APES CHAPTER 11 NOTES extension (MRS. BAUCK)

MODULE 32 extension: Pesticides

I. The Need for Pest Control

A. **pest**—an organism that is noxious, destructive, or tiresome; an *injurious plant or animal*, especially one harmful to humans

B. categories

1) **agricultural pests** *(plant pests)—organisms which feed on crops or ornamental plants*

a) *vertebrate pests* such as **scale insects** *which extract plant liquids*

b) *weed pests:* annual and perennial grasses, annual and perennial broadleaf (**weeds** *compete with other plants for resources*)

c) *invertebrate or insect/arthropod pests*

d) *microbial pests or pathogens*: nematode, fungi, viruses

2) *arachnids*: spiders, ticks, flour/grain/cheese mites

3) *crustaceans*: woodlice, pill bugs, flour/grain/cheese mites

4) *pathogens*: bacteria, viruses, fungi

5) *rodents*: house mouse, common rat, black rat

6) insect pest examples

Cluster Fly	Common Cricket	Pharaoh Ant
American Cockroach	Earwig	Sawtooth Grain Beetle
Angoumois Grain Moth	Human Flea	Silverfish
Black Ant	Cat Flea	Brown Banded Cockroach
Australian Cockroach	Dog Flea	Mealworm Beetle
Australian Spider Beetle	Tropical Rat Flea	Termite
Biscuit / Drugstore Beetle	Bird Flea	Carpet Beetle
Bluebottle	Flour Beetle	Grain Weevil
Booklouse	Fruit Fly	Rice Weevil
Brown House Moth	German Cockroach	Rust Red Grain Beetle
Brown Tail Moth	Horse Fly	Khapra Beetle
Bed Bug	Common House Fly	Dried Bean Beetle
Carpenter Ant	Indian Meal Moth	Grain Borer
Tropical Warehouse Moth	Mill Moth	
Common Clothes Moth	Mosquito	
	Oriental Cockroach	

C. Importance of pest control

1) general types

a) **herbicide**—chemical that kills *weeds*

b) **insecticide**—chemical that kills *insect pests*

c) **pesticide**—chemical that kills *pests in general (insects/animals)*

d) **fungicide**—chemical that kills *pathogens*

e) **rodenticide**—chemical that kills *rodents*

2) two parts to these chemicals

a) *active ingredients*—chemicals that kill the targeted pests

b) *formulants*—chemicals acting as emulsifiers, dilutants, or solvents (sometimes more dangerous than the active ingredients)

3) other characteristics

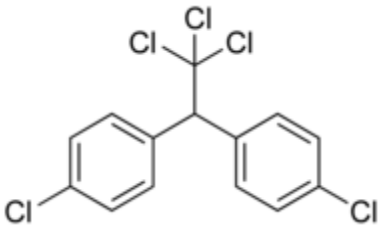
a) **broad spectrum**—effective against a *wide variety* of pests OR **selective**—effective against a specific, *narrow range* of organisms

c) **persistence**—*the ability of a chemical to last; to not break down*

D. Different philosophies of pest control
1) **chemical treatment**—*use of various chemicals to eliminate or reduce pest presence and effects*
a) short-term
b) risk of environmental damage
c) risk of damage to beneficial organisms
2) **ecological control**—*protection from damage*, not pest elimination
3) **IPM—Integrated Pest Management**
a) *combination of chemical and ecological approaches*
b) uses sustainable methods
c) long-term solutions
d) minimal environmental impact

"A weed is a plant whose virtues have not yet been discovered." – Ralph Waldo Emerson

II. The Chemical Approach
A. development of chemical pesticides and their successes
1) **first-generation pesticides**
a) (1400s +) *chemical*: contained *Hg, As, Pb*
b) (1800s +) *botanical*: contained *natural plant extracts* such as nicotine (from tobacco leaves), pyrethrum (from chrysanthemum flowers) and rotenone (from the root of the derris plant)
c) pests built up *resistance*
2) **second-generation pesticides**
a) over 1600 different chemicals
b) famous example: *DDT*



