PRO Green EXPO

Colorado Convention Center

Denver, CO | February 5 - 7, 2020

A Review of Insecticide Classes and Characteristics

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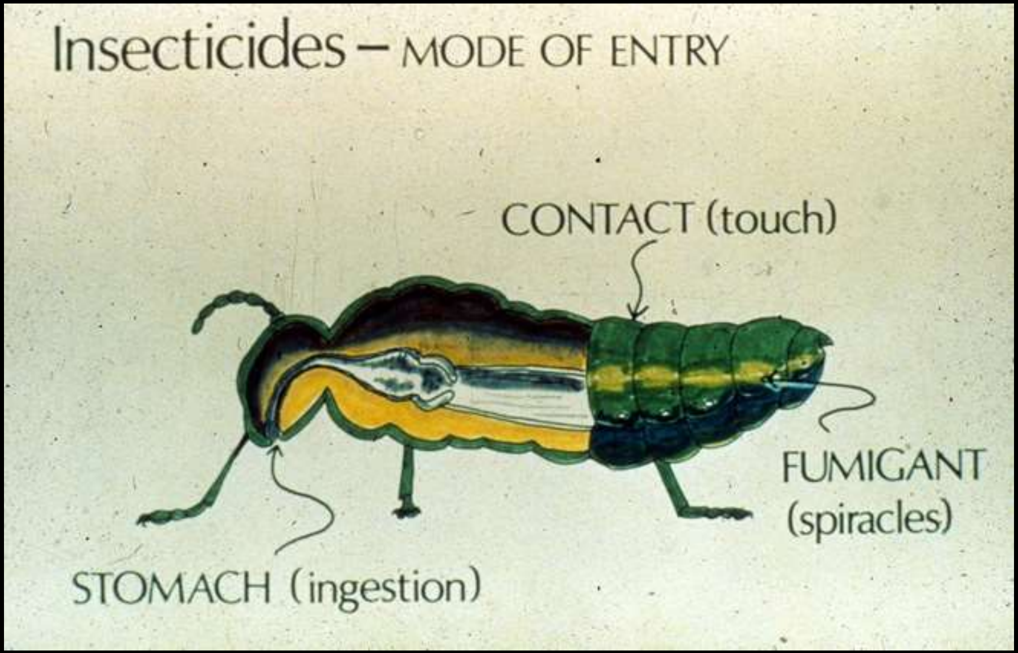
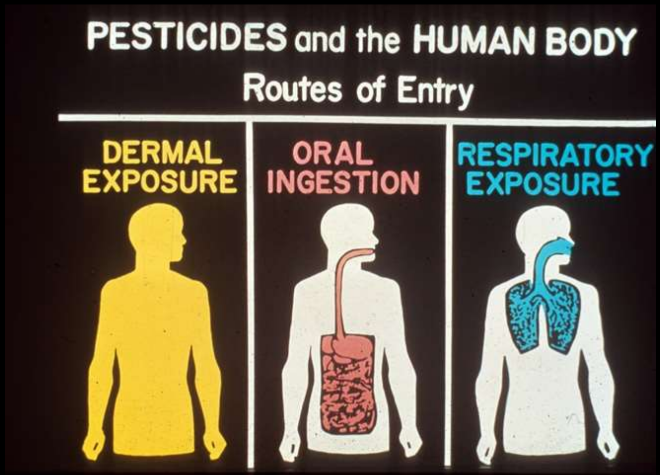
Colorado State University

Common Types of Pesticides
(*Organisms Controlled*)

- **Herbicides**
  - ***Higher Plants***
- **Algacides**
  - *Algae*
- **Fungicides**
  - ***Fungi***
- **Bactericides**
  - ***Bacteria***
- **Insecticides**
  - ***Insects***
- **Acaricides/ Miticides**
- **Molluscicides**

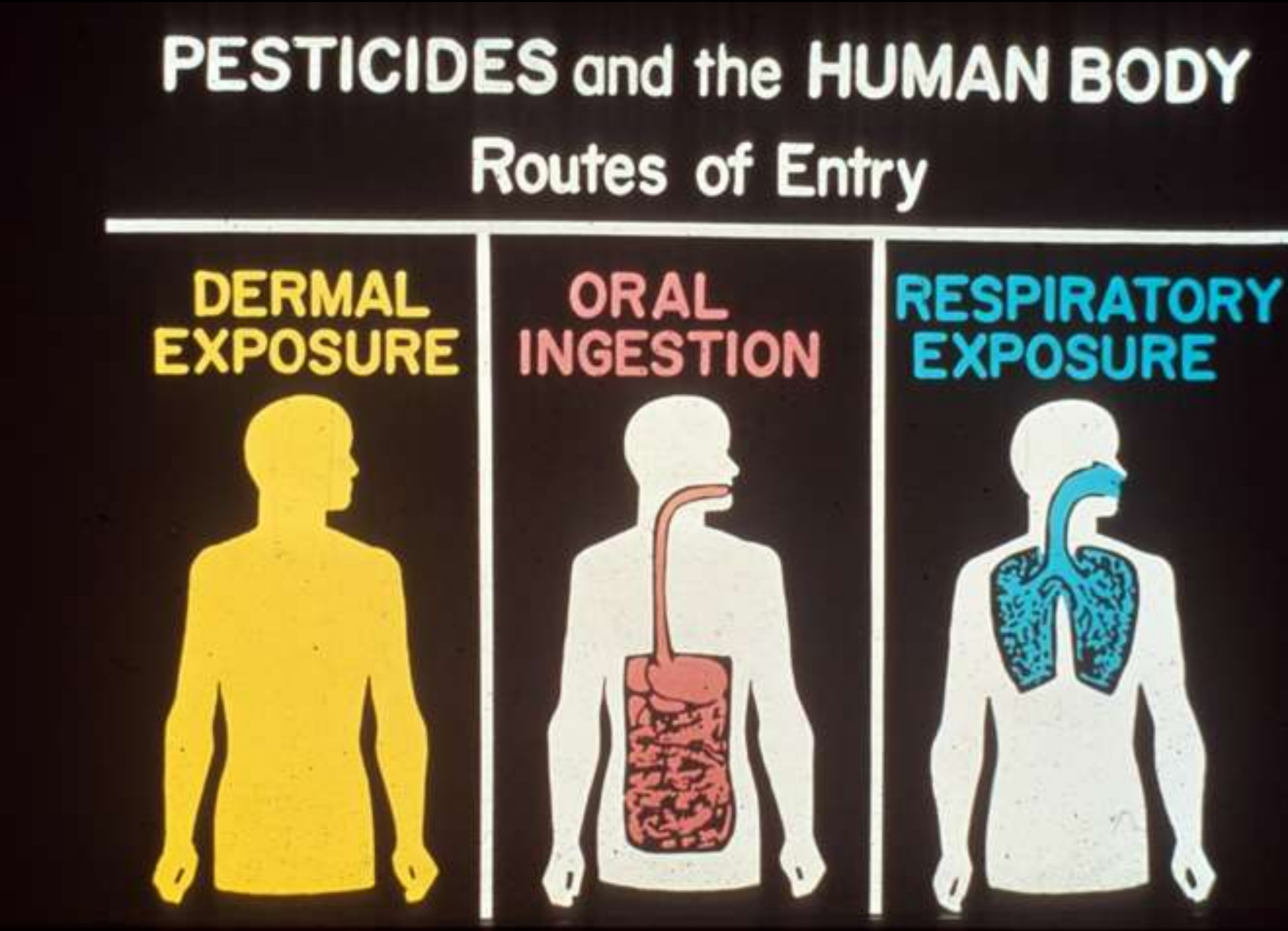
Classification of Insecticides





Mode of Entry

Insecticides – MODE OF ENTRY

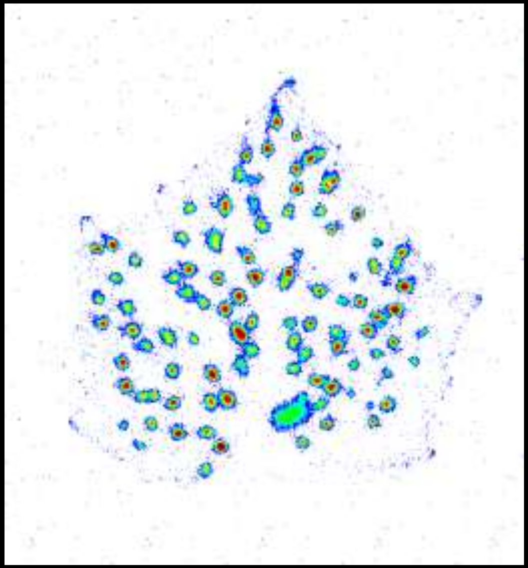

PESTICIDES and the HUMAN BODY
Routes of Entry
DERMAL EXPOSURE
ORAL INGESTION
RESPIRATORY EXPOSURE

Classification of Insecticides

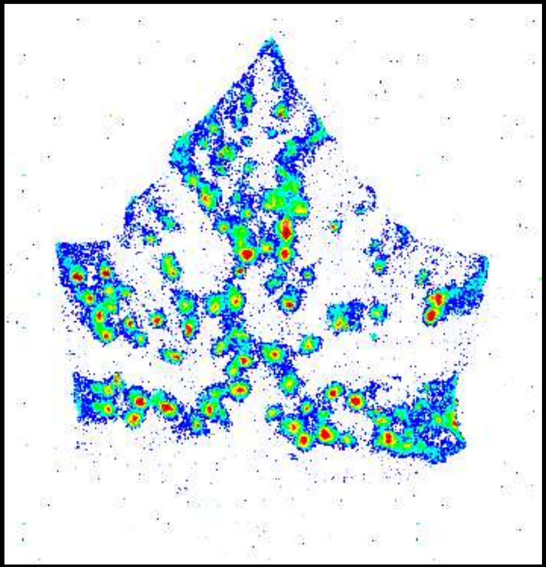
Systemic or Not Systemic?

Are they capable of moving within the plant?

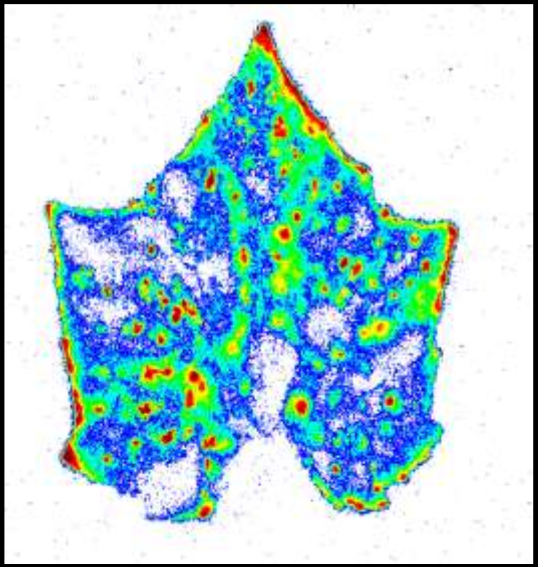
Distribution of C^{14} labeled Thiamethoxam™ 25WG after a foliar application to cucumber leaves



1 hour after application

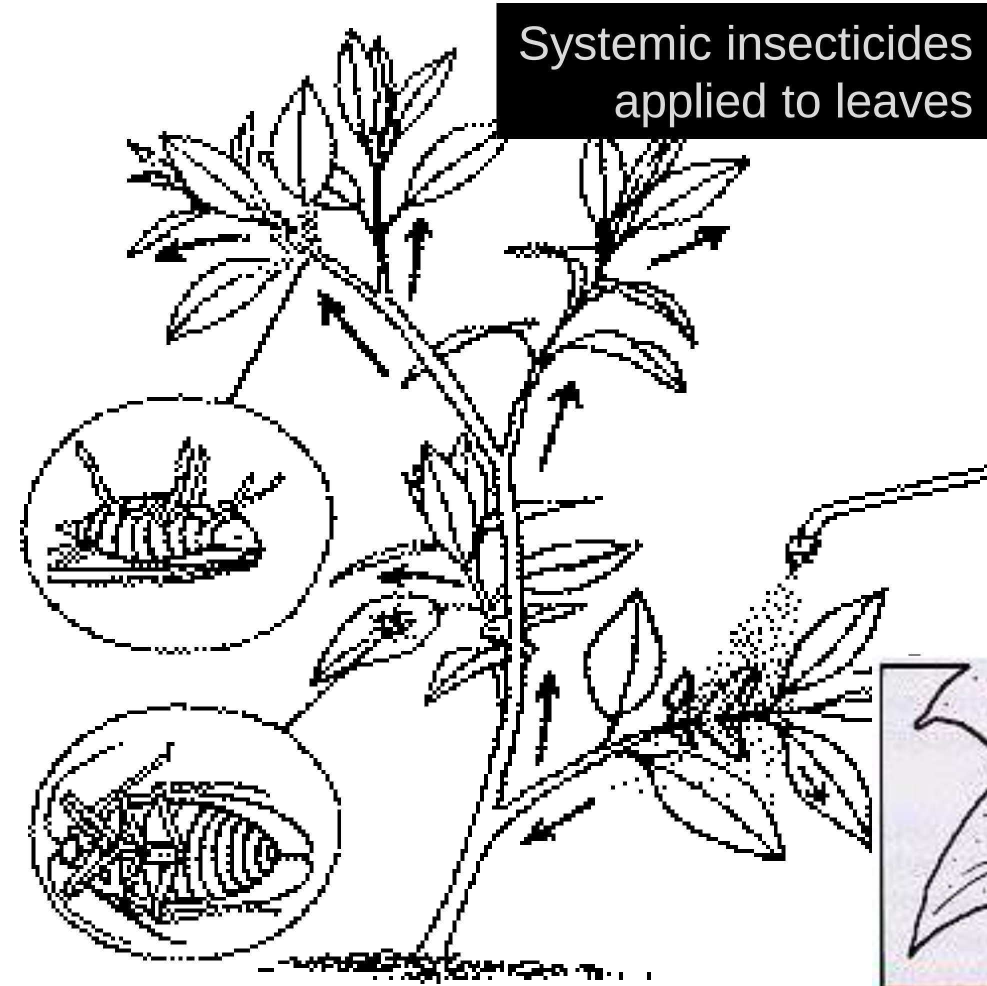


8 hour after application



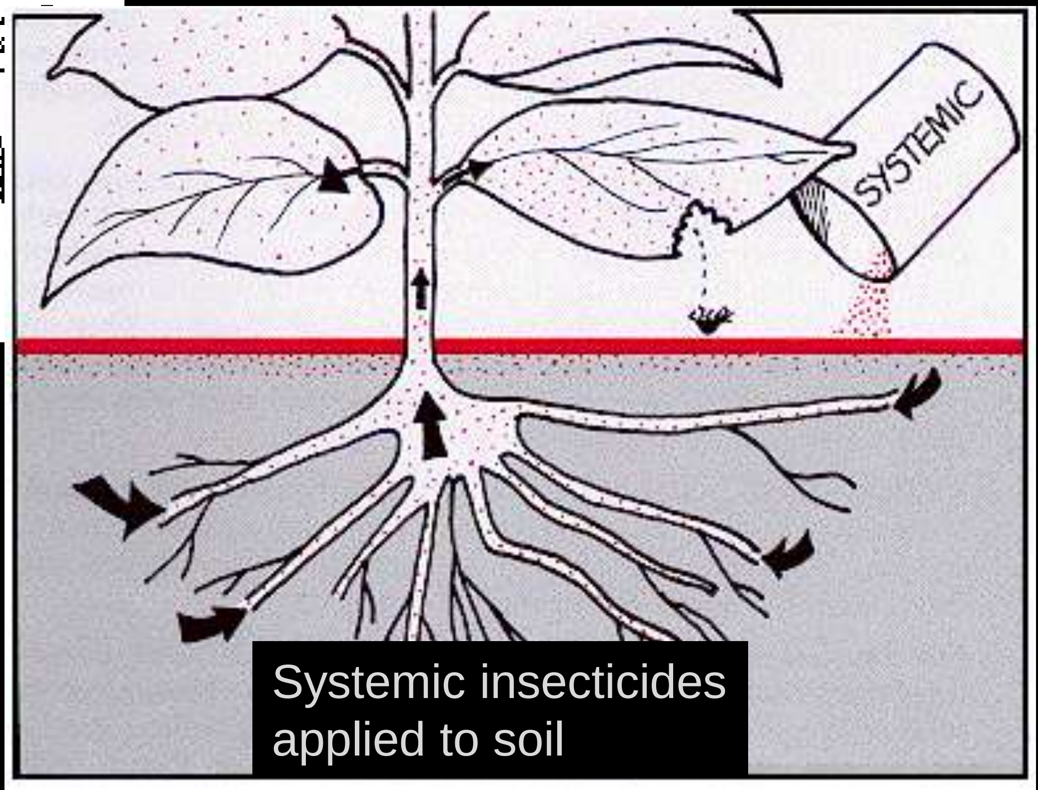
24 hour after application

Slide Credit: N. Rechcigl



Some systemic insecticide can move into plants when sprayed onto leaves.

