Herbivores insects

Lifestyles of herbivores

•**Phytophagy :** Ability of insects to feed on plants

•**Phytaphagous** : Plant eating insects

• **Feed plants** :

Externally : Borers

Internally : Leaf miners

• **What do plants provide** :

Direct use:

• Fats - low except seeds and some fruits

• Proteins - < 2% of biomass

– Amino acid balance different than animals'

• Carbohydrates - mostly indigestible

– cellulose, hemicellulose, in cell wall

• Vitamins and Minerals

Indirect use:

Plants/leaves are used for shelter

Leaf cutter bees : use leaves to line the nest

Leaf cutter ants – use leaves for substrate for growing fungi in their nest

Leaf cutter ants and their fungal garden

Megachile constructing nest

Leaf cutter bees and their nests

Lifestyles of herbivores

Monophagous: Insects feeding on single plant species
Ex: Silkworm

Oligophagous: Feeding on single group of plants
Ex: Colarado potato beetle – feeds on plants of genus solanum
Cabbage worm – feeds on plants of genus crucifera

Polyphagous: Insects feeding on diversity of plants
Ex: Gall wasps
Gypsy moth caterpillars

Omnivorous: Insects that feed both on plants as well as animals
Ex: cockroaches crickets and ants.

How do herbivores find their host

- Host may be selected by **trial and error**

  Ex: Grasshopper

- Host may be **selected by mother** who lays eggs depending on chemical cues

  Ex: Moths and butterflies

- Insects may **live in aggregates** that extend through several generation, so that young find themselves settled on the host

Stages in host finding

- **Host Habitat location**
- **Host location**
- **Host recognition**
- **Acceptance**
- **Host suitability**

• **Olfactory cues:**

- Use to differentiate between odours even when the volatile substances are closely related

- Olfactory receptors in the antennae of insects which are responsible for distinguishing different odor through modulation of nerve impulse producing a pattern.

- Chemokinesis/Chemotaxis – leads to reduced locomotion when the source is reached, applicable to mono and oligophagous insects

- Polyphagous insects on the other hand respond to generalized cues i.e accept plants based on certain phagostimulants (feeding stimulants), presence or absence of feeding detterdents or toxins.

- Certain oduor cues may serve as feeding stimulants to only a specific group of species.

Ex: Milkweed plants secrete cardonolides – deter feeding by phytophagous insects

- attract monarch butterflies which can digest these

HOST-HABITAT LOCATION

- **Location of the habitat and host**
  - Light
  - Wind
  - Temperature and humidity
- **Visual cues:**
  - help in locating host from a distance
  - Could be simple as vertical shape of the tree

    Contrast of white flowers against dark foliage
  - Some insects strongly attracted to certain shapes and colors which they associate with food

    Ex: Red spheres: attract adult apple maggots

    White pans of water: Attract aphids

    Bright yellow traps: attract leafhoppers

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Host Recognition and acceptance

- Insect herbivores have a **cyclical pattern** of feeding and behavior

- Initial phase of attraction to the host plants, appropriate **tactile (touch)** and **olfactory (odor)** cues trigger the impulse for first bite.

- **Gustatory (taste)** stimuli (phagostimulants) must be present in order for continues feeding to occur.

- Phagostimulants may be secondary plant metabolites or nutrients including minerals amino acids and sugars.

Ex: **Sinigrin** – glucoside serves as phagostimulant and attractant for oviposition for mustard aphids, cabbage worm.

Morin, inisitol, sucrose – from mulberry leaves elicit biting swallowing and continuous feeding

Sucrose concentration in corn- triggers feeding response in european corn borers.

- Other physical factors such as leaf surface, waxes may be important in feeding and oviposition

Ex: **Female of diamond black moth** lays eggs more readily on rough than on smooth surface.

Insects damage almost every part of a tree that serve as food.

Generally, the important forest insects pest species of importance belong to Orders:

Phasmatodea

Orthoptera

Hemiptera

Coleoptera

Isoptera

Hymenoptera

Lepidoptera

Diptera

Thysanoptera

Feeding Strategy

Feeding habits vary, not only between but also within pest groups.

Generalist feeders

- Wide range of tree hosts
- Variable host quality
- Flexibility to avoid predators
- Asian gypsy moth recorded over 600 hosts both conifers and hardwoods

Specialist feeders

- Restricted to a single species
- Limited host quality
- Difficult to avoid predator

The diversity of herbivore insects is also reflected by their feeding strategy.

