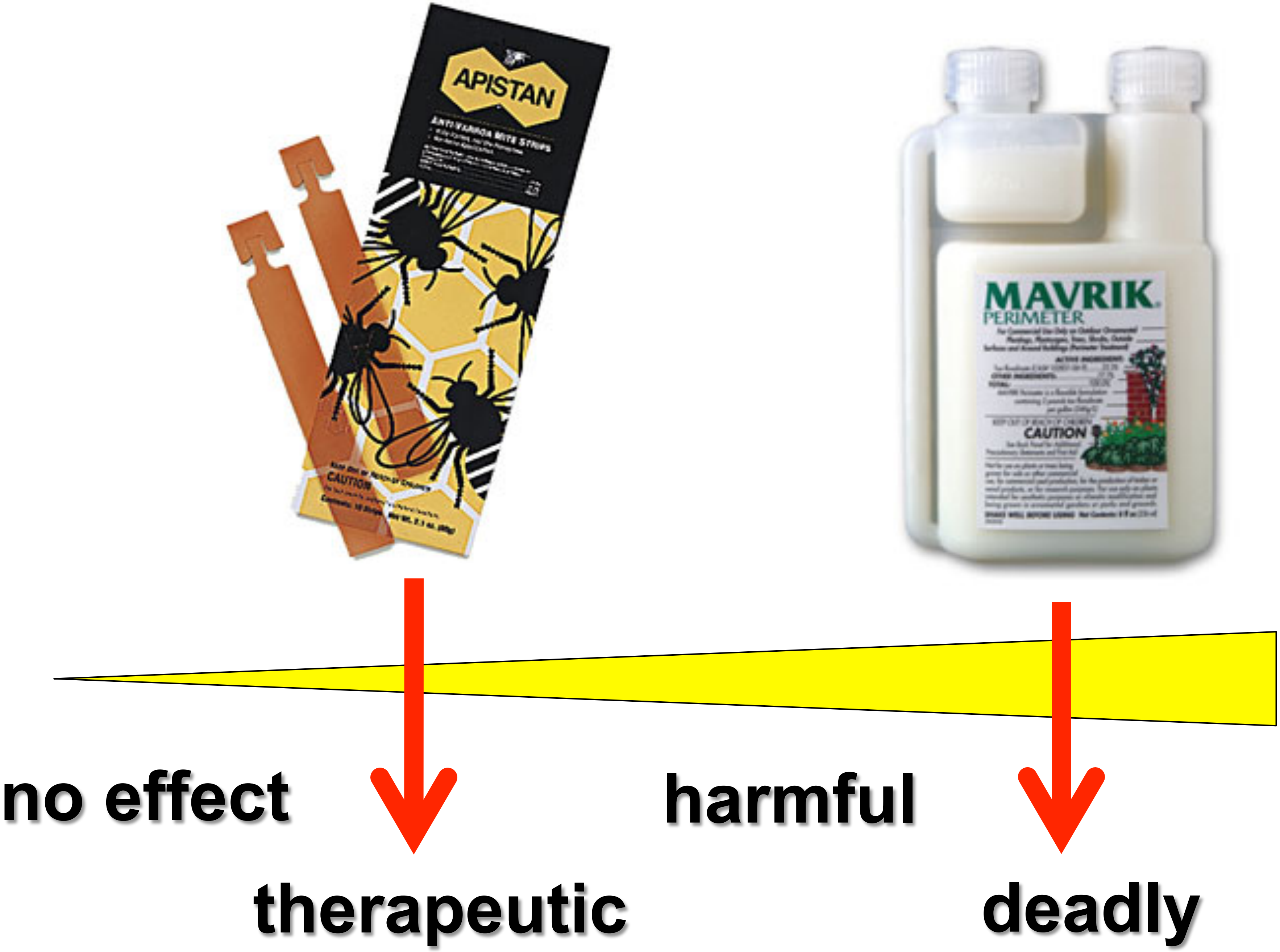


no effect

therapeutic

harmful

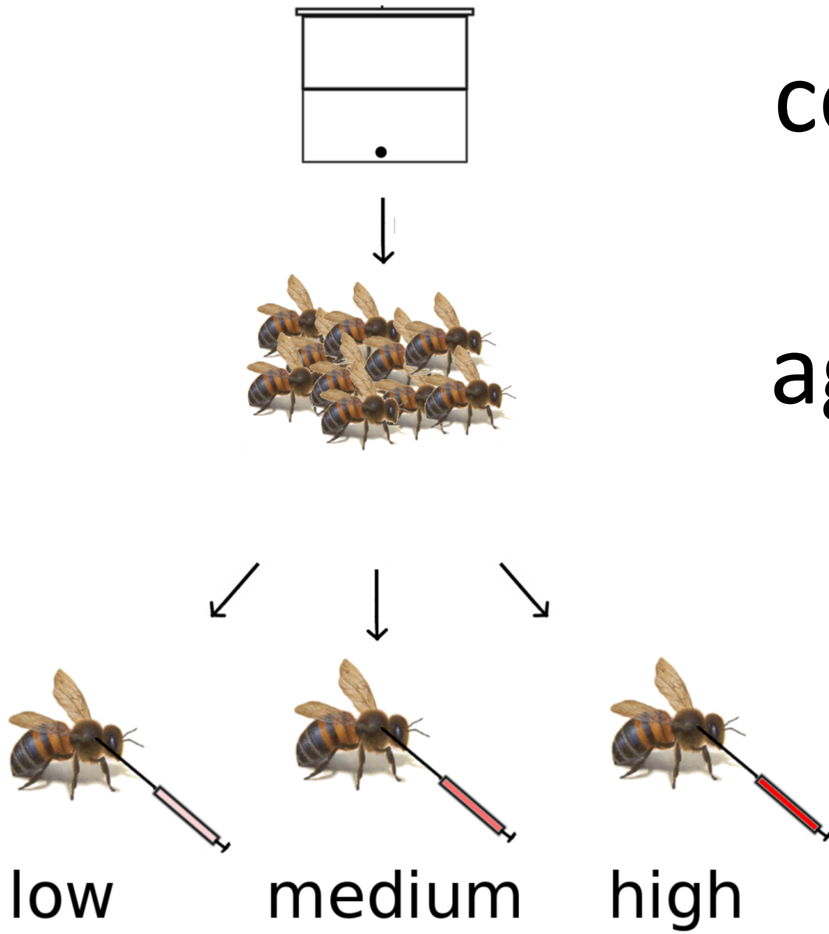
deadly


APISTAN
ANTI-VARROA MITE STRIPS
CAUTION
MAVRIK
PERIMETER
CAUTION
no effect
therapeutic
harmful
deadly

What is a safe dose?
What is a toxic dose?

Lethal Dose 50%
(LD_{50})