- $C_{14}H_9Cl_5$
- dichloro-diphenyl trichloroethane [1,1,1-trichloro-2,2-bis-(p-chlorophenyl) ethane]
- first prepared in 1873; rediscovered in 1938 by Paul Muller (subsequently awarded the Nobel Prize for it in 1948!)
- *water insoluble, lipid soluble (can't wash it away), so it stays in the environment and in organisms*
- it is a **broad spectrum** and **persistent PCB**

- *accumulation*—the buildup of DDT in the body; continues until saturation is reached

from http://www.chem.ox.ac.uk

"The use of DDT increased enormously on a worldwide basis after World War II, primarily because of its effectiveness against the mosquito that spreads malaria and lice that carry typhus. The World Health Organization estimates that during the period of its use approximately 25 million lives were saved. DDT seemed to be the ideal insecticide—it is cheap and of relatively low toxicity to mammals… However, *problems related to extensive use of DDT began to appear in the late 1940s*. Many species of insects developed resistance to DDT, and DDT was also discovered to have a high toxicity toward fish.

The chemical stability of DDT and its fat solubility compounded the problem. DDT is not metabolized very rapidly by animals; instead, it is deposited and stored in the fatty tissues. *The biological half-life of DDT is about eight years; that is, it takes about eight years for an*

animal to metabolize half of the amount it assimilates. If ingestion continues at a steady rate, DDT builds up within the animal over time…

The use of DDT was banned in the United States in 1973, although it is still in use in some other parts of the world. *The buildup of DDT in natural waters is a reversible process:* the EPA reported a 90% reduction of DDT in Lake Michigan fish by 1978 as a result of the ban.

additional info from http://www.usda.gov

3) focusing on crops
   a) *field crops*: corn, cotton, soybeans, wheat, potatoes, sorghum, peanuts, rice
   b) other crops: fruit, non-potato vegetables
   c) categories of **herbicides** (with examples) *widely used for corn, soybeans, and other crops*
      - http://www.alanwood.net/pesticides/summ_herbicides.html
   d) categories of **insecticides** *widely used for cotton and other crops*
      - http://www.alanwood.net/pesticides/summ_insecticides.html
   e) categories of **fungicides** *widely used for potatoes and other crops*
      - http://www.alanwood.net/pesticides/summ_fungicides.html
   f) pay attention to the categories: antibiotic, botanical, carbamate, desiccant, fumigant, organochlorine (chlorinated hydrocarbons), and organophosphorus including organophosphates

B. most common pesticides
   1) U.S. general: atrazine, metholachlor
   2) U.S. non agricultural: 2,4-D, chlorpyrifos, diazinon, glyphosate (RoundUp), malathion, dicamba, diuron naled, MCPP, carbaryl
   3) Florida stats
      a) FL = second largest user of all states
      b) 12,000+ pesticides are used in Florida with 600+ active ingredients, 45 of which are restricted use pesticides based on their acute toxicity to humans
      c) most commonly detected compounds in Florida groundwater: aldicarb sulfone, aldicarb sulfoxide, atrazine, alachlor, simazine, carbofuran, aldicarb, ethylene dibromide, DBCP, oxamyl

C. problems from chemical pesticide use
   1) development of *pest resistance*
      a) pesticides are made more potent
      b) *the most resilient individuals survive and reproduce*
      c) the pest population becomes more resistant
      d) *individuals may develop resistance to related chemicals even if they are not directly exposed to them*
      e) pesticides are made more potent again—the cycle continues…
   2) resurgences and secondary pest outbreaks: the "**pesticide treadmill**"
      a) **resurgence**—*a population exploding after being nearly wiped out*
      b) **secondary pest outbreak**—*small populations of other organisms explode as well, creating new threats*
   3) examples of *human health effects* of pesticide external exposure or ingestion

lymphoma, breast cancer dermatitis neurological disorders birth defects male sterility (banned) possible estrogen-like effects headaches dizziness nausea vomiting	mild irritations of skin/nose loss of appetite respiratory inflammations organ dysfunction diarrhea swelling nervousness hallucinations convulsions blue or yellow skin color	tremors shock sweating excessive thirst skin rashes lack of coordination excessive salivation eye irritant

