Supplementary Notes (PJ Shlachtman, Miller book):
Pesticides and Pest Control

Types of Pesticides and Their Uses

- **Pests:** Any species that competes with us for food, invades lawns and gardens, destroys wood in houses, spreads disease, or is a nuisance.
- **Pesticides:** (Biocides) Chemicals developed to kill organisms that we consider undesirable.
  1. Insecticides - Insect-killers
  2. Herbicides - Weed-killers
  3. Fungicides – Fungus-killers
  4. Nematocides – Roundworm-killers
  5. Rodenticides – Rat- and Mouse-killers

Plants have been producing chemicals to ward off herbivorous predators for ~225 million years. As herbivores adapt, so they don't starve, plants adapt so that they survive. This is an example of co-evolution.

The First Generation of Pesticides:

1. Sulfur – used as an insecticide since 500 BC
2. Arsenic (As), lead (Pb) and mercury (Hg) by the 1400's
3. Nicotine sulfate – extracted from tobacco leaves in the 1600s
4. Pyrethrum – obtained from the heads of chrysanthemum flowers
5. Rotenone – from the root of the derris plant

The Second Generation of Pesticides:

- About 2.5 million tons of pesticides are used yearly, worldwide. In the United States, about 630 different biologically active (pest-killing) ingredients and 1,820 inert (inactive) ingredients are mixed to make 25,000 different pesticide products.
  1. DDT – 1939, Entomologist Paul Mueller discovered that DDT (dichlorodiphenyltrichloroethane) was a potent insecticide. It soon became the world's most-used pesticide. Awarded a Nobel Prize in 1948.
  2. Broad-spectrum agents – toxic to many species
  3. Selective-spectrum agents – effective against a narrowly defined group of organisms.
- Since 1950 pesticide usage has increased 50 fold and toxicities have increased 10 fold.
- 10X more synthetic pesticides are used on the average home than on croplands in the US.
- ~75% of synthetic pesticides are used in the developed countries

1. **Persistence** – the length of time in which pesticides remain deadly in the environment; this may vary from days to years.
2. **Biomagnification –** the process by which toxins accumulate the higher you go in the food chain (generally because the toxin is not water soluble and therefore not easily excreted).

The Case For Pesticides:

1. **Pesticides save human lives:** Since 1945 DDT and other insecticides have probably prevented the premature deaths of at least 7 million people from insect-transmitted diseases.
2. **Pesticides increase food supplies and lower food costs:** About 55% of the world's potential human food supply is lost to pests pre or post harvest. Without pesticides, these losses would be worse, and could cause the prices of food in the U.S. to rise nearly 50%.
3. **Pesticides increase profits for farmers:** Overall, for every dollar spent on pesticides, there is an increase in U.S. crop yields worth approximately $4 for every $1 spent, this decreases to $2 for every $1 if environmental impacts are included.
4. **Pesticides work faster and better than alternatives:** Pesticides can control most pest quickly and at a reasonable cost, can use more if resistance occurs.
5. **The benefits overpower the health risks:** Safer and more effective pesticides are being developed. There is a greater use of botanicals and microbotanicals.
6. Genetically modified pest resistant crops are being developed.

The Case Against Pesticides:

1. **Genetic resistance** – Insects can develop immunities to pesticides in just a few years (5 – 10) through directional selection. Weeds and plants develop genetic resistance much more slowly.
2. **Broad-spectrum insecticides kill good organisms** – This includes killing natural predators and parasites that may have been maintaining the population of a pest species at a reasonable level.
3. **Pest Upset** – Wiping out natural predators and parasites can also unleash new pests whose populations the predators had previously held in check, causing other unexpected effects.
4. **Pest Resurgence** – natural predators and parasites are killed and pest population rebounds resistant to current pesticide and without natural predators.
5. **Circle of Poison** – banned pesticides are used on food crops outside of the US, the US imports these food crops and bring the pesticide back to the US.