Some systemic insecticides can move into plant when applied to the roots.



Most systemic insecticides will appear in highest concentration in the new growth

Systemic Insecticides

- *Capable of some translocation in plant*
- *Range exists in ability to move in plant*
  - Some limited to translaminar movement
  - Some broadly distribute in plant (usually to newer growth)
- *Systemic activity is limited to a small number of insecticides*
  - Most neonicotinoids
  - Diamides (limited)
  - Abamectin (translaminar only)

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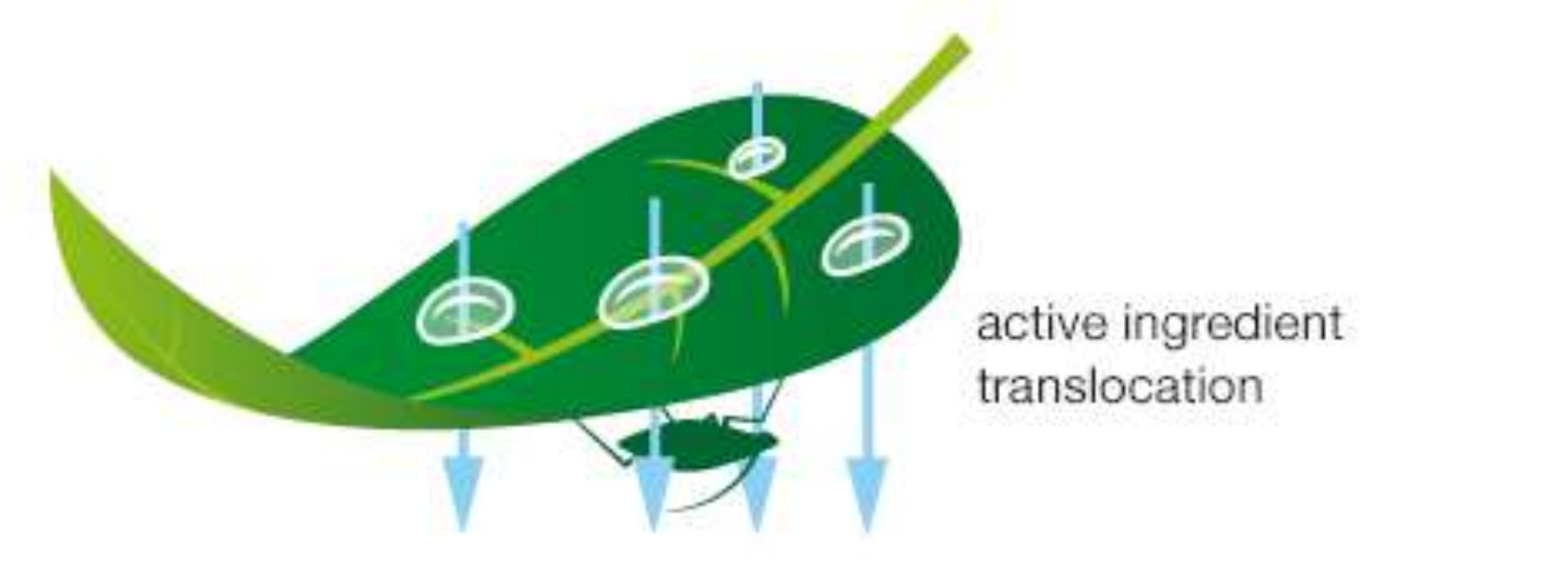
- ***Systemic activity is limited to a small number of insecticides***
  - **Some organophophates**
  - **All neonicotinoids**
  - **Diamides (limited)**
  - **Avermectins (translaminar only)**

Translaminar movement – Insecticide can move through a leaf (but not necessarily to another leaf)

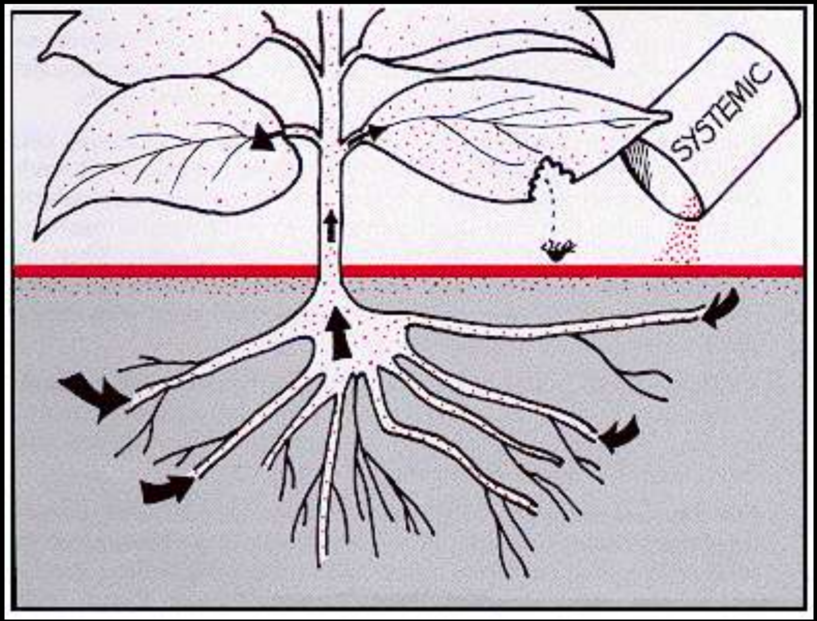


Example: **Foliar applications of abamectin (Avid)**

Essentially all systemic insecticide move primarily in the xylem of the plant.
Essentially all systemic insecticides primarily move upward.

Only one product moves both upwards and downwards - spirotetramat

This is labeled for greenhouse/nursery crops as **Kontos** and for fruits and vegetables as **Movento**



Common method of applying systemic insecticides – soil applications for root uptake

Soil injections

Soil drenches

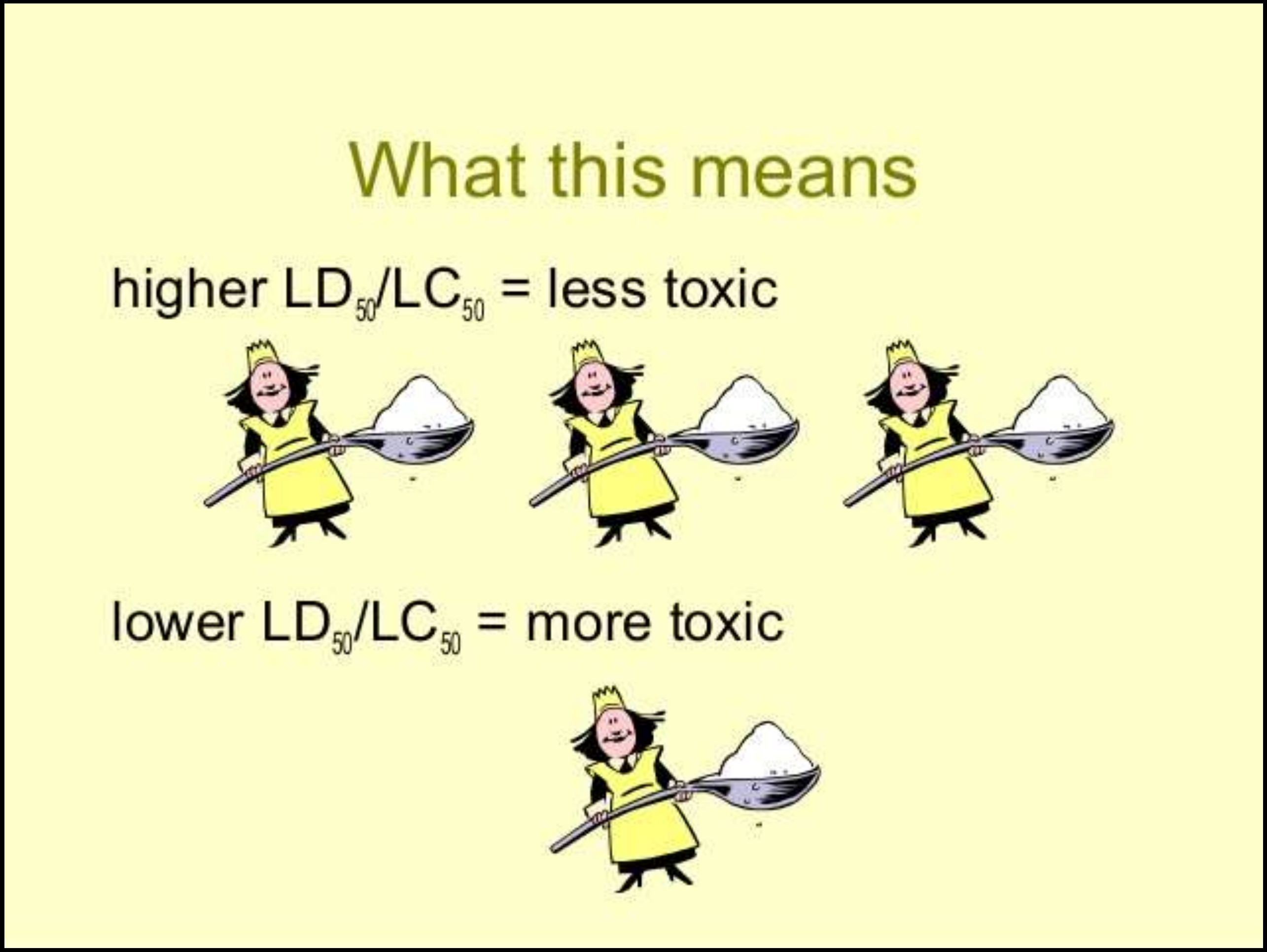
Foliar sprays are often used when soil active systemic insecticides are not available

Broad Spectrum
or Selective Activity?

Selectivity of Insecticides Can Derive from…..

- Differences in inherent toxicity of the insecticide to different insects
- Persistence of the insecticide
- Formulation of the pesticide
- Time when the insecticide is applied
- Where the insecticide is applied

Pesticide that is Selective because it is ***Inherent Toxicity of the Pesticide***



LD50: Lethal dose that will kill 50% of the test population

Acute Toxicity of Neonicotinoids to Adult Honey Bees

(Oral LD50 – micrograms/bee)

• Acetamiprid	14.53
• Imidacloprid	0.005
• Dinotefuran	0.056
• Thiamethoxam	0.005
• Chlothianidin	0.0003

Pesticide that is Selective in the ***Time it is Applied***

Applications made during the dormant season

Insecticides and Pollinators: Bottom Line

Always avoid applications to plants *that bees are visiting* – *It is the law!*

Systemic Insecticides and Pollinators: Bottom Line?

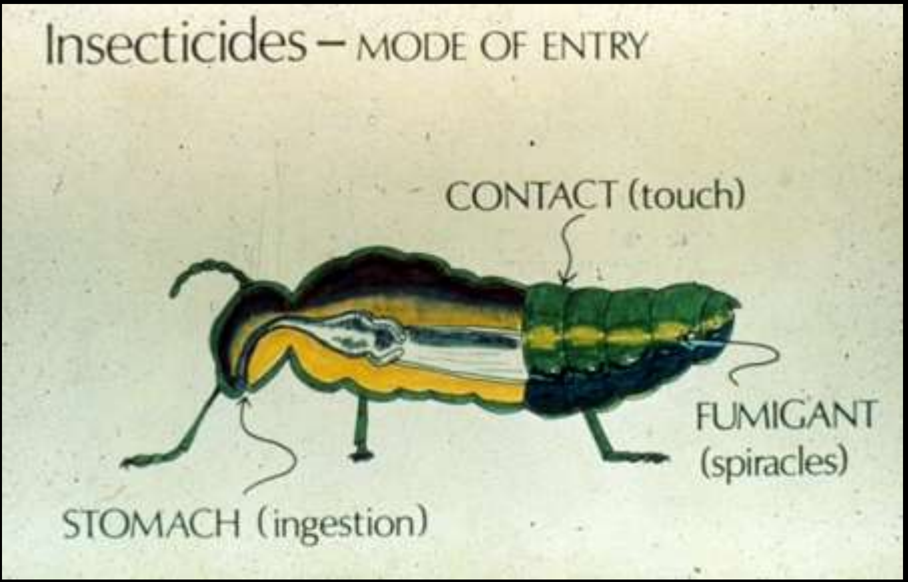
Avoid applications to plants *that bees visit* that are in bloom – *or soon will be in bloom*

Spider Mite Control Products

- *Least disruptive of natural enemies*
  - Floramite (bifenazate)
  - TetraSan (extoxazole)
  - Hexygon (hexythiazox)



Pesticide that is Selective in the ***Mode of Entry***



Bacillus thuringiensis example

Pesticide that is Selective because of its ***Persistence of Activity***

Pyrethrins

Insecticidal Soap

Insecticide Persistence

- General measure – half life
- Factors affecting degradation
  - Sunlight/UV
  - Moisture
  - pH
  - Microbial degradation

Examples of insecticides that are very rapidly degraded upon exposure to sunlight

Bacillus thuringiensis

Pyrethrins

Pyrethrins

An example of an insecticide that ***very rapidly breaks down upon exposure to light***

Tancetum (= *Chrysanthemum*) ***cineriariifolium***
Pyrethrum daisy – *source of pyrethrum*

Pyrethroid Insecticides
(a.k.a., synthetic pyrethrins)

Pyrethroid insectides are based on the chemistry of natural pyrethrins

Many pyrethroid insecticides have ability to persist for weeks - months

Pesticide that is Selective because of ***Where the Pesticide is Applied***

Spraying whole plant

Soil application of systemic insecticide

Pesticide that is Selective because of the ***Formulation of the Pesticide***

Baits

vs.

Sprays

Dusts

Selectivity of Insecticides Can Derive from…..