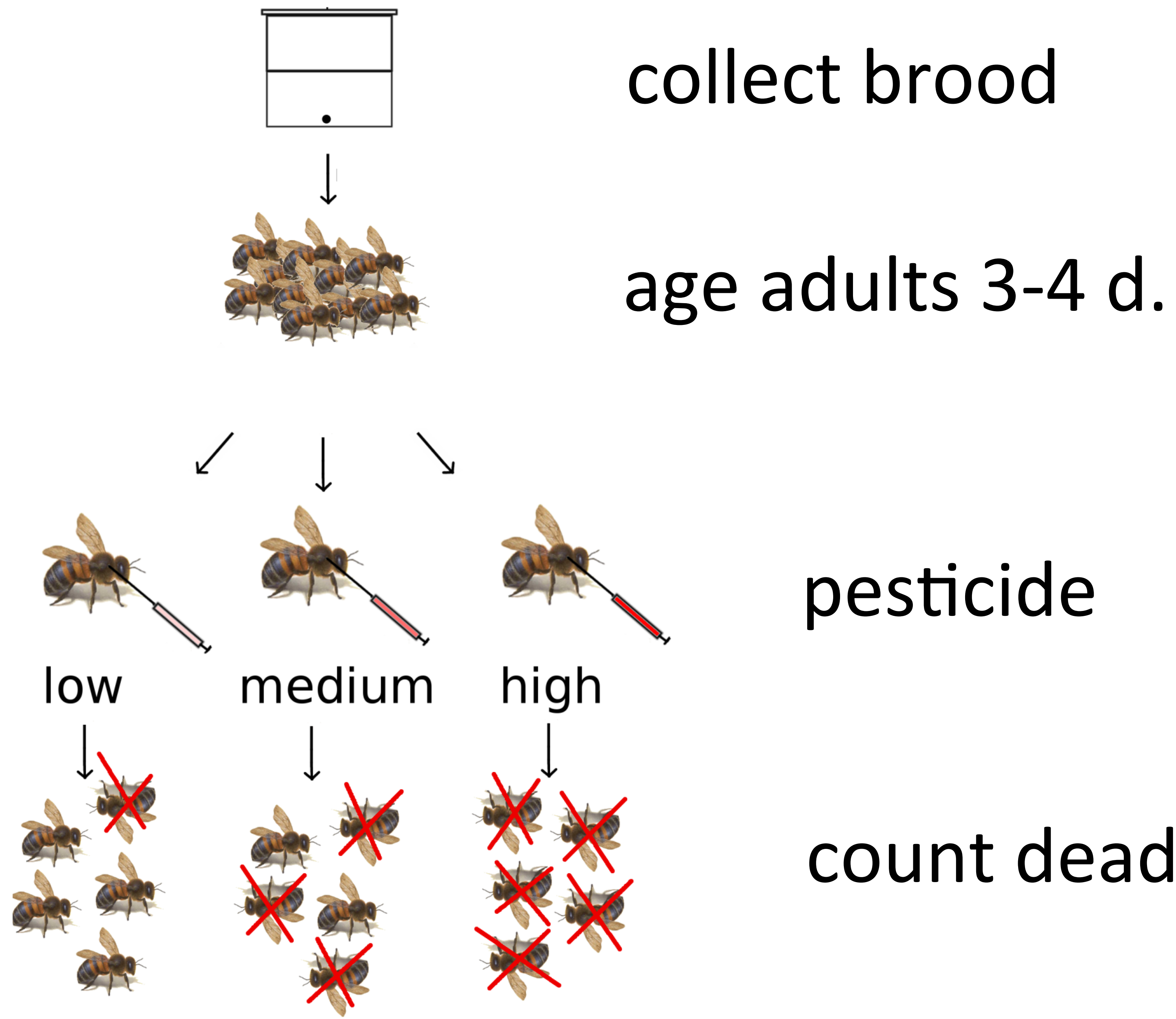
Lab LD_{50} Bioassays

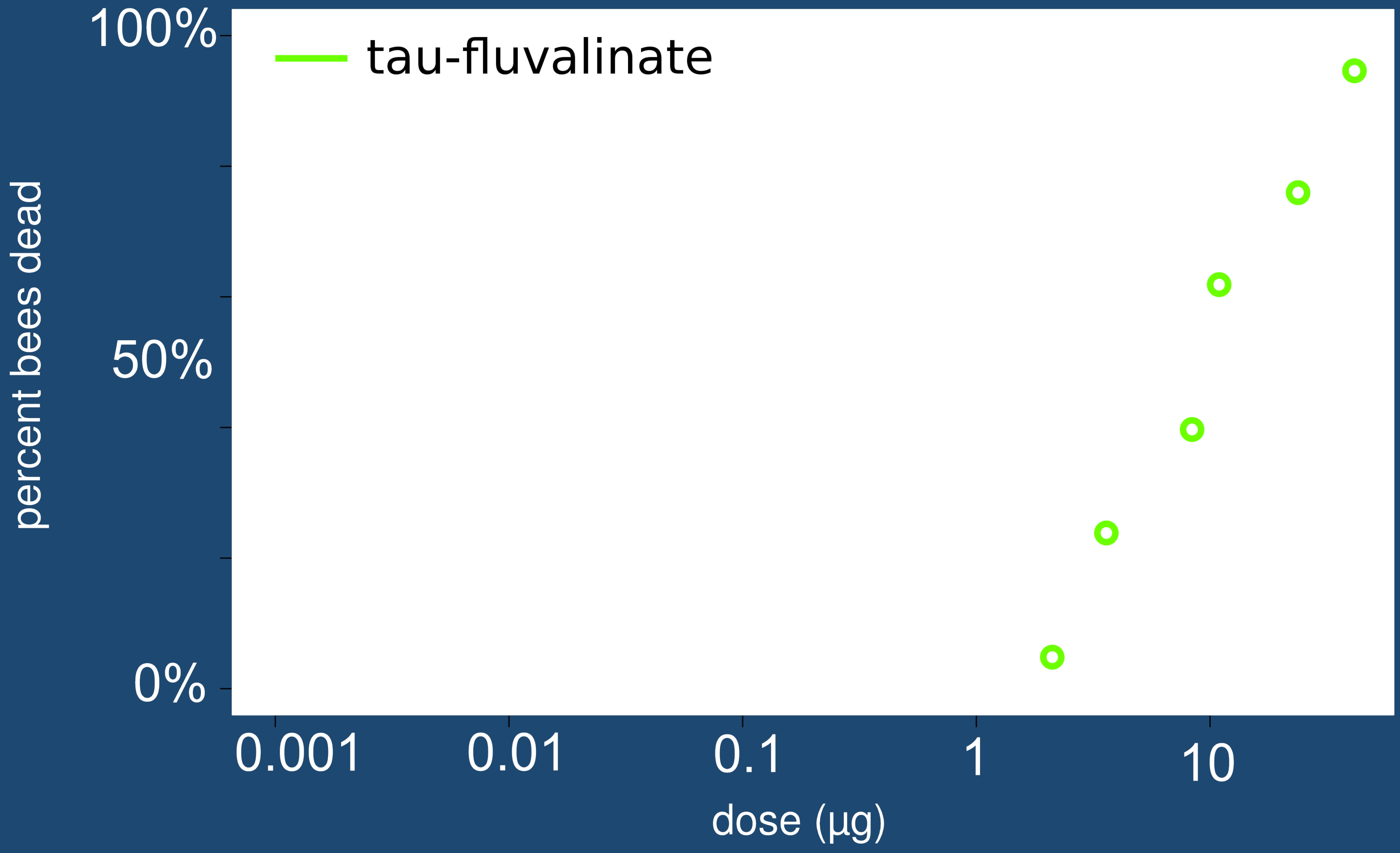


collect brood

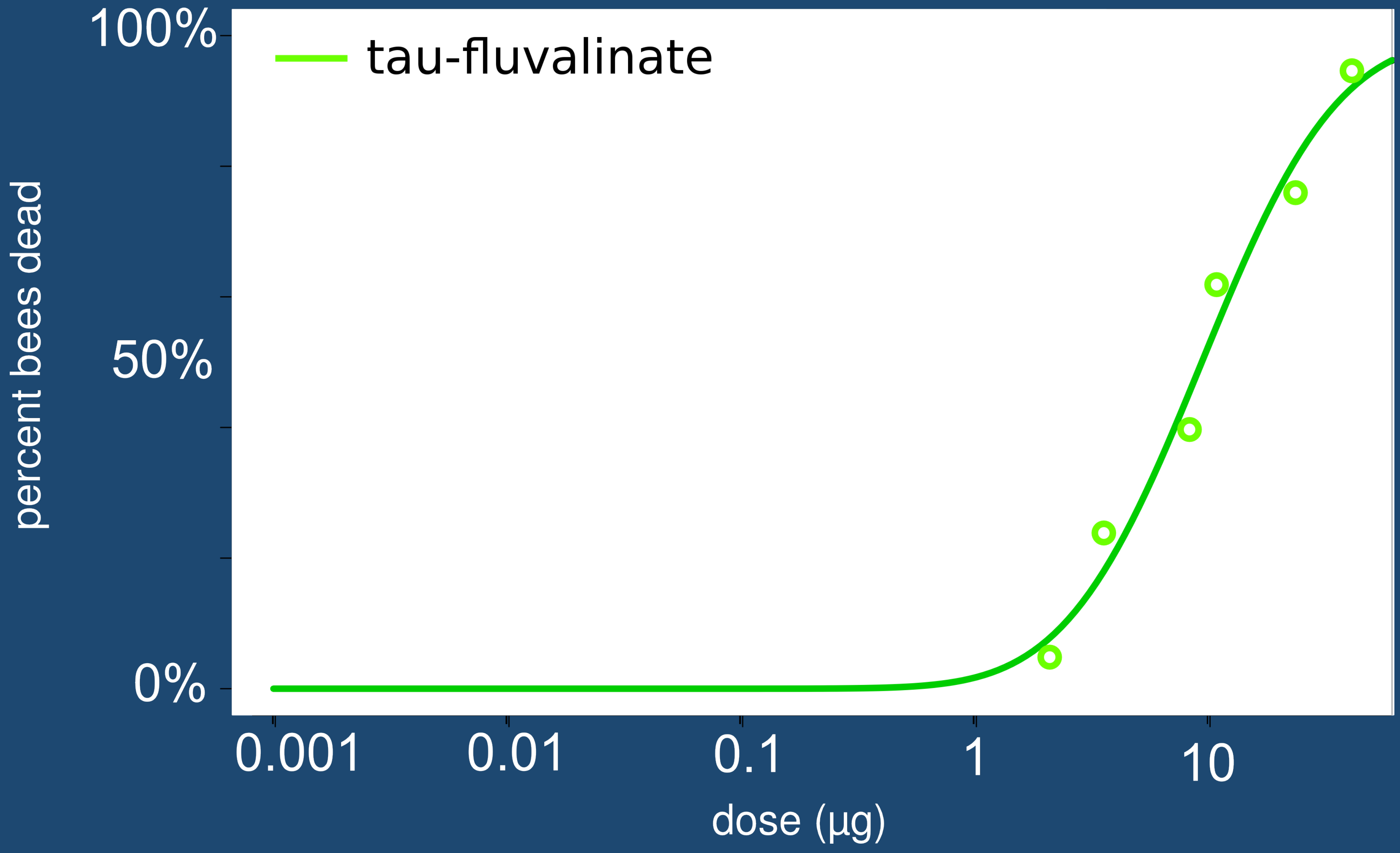
age adults 3-4 d.