4) *SUMMARY OF DISADVANTAGES OF PESTICIDE USE*
from http://www.greenventure.ca/

- *"threatens human health through direct exposure, and exposure to pesticide residues in food and water*
- *creates insects and weeds that are genetically resistant to pesticides, leading to more spraying and more toxic formulations (pesticide treadmill)*
- *destroys beneficial organisms, such as earthworms and bees*
- *harms wildlife, producing hormonal and genetic defects*
- *contaminates groundwater, including drinking wells, streams and lakes*
- *some pesticides accumulate and become amplified in the food chain (POPs :persistent organic pollutants)*
- *cost: homeowners spend an average of $300 per year on pesticide products or services*

5) examples of *environmental effects of pesticides*
additional info from http://extoxnet.orst.edu/tibs/ecologic.htm

- *decline of forests*, due to air pollution and acid deposition
- *loss of fish production in a stream*, due to death of invertebrates from copper pollution
- *loss of timber growth*, due to nutrient losses caused by mercury poisoning of microbes and soil insects
- *decline and shift in age* of eagle and hawk (and other top *predator) populations*, due to the effects of DDT in their food supply on egg survival
- *losses of numbers of species (diversity)*
- *loss of commercially valuable salmon &endangered species* from forest applications of DDT"
- water contamination
- cancer in animals
- death of pollinating insects and other beneficial insects
- thinning of egg shells, decreasing healthy hatching rate (DDE, a product of the partial breakdown of DDT, causes this)
- **bioaccumulation**—*increase in concentration of a pollutant from the environment to the first organism in a food chain*
- **biomagnification**—*increase in concentration from one link in a food chain to another pollutant must be long-lived, mobile, soluble in fats, and biologically active*

D. *Silent Spring (1962)* by Rachel Carson (1907-1964)
from https://www.nrdc.org/stories/story-silent-spring

"Silent Spring… meticulously described how DDT entered the food chain and accumulated in the fatty tissues of animals, including human beings, and caused cancer and genetic damage. A single application on a crop, [Carson] wrote, killed insects for weeks and months, and not only the targeted insects but countless more, and remained toxic in the

environment even after it was diluted by rainwater. Carson concluded that DDT and other pesticides had irrevocably harmed birds and animals and had contaminated the entire world food supply."

D. *nonpersistent pesticides*
   1) *they break down into nontoxic components*
   2) **** pesticide impact is a function of persistence, toxicity, dosage, and application location ****
   3) all insects can be affected, beneficial as well as pests
   4) **resurgence** and **secondary pest outbreaks** are still possible

A SUMMARY OF PEST CONTROL METHODS:
• **Chemical control**: mortality (*toxicants*), disrupt developmental processes (*growth regulators*), prevent reproduction (sterilants), or modify insect behavior (*semiochemicals*) • **Cultural (ecological) control** – non-chemical control • **Natural/Biological control** – use of living pest controls • *Legal control* – legislation, border quarantines, licensing or certification programs • *Physical / Mechanical control* • **Genetic (such as Eugenic) control** • **IPM – Integrated Pest Management**

III. Alternative Pest Control Methods

A. background info: **natural control/biological control**

- *the use of living organisms (parasites, predators, and pathogens) as pest control agents*
- *considers the relationship of the pest to other organisms and to the ecosystem*
   1) *importation*, such as obtaining pests' exotic natural enemies
   2) *conservation*, such as decreasing use of pesticides which kill pests' natural enemies
   3) *augmentation*, such as raising and periodically releasing natural enemies which don't do well in that environment on their own

B. **IPM** substances used (from http://edis.ifas.ufl.edu/in197)
   1) *botanical insecticides (extracts)*
      a) imonene and linalool (from citrus extracts)
      b) neem (from the Indian neem tree)
      c) nicotine (from tobacco)
      d) pyrethrum / pyrethrins (from African daisies)
      e) rotenone (from tropical legumes)
      f) ryania (from a specific South American plant)
      g) sabadilla (from ripe tropical lilly seeds
   2) *soaps and oils*
      a) horticultural oils (examples: vegetable)
      b) insecticidal soap (from plant oils or animal fat)
   3) *mineral insecticides*
      a) diatomaceous earth (fossilized diatom shells; a desiccant)
      b) sulfur
   4) *water spray* (to drown aphids, mites, and some caterpillars)

