Many animal and plant diseases are transmitted by insects.

**New threats from an old disease:**

**Case 1.** Malaria.
- $3 \times 10^6$ new cases each year; 50% of world population at risk.
- $1 \times 10^6$ deaths/year - mainly children.
- resistant to nearly all drugs.
- in Honiara, Solomon Islands- 1,120 bouts of malaria for every 1,000 people.
- recently cases of malaria in Eastern Canada (acquired in that area).

**Emerging diseases.**

**Case 2.** Rapid movement of material and people.
- *Aedes albopictus* mosquito native to Asia established in United States.
- introduced as the result of importation of used tires from Asia.
- known to vector several viruses transmissible to humans; including dengue fever (flavivirus) a major disease in Asia.
- also shown to transmit EEE (eastern equine encephalitis); rare endemic disease, but with a fatality rate of 30%.
- West Nile virus - infects and kills some birds, horses, reindeer, etc.
- transmitted to people by mosquitoes – mortality in humans.

**Case 3.** Changing lifestyles - wooded areas and Lyme Disease.
- living in appropriate habitat.
- vectored by ticks and possibly horseflies.

- diseases transmitted by arthropods to animals including humans is the subject of another course: ENT 392 Medical and Veterinary Entomology.

- main points of examples:
  - diseases once managed may become a problem once again.
  - new diseases occur.

- restricted to plant pathogens - a brief overview.

- associations between pathogen and vector may range from casual to obligate.

- casual association is the result of the "accidental contamination" of an insect on a diseased plant.
- insect carrying infectious material then moves to uninfected plant and under the appropriate conditions; this plant becomes infected.

**QUESTIONS:**

1. What might be required before this plant becomes infected?
2. How might an insect contribute to the transmission of this associated pathogen?

There are several ways in which insects may aid plant pathogens (still dealing with relatively casual associations).

**Fireblight** (*Erwinia amylovora*)

- a bacterial disease that causes significant losses in pear (most destructive), apple, and related species - mountain ash.

See HANDOUT PART 1
first bacterial plant disease shown to be vectored by insects (1891).
- vectored by more than 100 species of insects.
- also disseminated by rain and possibly wind.

- **Start:**
  - overwintering bacteria in cankers - produces a sweet sticky exudate when tree is in blossom.
  - attracts insects which become contaminated (on the body surface, also ingest bacteria) then contaminate flowers; rain splash from a canker high on a tree will also spread bacteria to flowers below.
  - bacteria multiply in flowers, infect nectarthodes.
  - bees visiting an infected flower will infect successive healthy flowers.
  - other insects may pick up bacteria by feeding on diseased vascular tissue, then transmit it to an uninfected plant.

**Losses**
1) reduced fruit set.
2) twigs and branches die; eventually whole tree may die.
3) causes cankers - growth reduction.

**QUESTIONS**
1) How would you control this disease?
2) Would you try to control the insects?

**Methods**
(i) remove infected material during winter (tools sterilised between uses).
(ii) remove any alternate hosts in the area (if possible).
(iii) antibiotics have been applied to trees, however resistant strains have developed.

See HANDOUT PART 2

i). **aid survival** - the pathogen survives within an insect when suitable substrate is not available; e.g. bacteria *Erwinia tracheiphila* causing a wilt in cucurbitis (cucumber, squash, etc.) survives overwinter in the gut of several beetle species which feed on these plants--beetle is dormant during winter months.
- begins to feed on new plants and contaminates area near wound with bacteria-laden frass -- disease cycle is continued.

ii). **disseminate inoculum**.

iii). **provide wounds**.

iv). **deposit inoculum** in a protected (from unfavourable environmental conditions) location; e.g. under dry conditions insects may oviposit on leaves which are more protected -- higher humidity (also sought by insect).
- wounds made by developing larvae are readily infected.

**QUESTIONS:**
1) How would this association be described?
2) How is this different from the first example?
3) Are there any advantages to the beetles as a result of this association?
4) What is a reasonable control strategy?

See HANDOUT

**Dutch elm disease (**Ceratocystis ulmi)***
- a fungal disease - an indispensable insect vector.
- thought to have originated around 1917-18 in Europe, possibly the result of a mutation induced by mustard gas used during WW I.
- importation of logs for veneer production in the 1930s also brought the disease and vector, a bark beetle, *Scolytus multistriatus*, European elm bark beetle.
- a native beetle species can also transmit the fungus *Hylurgopinus rufipes*, native elm bark beetle.
- transmitted by root grafts.
- start:
  - young beetle in the tunnel, surfaces become contaminated with conidia (spores).
  - inoculates healthy trees (springtime, trees susceptible) while feeding, however
doesn't construct brood galleries in these trees.
  - lays eggs in recently killed or dying trees which may or may not have fungus
disease.
  - fungus will grow in an already dead tree not killed by fungus and therefore
infect the brood when it emerges.

Losses - results in the death of American elm, a widely planted shade tree.

QUESTIONS
1) Does the beetle benefit from this association - what type of relationship?
2) How would you control this disease?
3) Would you try to control the insects?

methods
(i) chemical control of the beetles - difficult to reach insect in protected habitat.
(ii) sanitation - removal of dead and dying trees.
  unsuccessful - disease has spread across U.S. - American elm are being
  replaced in most locations.-some resistance found in Asian elm.
(iii) high value trees are injected with fungicide.

lessons: - problem with monocultures, a recurring theme in agriculture, in this case
  American elm.
  - demonstrates the difficulty of preventing the spread of both plant disease
  and imported insect pest species.
According to some estimates many thousands of diseases infect cultivated plants. Of this number, some hundreds are vectored by insects. Of the insects around 80% of the known vectors are found in the HOMOPTERA (piercing/sucking mouthparts).