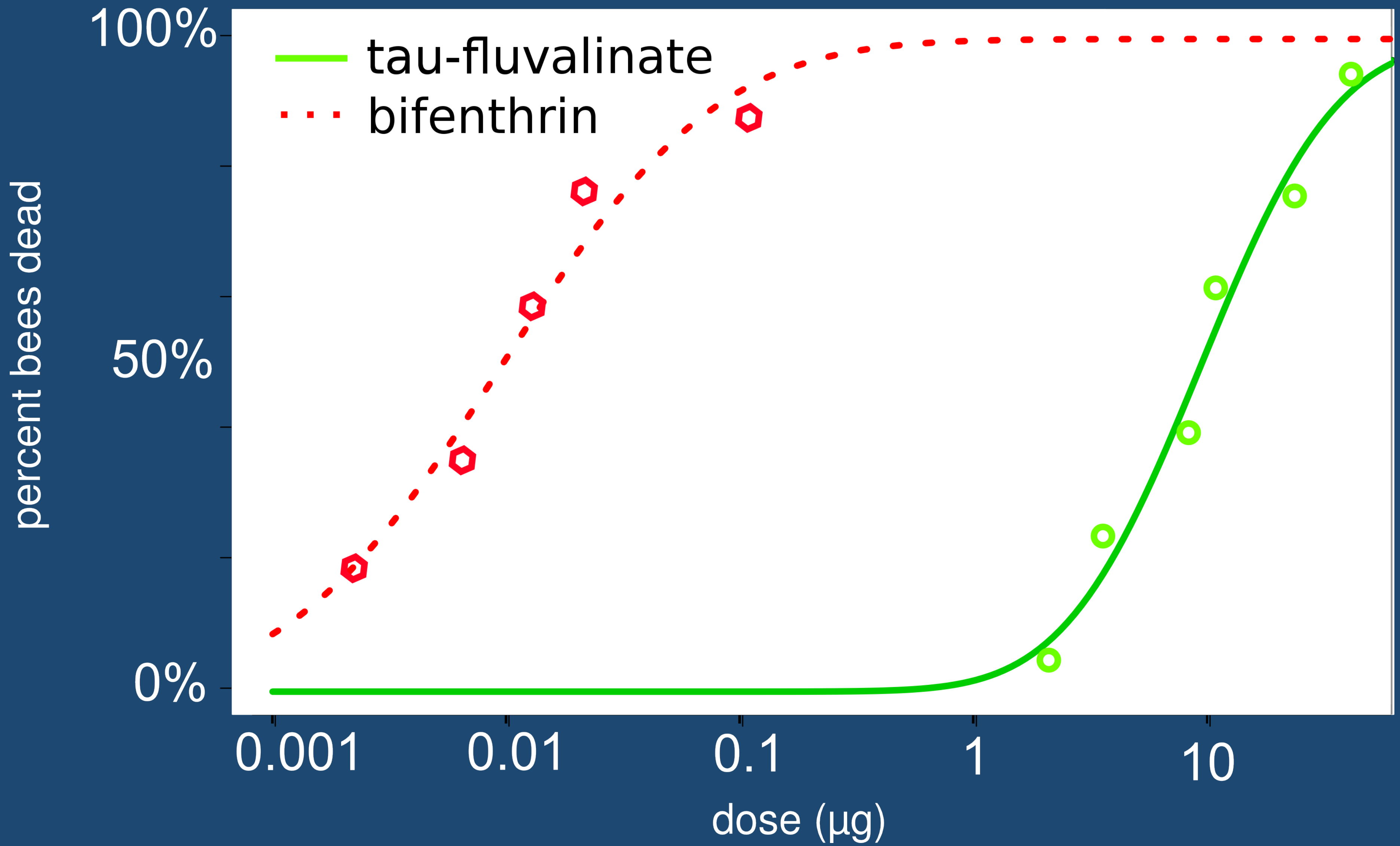
pesticide


collect brood
age adults 3-4 d.
pesticide
low
medium
high
count dead

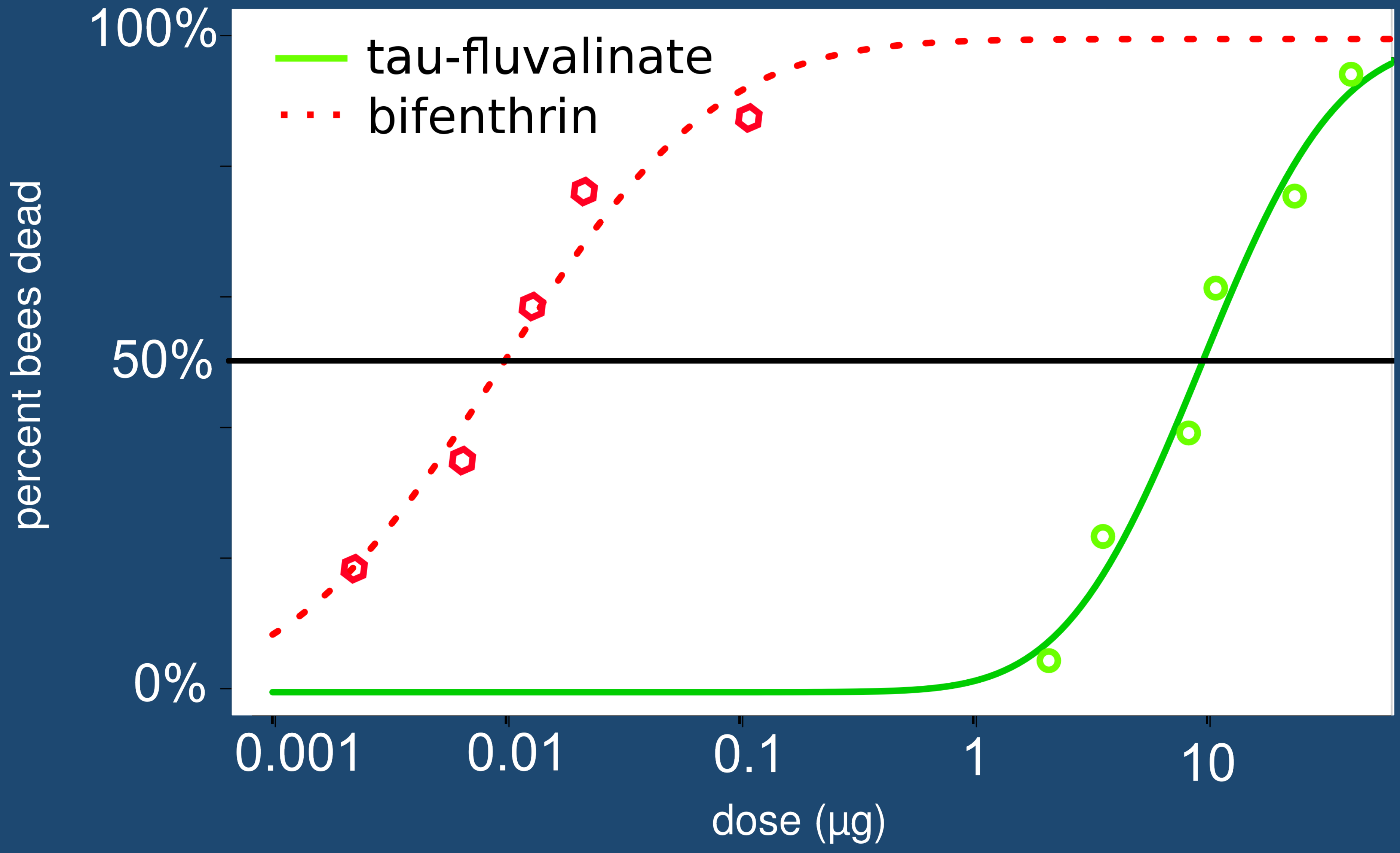


tau-fluvalinate
100%
50%
0%
percent bees dead
0.001
0.01
0.1
1
10
dose (µg)

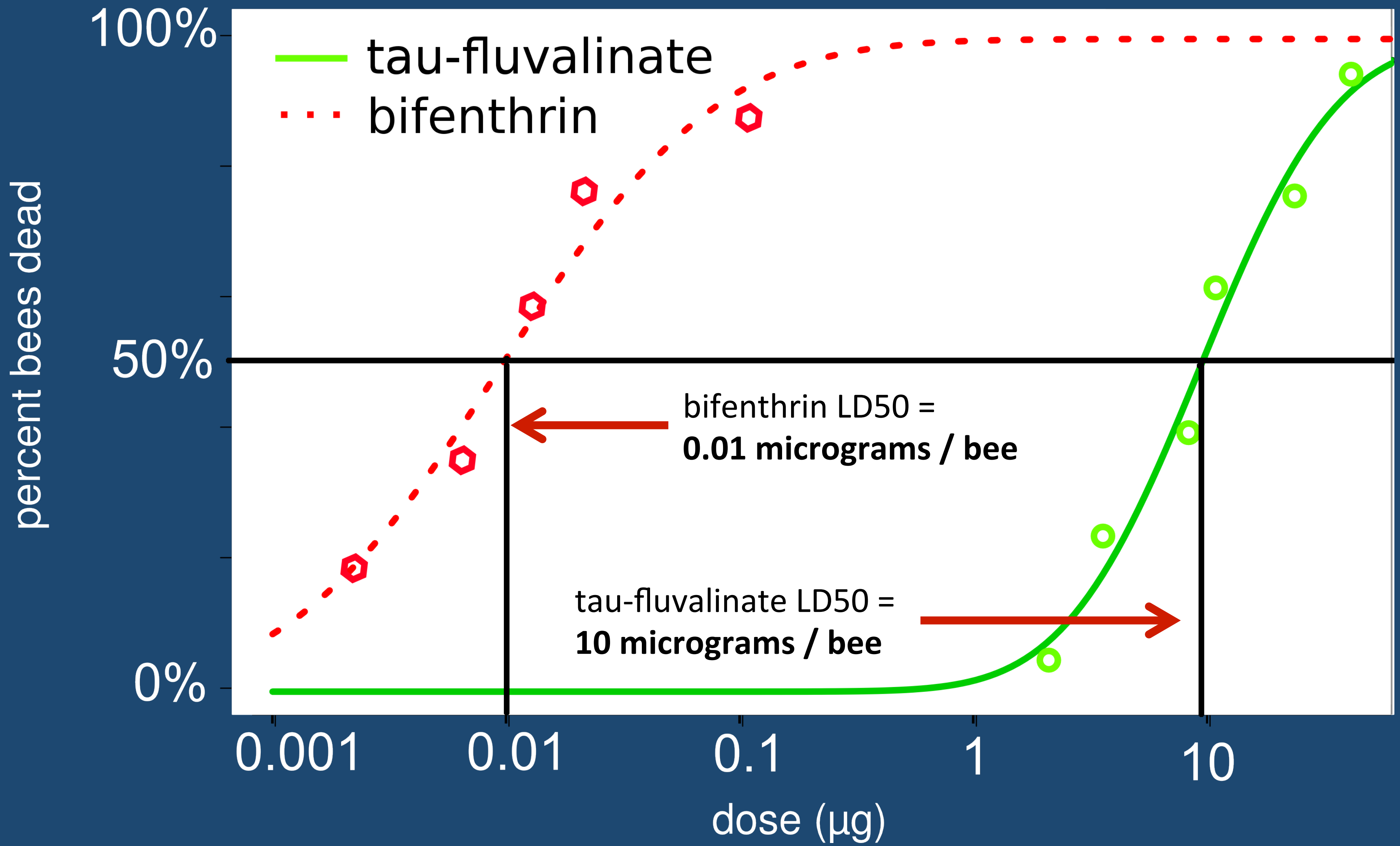

tau-fluvalinate
100%
50%
0%
percent bees dead
0.001
0.01
0.1
1
10
dose (µg)



100%
50%
0%
percent bees dead
tau-fluvalinate
bifenthrin
0.001
0.01
0.1
1
10
dose (µg)



tau-fluvalinate
bifenthrin
100%
50%
0%
percent bees dead
0.001
0.01
0.1
1
10
dose (µg)



100%
50%
0%
percent bees dead
tau-fluvalinate
bifenthrin
bifenthrin LD50 =
0.01 micrograms / bee
tau-fluvalinate LD50 =
10 micrograms / bee
0.001
0.01
0.1
1
10
dose (µg)

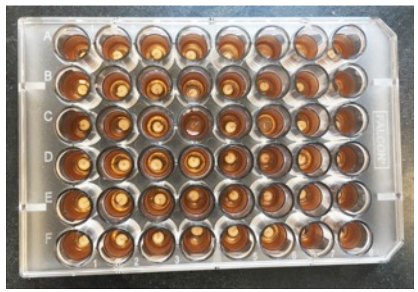
USEPA and PMRA are now “requiring” 5 LD_{50}-style tests for pesticide registration

1. Adult acute topical
2. Adult acute oral (in sugar water)
3. Adult chronic (in sugar water over 10 days)
4. Larval acute (in jelly)
5. Larval chronic – to adulthood (in jelly)

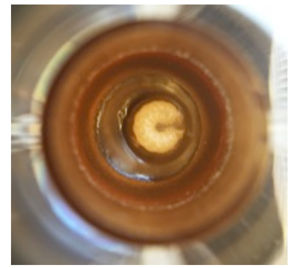
Larval rearing protocol (acute and chronic)

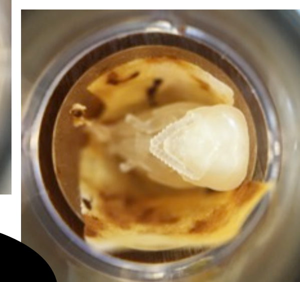
Larval Rearing Bioassay (OECD Ring Test Protocol)

Graft young larvae from brood frames



Tissue culture plates,
Cells containing diet





Exposure to pesticide in diet

adult bee emergence and mortality recorded daily

Wide variability in insecticide toxicity (hazard) to bees

- Some pesticides have low toxicity to bees and can be safely used inside the hive

- Others have high toxicity to bees and should not be used if bees will contact them

- LD_{50} is useful for comparing toxicity:

Lab LD_{50} testing

Advantages:

- Reliable and straightforward to compare
- Topical, contact, oral LD_{50} (or LC_{50})
- Adults or larvae
- Possible to test workers, queens and drones
- Possible to test other bee species

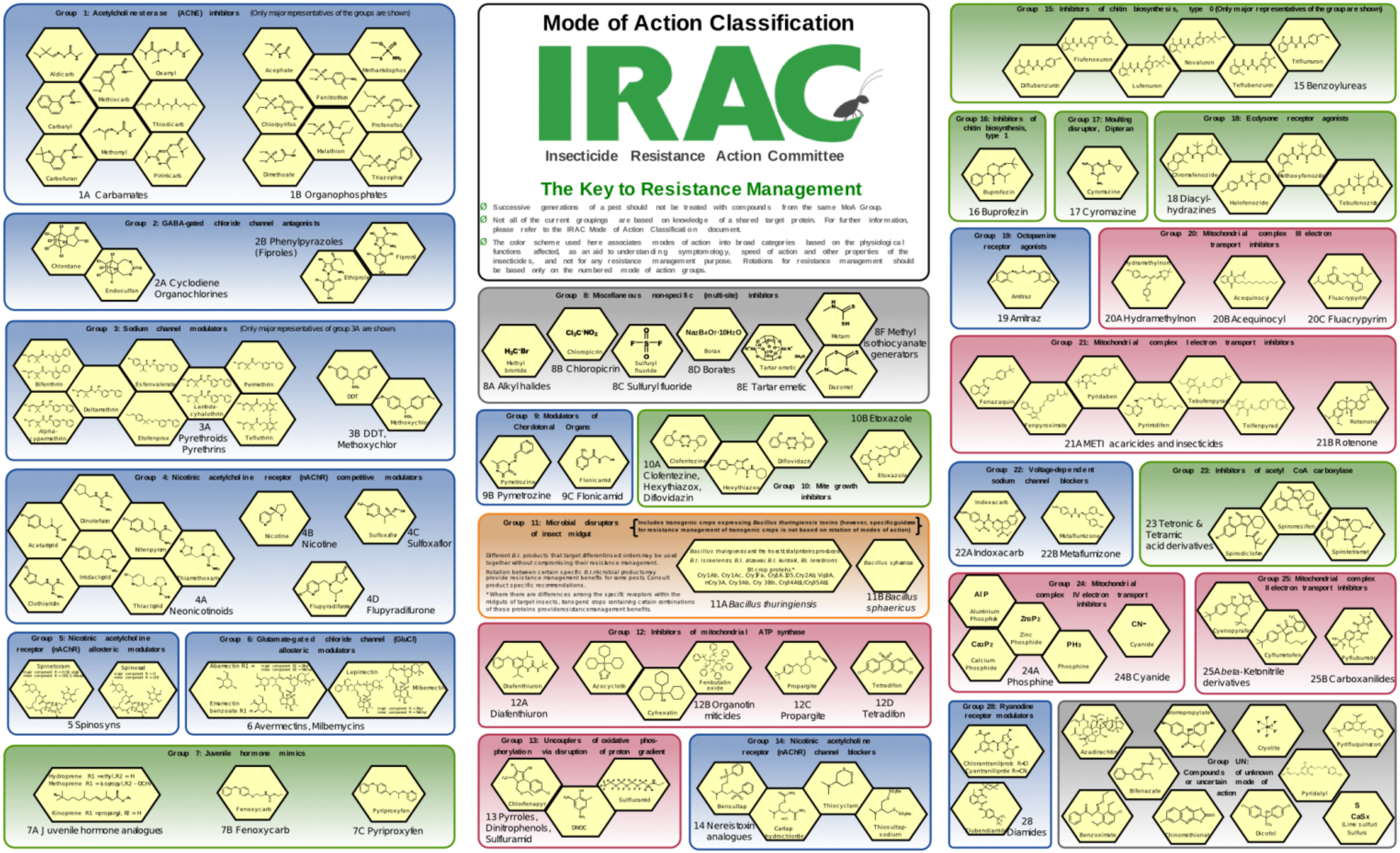
Disadvantages:

- Does not test **colony-level effects**
- Does not test **long-term** or **sub-lethal** effects

Risk = Hazard x Exposure

LD_{50}

Formulation
Function
Label restrictions and Laws



Nerve & Muscle

Growth & Development

Respiration

Midgut

Unknown or Non-specific

The Universe of Insecticides

Insecticides: **Organophosphates**

- Nerve action
- Relatively high toxicity to humans

Lorsban

Chlorpyrifos
LD_{50} = 0.059

Malathion

Malathion
LD_{50} = 0.20

Checkmite+ (Bayer)

Coumaphos
LD_{50} = 20.3

Insecticides: **Carbamates**

- Nerve action
- Somewhat toxic to humans

Temik (Bayer)	**Sevin**	**Larvin (Bayer)**
Aldicarb $LD_{50} = 0.285$	Carbaryl $LD_{50} = 1.02$	Thiodicarb $LD_{50} > 25$

Insecticides: **Pyrethroids**

- Nerve action
- Based on natural product in chrysanthemums
- Relatively safe for humans
- Repellent effect on bees
- Contact toxicity

Ortho Home Defense Max	**Pyrethrum 5EC**	**Apistan (Wellmark)**
Bifenthrin LD_{50} = 0.015	Pyrethrum LD_{50} = 0.02	Fluvalinate LD_{50} = 1.9

Insecticides: **Neonicotinoids**

- Nerve action
- Analogs of nicotine
- relatively safe for humans

Bayer Advanced

Imidacloprid
LD_{50} = 0.044

Safari (Valent)

Dinotefuran
LD_{50} = 0.047

Assail (United Phosphorus)

Acetamiprid
LD_{50} = 7.07

Insecticides: New Relatives of **Neonicotinoids**

Sivanto (Bayer)

Flupyradifurone
LD_{50} = 122

Transform (Dow)

Sulfoxaflor
LD_{50} = 0.13

Insecticides: **Diamides**

- nerve and muscle action
- contact poison
- relatively safe for humans

Altacor (DuPont)	**Belt (Bayer)**	**Cyazapyr (DuPont)**
Chlorantraniliprole	Flubendiamide	Cyantraniliprole
$LD_{50} > 100$	$LD_{50} > 200$	$LD_{50} = 0.55$

Other Insecticides

Insect Growth Regulators (IGRs): Diflubenzuron, methoprene

- LD_{50} **> 100 micrograms / bee** to adults
- Cause problems in **brood development**

Energy metabolism: Rotenone, fenpyroximate

- LD_{50} **0.024 – 60 micrograms / bee**

Lipid synthesis inhibitors: Spirotetramat

- LD_{50} **> 100 micrograms / bee**

Fungicides

- May be applied during bloom
- Very high exposure is possible
- Can be found in pollen (up to 400 ppm)
- LD_{50} **> 10 micrograms / bee**
- High doses may have effects on brood??

Captan **Rovral** **Ziram**

Mussen et al., 2004; http://dx.doi.org/10.1603/0046-225X-33.5.1151

Herbicides

- Kill flowering “weeds” bees on which bees feed
- Bees may be present
- High exposure is possible
- LD_{50} > **100 micrograms / bee**
- Possible effects at high doses??

2,4-D

Paraquat

INCLUDES UPDATED INFORMATION

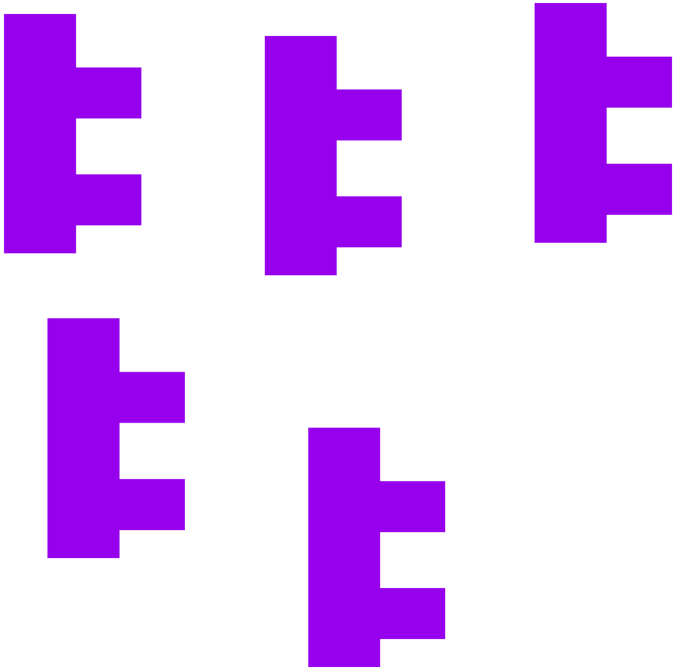
DEADLY DRUG INTERACTIONS

The Bee's Pharmacy Guide

By the authors of the multimillion-copy #1 bestseller *The People's Pharmacy*

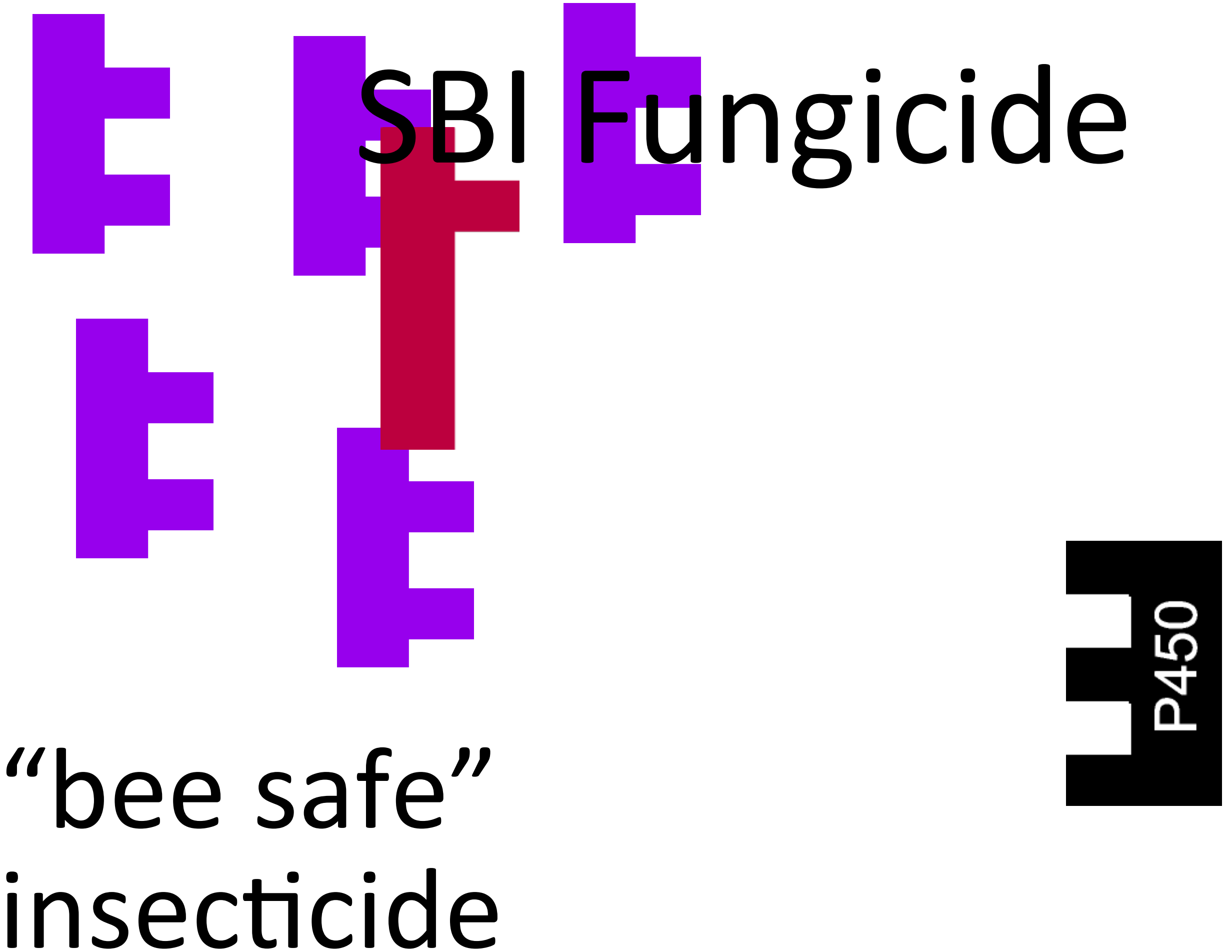
How to Protect Yourself from Harmful Drug/Drug, Drug/Food, Drug/Vitamin Combinations

Joe Graedon and Teresa Graedon, Ph.D.