- Differences in inherent toxicity of the insecticide to different insects
- Persistence of the insecticide
- Time when the insecticide is applied
- Where the insecticide is applied
- Formulation of the pesticide

“Historical” Classes of Insecticides

Heavy metal/ inorganic insecticides

Chlorinated hydrocarbon insecticides

Organophosphate Insecticides

Insect Control Products Available a Century Ago

- Lead Arsenate/Calcium Arsenate
- Sulfur/Lime Sulfur
- Dormant Oils
- Nicotine Sulfate
- Rotenone
- Pyrethrins
- Ryania

Insect Control Products Available a Century Ago

- ~~Lead Arsenate/Calcium Arsenate~~
- Sulfur/~~Lime Sulfur~~
- Dormant Oils
- ~~Nicotine Sulfate~~
- ~~Rotenone~~
- Pyrethrins
- ~~Ryania~~

Aerial application of lead arsenate for gypsy moth control

What we used 35 years ago

- Dursban
- Malathion
- Methoxychlor
- Diazinon
- Carbaryl
- Cygon
- Orthene
- MetaSystox-R
- Furadan

Chlorinated Hydrocarbons

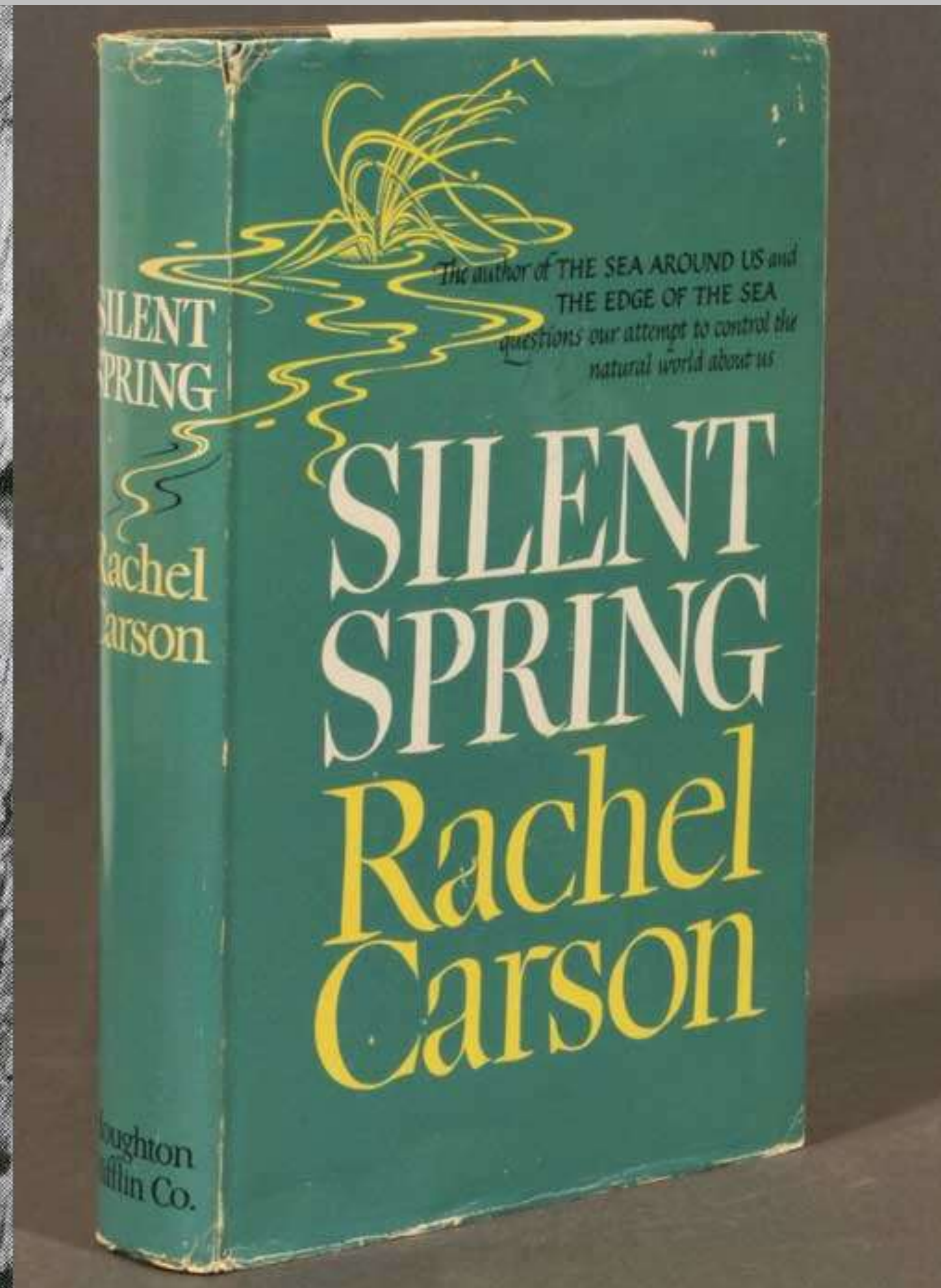
- First widely used class of synthetically produced insecticides
  - Post World War II
- Generally broad spectrum of activity against insects
- Low to moderate acute toxicity to humans
- Very long persistence – weeks to months, sometimes longer
  - Some soil applications lasting many years

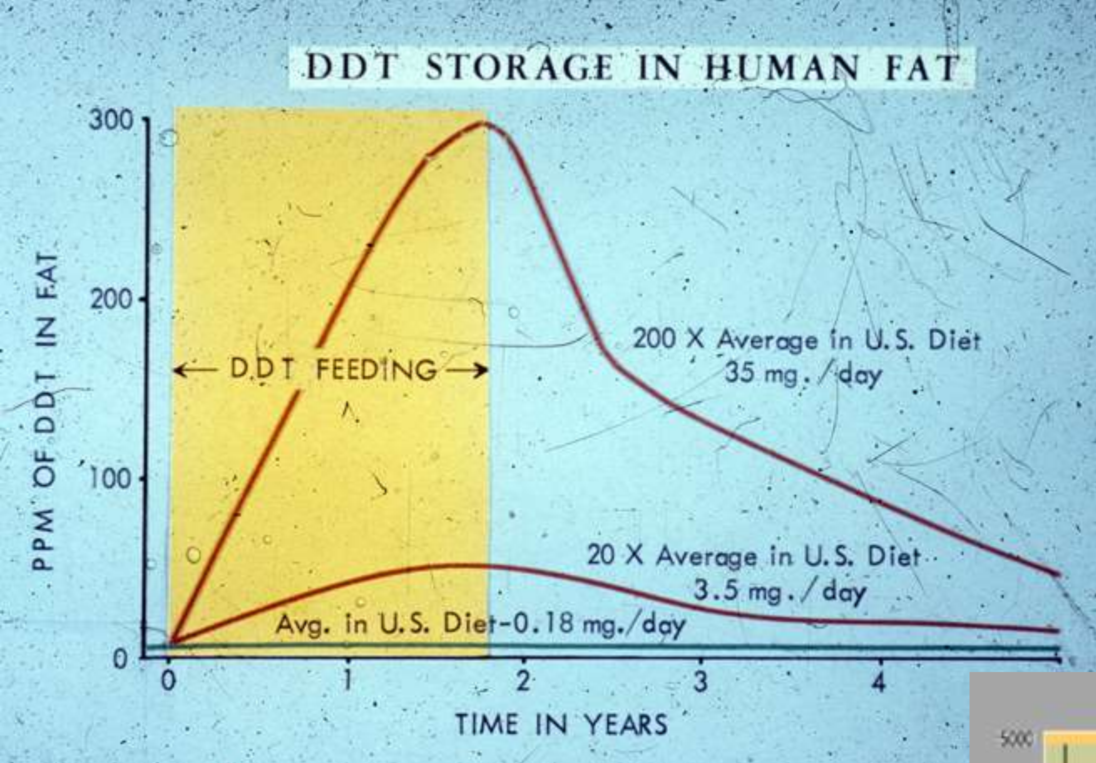
When first introduced, originally to stop epidemic typhus during World War II, DDT and the new chlorinated hydrocarbons were considered nearly miraculous

Chlorinated Hydrocarbons

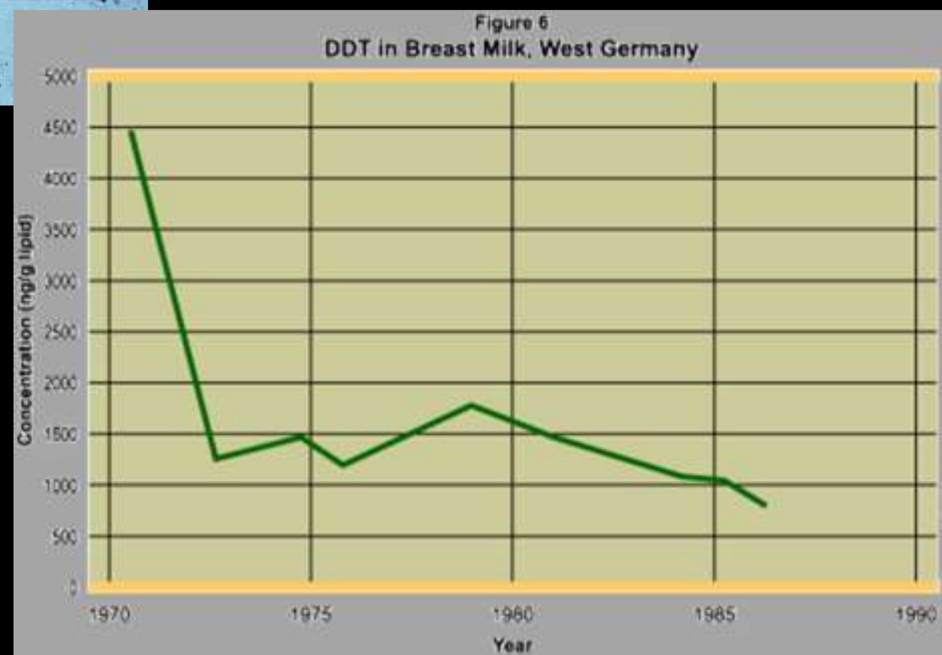
- Fat soluble
- Persistent in the environment
  - Concentrated in fat tissues
  - Biomagnification in ecosystems
  - Showed some hormonal effects at high concentrations (*estrogen mimics*)

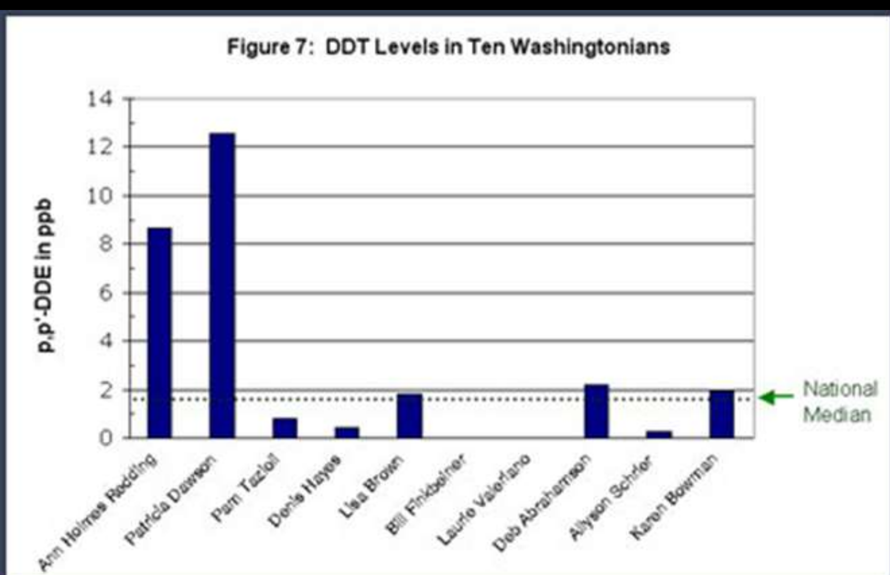
The book that started a rethinking about insecticide use

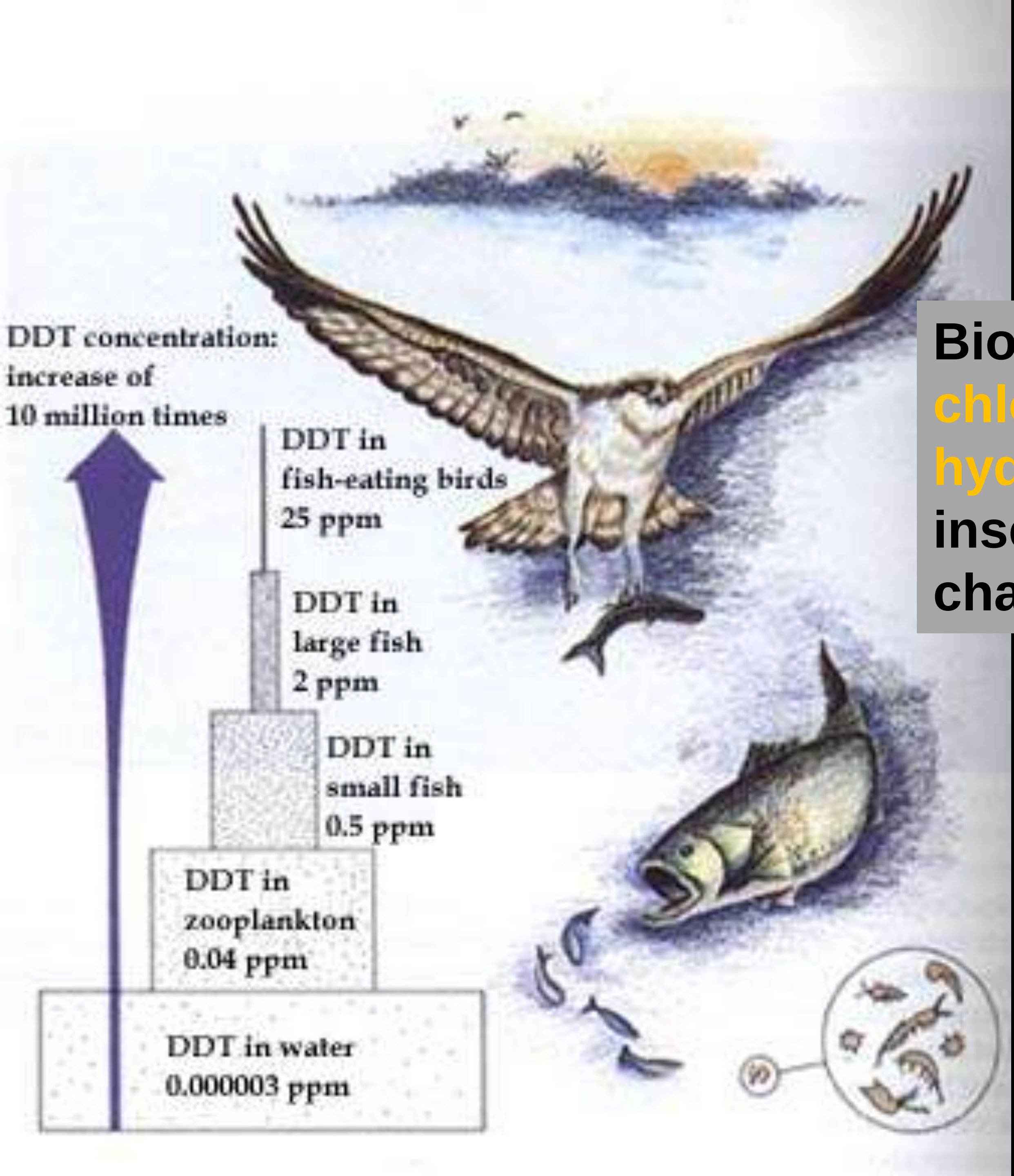




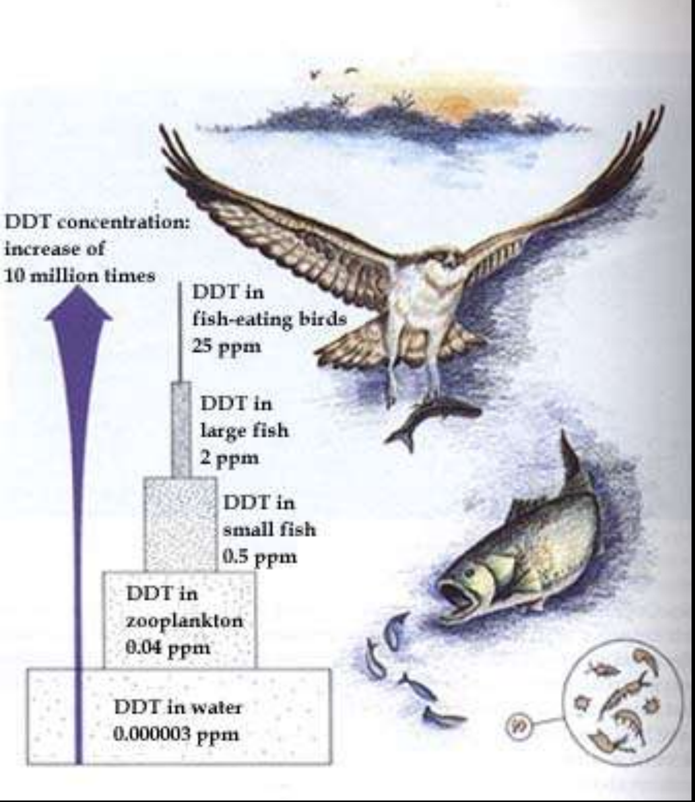
Chlorinated hydrocarbons, such as DDT, are persistent and concentrate in fat