Different feeding behaviour are found in the forest insect pest.

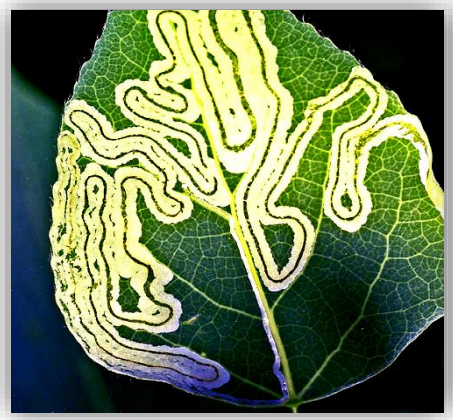
- Chewers
- Leaf feeders
- Leaf mining
- Sapsuckers
- Root feeders
- Bark feeders
- Flower, nectar, pollen, and seed feeders
- Dead-wood feeders
- Gall makers
- Stem feeders
- Shoot borers

Chewers

- Chewers feed on leaf tissue, resulting in complete or partial destruction of leaves. Insects may, Eat the whole leaf, Feed at the margin of the leaf.
- Biting type mouth parts with stout and strong mandibles which serve to cut and grind food
- Phytophagous insects belonging to the orders
    - Orthoptera, Coleoptera and Hymenptera – both adult and larval stages have chewing mouthparts
    - Diptera and Lepidoptera – only larva have chewing mouthparts

Leaf Miners

- **Leaf miner:** feed on tissue between upper and lower surface of leaf.
- Some leaf miners chew out a broad patch forming **blotchmines**
- **Leaf skeletonizers:** eat the leaf tissue between the network of leaf veins.
- **Leaf tiers:** Larvae of several moth construct shelters for protection against predators such as birds.
- **Leaf rollers:** webbing or rolling of leaves together and feed on foliage within the shelter
- Leaf mining are found in Lepidoptera Diptera Hymenoptera and Coleoptera.



Leaf miner

Blotchmines

Leaf skeletonizers

Leaf tiers

Leaf rolling

Stem borers/feeders

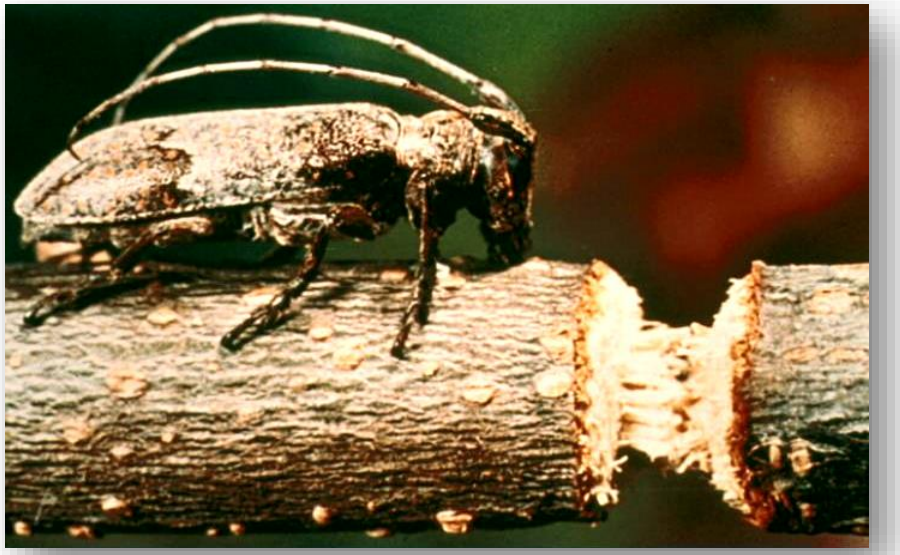
- Live in **woody tissue** of plants and fruits
- **Tree borers** have **strong mandibles** capable of grinding the hard particles to a usuable size.
- Borers have **intestinal symbionts** which aid in digestion
- Larva bores into the pith of the stem of saplings.

Example

Longicorn beetle (Coleoptera)

Stem borer: Tryporyza incertulas

Fruit borers: Leucinodes orbonalis



Longicorn beetle

Tryporyza incertulas

Leucinodes orbonalis

Bark and Wood Feeding

Larval stages cause most of the damage to the wood and bark.

