

Get the Pest, Spare the Rest

The What, Where, How, & Why of Pesticides

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Topics for Today

Introduction and Goals

- What are pesticides?
- Why are pesticides used?
- Where are pesticides used?
- How are pesticides used?
- How do pesticides work?
- Resources

Introduction and Goals

The What, Where, How, and Why of Pesticides

These questions are answered, at least in broad strokes

You should have a better idea of what these products do, where, how, and why they are used, and most importantly,

How do they work?

What are pesticides?

First thing to know:

Not “pesticides”!
Pesticides are bad!

These are:

Crop Protection Chemicals (CPCs)

or

Crop Protection Products (CPPs)

(pesticides are nasty and kill things)

What are pesticides?

CPCs/CPPs protect crop plants from:

Enemy plants (i.e., weeds)

Enemy insects

Enemy fungi

Enemy viruses

(somewhat the same as human medicine)

What are pesticides?

Pesticides are chemicals, substances, or products used to control pests.

Despite the name, they don't always kill,

Sometimes just weaken, prevent predation, prevent reproduction, deter, incapacitate, or otherwise discourage the pest

What are pesticides?

Requirements:

Must control pest

Mustn't harm crop plant

Mustn't harm people, pets, livestock

Must biodegrade (not persist)

Mustn't translocate (limit drift and runoff)

Must spare off-target organisms

Cartoon # vsh0878 at:
cartoonstock.com

Where are pesticides used?

Large-scale agriculture
Grains, vegetables, fruits, nuts

Treatments must be approved for climate,
hydrology, season

Strict limitations on amounts and frequency
Use must be according to the label

How are pesticides used?

Application at specified rates
according to the label
(dosing)

Most applications as
aqueous solution or suspension

Various formulations

How are pesticides used?

Formulations:

Dry flowable (DF)

Flowable liquid (FL)

Emulsifiable concentrate (EC)

Soluble liquid (SL)

Water dispersible granule (WDG)

Water dispersible powder (WDP)

Wettable powder (WP)

How are pesticides used?

Application methods:

Preemergence

Postemergence

Seed treatments

Contact methods (blanket, wick)

Selective & nonselective treatments

Systemic & nonsystemic treatments

How are pesticides used?

Carefully!



Photo by Tim McCabe, courtesy of USDA Natural Resources Conservation Service

Why are pesticides used?

Most important in large-scale agriculture

Increases the yield and quality of crop

Reduces/eliminates toxins and vermin

Increases storage life

Reduces manual labor required

How do pesticides work?

Differently, depends on the target species

Herbicides (weeds)

Fungicides (molds and mildew)

Insecticides (insects, broadly)

How do herbicides work?

What is a weed, anyway?

**A weed is any plant
growing somewhere
that it shouldn't**

some plants are crops or weeds
depending on season and place

How do herbicides work?

Modes of action unique to plants

Photosynthesis enzymes

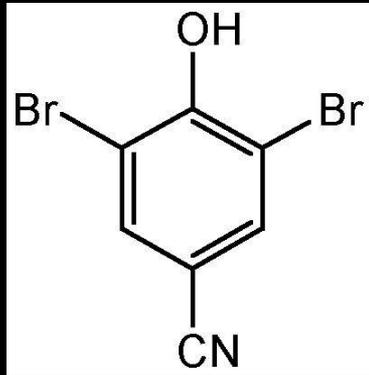
Inhibitors of

Photosystem II

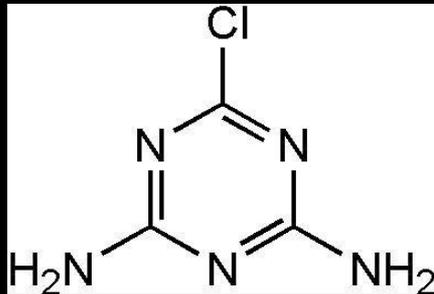
Humans don't photosynthesize

How do herbicides work?

Photosystem II inhibitors



bromoxynil (Buctril®)



atrazine (AAtrex®)

How do herbicides work?

Modes of action unique to plants

Lipid biosynthesis enzymes

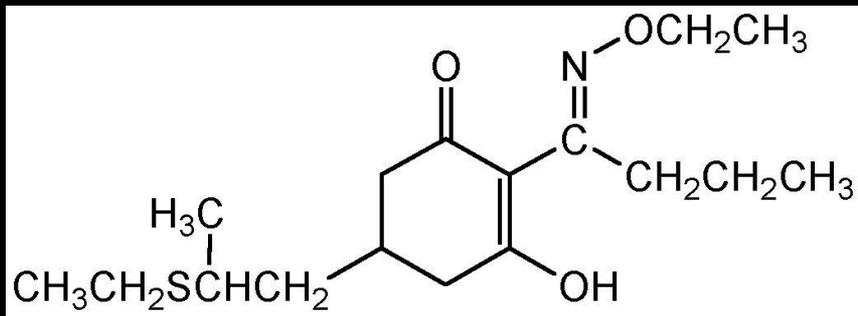
Inhibitors of

acetyl CoA carboxylase (ACCase)