“bee safe” insecticide

Cytochrome P450 monooxygenases detoxify


SBI Fungicide
“bee safe” insecticide
P450

Risk = Hazard x Exposure

LD_{50}

Formulation

Function

Label restrictions and Laws

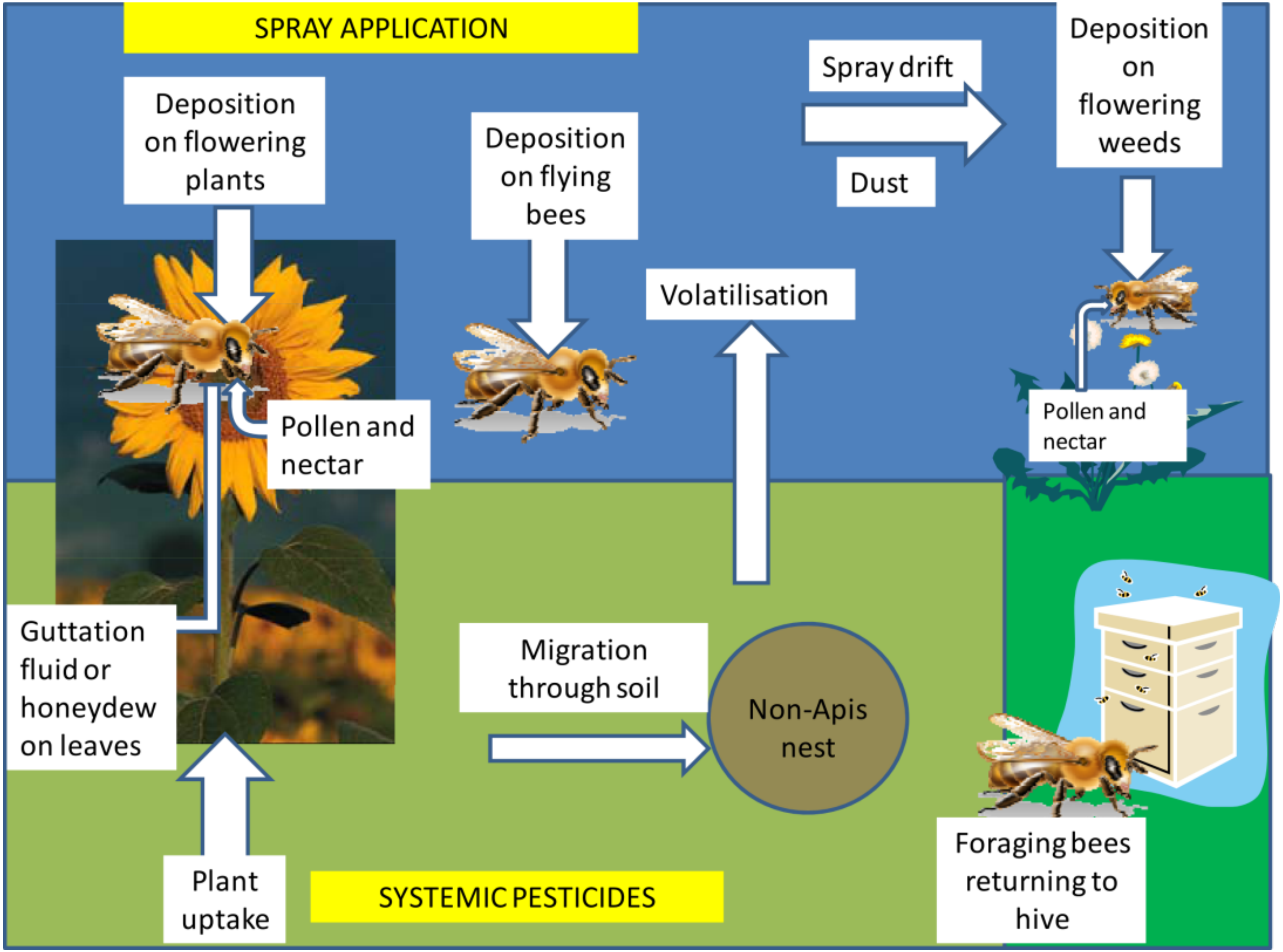
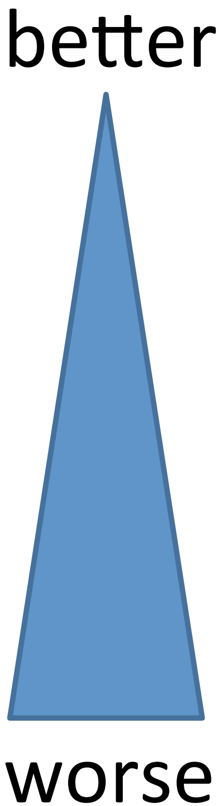


Figure 3.1, "Risk assessment for bees", EFSA, 2012

Formulation determines bee exposure

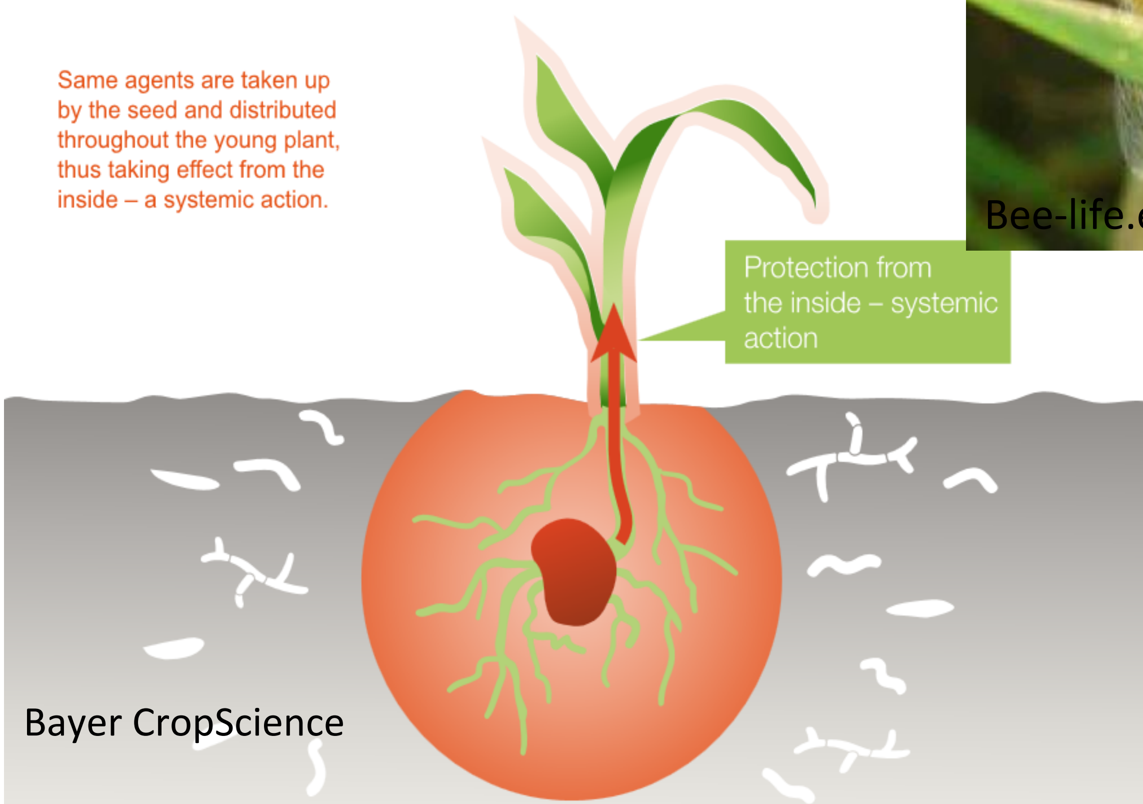


- Impregnated material
- Seed treatment
- Bait
- Granular
- Concentrates / suspensions (spray)
- Wettable powder (spray)
- Dust
- Microencapsulated

Systemicity determines exposure


Bee-life.eu

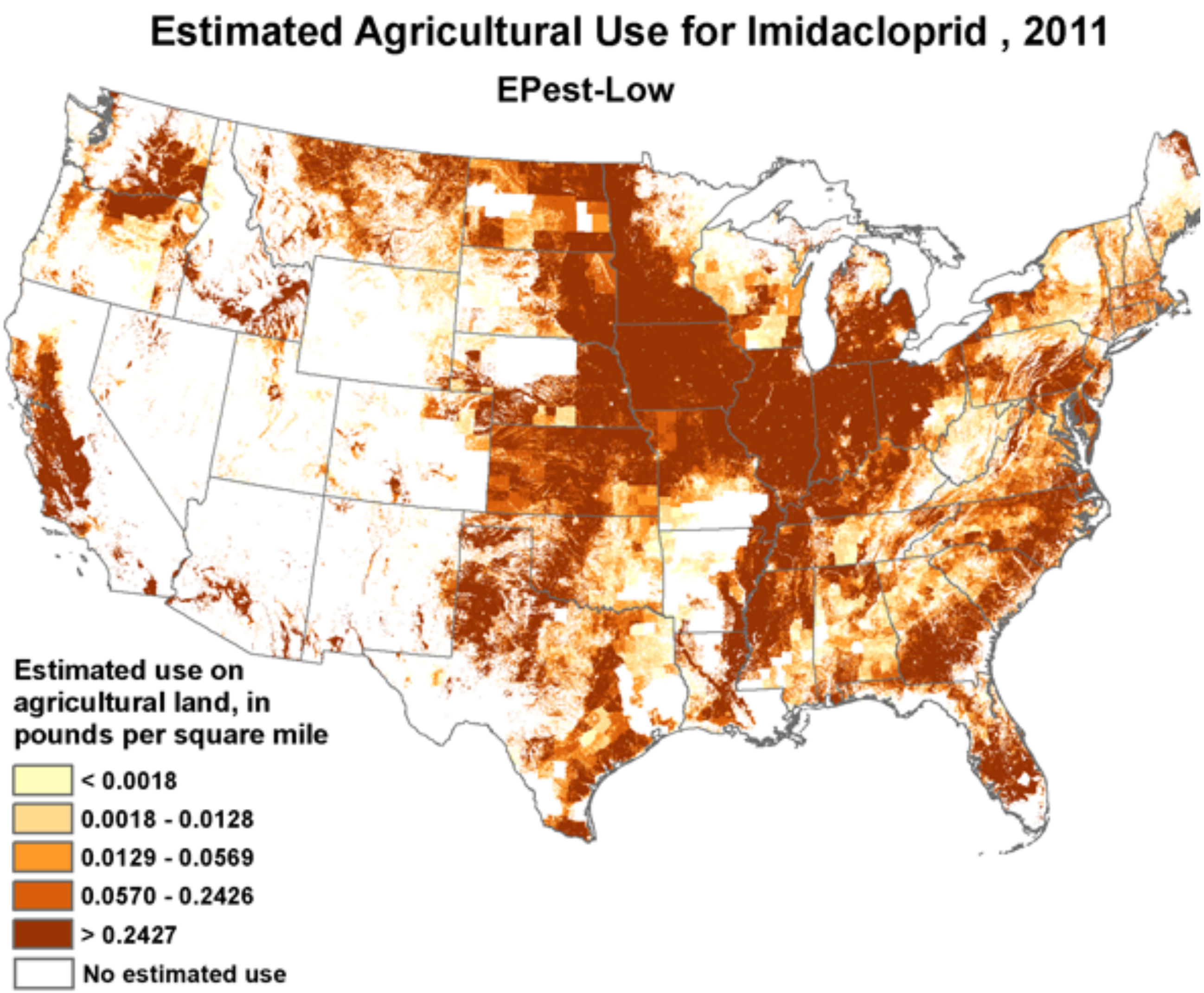
Guttation water
Pollen
Nectar



Bayer CropScience


Purdue Extension

Where are pesticides used?



http://water.usgs.gov/nawqa/pnsp/usage/maps/

Label restrictions determine bee exposure

INNOVA BIFENTHRIN 100 MITICIDE/INSECTICIDE 16 October 2007
Approved Label Text Page 1 of 12

POISON
KEEP OUT OF REACH OF CHILDREN
READ SAFETY DIRECTIONS BEFORE OPENING OR USING

innova®

Bifenthrin 100

MITICIDE / INSECTICIDE

ACTIVE CONSTITUENT: 100 g/L BIFENTHRIN
SOLVENT : 763 g/L LIQUID HYDROCARBONS

GROUP 3A INSECTICIDE

For the control of Helicoverpa spp in Cotton, Tomatoes, Lucerne Seed Crops, Navy Beans; Carpophilus Beetle in Stone Fruit (except Cherries); certain species of mites in Bananas, Cotton and Tomatoes; Longtailed Mealy Bug in Pears; Banana Weevil Borer and Banana Rust Thrips in Bananas; Mirids in Cotton; Whitefly in Tomatoes; Redlegged Earth Mite, Blue Oat Mite, Bryobia Mite, Webworm and Brown Pasture Looper in Faba Beans, Subterranean Clover, Clover, Canola, Wheat, Barley, Field Peas, Lupins and Lucerne; certain species of Wireworms in Cotton and Sugarcane; and Fig Longicorn in Grapes and Citrus Leafeating Weevil in Citrus as per the Directions for Use

IMPORTANT: Read the attached booklet before use

20 LITRES

Syngenta Crop Protection Pty Limited
Level 1, 2-4 Lyonpark Road, Macquarie Park NSW 2113

In a transport emergency dial 000, Police or Fire Brigade
For specialist advice in an emergency only,
call 1800 033 111 (24 hours)

APVMA Approval No: 62211/20/0707
lbf0807

syngenta®

PROTECTION OF LIVESTOCK

Dangerous to bees. **DO NOT** spray any plants in flower when bees are foraging. Spray in the early morning when bees are not actively foraging.