C. **cultural control** (also called *ecological control*)—*non-chemical ways of rendering the environment undesirable or inaccessible to pests* (purposeful manipulation of the pest's environment)

1) affecting humans
   a) *proper disposal of sewage wastes*
   b) *avoid contaminated drinking water*
   c) *sanitation*
      - *personal hygiene* keeping the body and living space clean
      - sanitation of *food preparation and handling* facilities

2) affecting lawns, gardens, and crops

CROPS…

   a) *crop rotation*
      - increases the diversity of the environment
      - creates discontinuity in pests' food supply
      - avoids monoculture
   b) *intercropping* (*mixed cropping*)
      - lowers the overall attractiveness of the environment to pests
      - concentrates the pest in a smaller, more manageable area
   c) *phenological asynchrony*—altering time of year for planting / harvesting
      - creates discontinuity in the pest's food supply
   d) *managed application of water or fertilizer*
      - irrigation
   e) *sanitation of planting area*
      - removal of debris such as fallen fruit or branches
      - pruning
   f) *plowing and/or burning of plant residue* to kill spores
   g) actions of the U.S. Customs Bureau and State Depts. of Agriculture

LAWNS…

   h) letting *grass* grow to at least *3-inch height*
   i) *increase diversity of wildflowers*
   j) elimination of pest host organisms
   k) elimination of plants that attract pests
   l) *encourage pest predators* by giving them refuge such as shelterbelts and hedges
   m) *use plants acting as natural insect repellents* www.ci.carlsbad.ca.us

Pest	**Plant Repellent**
Ants	Mint, Tansy, Pennyroyal
Aphids	Mint, Garlic, Chive, Coriander, Anise
Bean Leaf Beetle	Potato, Onion, Turnip
Codling Moth	Common Oleander
Colorado Potato Beetle	Green Bean, Coriander, Nasturtium
Cucumber Beetle	Radish, Tansy
Flea Beetle	Garlic, Onion, Mint
Harlequin Bug	Radish, Turnip, Onion
Imported Cabbage Worm	Mint, Sage, Rosemary, Hyssop
Japanese Beetle	Garlic, Larkspur, Tansy, Rue, Geranium
Leaf Hopper	Geranium, Petunia
Mexican Bean Beetle	Potato, Onion, Garlic, Radish, Petunia, Marigold
Mice	Onion

Root Knot Nematodes	French Marigold
Slugs	Prostrate Rosemary, Wormwood
Spider Mites	Onion, Garlic, Clove, Chive
Squash Bug	Radish, Marigold, Tansy, Nasturtium
Squash Vine Borer	Clove, Onion, Garlic
Stink Bug	Radish
Tarnished Plant Bug	Garlic, Pepper
Thrips (thunderflies, thunderbugs, storm flies, corn lice)	Marigold
Tomato Heartworm	Marigold, Sage, Borage

D. **control by natural enemies**
from http://www.anbp.org

1) general examples

ladybug (ladybird beetle)	viral agents
scale insects	rabbit population in Australia
parasitic wasps	Brazilian weevil
some caterpillars, mealybugs	water hyacinth
"Bt" *Bacillus thuringiensis*	"Green Muscle" (fungal spores in oil)
Japanese beetle	desert locust

2) more examples of *predators of pests*

Predator	**Pest**
green lacewing	small insects and mites; aphids
Orius - minute priate bug	mites and small insects
Geocorus – bigeyed bug	insects and mites
Persimilis – predatory mite	spidermites (esp. in strawberry fields and greenhouses; warm humid conditions)
Neoseiulus californicus – predatory mite	mites (tolerates hot and dry conditions)
Helveolus – predatory mite	Persea mite
Amblyseius occidentalis– predatory mite	various (on strawberry and mint plants)
Mesoseiulus longipes – predatory mite	various (warm and dry environments)
Amblyseius cucumeris	thrips (greenhouses)
Hypoaspis – soil mite	fungus gnats (greenhouses)