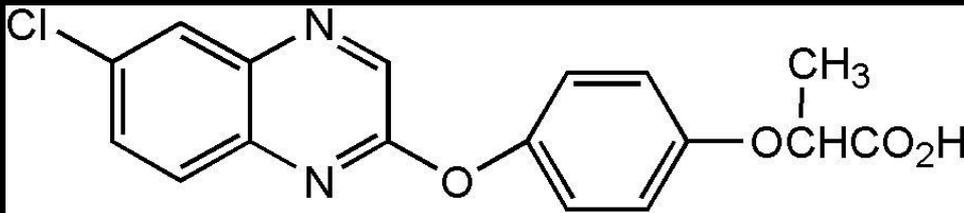
Humans have a different variant of this enzyme

How do herbicides work?

ACCase inhibitor herbicides



sethoxydim (Poast®)



quizalofop (Assure®)

How do herbicides work?

Modes of action unique to plants

Amino acid biosynthesis enzymes

Inhibitors of

acetolactate synthase (ALS)

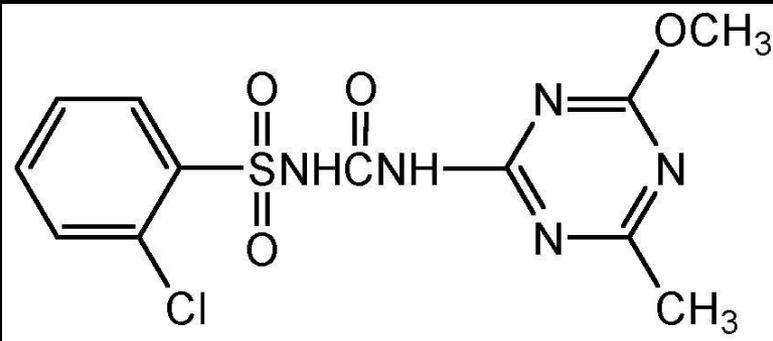
acetohydroxy acid synthase (AHAS)

5-enolpyruvyl-shikimate-3-phosphate (EPSP)

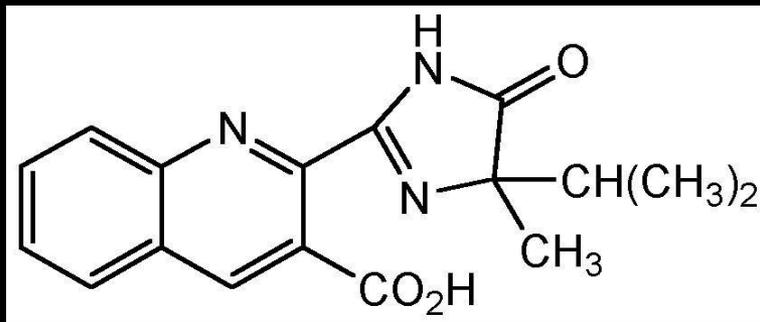
Humans don't have these enzymes

How do herbicides work?

ALS/AHAS inhibitor herbicides



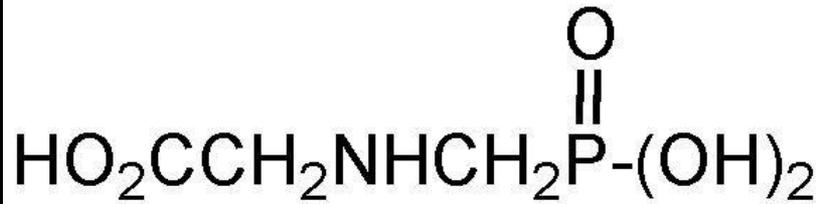
chlorsulfuron (Glean®)



imazaquin (Sceptre®)

How do herbicides work?

EPSP inhibitor herbicide



glyphosate (Roundup®)

How do herbicides work?