Application rate determines bee exposure

CUCURBITS (PHI – 3 Days)

chayote (fruit), Chinese waxgourd (Chinese preserving melon), citron melon, cucumber, gherkin, gourd, edible (includes hyotan, cucuzza), *(Luffa spp.)* (includes hechima, Chinese okra), *(Momordica spp.)*, (includes balsam apple, balsam pear, bitter melon, Chinese cucumber) muskmelon (hybrids and/or cultivars of *Cucumis melo*, includes: true cantaloupe, cantaloupe, casaba,Crenshaw melon, golden pershaw melon, honeydew melon, honey balls, mango melon, Persian melon, pineapple melon, Santa Claus melon, snake melon), pumpkin *(Cucurbita spp.)*, summer squash (includes: crookneck squash, scallop squash, straightneck squash, vegetable marrow, zucchini), winter squash (includes: butternut squash, calabaza, Hubbard squash (*C. mixta; C. pepo*) includes acorn squash, spaghetti squash), watermelon (includes hybrids and or varieties of *Citrullis spp.*)

PEST	RATE	APPLICATION INSTRUCTIONS AND PRECAUTIONS
aphids armyworms cabbage looper corn earworm cucumber beetles cutworm grasshopper leafhoppers melonworm pickleworm plant bug rindworm squash bugs squash vine borer stink bugs tobacco budworm	2.6 to 6.4 fl. oz. per acre (0.04 to 0.1 lb. ai per acre)	For spray applications, cover foliage with sufficient water to provide thorough, uniform coverage and distribution of spray mixture. For ground applications, use a minimum of 20 gallons of spray mixture per acre. For air applications, use a minimum of 5 gallons of spray mixture per acre. Use of emulsified oil (1 to 2 quarts) is allowed to replace some of the volume of water in the spray mixture. Do not apply more than 0.3 lb. ai (19.2 ounces formulated) per acre per season. Do not make more than two applications after bloom. Do not make applications less than 7 days apart.
Banks grass mite Carmine mite *Lygus spp.* two-spotted spider mite whitefly	5.12 to 6.4 fl. oz. per acre (0.08 to 0.1 lb. ai per acre	

Federal Insecticide Fungicide and Rodenticide Act (FIFRA) of 1947, revised 1972, 1988, 1996

“unreasonable adverse effects on the environment.”

Risk analysis of environmental effects includes a **cost-benefit analysis**

Not the same as the **“precautionary principle”** used in the European Union

$$\text{Risk Quotient (RQ)} = \frac{\text{Exposure (lb. a.i. / acre)}}{LD_{50}\ (\mu g\ /\ \text{bee})}$$

Level of Concern (LOC) reached when RQ > 0.4

Historically, reduces mortality to 10%

Pollinator Risk Assessment Framework Agency White Paper, US EPA, 2012

Big Changes in Regulatory Risk Assessment

FIGURE 1. Portion of apiary, at edge of citrus grove, killed by pesticide application to blooming citrus tree. Only three colonies out of 120 survived. (*Photo by E.L. Atkins*).

The Hive and the Honey Bee

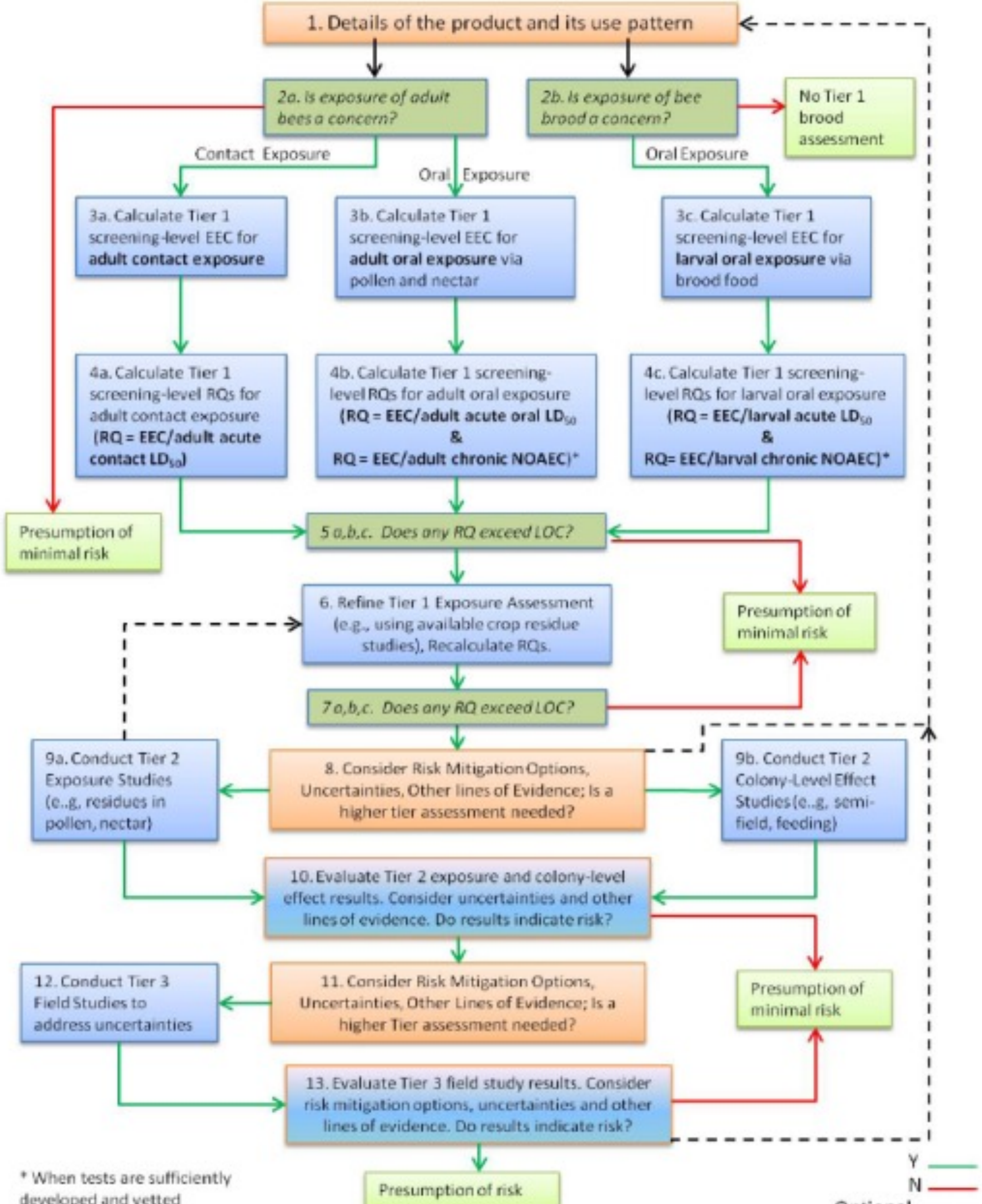
Old Protection Goal: Stop Bee Kills

New Pollinator Protection Goals:

1. Delivery of pollination services
2. Production of honey and hive products
3. Biodiversity of pollinators

EPA: Pollinator Risk Assessment Framework Agency White Paper, US EPA, 2012.
http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2012-0543-0004

EFSA: Scientific Opinion on the science behind the development of a risk assessment of Plant Protection Products on bees (*Apis mellifera*, *Bombus* spp. and solitary bees), EFSA, 2012.
http://www.efsa.europa.eu/en/efsajournal/pub/2668.htm



Tier 1: Laboratory studies on adults and larvae

Tier 2: Semi-field studies with whole colonies in tents

Tier 3: Full field studies with treated crop

Harmonized Pesticide Risk Assessment for USEPA and PMRA

Pollinator Protection

Pollinator Protection Home
Pollinator Health Concerns
— Colony Collapse Disorder
— Factors Affecting Pollinator Heath
— Risk Assessment
— EPA Actions to Protect Pollinators
— Partners in Pollinator Protection
What You Can Do
— Report Bee Kills
— Best Management Practices

Pollinator Risk Assessment Guidance

The EPA's Pollinator Risk Assessment Guidance is part of a long-term strategy to advance the science of assessing the risks posed by pesticides to bees, giving risk managers the means to further improve pollinator protection in our regulatory decisions. Among other things, the EPA anticipates the guidance will allow the Agency to assess effects from systemic pesticides quantitatively on individual bees as well as on bee colonies. This guidance is an outgrowth of the 2012 FIFRA Scientific Advisory Panel Meeting on Risk Assessment for Bees.

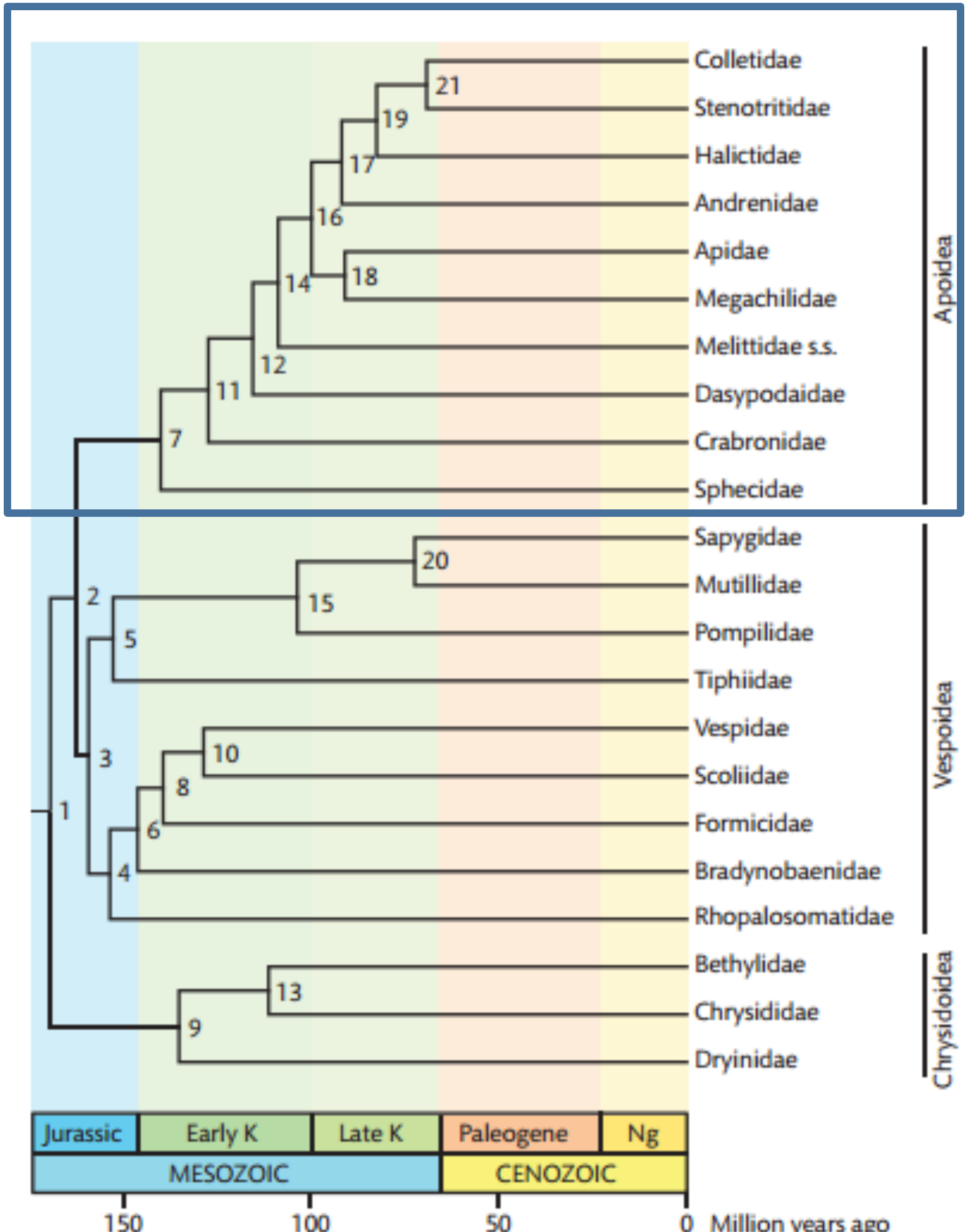
You may need Adobe Reader to view files on this page. See EPA's About PDF page to learn more.