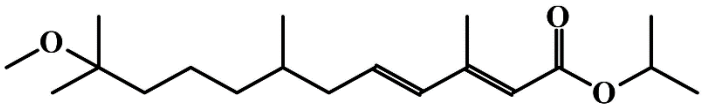
3) more examples of *parasites of pests*

Parasite	**Pest**
Aphioletes	some aphids
Goniozous	pink bollworm
Mucidifurax	some flies
Aphytis	California Red Scale
Tricogramma	many types of moth eggs
Encarsia	immature whitefly

4) challenges
   a) pests' natural enemies could attack unrelated desirable species
   b) pests' natural enemies could attack related but unthreatening species
   c) natural enemies are not always available (some are accidentally imported)
   d) conservation of natural enemies

E. **genetic / eugenic control**
   1) what plants do: control with *chemical barriers*
      a) *plants produce the toxins themselves*
      b) the pests many become more resistant over time, but there is still reduction in damage
      c) decreases the need for pesticides
   2) what plants do: control with *physical barriers*
      a) leafy hairs
      b) sticky leafy secretions
   3) human manipulation: control with sterile males: *eugenic control*
      a) causing (inducing) reproductive sterility
      b) ideal criteria for use
         - easy to mass-produce
         - females mate only once
         - males can be sterilized without loss of competitive vigor
         - low initial population
         - restricted geographic range
   4) human manipulation: strategies using biotechnology
      a) *autocidal control*—incorporating new and potentially deleterious genes or alleles into the genetic makeup of a pest population
      b) *plant-incorporated protectants (PIPs)*
      c) *genetically modified microbial pesticides*
      d) *herbicide-tolerant crops*
      e) *use of a powerful protein from "Bt"* <u>*Bacillus thuringiensis*</u>
   5) challenges
      a) impractical for developing countries
      b) "superweeds" with very high resistance
      c) increasing resistance of insects to Bt insecticide
      d) needing to develop different varieties of crops to circumvent the resistance problem

F. **natural chemical control**—use of *insect hormones and/or pheromones* to disrupt the target organism's life cycle
   1) advantages
      a) nontoxic
      b) species-specific
   2) examples
      a) use of **juvenile hormone (JH)** to prevent pupation
      example: methoprene



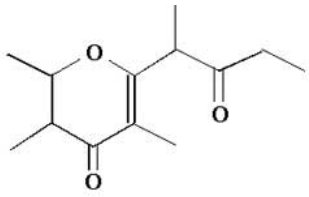
Juvenile hormone 0 – $C_{19}H_{32}O_3$
CAS methyl (2E,6E)-10R,11S-(oxiranyl)-3,7-diethyl-11-methyl-2,6-tridecadienoate
Juvenile hormone I – $C_{18}H_{30}O_3$
CAS methyl (2E,6E)-10R,11S-(oxiranyl)-7-ethyl-3,11-dimethyl-2,6-tridecadienoate
Juvenile hormone II – $C_{17}H_{28}O_3$

CAS methyl (2E,6E)-10R,11S-(oxiranyl)-3,7,11-trimethyl-2,6-tridecadienoate
Juvenile hormone III – $C_{16}H_{26}O_3$
CAS methyl (2E,6E)-10R-(oxiranyl)-3,7,11-trimethyl-2,6-dodecadienoate
Juvenile hormone JHB3 – $C_{16}H_{26}O_4$
CAS methyl (2E,6E)-6S,7S,10R-(dioxiranyl)-3,7,11-trimethyl-2,6-dodecadienoate