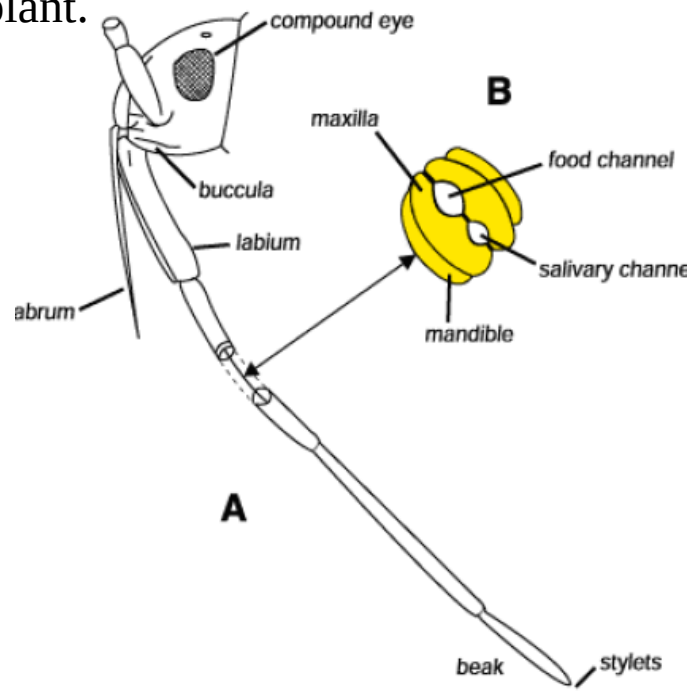
Include four main orders:

1. Coleoptera **(bark beetles, longicorn beetles, scarab beetles, weevils)**
2. Hymenoptera **(wood wasps)**
3. Isoptera **(termites)**
4. Lepidoptera **(wood moths)**

Extensive tunneling cause structural weakness in stems and branches.

Sap suckers

- Sap feeding insects suck liquid or semi-liquid material from succulent parts of the host plant.
- Mouthparts are adapted to pierce through tissue and extract fluid or plant sap.
- Labium is modified into sheath enclosing stylet maxillae
- Stylets pierce the cuticle and they inject toxic saliva into their hosts, causing necrosis of plant tissue
- These either consume xylem (cicada) or phloem (aphids), macerate the contents and suck the liquified material through proboscis.
- Moreover, they excrete clear, sugary liquid called honeydew which causes black moulds
- Reduced photosynthetic efficiency results in stunting, distortion or wilting.
- Honey dew on other hand serves as a food source for many insects like bees, wasps.