**Insect Vectors of Plant Viruses, MLOs, spiroplasmas, RLOs.**

The piercing/sucking insects shown are Homoptera 

**exception:** plant bug (Heteroptera-Miridae).

1) aphids transmit around 60% of these diseases, almost exclusively viruses.
2) leafhoppers around 28% including viruses, (MLO’s - mycoplasmas, spiroplasmas, and rickettsia-like organisms-RLO’s).
3) planthoppers around 6%, mostly viruses.

**QUESTIONS:**

1) Where would you expect to find the pathogens in the plant? - on surface, in cells, or in vascular tissue?
2) ... in the insect?
3) How is the pathogen transmitted? - wounding plus injection into the wound.
4) Are the insects dispensable/indispensable (in cultivated plants) to the pathogen?

Although many aphids, viruses and plants may have had a 200 million year history of coexistence, agricultural practices have had major influences on the distribution of aphids and the plant viruses.

e.g. **Solanaceae** (Potatoes) 62 virus diseases; around 20 are aphid-transmitted- - most of these vectors were introduced to potatoes in the last 400 years.
- most of the recorded virus transmission in North America is by introduced aphids on introduced plants

**TABLE 1 Planthopper Vectors and Associated Diseases**

**Note:**

1) Some planthopper species can vector more than one disease.
2) Some diseases are transmitted by more than one planthopper species.
3) Some diseases are transmitted by a single planthopper species.

**QUESTION:**

What may be the implications of this type of information on the control strategy to be employed? 

- e.g. chemicals (many vector species in same area) versus biological control (single vector species).
Return to aphids; some information applies to plant- and leafhoppers.
- large number of diseases - viruses.
- main types of relationships.

(1) NONPERSISTENT

- stylet-borne (contaminated mouthparts); most aphid-vectored viruses.
- these aphids pick up the virus rapidly (15-60 second probes are optimal).
- virus replicates in epidermal cells and/or parenchyma - accessed rapidly.
- can inoculate (transmit) a healthy plant in a few seconds.
- retention lasts for only a few minutes to several hours.
- if aphid remains on a single plant for a few minutes, it loses the ability to transmit.

(2) SEMIPERSISTENT

- these aphids require a long time to acquire virus.
- the probability of transmission increases with feeding periods 12-24 hours.
- once acquired, retained for a longer period.
- virus appears to accumulate in the anterior gut - possibly binding at specific protein site.
- virus not found in the haemolymph.
- virus deep in plant tissue - phloem.

QUESTIONS:
1) How long do you think aphids can transmit virus?
   - not retained after a moult.
2) Mechanism?-possibly pH changes

(3) PERSISTENT

- pathogen once acquired may persist for life of insect.
- however two categories based on whether or not replication of the virus takes place in the vector.
  A) circulative, nonpropagative - replication doesn't occur.
  B) circulative, propagative - replication does occur.

Common Features
1) these viruses usually picked up from phloem tissue.
   - requires time for aphid to penetrate to phloem, may require many hours for the aphid to ingest enough virus for transmission.
2) some virus can be excreted but also find virus in the haemolymph.
3) infectivity is retained through a molt; may be transmitted to eggs, transovarial transmission.
4) latent period - time required between the acquisition of the virus and the ability to transmit - does not imply replication.
5) if infected aphid disturbed during feeding leading to several probes - more likely to transmit virus.

Unique Features

A. circulative, nonpropagative.
   - in this relationship some of the viruses pass through the midgut wall into the haemocoele.
   - in the best case studied this virus has been observed to accumulate in the salivary gland.
   - from here it is believed that the virus is then introduced by salivation during probing into the phloem of the next host.
B. circulative, propagative.
- in this system not only do the viruses circulate in the haemocoele, they replicate in the insect tissue.
- few economically important viruses are included here:
  (e.g. lettuce necrotic yellows; pea enation mosaic).

The majority of aphid-borne viruses are transmitted in a nonpersistent or semipersistent manner, however a lot of the economically important viruses are of the persistent type (e.g. barley yellow dwarf).

The majority of viruses in leafhoppers and plant-hoppers are transmitted in a persistent manner.

Leafhoppers and planthoppers transmit a variety of diseases:

<table>
<thead>
<tr>
<th>Aphid Group</th>
<th>Number of Viruses</th>
<th>Number of MLOs</th>
<th>Number of Spiroplasmas</th>
<th>Number of RLOs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leafhoppers</td>
<td>38 viruses</td>
<td>31 MLOs</td>
<td>4 spiroplasmas</td>
<td>4 RLOs</td>
</tr>
<tr>
<td>Planthoppers</td>
<td>17 viruses</td>
<td>1 MLO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Importance of Control

Process
- identify insect(s).
- identify disease.
- economics.

Solutions
- use resistant plants - classical breeding.
- crop rotation.
- sanitation of alternate hosts - especially used for aphids.
- control insects directly.
- use resistant plants - genetic engineering.
- do nothing - basis for this decision?

E.g. Sugar Beet Viruses
- many decrease yields of several tons/acre.
- led to increases of cane sugar prices - a benefit to tropical countries.
- in some cases value/unit increases so loss is to the consumer.