- **The Pesticide Treadmill:** A situation where farmers are forced to pay more for a pest control program that often becomes less effective as genetic resistance develops.
- Although the use of synthetic pesticides has increased 33-fold since 1942, it is estimated that more of the U.S. food supply is lost to pests today than in the 1940s. Losses due to insects have doubled even though insecticide use has increased 10 fold.
- The estimated environmental, health, and social costs of pesticide use in the United States range from $4 billion to $10 billion per year.
- Alternative pest control practices could halve the use of chemical pesticides on 40 major U.S. crops without reducing crop yields.
- A 50% cut in U.S. pesticide use would cause retail prices to rise by only about .2% but would raise average income for farmers about 9%.

Where Do Pesticides Go?

Environmental Effects:

- Less than 2% of the insecticides applied to crops by aerial spraying or by ground spraying actually reach the target pests, less than5% of herbicides reach their intended weed targets.
- **Pesticide Mobility –** pesticides travel → through the air, surface and groundwater, bottom sediments
- **Biomagnification** - Some pesticides can harm wildlife – DDT had harmful effects in the environment when it biologically magnified in food webs. This resulted in certain birds being listed on the endangered species list in the U.S. because of fatal effects.
- Each year 20% of honeybee colonies in the U.S. are wiped out by pesticides, while another 15% are damaged, costing farmers over $200 million annually.
- More than 67 million birds and 6 –14 million fish are killed annually due to pesticides

Human Health:

- An estimated 25 million agricultural workers in developing countries are seriously poisoned by pesticides each year. 220,000 deaths result.
- In developed countries an estimated 300,000 farm workers suffer from pesticide-related illnesses yearly. 250,000 Americans get sick each year from home use / misuse of pesticides. This may be an underestimate due to poor record keeping and inaccurate diagnoses.
- Approximately 13% of vegetables and fruits consumed in the United States may contain illegal pesticides and levels of approved pesticides above their legally allowed limits.
- At least 75% of the active ingredients approved for use in U.S. pesticide products cause cancer in test animals.
- According to the EPA, 165 active ingredients are know or suspected human carcinogens, and to date, only 41 have been banned or voluntarily discontinued.
- Concern about genetic mutations, birth defects, impacts on the nervous, immune and endocrine systems.

Pesticide Regulation In The United States:

FIFRA – Federal Insecticide, Fungicide and Rodenticide Act

- Passed in1947, amended 1972
- All commercial pesticides must be approved by the EPA for general or restricted use
- When a pesticide is legally approved for use of fruits or vegetables, the EPA sets a tolerance level, which specifies the amount of toxic pesticide residue that can legally remain on the crop when the consumer eats it.

- Between 1972 – 2001 – banned or severely restricted 56 active ingredients
- EPA ordered all pre 1972 ingredients to be re evaluated; as of 2002 only ~10% of the 600 ingredients had been re evaluated.
- According the a National Academy of Sciences study, federal laws regulating the use of pesticides in the United States are inadequate and poorly enforced by the EPA, FDA, and USDA.
- Exposure to pesticide residues in food causes 4,000-20,000 cases of cancer per year in the United States.
- A 1993 study of pesticide safety by the U.S. National Academy of Sciences urged the government to do the following things:
  - Make human health the primary consideration for setting limits of pesticide levels allowed in food.
  - Collect more and better data on exposure to pesticides for different groups, including farm workers, adults, and children.
  - Develop new and better test procedures for evaluating the toxicity of pesticides, especially for children.
  - Consider cumulative exposures of all pesticides in food and water, especially for children, instead of basing regulations on exposure to a single pesticide.