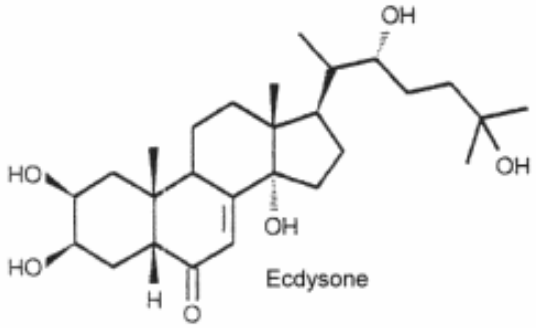
b) *prothoracicotrophic hormone (PTTH)* used to prevent molting

c) *pheromones*

- chemicals emitted by living organisms to send messages to individuals of the same species
- used for confusion or luring into traps
- example: stegobinone, drugstore beetle sex pheromone:



d) **ecdysone**—a steroid which causes incomplete molting



IV. Socioeconomic Issues in Pest Management

A. ample pressures to use pesticides
B. chemical treatment is readily available and fast ("quick fix")
C. **economic threshold**—the point at which *economic loss outweighs the drawbacks of using a pesticide*
D. **insurance spraying**—applying pesticide as a *preventative measure*
E. **cosmetic spraying**—applying pesticide to prevent blemishes (not real damage)

V. Pesticides and Public Policy

A. **FIFRA** – **Federal Insecticide, Fungicide, and Rodenticide Act**
1) established in 1947
2) amended by the *Food Quality Protection Act of 1996* and the *Pesticide Registration Improvement Act of 2003*
3) new pesticides must be tested and approved by the EPA
4) cancellations may be based on *potential risk to humans*
5) cancellations may be based on *damage to the environment*
6) *active ingredients, usage, and risks* must be listed on the label

B. **FQPA – Food Quality Protection Act** of 1996 (from the EPA)

"The pesticide re-registration program acquired significant new dimensions on August 3, 1996, when the Food Quality Protection Act was enacted. FQPA, which amends both FIFRA and the Federal Food, Drug, and Cosmetic Act (FFDCA), *establishes a new safety standard for pesticide residues in food and emphasizes protecting the health of infants and children*.

Under FQPA, all pesticide food uses must be 'safe'; that is, EPA must be able to conclude with 'reasonable certainty that no harm will result from aggregate exposure' to each pesticide from dietary and other sources. In determining allowable levels of pesticide residues in food, *the Agency must conduct a comprehensive assessment of each pesticide's risks, considering:*

- *Aggregate exposure of the public to residues from all sources including food, drinking water, and residential uses;*
- *Cumulative effects of pesticides and other substances with common mechanisms of toxicity;*
- *Special sensitivity of infants and children to pesticide; and*
- *Estrogen or other endocrine effects.*

…EPA is using re-registration to accomplish tolerance reassessment, the cornerstone of the FQPA... All pesticides will be re-examined periodically in the future through registration review. This new program created by FQPA requires EPA to *review every registered pesticide on a suggested 15-year cycle*."

C. USDA PDP: Pesticide Data Program

1) a partnership between the federal government and states
2) federal laboratories providing testing services

From http://www.ams.usda.gov

"The Pesticide Data Program (PDP) is a national pesticide residue database program. Through cooperation with State agriculture departments and other Federal agencies, PDP manages the collection, analysis, data entry, and reporting of pesticide residues on agricultural commodities in the U.S. food supply, with an emphasis on those commodities highly consumed by infants and children."

D. Pesticides in *developing countries*

1) chemical pesticide use has increased in the past 50 years
2) those countries will probably have similar or identical health problems and environmental damage like we had years ago
3) world market of pesticides is ~ $30 billion, *1/3 for developing countries*
4) more than 1 million acute poisonings reported per year
5) **PIC: prior informed consent** http://www.pic.int/
   a) 1998 Rotterdam Convention approved an international process to inform countries receiving imported goods about the pesticide restrictions used
   b) ongoing training and awareness workshops
6) *factors why people in developing countries are more vulnerable to the effects of pesticides*
   - *"weak or absent legislative frameworks*
   - *climatic factors (which make the use of protective clothing while spraying pesticides uncomfortable)*
   - *inappropriate or faulty spraying technology*
   - *lower nutritional status (less physiological defense to deal with toxic substances)"*