Modes of action unique to plants

Pigment synthesis enzymes

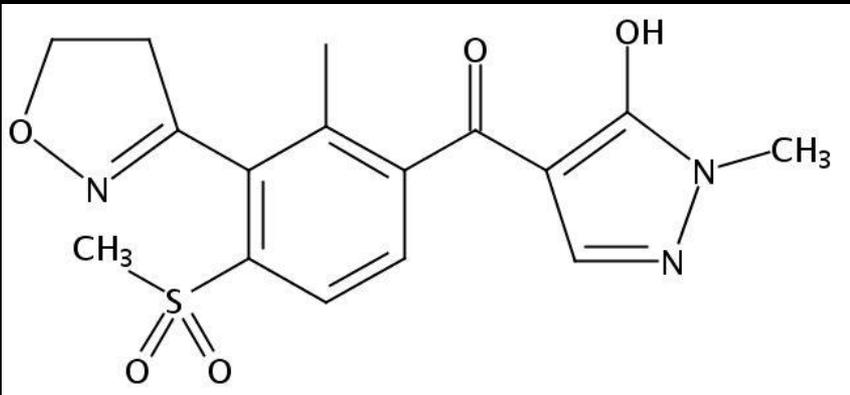
Inhibitors of

4-hydroxyphenylpyruvate dioxygenase (HPPD)
diterpene synthesis enzymes

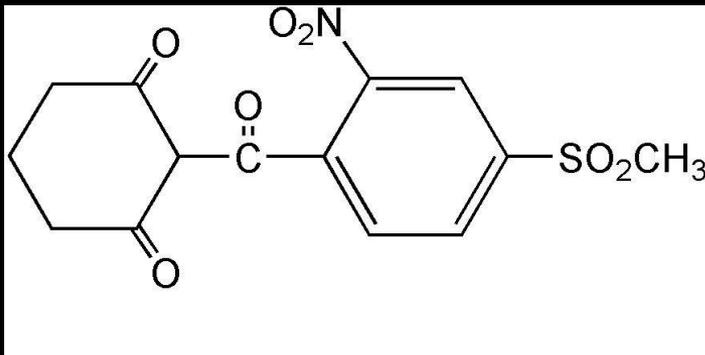
Humans don't make pigments like carotene

How do herbicides work?

HPPD inhibitor herbicide



topramezone (Impact®)



mesotrione (Callisto®)

How do herbicides work?

How are herbicides discovered?

Generally by accident or random chance
(like artificial sweeteners!)

Screen large numbers of chemical substances

Some are active, leads are followed

Rational design is still elusive

How do herbicides work?

Nature also produces herbicides

Black walnut

Pine trees

Buckwheat

Garlic mustard

Tree of heaven (臭椿)

all produce herbicidal compounds
for competitive advantage

How do herbicides work?

Enzyme inhibition – active site:

Graphic at:

[socratic.org/biology/enzymes/inhibitors-competitive-and-non-competitive]

How do herbicides work?

Enzyme inhibition – allosteric site:

Graphic at:

[teachmephysiology.com/basics/enzyme-activity/enzyme-inhibition/]

How do herbicides work?

Herbicide-resistant weeds!

Evolve resistance to inhibitors

What to do?

Make new compounds

Try new modes of action

Try multiple modes of action

How do herbicides work?

Weeds more easily thwart
allosteric inhibition modes of action

Just evolve to eliminate
allosteric enzyme site

Active site inhibitors should be
“immune” to resistance

But...

How do herbicides work?

...Nature finds a way

Standing tall:
glyphosate-resistant
pigweed growing in
Roundup Ready
cotton.

Photo: Bill Barksdale/AgStock Images/Corbis

[www.nature.com/news/war-on-weeds-loses-ground-1.10691]



How do herbicides work?

Glyphosate-resistant crops
(Roundup Ready[®])

Glyphosate is a total herbicide
(kills everything, no selectivity)

Active-site inhibitor

How to spare the crops?

How do herbicides work?

Early 1980s, Monsanto starts
molecular biology group

CPC scientists noticed
bacteria that seemed
glyphosate tolerant

MB group tasked to
find the gene and put it in crops

How do herbicides work?

"If all we can do [with biotechnology] is sell more damned herbicide, we shouldn't be in this business."

*(Robb Fraley, MB group leader
ca. 1980)*

Initial results promising
(petunias)

but no commercial level tolerance

Then, a breakthrough...

How do herbicides work?

~1989, Luling, LA,
Monsanto glyphosate factory
waste pond

Key glyphosate-tolerant
bacterium discovered

Partnered with biotech firms
& a seed company (Pioneer),
1996: Roundup Ready[®] soybean seed

How do herbicides work?

Cartoon # dgrn70 at:
cartoonstock.com

How do fungicides work?

A bit more challenging than herbicides

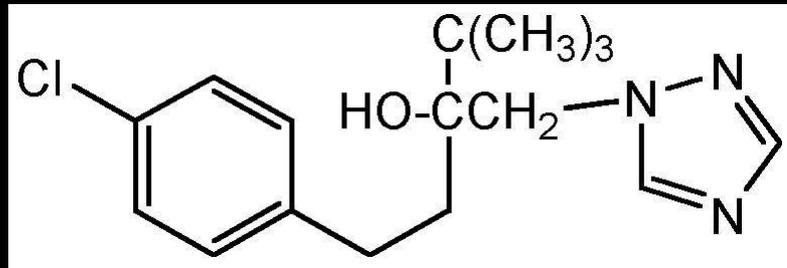
Humans are not too similar to fungi

We still share common enzymes
and biological systems, though

How do fungicides work?