Biomagnification of chlorinated hydrocarbon insecticides in food chains



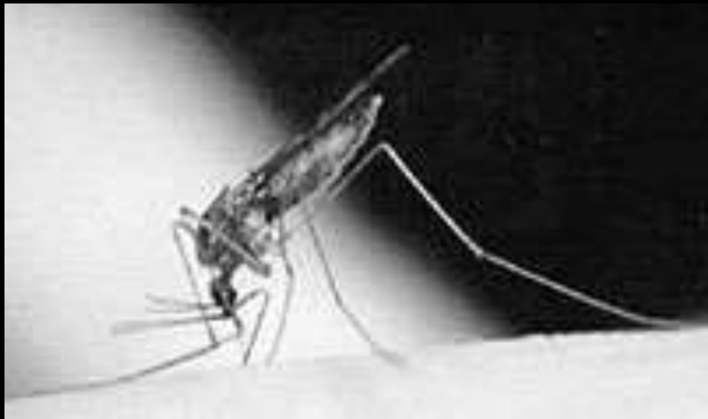
Biomagnification of chlorinated hydrocarbon insecticides in food chains

In high levels chlorinated hydrocarbons act as **estrogen mimics**

Primary effect on top predators – egg shell thinning

Paul Muller – Received 1948 Nobel Prize for Medicine/Physiology for his discovery of the insecticidal activity of DDT

Malaria mosquito



Chlorinated Hydrocarbons

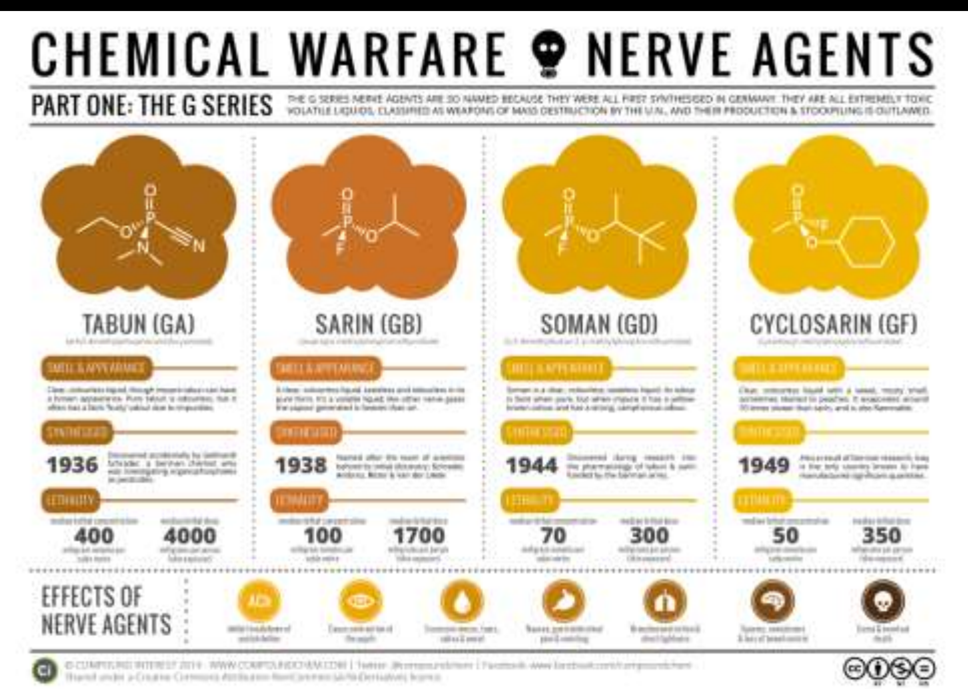
- Fat soluble
- Persistent in the environment
  - Concentrated in fat tissues
  - Biomagnification in ecosystems
  - Showed some hormonal effects at high concentrations (estrogen mimics)
- Current Status
  - DDT banned 1972
  - Termiticide uses eliminated in 1990s
  - Methoxychlor used for bark beetles into the 1990s; all uses ended in 2002

Organophosphates

- Primary class used during 1960s through early 1990s
- Some have systemic activity
- Mode of Action: Inhibition of cholinesterase
  - Effects persist and can accumulate with repeated exposure
- Acute Toxicity (to humans): Moderate to very high

Organophosphates **were originally developed in Nazi Germany as** **Chemical Warfare (Nerve Gas) Agents**

G Class (Sarin, Tabun), VCX series



Organophosphate Insecticides Historically Used for Landscape Pest Management

- Chlorpyrifos (Dursban)
- Diazinon
- Acephate (Orthene)
- Dimethoate (Cygon)
- Malathion
- Disulfoton (DiSyston)
- Oxydemetonmethyl (MetaSystox-R)

Organophosphates

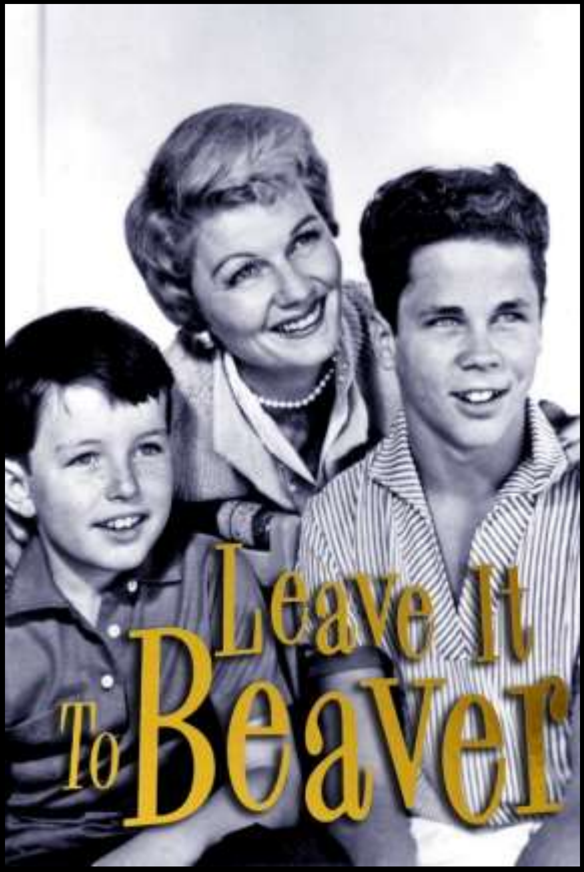
- Non-target Effects:
  - Birds: Moderate to very high toxicity to birds
  - Fish: Moderately toxic
- Other: Many organophosphates have a strong associated odor
- Current Status
  - Steady reduction in registrations since late 1990s

Organophosphate Insecticides Presently Used in Landscape Care

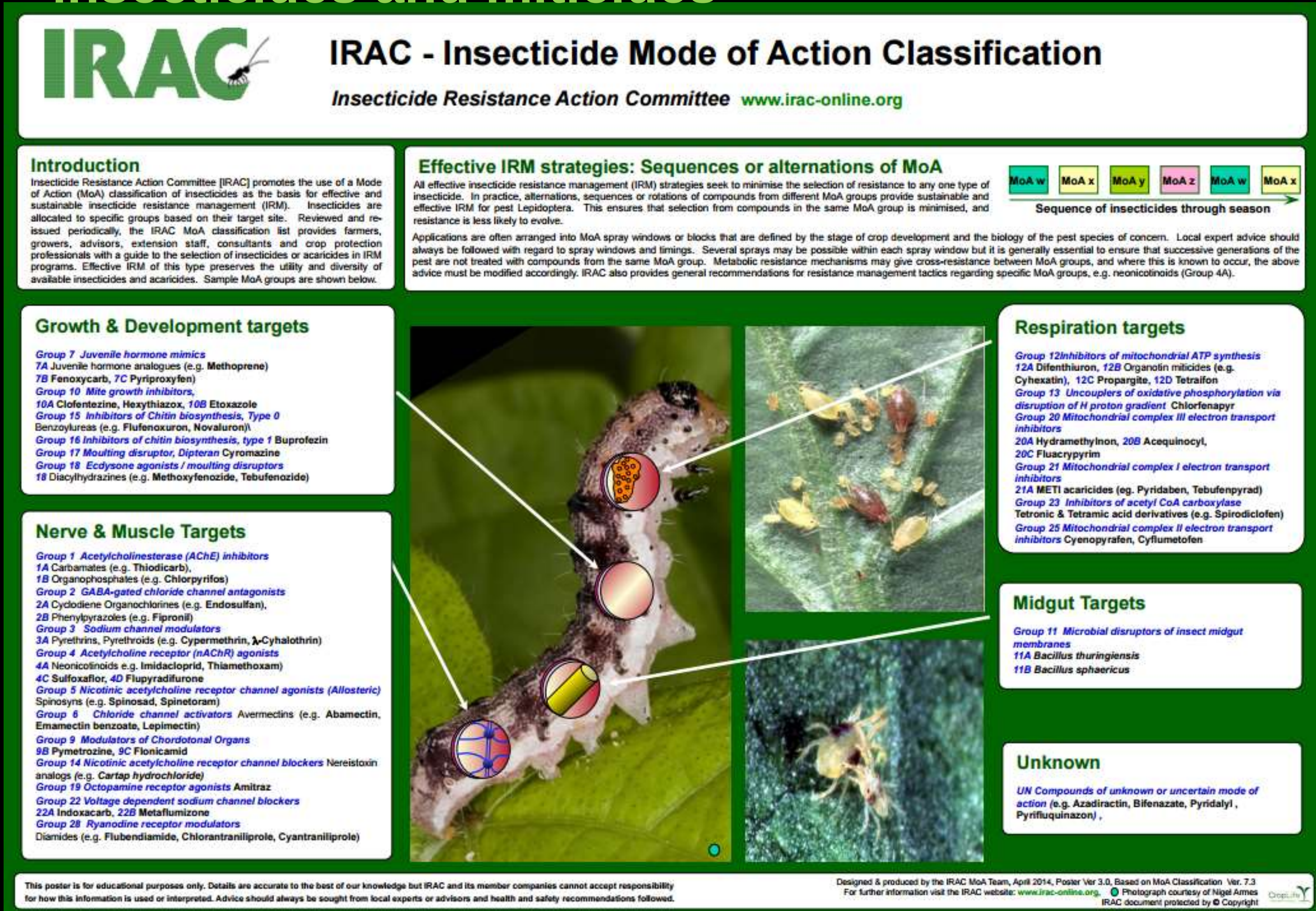
- Acephate (Orthene, Lepitect)
- Malathion?


Hi-Yield
55%
Malathion
SPRAY
1 1/2 Teaspoons Makes 1 Gallon Of Spray.
NET CONTENTS ONE QUART (32 Fl.Ozs.)

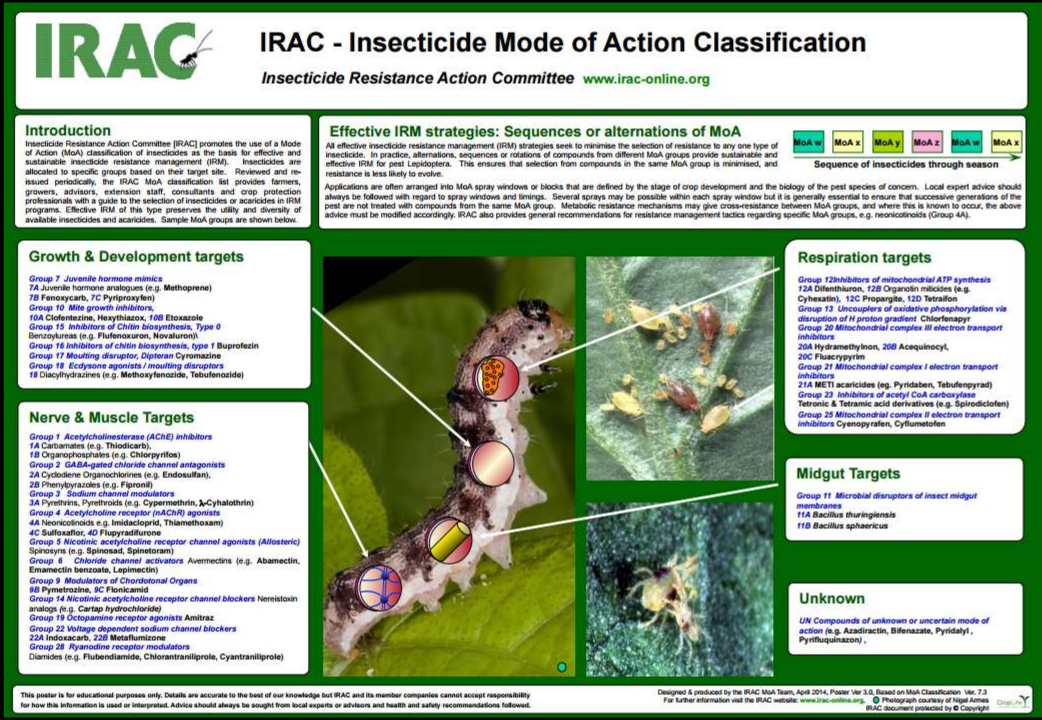

Hi-Yield
55%
Malathion
SPRAY
Spider Mite
Mealybug
Whitefly
• 1 1/2 Teaspoons Makes 1 Gallon Of Spray.
NET CONTENTS ONE QUART (32 Fl.Ozs.)


Leave It To Beaver

There are over two dozen modes of action of insecticides and miticides

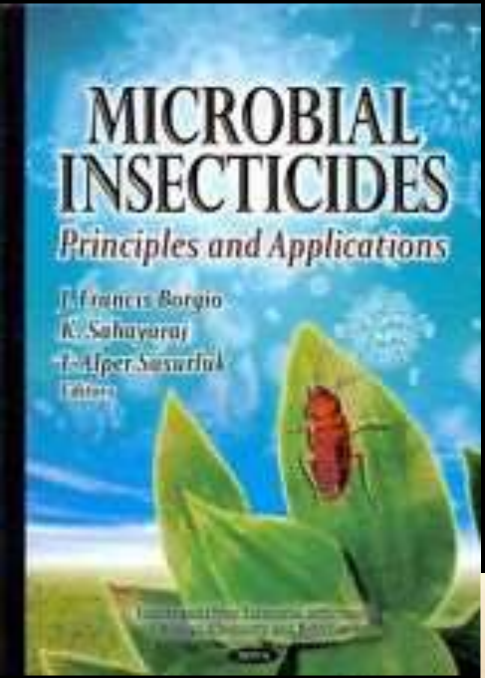


A great source of information on insecticide classes and their mode of action



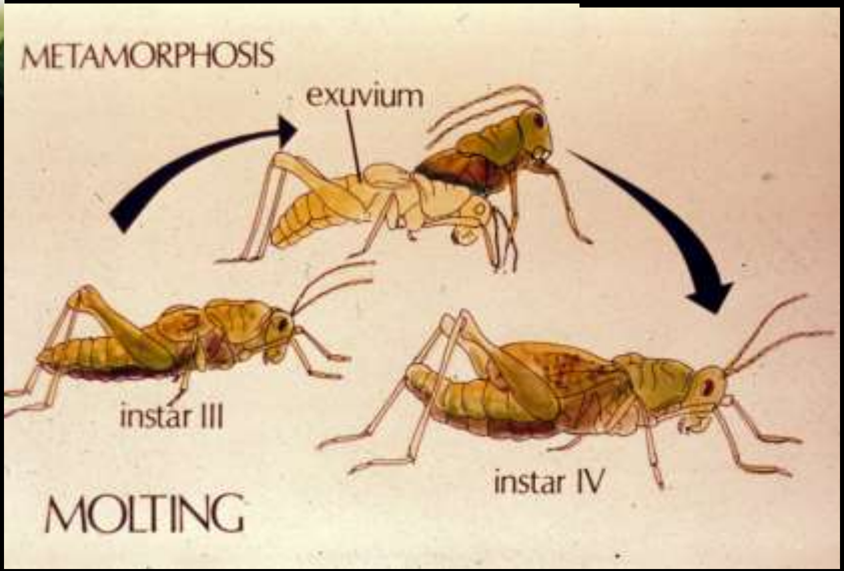
IRAC – Insecticide Resistance Action Committee

How were most presently used insecticides discovered?