- Guidance for Assessing Pesticide Risks to Bees (PDF) (59 pp, 2 MB)
- Guidance on Exposure and Effects Testing for Assessing Risks to Bees (PDF) (44 pp, 1 MB)

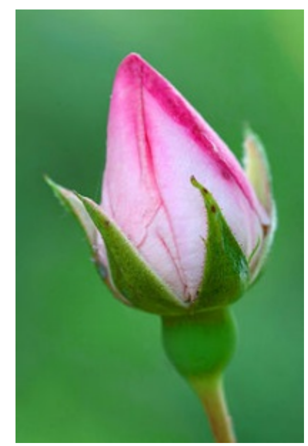
The other 20,000 bees . . .
(3500 in North America)

All bees eat pollen and nectar

Branched body hair is adaptation for pollen collection

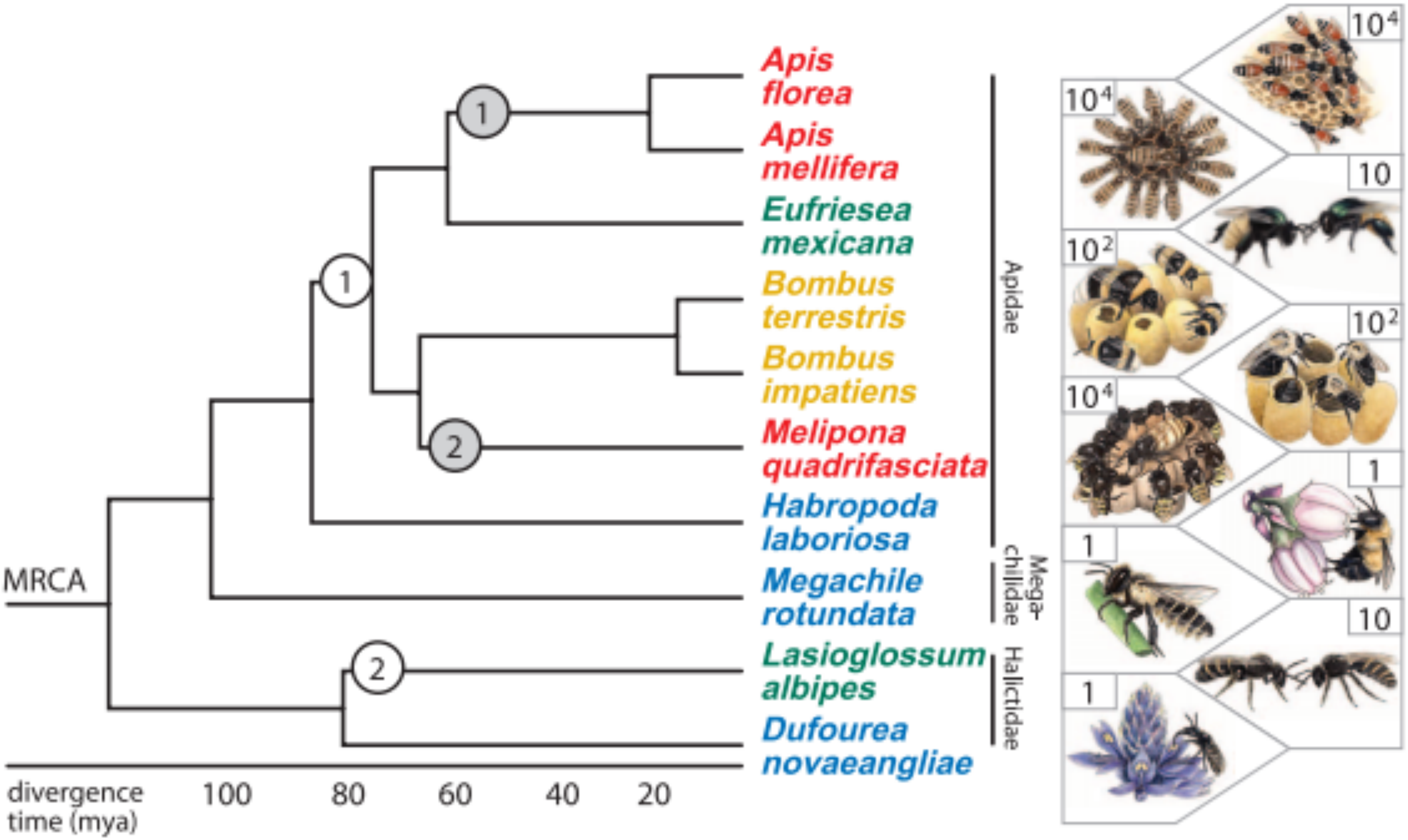


Bees are wasps that eat nectar and pollen. Coevolved with flowering plants ~100 mya



Brady et al., 2009, The Timetree of Life

10 bee genomes sequenced



Similar detox gene repertoire across bee species (~50 P450s)