14 α -demethylase inhibitors (DMI)
(steroid synthesis inhibitors)

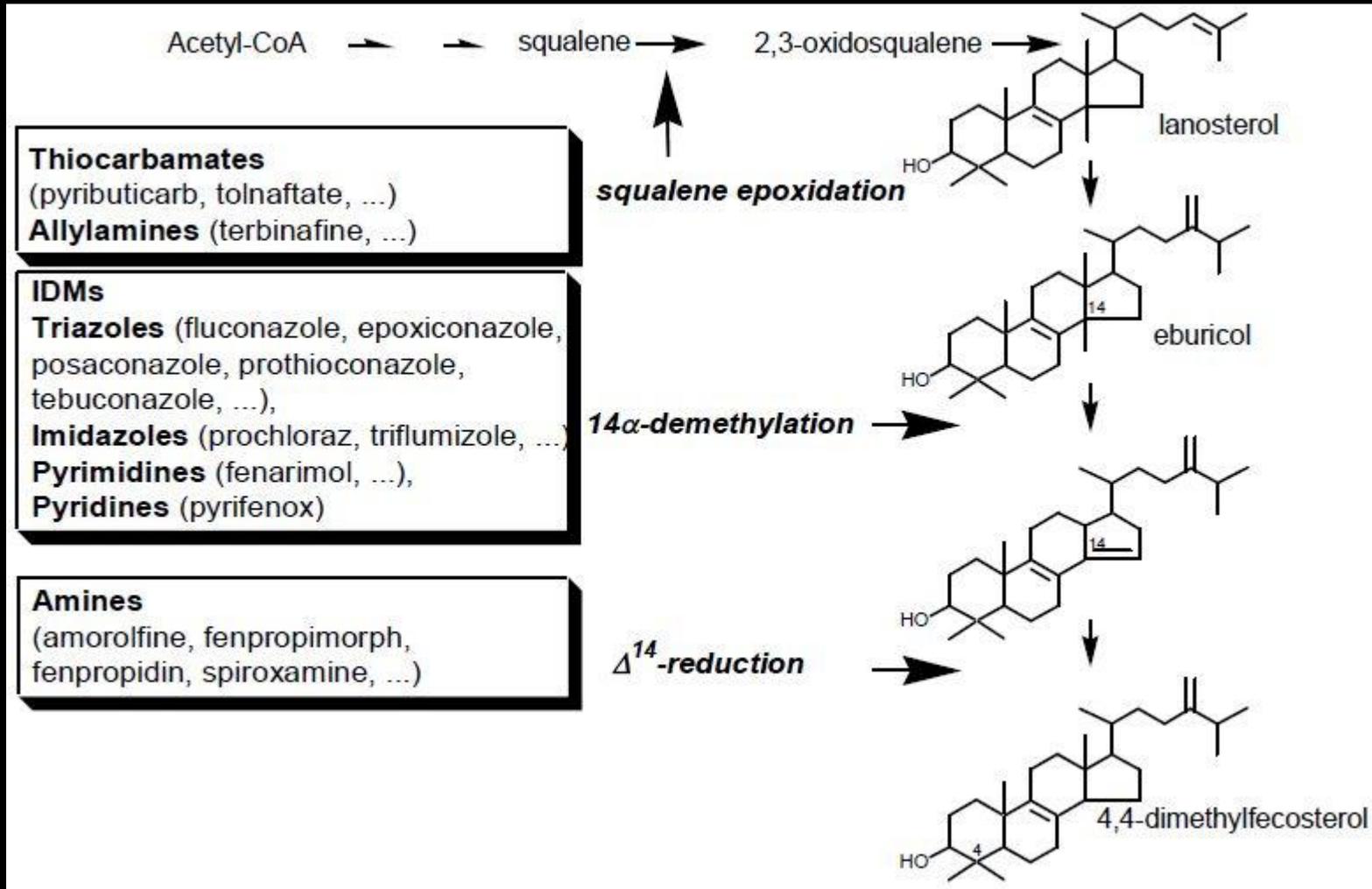
Disrupts synthesis of ergosterol
necessary for building cell walls



Triazoles
tebuconazole (Folicur[®])

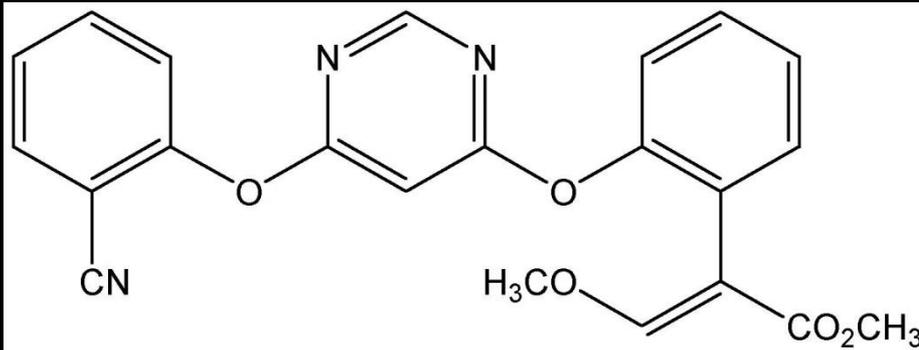
How do fungicides work?