Derived from microbes

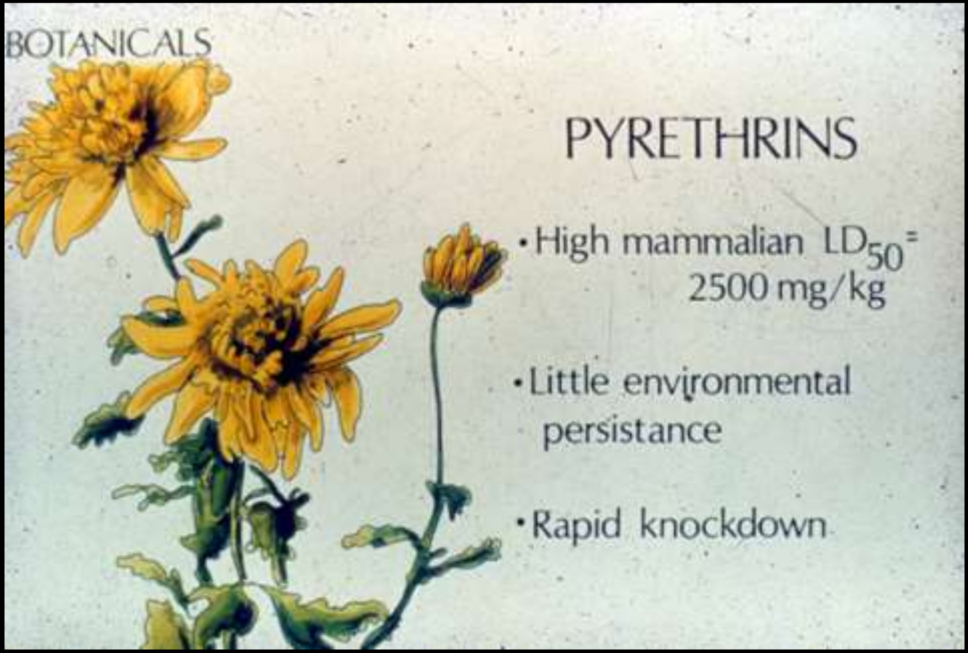
Derived from active ingredients found in plants



Derived from hormones used in insect growth

Pyrethroid Insecticides
(a.k.a., synthetic pyrethrins)

Pyrethrins are the active ingredient extracted from pyrethrum flowers



Tanacetum (=Chrysanthemum) cinaeriafolium Pyrethrum Daisy

Botanical source that lead to development of the pyrethroid insecticides

Extracts of pyrethrum flowers contain active ingredients known as pyrethrins

Dalmatian (Pyrethrum) Daisy

Tanacetum (=Chrysanthemum) cinaeriafolium

A Colorado *Plant Select* Selection

Pyrethroid Insecticides
(a.k.a., synthetic pyrethrins)

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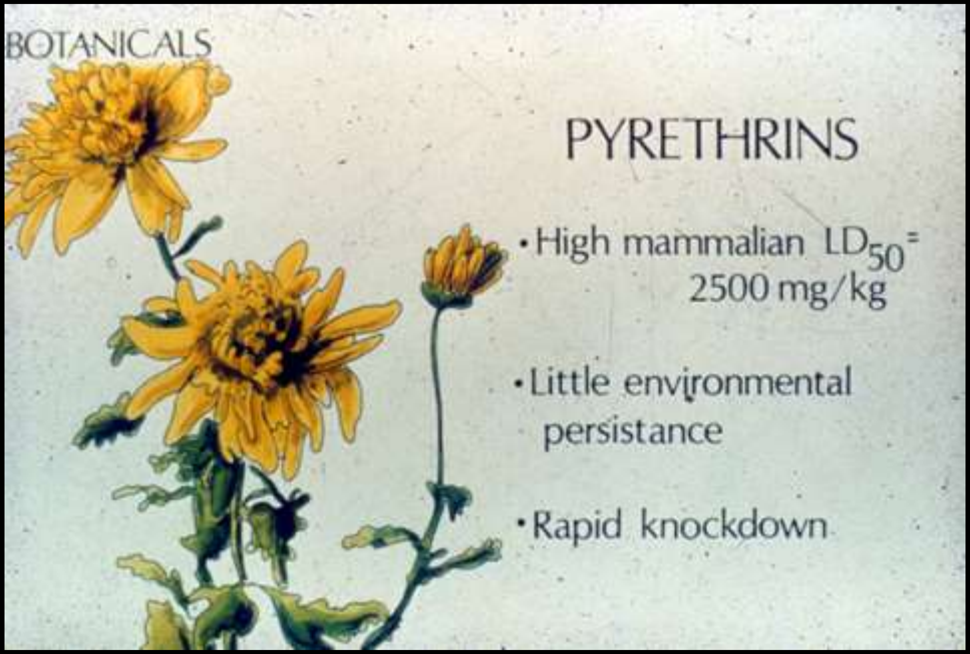
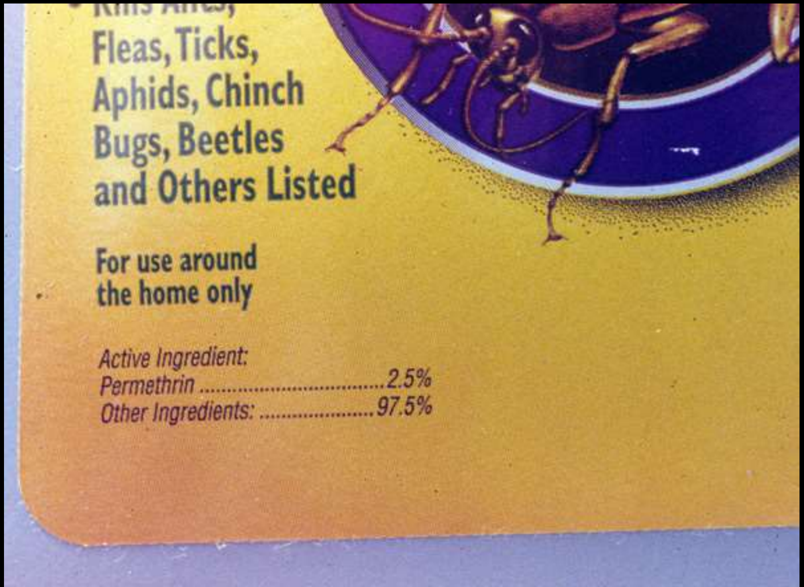


Some Presently Marketed Pyrethroid Insecticides

- Permethrin
- Cypermethrin
- Bifenthrin
- Resmethrin
- Sumithrin
- Tetramethrin
- Tralomethrin
- Deltamethrin

- Esfenvalerate
- Cyfluthrin
- Cyhalothrin
- Allethrin



Some Pyrethroid Insecticides

Pyrethrins

Pyrethroid Uses

- Non-systemic, attaches well to organic matter (high Koc)
- Persistence ranges widely
  - Bifenthrin, cypermethrin most persistent (days to a couple weeks)
  - Permethrin, cyhalothrin, cyfluthrin quite persistent (days)
  - Resmethrin, sumithrin, pyrethrins non-persistent (hours)

Pyrethroid Uses for Tree/Shrub Insect Control

- Generally broad spectrum
  - Standards for bark beetle and borer sprays
  - Strong on most beetles, caterpillars, sawflies, scale crawlers
  - OK on most Hemiptera (e.g., aphids, whiteflies, leafhoppers, bugs)
  - Fair to poor on spider mites

OTC Pyrethroids with Uses on Ornamental Plants

- **Bifenthrin/Cypermethrin (combination)**
  - Ortho Max Insect Killer for Lawns & Gardens
- **Cyfluthrin**
  - Bayer Advanced Rose & Flower Insect Killer, Bayer Advanced Vegetable & Garden Insect Spray
- **Gamma-cyhalothrin**
  - Spectracide Triazicide Insect Killer for Lawns & Landscapes
- **Permethrin**
  - Bonide Eight Insect Control Vegetable, Fruit & Flower; Bayer Advanced Complete Insect Dust for Gardens; Ace House & Garden Bug Killer2; probably many others

Primary Pyrethroid Insecticide Found on Nursery Shelves – *That Can Be Used on Fruits/Vegetables*

- **Permethrin**

A Pyrethroid Insecticide Found on Nursery Shelves – *That Can Be Used on Many Fruits/Vegetables*

Active Ingredient:
Gamma-cyhalothrin

Active Ingredients of Wood Borer Insecticides (Trunk Sprays)

- **Permethrin** (Astro, Permethrin, etc.)
- **Bifenthrin** (Onyx)

Only One OTC product, **containing permethrin**, has a label and use rate that allows effective use against Borers and Bark Beetles!

Pyrethroids are non-selective

…and can be rough on insect natural enemies

Pyrethroids are highly toxic to bees

Treated flowers may kill flower visitors for a couple of days after application

My favorite/"go to" publication on this subject

Table 4. Active ingredients of commonly used pesticides and their effect on bees in California, Idaho, Oregon, and Washington

Active Ingredient	Highly Toxic to Bees (RT)	Toxic to Bees (RT)	No Bee Precautionary Statement (PS) on Label	Common Product Names	Notes and Special Precautions
Abamectin (Avermectin) *Fermentation products derived from soil bacterium, affects nerve and muscle action of insects and mites*	X 0.025 lb ai/acre 1-3 days ERT, ≤ 0.025 lb ai/acre 8 hours RT [1] Can vary with formulation and application rate			Abacide, Abacus, Abba, Agmectin, Agri-Mek, Ardent, Avert, Avicta, Avid, Epi-Mek, Reaper, Solera, Solero, Temprano, Timectin, Zoro	ERT to bumble bees [2], short RT to alfalfa leafcutting bees and alkali bees at 0.025 lb ai/acre [1].
Acephate *Organophosphate insecticide*	X >3 days ERT [1] Can vary with formulation and application rate			Bracket, Orthene, Orthonex	Incompatible with bumble bees [2], ERT to alfalfa leafcutting bees and alkali bees [1].
Acequinocyl *Quinolone insecticide/miticide, metabolic poison*			X	Kanemite, Shuttle	
Acetamiprid *Neonicotinoid insecticide (cyano group)*		X Yes		Assail, Tristar, Transport	Length of residual toxicity to honey bees is unknown. ERT to alfalfa leafcutting bees and alkali bees [3]. 2 day ERT to bumble bees [2]. Cyano group neonicotinoids exhibit lower toxicity to bees than nitro group neonicotinoids [4].

Pyrethroids

- **Acute Toxicity to Humans:** **Low to moderate**
- **Non-target Effects:**
  - **Birds: Low to very high acute toxicity**
  - **Fish: Extremely toxic**

- **Current Status**
  - **Broadly registered and available – *although under review***

Botanical source that led to development of neonicotinoid insecticides

Nicotine

Older nicotine sulfate insecticide

Neonicotinoids

- Insecticide class originally developed commercially in the late 1980s
- Mode of Action
  - Nicotinic acetylcholine receptor agonist
  - IRAC Mode of Action Group 7A
  - Nicotine mode of action similar

Neonicotinoids

- Insecticide class originally developed commercially in the late 1980s
- Mode of action - Nicotinic acetylcholine receptor agonist
  - IRAC Mode of Action Group 7A
  - Nicotine mode of action similar
- **Emerged in early 1990s**
  - First new class of insecticide with systemic activity in plants in 30+ years
- **Low toxicity to vertebrates accelerated registration as “reduced risk” products**

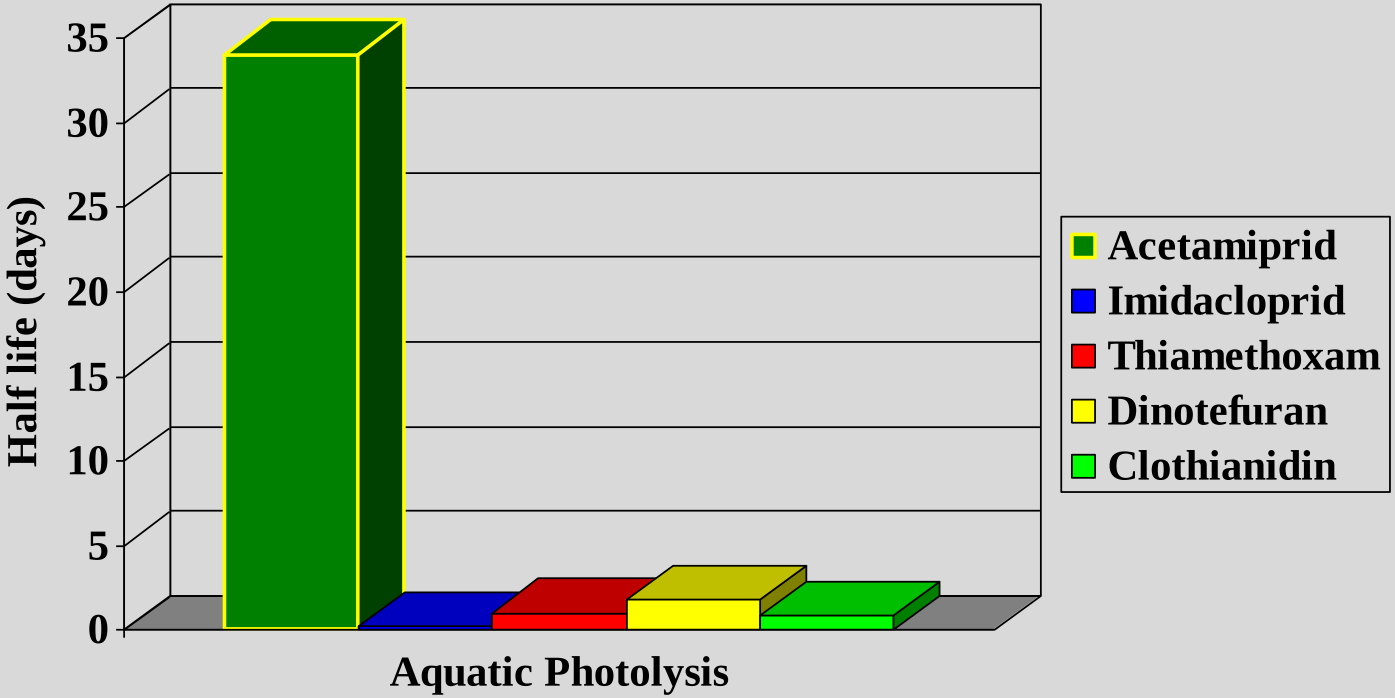
Primary Neonicotinoid Insecticides Used in Landscape Plant Care

- **Imidacloprid (Merit, Marathon, Zenith, Mallet, etc.)**
- **Dinotefuran (Safari, Zylam, Transtect)**
- **Acetamiprid (Tristar)**

Not all Neonicotinoids are alike:

- UV stability
- Water solubility
- Rate of uptake by plants
- Mobilization within plants
- Host range of susceptible insects

Comparison of UV Stability



Data obtained from published EPA registration documents

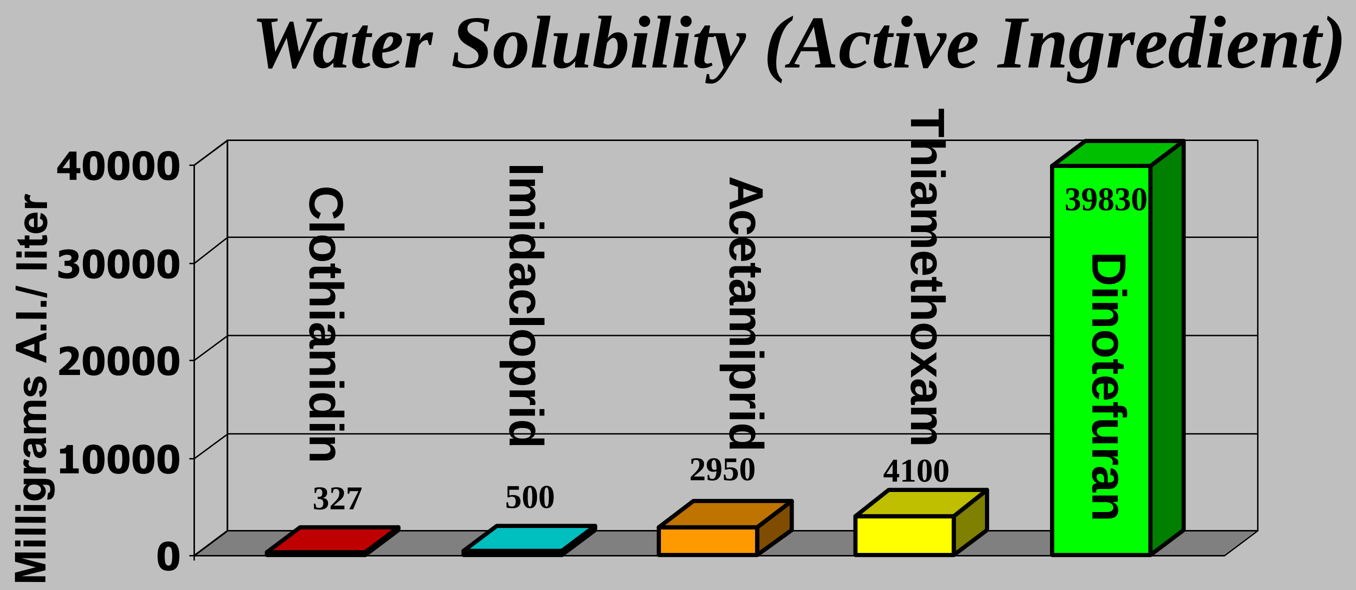
Slide Credit: R. Fletcher

UV Stability

Neonicotinoids are generally not UV stable. Foliar persistence can be shortened by this feature.