Kapheim et al., Science, 2015

Considerable similarity among bees when acute toxicity is adjusted for mass

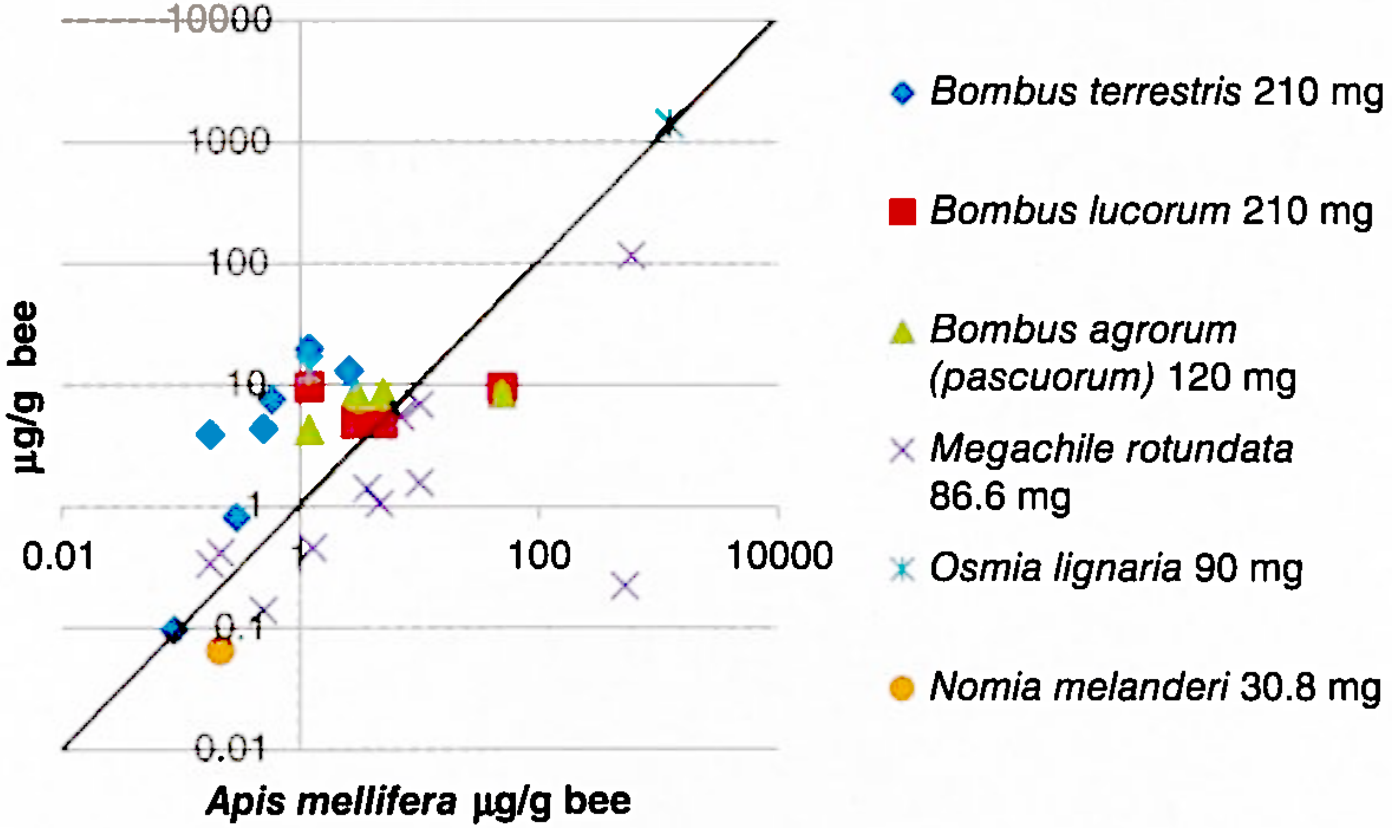


Figure 8.1, Fischer and Moriarty, 2014

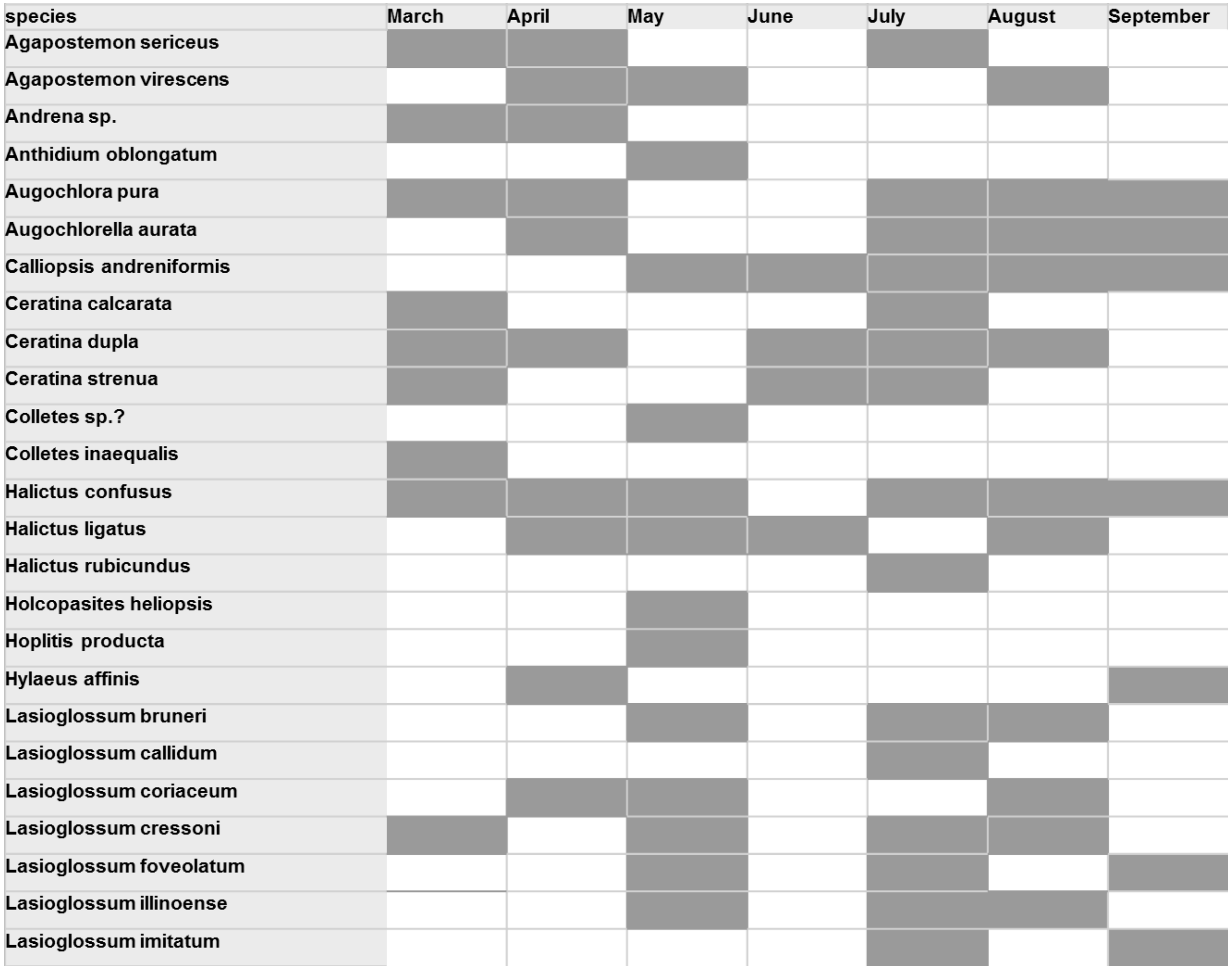
Risk = Hazard x Exposure

Variation in pesticide sensitivity

Risk = Hazard x Exposure

Differences in biology lead to differences in exposure

Seasonality: When are bees active?



Most activity in spring and early summer, but some species may be active throughout the season

J. Wallace, unpublished

Nest Site – Ground Nesters

Alkali bee

Bumble bee

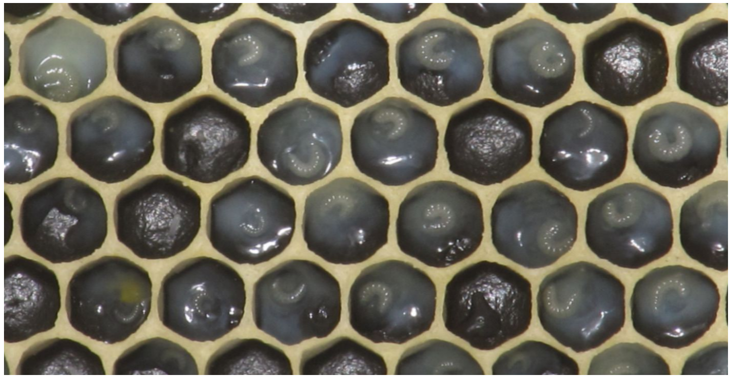
Nest Site – Stem/Cavity Nesters

Stem nesters – cell arrangement

Plug Male cells Female cells

Larval Feeding

Progressive provisioning



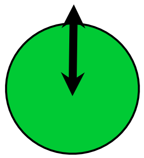
Apis spp. – "jelly" secretions from adults

Bombus spp.
Pollen and
nectar

Mass provisioning

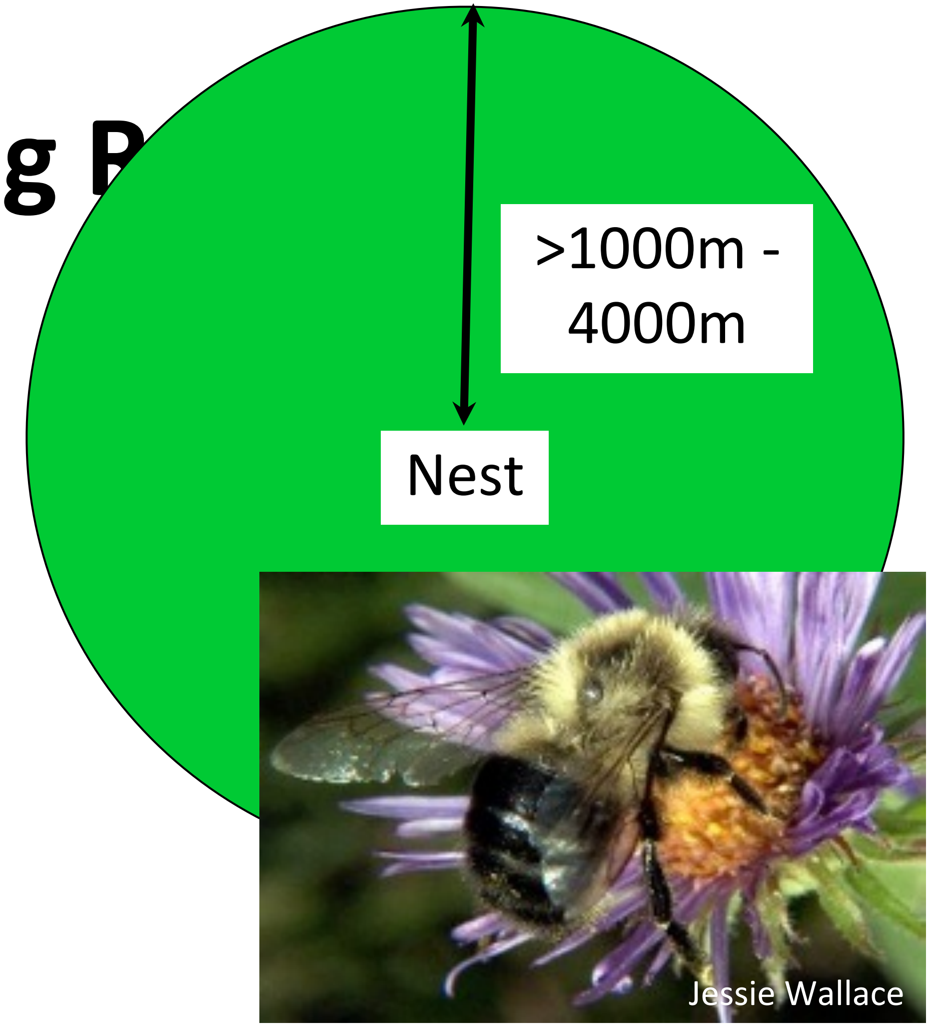
Larva provisioned with ball of pollen and nectar sufficient to complete development

Foraging R



100m - 400m

3 mm

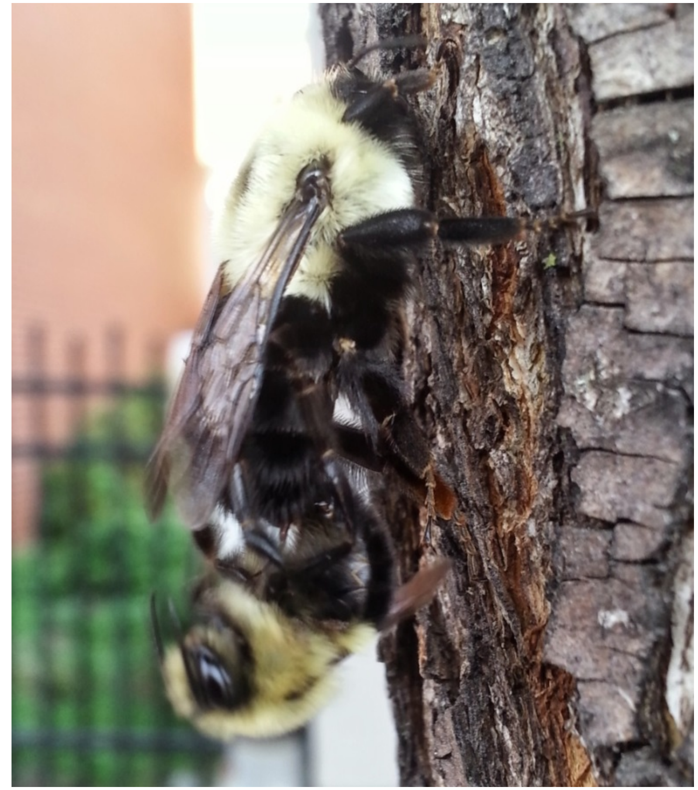


15-20 mm

Big bee = big foraging range

Small bee = small foraging range

Floral Specialization

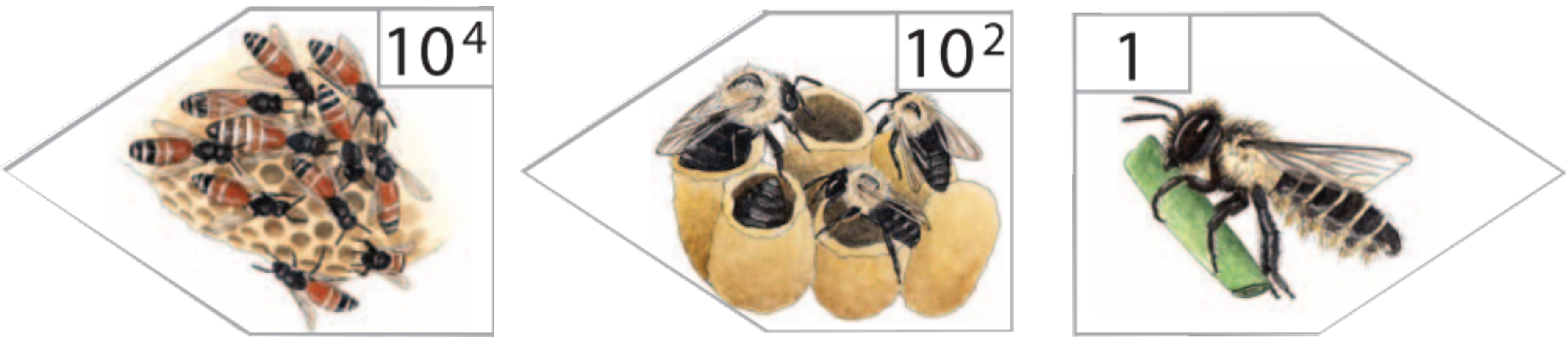


Common Eastern Bumble Bee – a broad generalist

Sociality

obligate
complex
eusociality

solitary



Kapheim et al., Science, 2015

Sociality changes exposure

Suggested reading:

1. Atkins E (1992) Injury to honey bees by poisoning. The Hive and the Honey Bee. Hamilton, IL: Dadant & Sons, Inc. pp. 1153–1208.
2. How to Reduce Bee Poisoning from Pesticides PNW 591, A Pacific Northwest Extension Publication. 2016. https://catalog.extension.oregonstate.edu/pnw591
3. Pesticide Risk Assessment for Pollinators: Executive Summary from SETAC. 2011 http://www.setac.org/node/265
4. USEPA Pollinator Risk Assessment Guidance

   https://www.epa.gov/pollinator-protection/pollinator-risk-assessment-guidance

Information about specific pesticides:

US EPA Ecotox Databases
https://cfpub.epa.gov/ecotox/

Insecticide Resistance Action Committee Mode of Action Guide
http://www.irac-online.org

PMRA Label database
http://pr-rp.hc-sc.gc.ca/ls-re/index-eng.php