Steroid synthesis inhibition



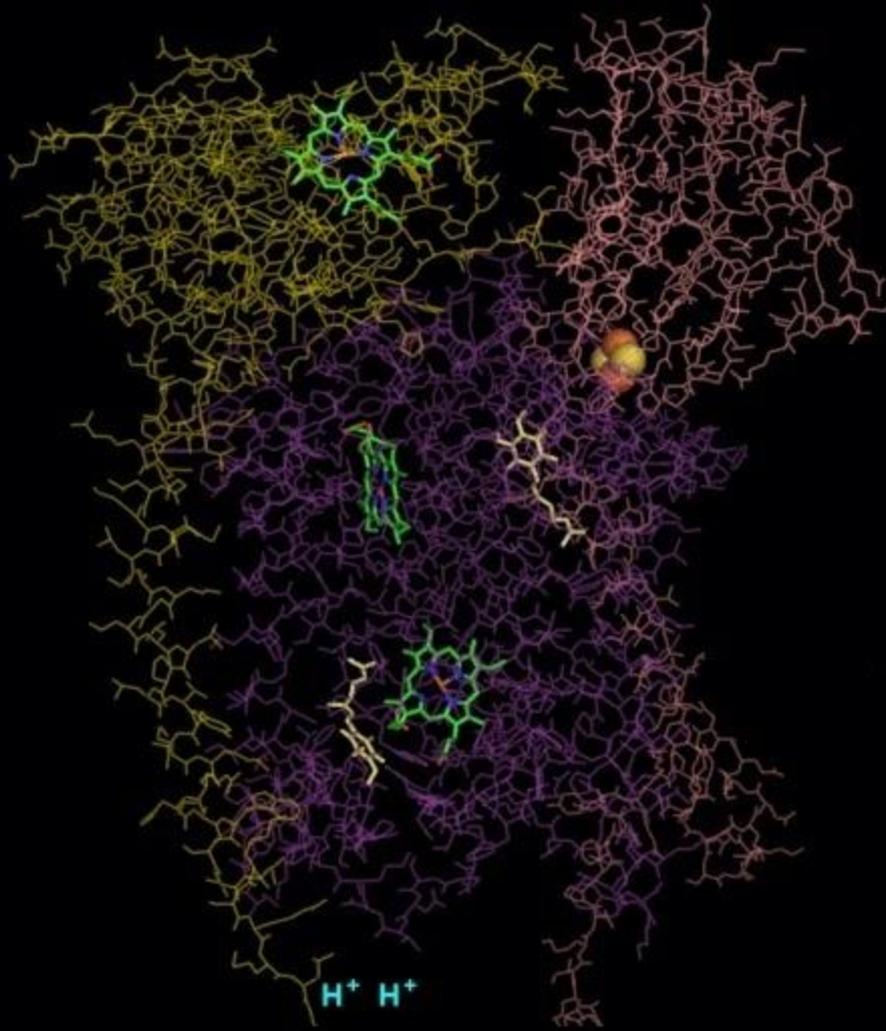
How do fungicides work?

Mitochondrial respiration inhibitors
(cytochrome b complex III at the Q_o site)
and disrupt electron transport



Strobilurins
azoxystrobin (Quadris[®])

How do fungicides work?



Cytochrome bc_1 complex

Q_o inhibitors (Q_oI) act at
quinol outer binding site



Tight binding at this site
disrupts mitochondrial
electron transport &
prevents ATP production

Watch the movie!

[<https://upload.wikimedia.org/wikipedia/commons/thumb/e/ed/Theqcycle.gif/600px-Theqcycle.gif>]

How do fungicides work?

Nature also produces fungicides

Strobilurus tenacellus (strobilurin)

Cinnamon (cinnamaldehyde)

Cananga odorata (sampangine)

Garlic

Sweet lupine (BLAD)

all produce fungicidal compounds
for competitive advantage

How do insecticides work?