Acetamiprid is an exception.

Relative Water Solubility of Neonicotinoids:



Information sources
Clothianidin (Celero), Acetamiprid (Tristar), Dinotefuran (Safari) – EPA Pesticide Fact Sheet
Imidacloprid (Marathon), hiamethoxam (Flagship) – MSDS for Products

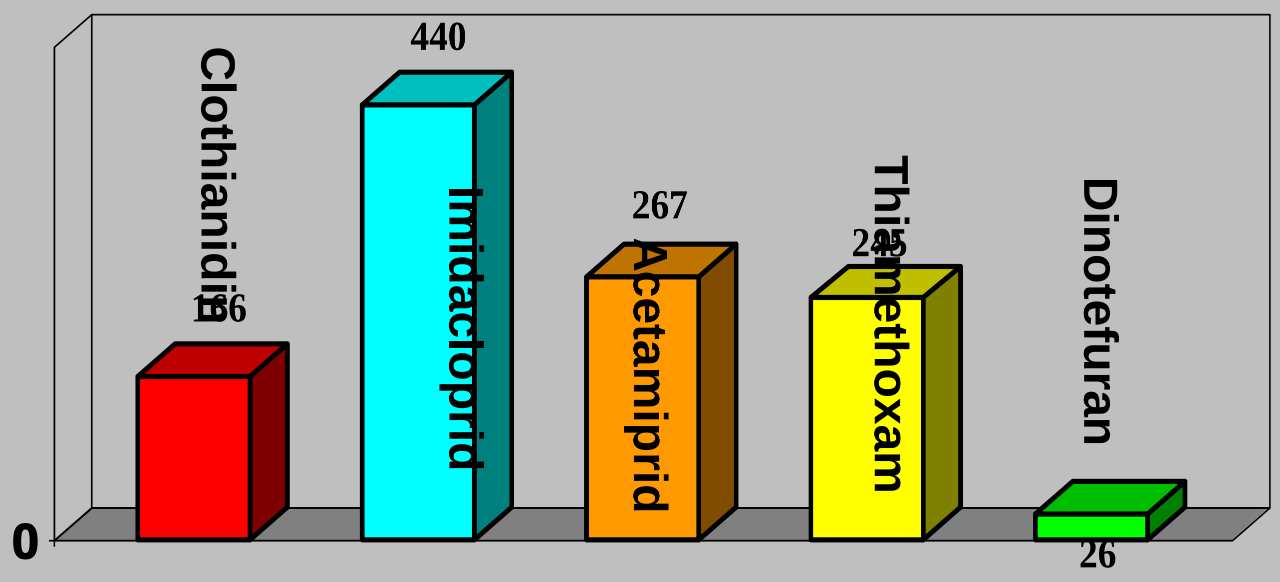
Slide information courtesy J. Chamberlin

Water Solubiility

There is wide range of water solubility among the neonictoinoids.

Dinotefuran (Safari, Transtect, Zylam) ***is highly water soluble.***

K_{oc} Values of Neonicotinoids:



Source Data: EPA Pesticide Fact Sheets

Koc Value

There is wide range of Koc values (measure of adsorption to organic matter) among the neonicotinoids. This affects mobility within plants.

Dinotefuran (Safari, Transtect, Zylam) *has a much lower Koc value than do other neonicotinoids*

Dinotefuran (Safari, Zylam, Transtect)

Not all Neonicotinoids are alike:

- UV stability
- Water solubility
- Rate of uptake by plants
- Mobilization within plants
- Host range of susceptible insects

Acute Toxicity of Neonicotinoids to Adult Honey Bees

(Dermal LD50 in micrograms/bee)

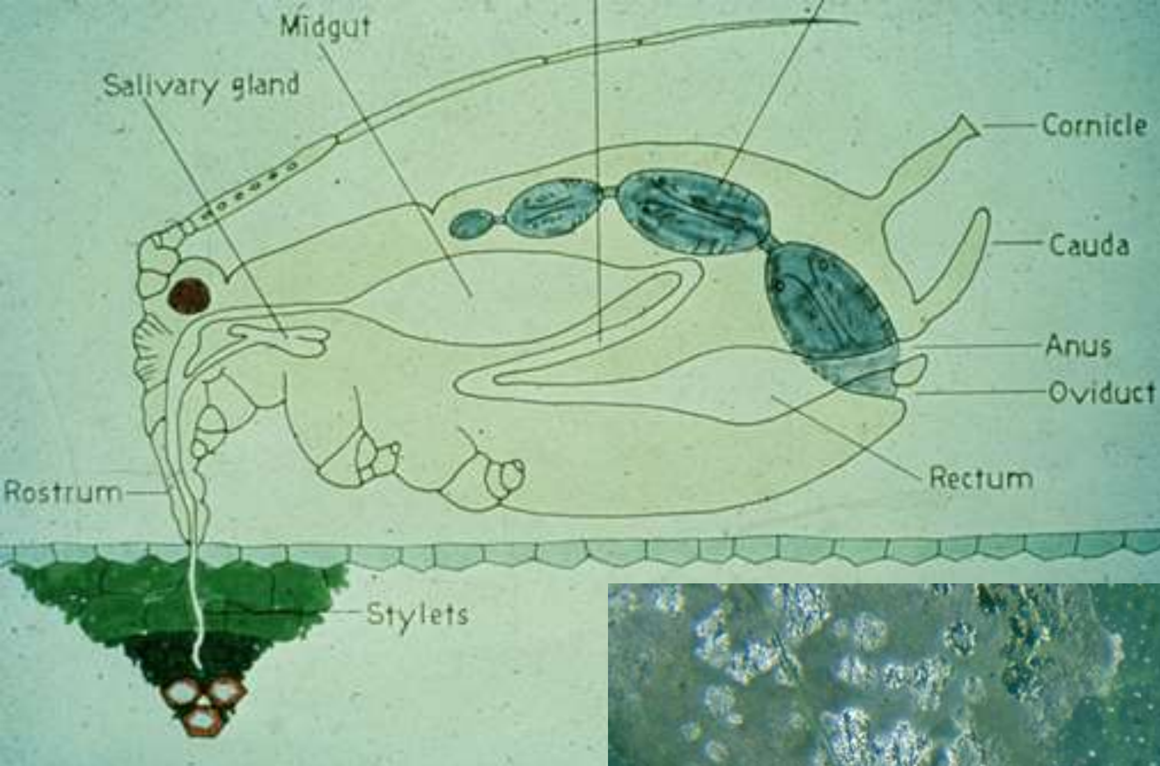
• Acetamiprid	8.09
• Imidacloprid	0.08
• Dinotefuran	0.022
• Thiamethoxam	0.024
• Chlothianidin	0.044

Acute Toxicity of Neonicotinoids to Adult Honey Bees

(Oral LD50 – micrograms/bee)

• Acetamiprid	14.53
• Imidacloprid	0.005
• Dinotefuran	0.056
• Thiamethoxam	0.005
• Chlothianidin	0.0003

Neonicotinoids are effective against most phloem-feeding insects



Aphids and soft scales suck sap from the phloem and excrete honeydew

If the insect excretes honeydew, neonicotinoids will almost always work well for its control

Most all neonictoinoids have **good activity against beetle larvae and sawfly larvae**

Armored scales – poor, with an exception

Spider mites – often terrible

Neonicotinoid host range, continued

Caterpillars/Lepidoptera – poor with some exceptions

Imidacloprid formulations

Over-the-Counter Imidacloprid Formulations

Some imidacloprid formulations sold to control parasites of pets

Active ingredient: imidacloprid

Active ingredients: imidacloprid, permethrin, pyriproxifen

Imidacloprid Characteristics and Niche

- **Advantages**
  - Good persistence with soil application
  - Easy to apply soil treatment
  - Inexpensive

Imidacloprid Characteristics and Niche

- **Limitations**
  - **Poor on caterpillars**
  - **Weak on armored scales**
  - **Tends to make spider mite problems worse**
  - **High risk for pollinators**

Imidacloprid Control Range

Yes – Soft Scale

No – Armored Scale

Soft Scales Families Coccidae, Eriococcidae

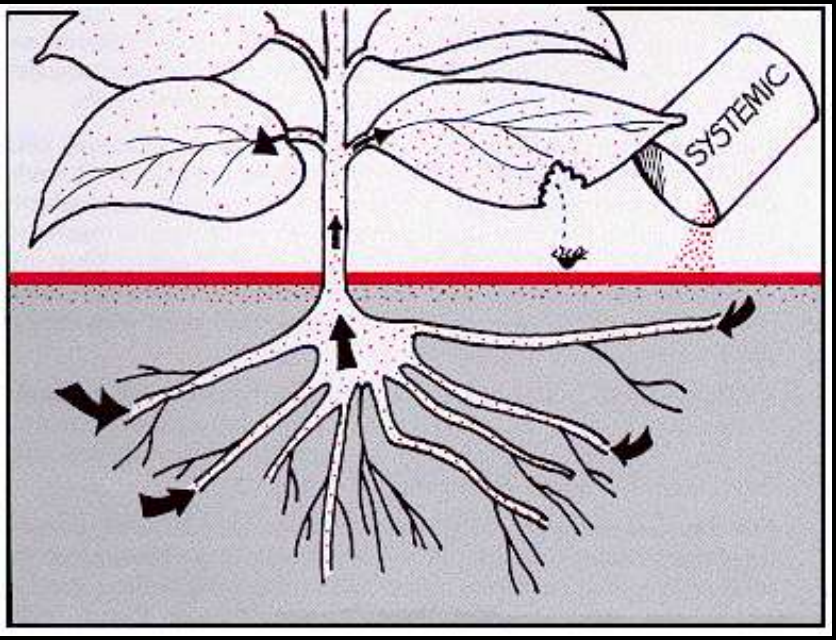
Soft Scales vs. Armored Scales

Feeding Site: Phloem

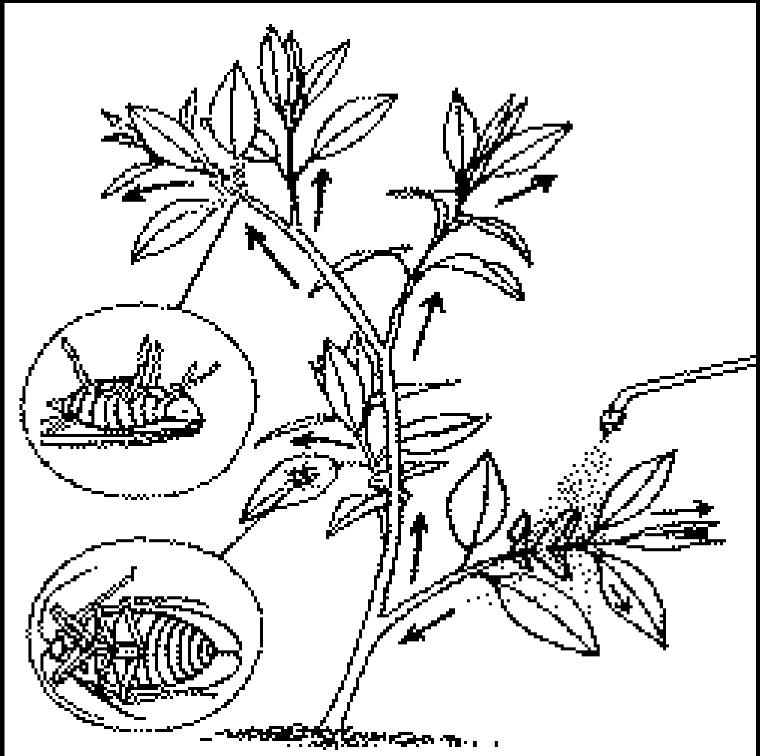
Soft scales produce honeydew

Feeding Site: Cells, often of the cambium

Armored scales do not produce honeydew



Systemic insecticides for wood borers?



Imidacloprid for Borers?

Yes*…..but*

Imidacloprid will not work well on borers that are the larval stage of moths

Lilac/ash borer

Not effective

Peach tree borer larval tunneling in base of plant

Not effective

Zimmerman pine moth injury

Not effective

Imidacloprid *will not* work well if the borer spends much of its life in the heartwood of the plant

Imidacloprid soil drenches *may work well* against flatheaded borer larvae (aka metallic wood borers)

Four common *Agrilus* species metallic wood borers

Imidacloprid as a soil injection, soil drench

Neonicotinoids for emerald ash borer (and other flatheaded borers)

Dinotefuran as a bark spray

Commercial formulations for ornamentals

Retail formulation

Dinotefuran formulations

Dinotefuran Characteristics and Niche

- **Advantages**
  - **Rapid uptake**
  - **Mobile in plant**
  - **Capable of trunk spray use**
- **Limitation**
  - **High risk for pollinators**

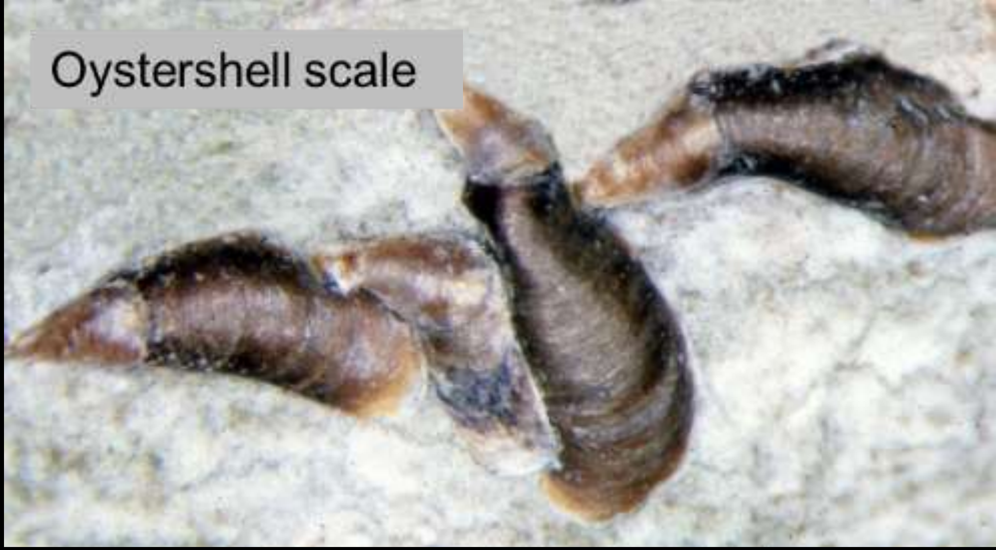
Soil Systemic Insecticides and Scale Insects?