Progress made with the passage of the 1996 Food Quality Protection Act:

- Requires new standards for pesticide tolerance levels in foods, based on a reasonable certainty of no harm to human health.
- Requires manufacturers to demonstrate that the active ingredients in their pesticide products are safe for infants and children.
- Allows to EPA to apply an additional 10-fold safety factor to pesticide tolerance levels to protect infants and children.
- Requires the EPA to consider exposure to more than one pesticide when setting pesticide tolerance levels.
- Requires the EPA to develop rules for a program to screen all active and inactive ingredients for their estrogenic and endocrine effects by 1999. (As of Dec. 2002 this has not been achieved)

Solutions:

Economic Threshold – when economic losses caused by pest damage outweigh the cost of applying pesticides.

How Can Cultivation Practices Control Pests:

- Crop rotation
- Planting rows of hedges or trees around fields to hinder insect invasions.
- Adjusting planting times so that major insect pests either starve or get eaten by their natural predators.
- Planting trap crops to lure pests away from the main crop.
- Increase the use of polycultures (as opposed to monocultures)
- Grow crops where major pests don't exist

How Can Genetically Resistant Plants Help Lower Pest Losses:

- Plants and animals that are genetically resistant to certain pests - insects, fungi, and diseases can be developed.
- Use genetic engineering to build pest and disease resistance into crops and thus reduce the need for pesticides.

Using Natural Enemies to Help Control Pests – Biological Control

- Use natural predators, parasites, and pathogens to regulate pest populations.
- Pros
  - Species specific
  - Saves ~$25 for every $1 invested (in the US)
  - Nigeria – used a parasitic wasp to fight the cassava mealy worm – Saved $178 for every $1 invested
  - Difficult to develop genetic resistance
- Cons
  - Can't always be mass produced
  - May be slower acting
  - May be killed off by pesticides from adjacent fields (as a result of pesticide mobility)

Insect Birth Control, Sex Attractants, and Hormones:

- Sterile Male Technique - Males of some insect pest species can be raised in the laboratory, sterilized by radiation or chemicals, and then released into an infested area to mate unsuccessfully with fertile wild animals. Has been used on the screwworm fly and the Mediterranean fruit fly.
- Pheremones – sex attractants – bait traps and capture males
- Juvenile hormones, molting hormones – halt metamorphosis – prevent maturation and reproduction

Alternate Methods

- **Hot Water:** The 'Aqua Heat' Machine sprays boiling water on crops to kill weeds and insects. Has been used on cotton, alfalfa, potatoes and citrus plants (wouldn't be effective in a rice paddie)
- **Radiation:** Exposing certain foods after harvest to gamma rays emitted by radioactive isotopes will extend food shelf life and kill harmful insects, parasitic worms, and bacteria.

Integrated Pest Management (IPM): In this approach, each crop and its pests are evaluated as parts of an ecological system. Then a control program is developed that includes a mix of cultivation and biological and chemical methods applied in proper sequence with the proper timing.

- The overall goal is not to eliminate pest populations, but reduce crop damage to an economically tolerable level.
- IPM requires expert knowledge about each pest situation, and is much slower acting then conventional pesticides.
- At times, more labor intensive
- Although long-term costs are typically lower than the costs of using conventional pesticides, initial costs may be higher.
- Can reduce pesticide usage and control costs by 50 – 90%
- Reduce pre harvest losses by 50%
- Improve crop yield (Indonesia → reduced pesticide usage by 65%, increased rice yields by 15%)
- Reduce fertilizer and irrigation inputs
- Hindered by government subsidies and opposition from agricultural chemical companies
- In a 1996 NAS study, Scientists urge the USDA to promote IPM in the U.S. by:
    i) Adding a 2% sales tax on pesticides and using revenue to fund IPM research and education.
    ii) Setting up a federally supported IPM demonstration project on at least one farm in every county.
    iii) Training USDA field personnel and county farm agents in IPM so that they can help farmers use this alternative.
    iv) Providing federal and state subsidies to farmers who use IPM.
    v) Gradually phasing out subsidies to farmers who depend almost entirely on pesticides, once effective IPM methods have been developed for major pest species.