Most challenging

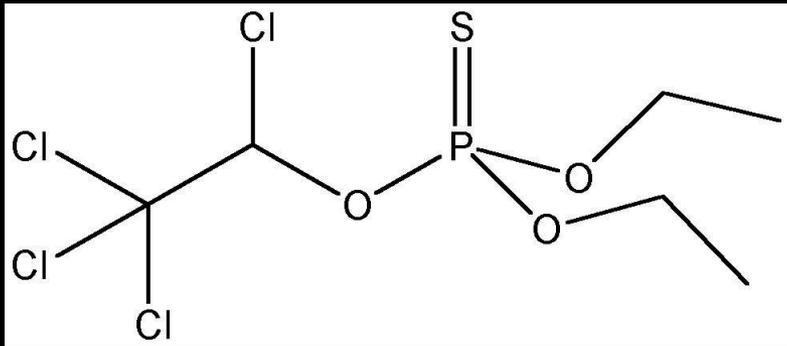
Humans are more similar to insects
than to weeds and fungi

Harder to find modes of action
that don't also affect humans

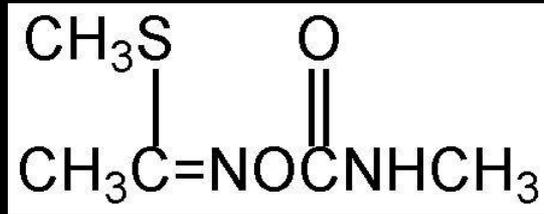
Cartoon # mban1414 at:
cartoonstock.com

How do insecticides work?

Acetylcholinesterase (AChE) Inhibitors (neuromuscular disruptors)



Organophosphates
chlorpyrifos (Fortress[®])



Carbamates
methomyl (Lannate[®])

How do insecticides work?

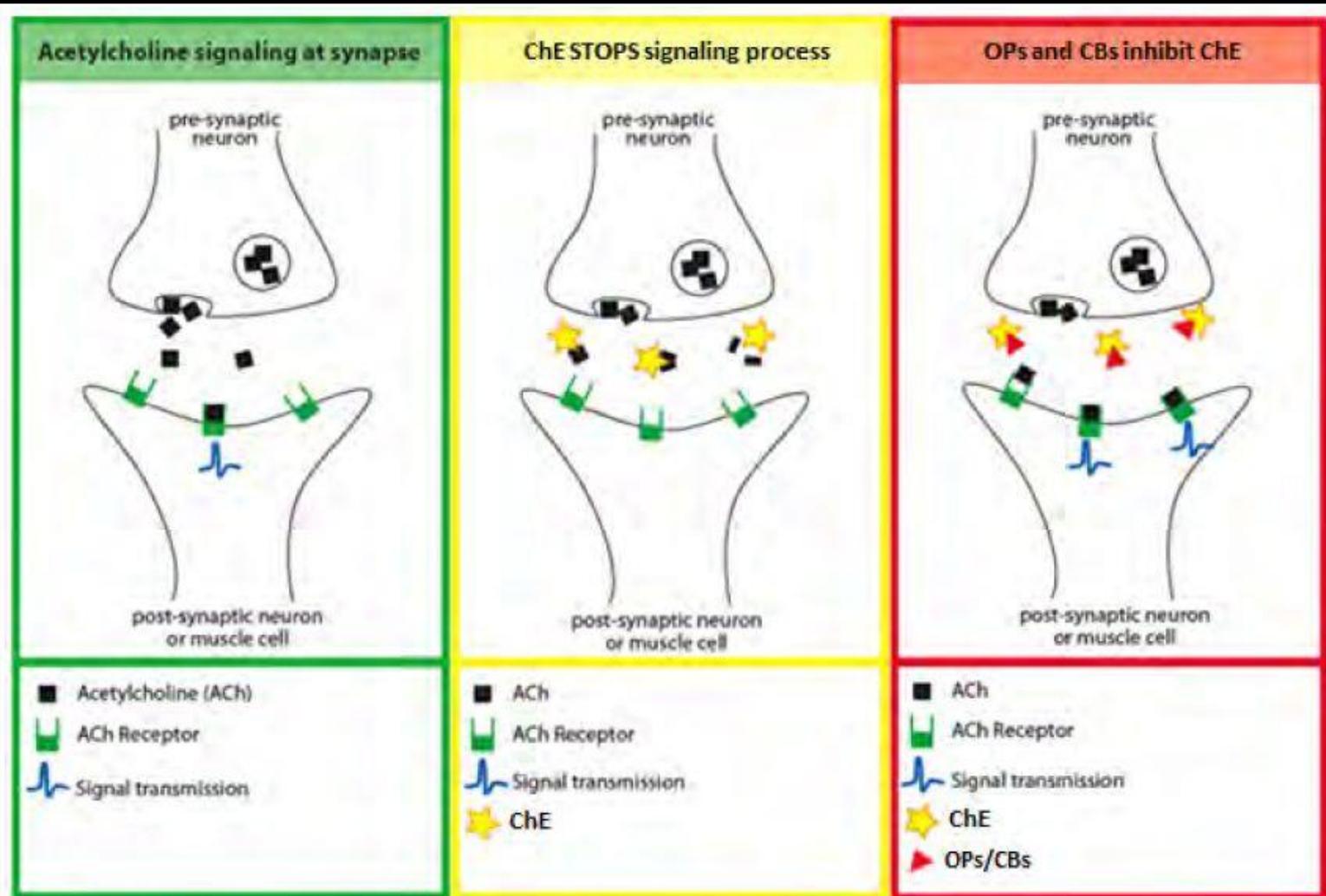
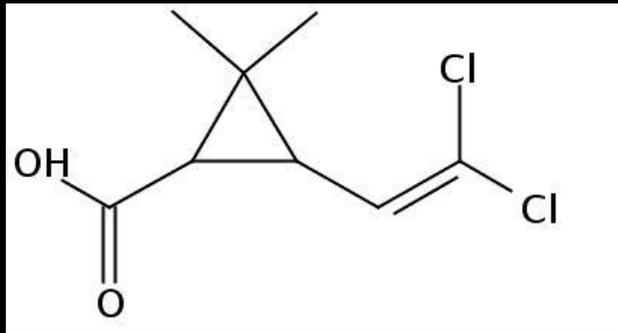