- Imidacloprid (Merit, Mallet, Zenith, etc.)
  - *Soft scales only*
- Dinotefuran (Safari, Zylam, Transtect)
  - *Soft scales and armored scales*

Dinotefuran Control Range

Yes – Soft Scale

Yes – Armored Scale



Armored Scales Family Diaspididae

Basal trunk spray with dinotefuran (Safari, Zylam)

Whole tree sprays produce surface residues on all foliage. Natural enemies are killed. Natural controls are wasted.

Treatment area limited to bark of lower trunk. Impacts on natural enemies are minimized

Commercial formulation for ornamentals

Retail formulations

Acetamiprid products

Commercial formulation for fruits and vegetables

Acetamiprid Characteristics and Niche

- **Advantages**
  - **Stable in UV**
  - **Good on caterpillars**
  - **Fairly mobile in plant**
  - **Low toxicity to honey bees**
- **Limitation**
  - **Not suitable for soil application**

Acetamiprid can be used as a *systemic insecticide to be sprayed*

Ryania speciosa

Botanical source that lead to development of the anthranilic diamides

Powdered stems are the source of the insecticide ryania.

Active ingredient: ryanodine

Anthranilic Diamides

- Based on chemistry of active compounds in ryania (ryanodines)
  - Effects ryanodine receptors associated with insect muscle
- Some systemic activity in plants
- Extremely low toxicity to mammals (Category IV)
- Recently registered products:
  - chlorantraniliprole (Acelepryn)
  - cyantraniliprole (Ference – *turfgrass label only*)

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Chlorantraniliprole
(Acelepryn, Grub-Ex)

HAZARDS TO HUMANS AND DOMESTIC ANIMALS

When used as directed this product does not present a hazard to humans or domestic animals.

Personal Protective Equipment

Applicators and other handlers must wear:

- Long-sleeved shirt and long pants.
- Shoes plus socks.

Applicator caution with chlorantraniliprole/Acelepryn

Class IV Toxicity – No Caution Label

No cautionary language for protection of bees

TABLE 3: Foliar Ornamental Application Rates

Acelepryn Ornamental Foliar Application Rates					
Target Pests	Product (fl oz) per 100 Gallons	Lb AI per 100 Gallons	PPM	Percent AI (wt/vol)	Maximum Gallons per Acre per Year
Leaf-feeding caterpillars (such as bagworms and tussock moth caterpillars [including whitemarked tussock moth])	1	0.013	15.6	0.00156	3840
	2	0.026	31.3	0.00313	1920
	4	0.052	62.5	0.0625	960
	8	0.104	125	0.0125	480
For maximum residual control of the pests listed above	16	0.208	250	0.025	240

Soil Applications:

Acelepryn is a systemic product and will be translocated upward into the plant from root uptake. Soil treatment application rates are listed in Table 4. To assure optimum effectiveness, the product

The original federal label just includes certain caterpillars as target pests

Section 2(ee) recommendation indicates uses for control of many other insects – ***including Japanese beetle adults***

Section 2(ee) Recommendation

Effective: 07/10/2015 **Expires:** 11/19/2018

AK1489002BC0715 Additional Pests of Ornamental Plants (Exterior Landscapes and Interior Plantscapes) in AK, AL, AR, AZ, CO, CT, DC, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, OH, OK, PA, RI, SC, SD, TN, UT, VA, VT, WA, WI, WV and WY

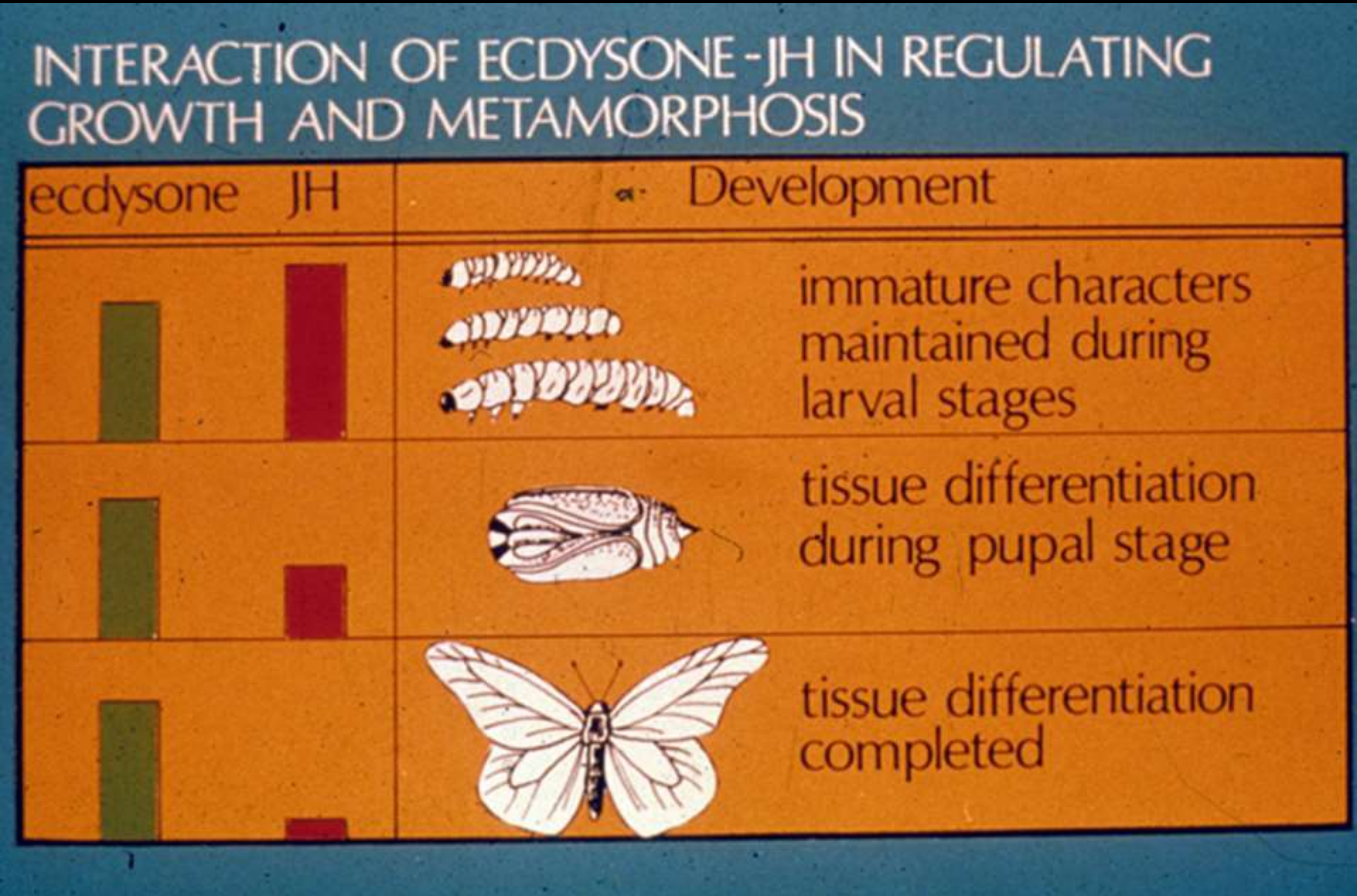
For Use Against: Banded ash clearwing, Fall webworm, Gypsy moth caterpillars, Hemlock Wooly Adelgid, Japanese beetle (adult), Lesser peachtree borer, Magnolia scale, Rhododendron borer, Rhododendron lace bug, Sawfly, Viburnum borer, Zimmerman pine moth

Chlorantraniliprole Niche

- **Very low hazard to vertebrates**
- **Very low hazard to bees**
- **Target pests include:**
  - All leaf chewing caterpillars
  - Wood borers that are caterpillars
  - Leaf chewing beetles, including Japanese beetle
  - White grubs in lawns

Insect Growth Regulators (IGRs)

- **Affect growth processes of arthropods/disrupt hormones**
- **Diverse chemistry, mode of action**
  - ***Mimic/disrupt molting hormone (ecdysone)***
  - ***Mimic/disrupt juvenile hormone***
  - ***Prevent normal chitin synthesis***


INTERACTION OF ECDYSONE-JH IN REGULATING GROWTH AND METAMORPHOSIS
ecdysone
JH
Development
immature characters maintained during larval stages
tissue differentiation during pupal stage
tissue differentiation completed

Colorado Potato Beetle

Larva

Pupa

Potato beetles (top row) killed by IGR insecticide that prevented successful molting to pupal stage

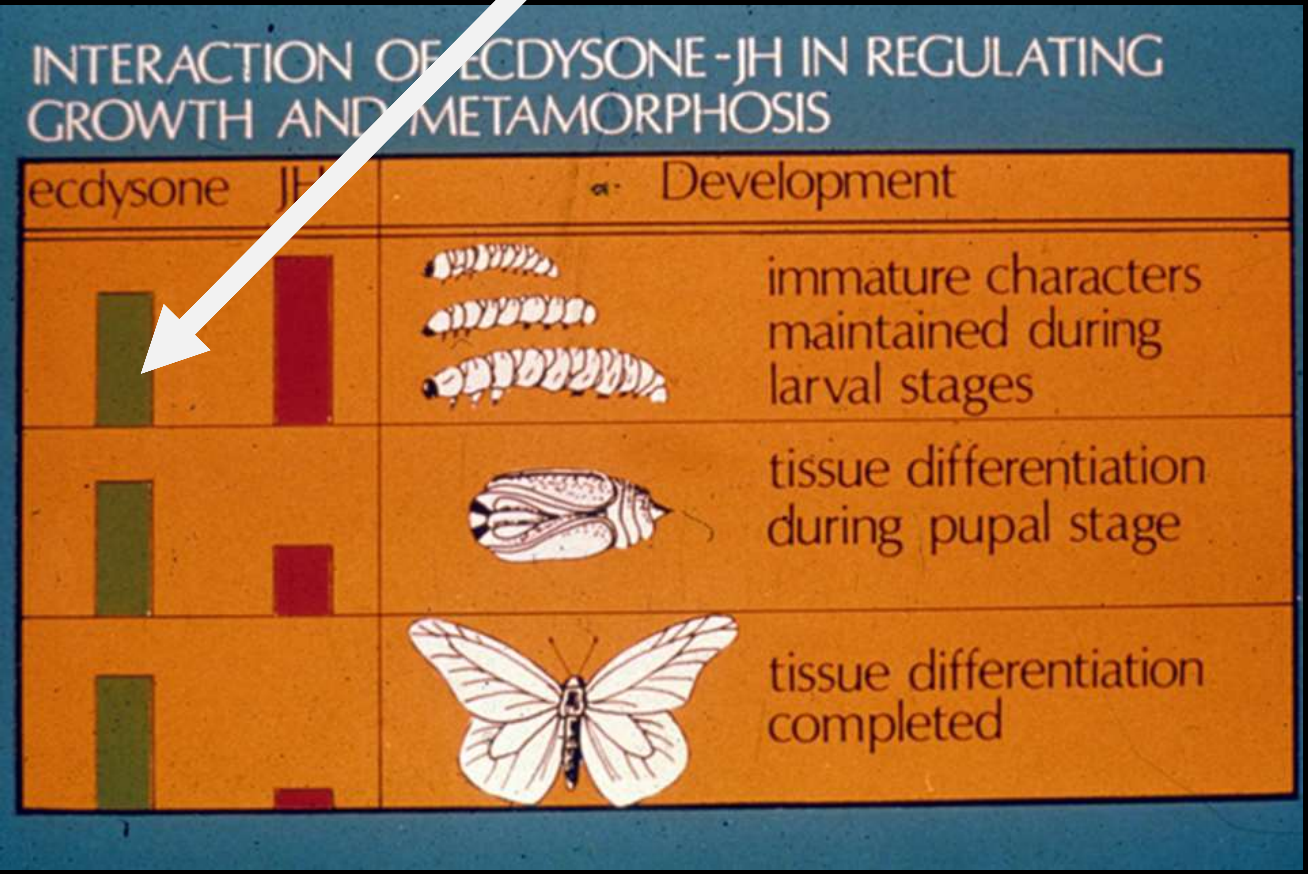
Insect Growth Regulators (IGRs)

- **Acute Toxicity to Humans: Low**
- **Non-target Effects:**
  - Birds: Low toxicity
  - Fish: Low toxicity
- **Most are highly selective in effects on beneficial insects**

Azadirachtin indica (Neem)

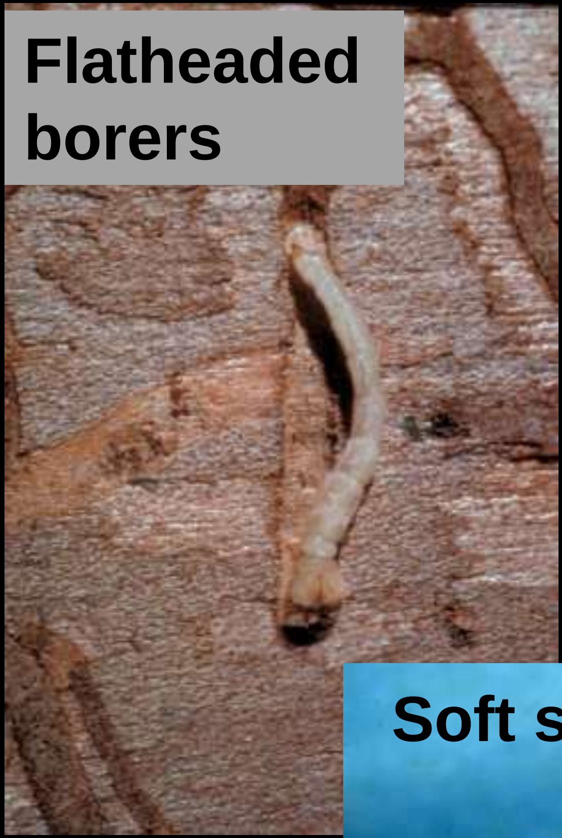
Neem seed extracts contain the active ingredient azadirachtin

Azadirachtin affects the molting hormone ecdysone



This disrupts many things including ability to molt and to reproduce successfully.

Some target pests of azadirachtin



Neem

- **Active Ingredients:** ***Azadirachtin*** **primarily, oil fractions have some uses.**
- **Disrupts the molting hormone (ecdysone) of susceptible insects**

Whole need seed extract

Neem oil - **Oil fraction only**

Examples of products that contain azadirachtin – but no neem oil

Examples of products that contain the oil fraction from neem seed extracts, but has had the azadirachtin removed

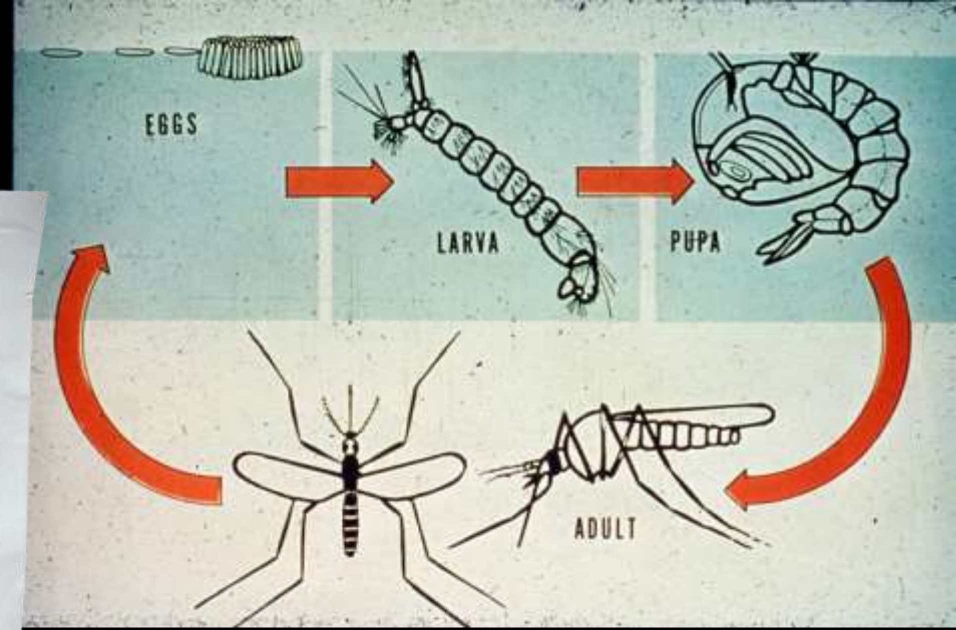
Horticultural Oils

Mineral oils

Horticultural oils may also be derived from cottonseed, soybean, neem seed, sesame, fish, and many other sources

Neem seed oils

Methoprene



A juvenile hormone-derived insecticide

Mosquito Life Cycle

Adult (left)

Larvae/wrigglers (lower left)

Pupae/tumblers (below)

Pyriproxifen

Mimics juvenile hormone.
Target pests: Scale insects, whiteflies, aphids (suppression)

Special Colorado Niche: *A selective insecticide for use on* ***scale insects***

Excellent against neonicotinoid-resistant European elm scale

Microbial Insecticides

- Microbes Used as Insecticides
  - Bacteria
  - Viruses
  - Fungi
    - Microsporidia
- Insecticides Derived from Microbes

Bacillus thuringiensis

- **Derived from a widely distributed soil bacterium**
- **Active ingredient a toxic protein crystal that destroys cells of the midgut**
- **Used as a stomach poison**

Treated Foliage Consumed


Feeding Inhibition (1 Hour)
Toxin Crystals Dissolve in Gut.
Larvae Stop Feeding.
Growth Stops.
Insect Gut

Death (2-5 Days)

- Starvation
- Gut Disruption

Bacillus thuringiensis var. *kurstaki* *and* B.t. var. *aizawi*

Used to control leaf feeding caterpillars

Bacillus thuringiensis var. *israelensis*

Used to control larvae of certain kinds of flies (e.g., mosquitoes, fungus gnats, black flies)

Bacillus thuringiensis var. *galleriae*

A newly developed strain of Bt that can control adult Japanese beetles - and can be used on plants in flower!

Key problem with control of Jpanese beetle adults on many plants

Overlap of adult feeding on flowers – ***and use of those flowers by pollinators***

Never apply persistent insecticides to plants that are in flower and attractive to pollinators!!

Treated with *Bacillus thuringiensis* var. *galleriae*

Water check

Bacillus thuringiensis va. galleriae for adult Japanese beetle?

Provides **good reduction in feeding** injury by Japanese beetle

Provides **fair mortality** of Japanese beetles and mortality is slow

Persistence of effects probably **a few days**

Bee hazard warnings and use restrictions?

None. You can apply this product to plants in bloom when bees are visiting.

After application:

Are they dead?
(probably not)
Are they still feeding?
(probably not)

Controls Most Effective for Control of Japanese Beetle Adults…….

- ~~Most pyrethroids (e.g., cyfluthrin, permethrin, bifenthrin)~~
- ~~Carbaryl~~
- ~~Imidacloprid~~
- ~~Acetamiprid~~
- Chlorantraniliprole
  – Acelepryn
- *Bacillus thuringiensis* var. *galleriae*
  – BeetleGON
  – BeetleJUS

Do not treat plants with flowers in bloom!

….and can be used on plants in bloom!

Microbial Insecticides

- Microbes Used as Insecticides
  - Bacteria
  - Viruses
  - Fungi
    - Microsporidia
- Insecticides Derived from Microbes

Spinosad

- **Microbial derived insecticide (spinosyns)**
  - Secreted by a bacterium (*Saccharopolyspora spinosa*)
- **Low mammalian toxicity**
  - Low hazard to most beneficial insect
  - Some formulation allowed in Certified Organic production
- **Target Species**
  - Leaf chewers (caterpillars, beetles, sawflies)
  - Thrips

Some Spinosad Formulations

Turfgrass, ornamentals, many fruits and vegetables

Agricultural label - Organic

Agricultural label

One of many products sold through nurseries

Some insects that are well-controlled by spinosad


"WORKS LIKE A CHARM"
MAGIC®
BRAND
PEST SCOURGE
• KILLS EVERYTHING
• USE ON ALL PLANTS
• WORKS INSTANTLY
• COMPLETELY SAFE
INSECTS
MITES
WEEDS
DISEASES
IRS AGENTS
RODENTS
TRY ME!

There are over two dozen modes of action of insecticides and miticides

IRAC - Insecticide Mode of Action Classification

Insecticide Resistance Action Committee www.irac-online.org

Introduction

Insecticide Resistance Action Committee [IRAC] promotes the use of a Mode of Action (MoA) classification of insecticides as the basis for effective and sustainable insecticide resistance management (IRM). Insecticides are allocated to specific groups based on their target site. Reviewed and re-issued periodically, the IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of insecticides or acaricides in IRM programs. Effective IRM of this type preserves the utility and diversity of available insecticides and acaricides. Sample MoA groups are shown below.

Effective IRM strategies: Sequences or alternations of MoA

All effective insecticide resistance management (IRM) strategies seek to minimise the selection of resistance to any one type of insecticide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide sustainable and effective IRM for pest Lepidoptera. This ensures that selection from compounds in the same MoA group is minimised, and resistance is less likely to evolve.

MoA w → MoA x → MoA y → MoA z → MoA w → MoA x

Sequence of insecticides through season

Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest species of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group. Metabolic resistance mechanisms may give cross-resistance between MoA groups, and where this is known to occur, the above advice must be modified accordingly. IRAC also provides general recommendations for resistance management tactics regarding specific MoA groups, e.g. neonicotinoids (Group 4A).

Growth & Development targets

Group 7 Juvenile hormone mimics
7A Juvenile hormone analogues (e.g. **Methoprene**)
7B **Fenoxycarb**, *7C* **Pyriproxyfen**)
Group 10 Mite growth inhibitors,
10A **Clofentezine, Hexythiazox**, *10B* **Etoxazole**
Group 15 Inhibitors of Chitin biosynthesis, Type 0
Benzoylureas (e.g. **Flufenoxuron, Novaluron**)\
Group 16 Inhibitors of chitin biosynthesis, type 1 **Buprofezin**
Group 17 Moulting disruptor, Dipteran **Cyromazine**
Group 18 Ecdysone agonists / moulting disruptors
18 Diacylhydrazines (e.g. **Methoxyfenozide, Tebufenozide**)

Nerve & Muscle Targets

Group 1 Acetylcholinesterase (AChE) inhibitors
1A Carbamates (e.g. **Thiodicarb**),
1B Organophosphates (e.g. **Chlorpyrifos**)
Group 2 GABA-gated chloride channel antagonists
2A Cyclodiene Organochlorines (e.g. **Endosulfan**),
2B Phenylpyrazoles (e.g. **Fipronil**)
Group 3 Sodium channel modulators
3A Pyrethrins, Pyrethroids (e.g. **Cypermethrin, λ-Cyhalothrin**)
Group 4 Acetylcholine receptor (nAChR) agonists
4A Neonicotinoids e.g. **Imidacloprid, Thiamethoxam**)
4C **Sulfoxaflor**, *4D* **Flupyradifurone**
Group 5 Nicotinic acetylcholine receptor channel agonists (Allosteric)
Spinosyns (e.g. **Spinosad, Spinetoram**)
Group 6 Chloride channel activators Avermectins (e.g. **Abamectin, Emamectin benzoate, Lepimectin**)
Group 9 Modulators of Chordotonal Organs
9B **Pymetrozine**, *9C* **Flonicamid**
Group 14 Nicotinic acetylcholine receptor channel blockers Nereistoxin analogs (e.g. *Cartap hydrochloride*)
Group 19 Octopamine receptor agonists **Amitraz**
Group 22 Voltage dependent sodium channel blockers
22A **Indoxacarb**, *22B* **Metaflumizone**
Group 28 Ryanodine receptor modulators
Diamides (e.g. **Flubendiamide, Chlorantraniliprole, Cyantraniliprole**)

Respiration targets

Group 12Inhibitors of mitochondrial ATP synthesis
12A **Difenthiuron**, *12B* Organotin miticides (e.g. **Cyhexatin**), *12C* **Propargite**, *12D* **Tetraifon**
Group 13 Uncouplers of oxidative phosphorylation via disruption of H proton gradient **Chlorfenapyr**
Group 20 Mitochondrial complex III electron transport inhibitors
20A **Hydramethylnon**, *20B* **Acequinocyl**,
20C **Fluacrypyrim**
Group 21 Mitochondrial complex I electron transport inhibitors
21A **METI** acaricides (eg. **Pyridaben, Tebufenpyrad**)
Group 23 Inhibitors of acetyl CoA carboxylase
Tetronic & Tetramic acid derivatives (e.g. **Spirodiclofen**)
Group 25 Mitochondrial complex II electron transport inhibitors **Cyenopyrafen, Cyflumetofen**

Midgut Targets

Group 11 Microbial disruptors of insect midgut membranes
11A Bacillus thuringiensis
11B Bacillus sphaericus

Unknown

UN Compounds of unknown or uncertain mode of action (e.g. **Azadiractin, Bifenazate, Pyridalyl, Pyrifluquinazon**) ,

Insecticide Resistance Action Committee (IRAC) Web Site

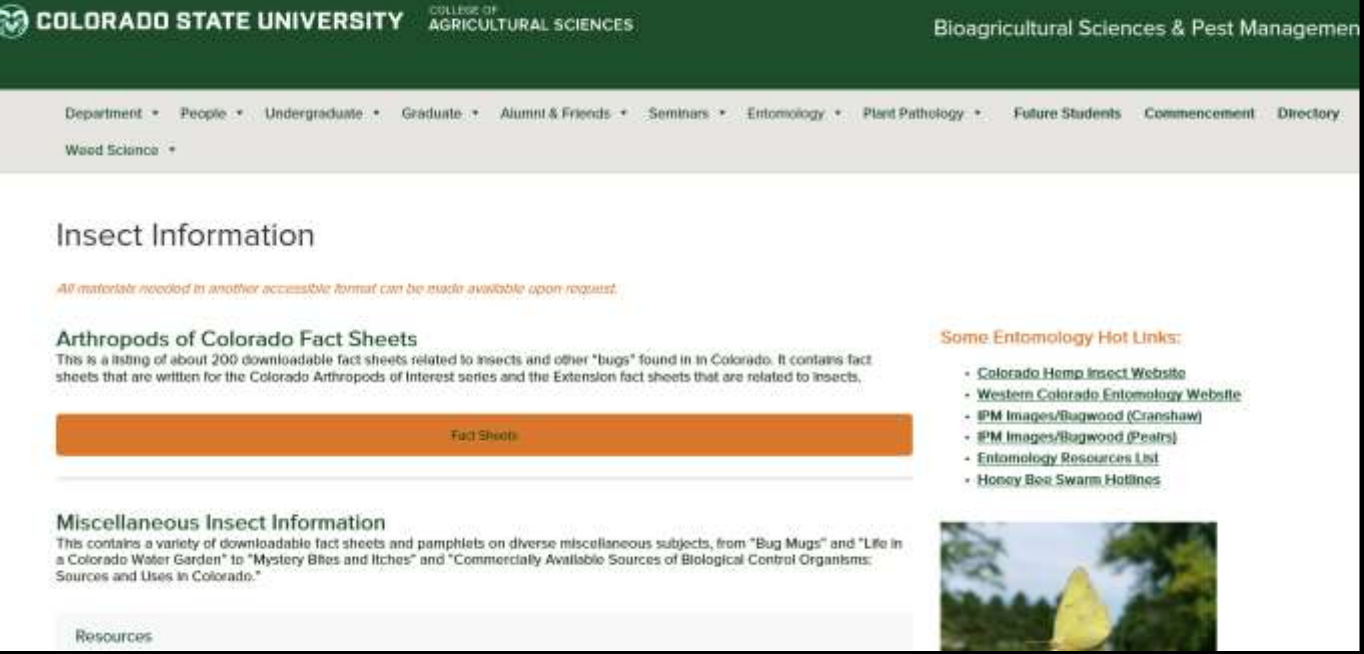
http://www.irac-online.org/

Check the section on Mode of Action to learn of the various classes of insecticides that have been developed

Presently there are 28 insecticide groups recognized with different modes of action.

This presentation will be posted at the Insect Information Website

- **Housed at Department of Bioagricultural Sciences and Pest Management**
  - **Search “BSPM CSU”**
- **Within “Entomology”**
- **“Insect Information”**
  - **Extension presentations are posted at the bottom of the page, most recent at end**



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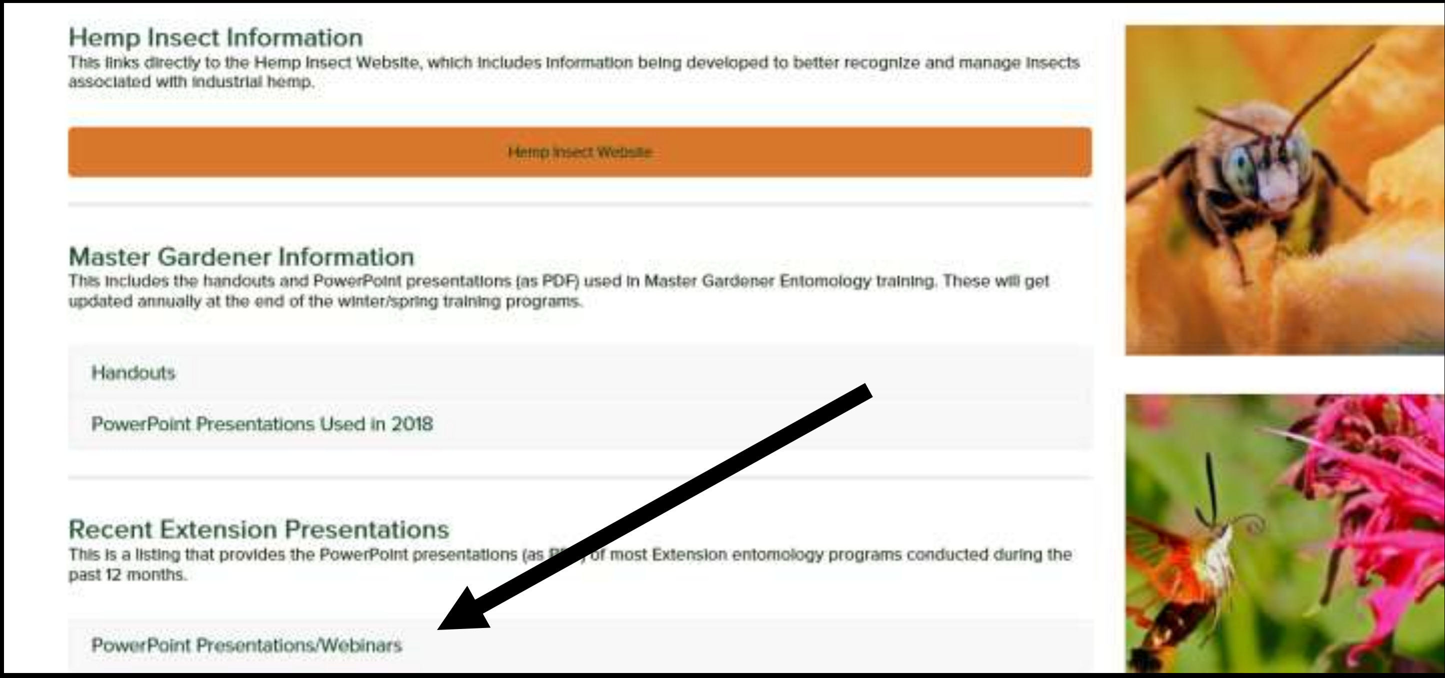

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PRO Green EXPO
Colorado Convention Center
Denver, CO | February 5 - 7, 2020

Thank you!

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