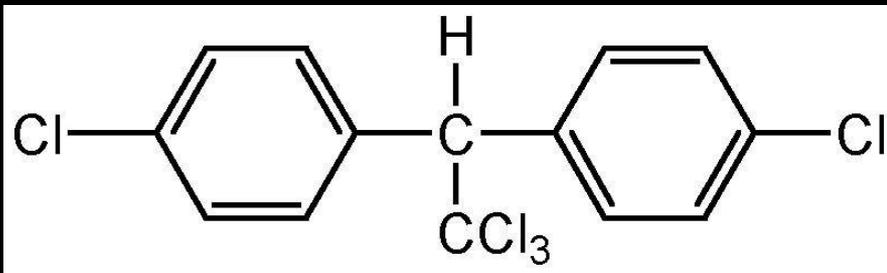
Figure A3a: Mode of action of OPs and CBs on ChE and nerve signal transmission. (Modified from <http://depts.washington.edu/opchild/acute.html>.)

How do insecticides work?

Sodium channel modulators



Pyrethrins
permethrin (Ambush®)



DDT
(no registered tradename)

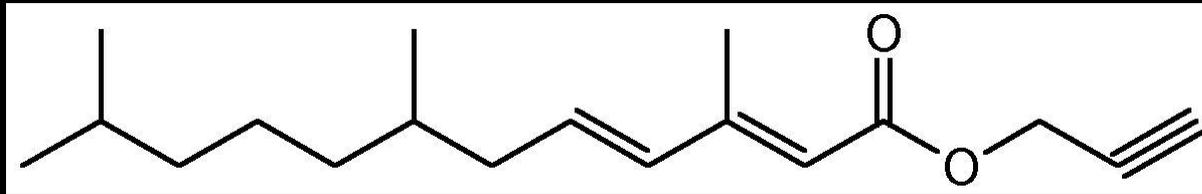
How do insecticides work?

Sodium channel Graphic at:

[From: <http://cues.cfans.umn.edu/old/em/MOA.html>]

How do insecticides work?

More selective agents
Little mammalian toxicity
Juvenile hormone mimics



kinoprene (Enstar[®])

How do insecticides work?

Nature also produces insect control agents

Tobacco (nicotine)

Jicama vine (rotenone)

Ryania (ryanodine)

Sabadilla (veratrine alkaloids)

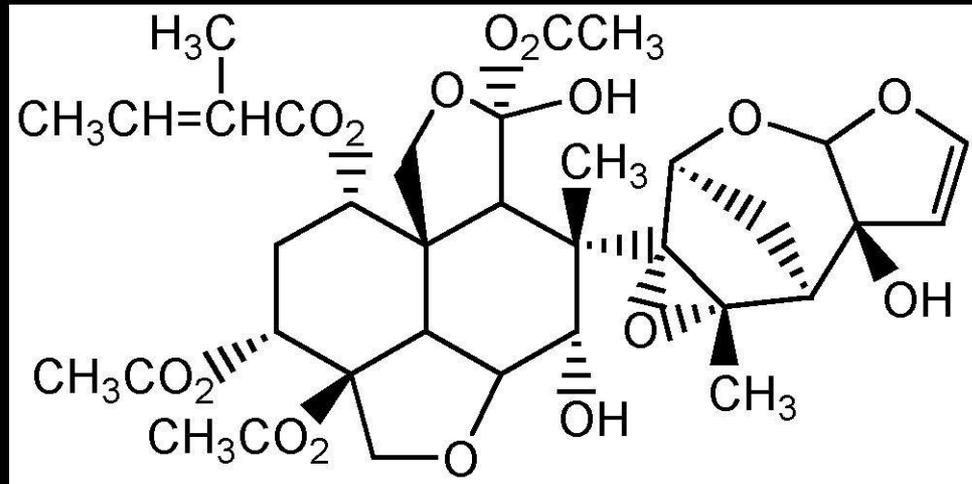
Neem (azadirachtin)

all produce insect control agents
for competitive advantage

How do insecticides work?

Neem (*Azadirachta indica*)

Novel mode of action: antifeedant



Azadirachtin

Makes insects stop eating

Get the Pest, Spare the Rest

The What, Where, How, & Why of Pesticides

Hopefully, you are now enlightened!

With responsible care and safe use,
pesticides are essential
to a stable, bountiful food supply

Identify your Pest

Bonus Technique

Finding the common name in your target language from a common name in the source:

Search the “source common name” + “scientific name (in source language)”

Will give the systematic scientific name

Scientific name gives the target language common name

Identify your Pest

Examples:

"イヌビエ" + "学名" => *Echinochloa crus-galli* => barnyardgrass

"gemeine Florfliege" + "wissenschaftlicher Name" => *Chrysoperla carnea*
=> common green lacewing

"mildiou de la pomme de terre" + "nom scientifique" => *Phytophthora infestans* => potato late blight

"quelite cenizo" + "nombre científico" => *Chenopodium album* =>
lambsquarters

quelite, quihuilla, tleconesh quilitl, (México); quinguilla (Chile); cañahua (Bolivia); cañihua (Peru)

Terms and Resources

Term	Definition
curative	ability of a fungicide to heal an extant infection
degradaphore	functional group introduced into a molecule to facilitate degradation in the environment
foliar application	spraying a treatment on leaves
fungigation	“fungicide” + “irrigation”
herbigation	“herbicide” + “irrigation”
insectigation	“insecticide” + “irrigation”
phytotoxicity	unintended damage to a crop plant (“phyto”)
postemergence	CPC applied after the crop plant has sprouted
preemergence	CPC applied before the crop plant has sprouted
preventative	ability of a fungicide to render a plant immune to infection
resistance	ability of a target organism to be immune to CPC effects
seed treatment	CPC applied to crop seeds before planting
systemic	ability of a CPC to enter crop roots and perfuse throughout the plant

Terms and Resources

Governmental resources

US Environmental Protection Agency

[<https://www.epa.gov/pesticides>]

Pesticides and Pest Management Canada / Pesticides et Lutte Antiparasitaire Canada

[<https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html>]

[<https://www.canada.ca/fr/sante-canada/services/securite-produits-consommation/pesticides-lutte-antiparasitaire.html>]

Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación

[<https://www.gob.mx/sagarpa>]

European Food Safety Authority (EFSA) (plant protection products, PPPs)

[<https://www.efsa.europa.eu/en/topics/topic/pesticides>]

Chinese Institute for the Control of Agrochemicals under the Ministry of Agriculture (ICAMA)

[http://english.agri.gov.cn/aboutmoa/ium/201301/t20130115_9535.htm]

独立行政法人 農林水産消費安全技術センター (Japan)

[<http://www.famic.go.jp/information/index.html>]

Food and Agricultural Materials Inspection Center (FAMIC)

[<http://www.acis.famic.go.jp/eng/indexeng.htm>]

[www.famic.go.jp/information/youran/pamph2018.pdf]

Terms and Resources

Informational resources

How Herbicides Work and Where They Go

[<https://discover.pbcgov.org/coextension/horticulture/pdf/commercial/How%20Herbicides%20Work.%20F.%20Fishel.pdf>]

Corn and Soybean Herbicide Chart

[https://www.soybeanresearchinfo.com/pdf_docs/weeds_herbicide_MOA.pdf]

History of Roundup Ready Crops

[https://www.sourcewatch.org/index.php/History_of_Roundup_Ready_Crops]

Fungicides 101

[<https://www.extension.iastate.edu/sites/www.extension.iastate.edu/files/greene/Fungicide101.pdf>]

Fungicide Groups, Modes of Action & Effective Pathogen Control

[<https://extension.oregonstate.edu/sites/default/files/documents/1/fungicide-resistance.pdf>]

IRAC: Mode of action classification and insecticide resistance management

[https://www.researchgate.net/publication/269730155_IRAC_Mode_of_action_classification_and_insecticide_resistance_management]

BASF Insecticide Mode of Action Technical Training Manual

[https://www.researchgate.net/publication/275959530_BASF_Insecticide_Mode_of_Action_Tec]

Terms and Resources

Terminology resources

IUPAC Pesticides Glossary (2006)

[<https://www.iupac.org/publications/pac/2006/pdf/7811x2075.pdf>]

Pesticides Glossary from the Compendium of Pesticide Common Names

[<http://www.alanwood.net/pesticides/glossary.html>]

Compendium of Pesticide Common Names

[<http://www.alanwood.net/pesticides/>]

EPA Pesticides glossary

[https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=Pesticides%20Glossary]

Integrated Pest Management (IPM) Pesticides Glossary

[<http://ipm.ucanr.edu/PMG/glossary.html>]

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