Example

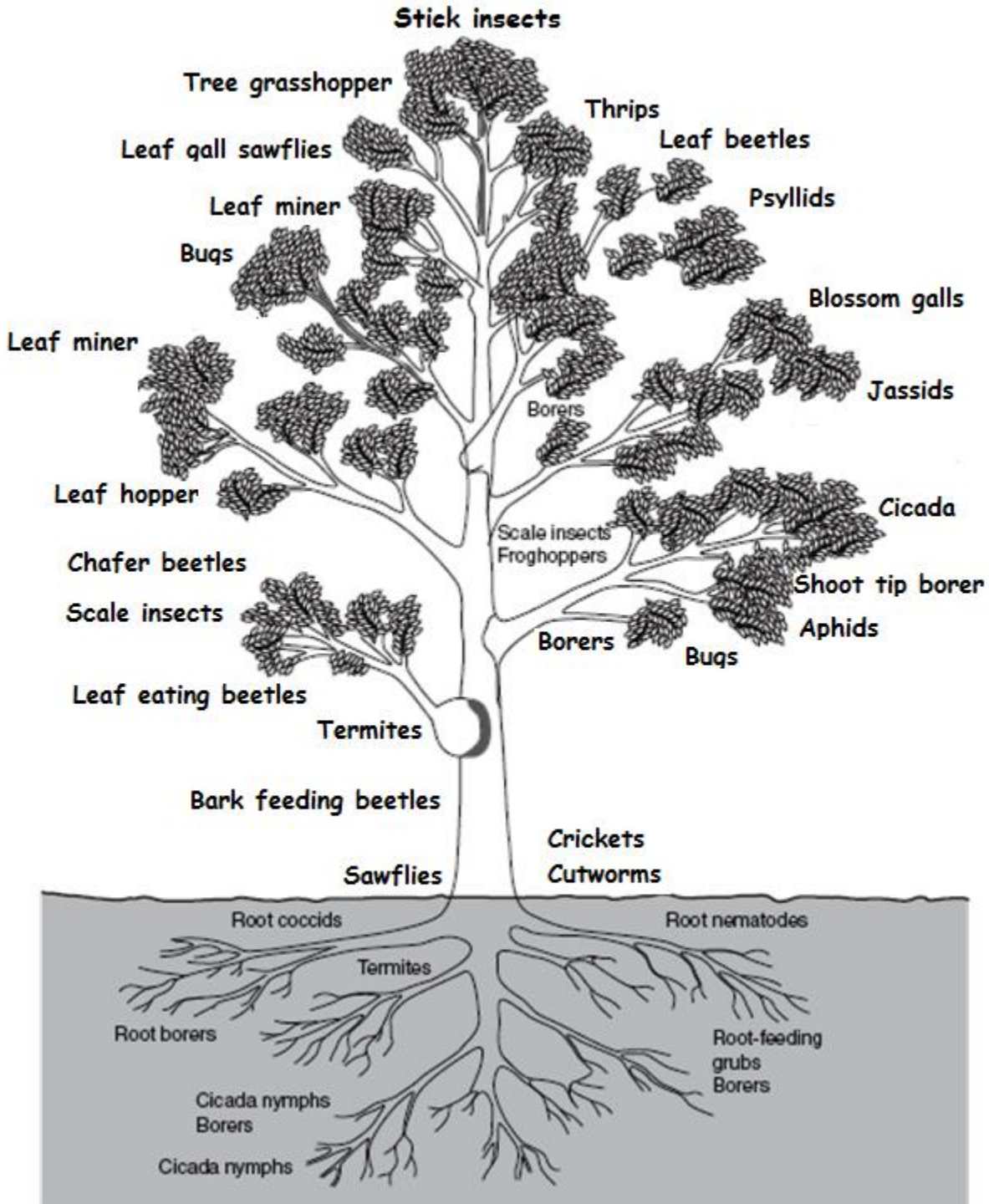
Psyllids, Mirid bugs, Aphids and coccids

Gall Forming

• Galls: Unusual plant growths, develop as a result of abnormal cell division or cell enlargements after infestation of plants by insects.
• These are diagnostics for species identification
• Indeterminate galls: Simolest gall with no major distortion or discolouration, in some case they expand to form pouch galls which are often open to the outside, Ex: Aphids
• Determinate galls: Distinct tissue layer, Ex: Oak galls, Gall midges and wasps, Willow cone gall
• Galls provide food and shelter for the invading insects.
• Produced by Diptera : Gall midges
Hymenptera : Gall wasps
Homoptera : Aphids

Gall midges

Gall wasps



A schematic tree showing the parts affected by various types of pest

Shoot Boring

Shoot or tip boring insects damage the apical terminal or leader of the tree.

Example
Pyralidae : *Dioryctria spp.*
Tortricidae : *Rhyacionia spp.*

Results in irregular stem growth or multiple branching when secondary terminals take over dominance.

Fruit and Seed Boring

Insects bore into the fruit, cones or seeds of forest trees.

Example

i. Torymid wasps lay eggs directly into the seed of young cones and their larvae feed within the seed.

ii. Bruchid beetles lay eggs on the pod or fruit and the larvae tunnel inwards to the seed.

Result in abortion of cones or fruit before the seeds have developed, or cause seed abortion.

Root Feeder/dead feeder

A wide range of insects feed on the roots of trees.
They can cause serious damage in nurseries and young plantations, where the trees have small and fragile roots.

Example

i. Termites are dead wood feeder.
ii. White grubs and root weevils burrows into the soil.

Stem and Branch Cutters

Damage trees by severing/cutting stems or branches completely.
Damage occurs mostly on nursery stock or newly planted trees.

Example

i. Some species of crickets and grasshoppers.
ii. Larvae of longicorn beetle make spiral tunnels across branches up to 10 cm in diameter.

Plant break off by wind or under their own weight

Defense mechanisms of plants against insects

Plant Defenses

- **Physical defenses :** Spines, thorns, Prickels
- **Chemical defenses:** Plant compounds derived from primary metabolism
- **Constitutive** : Defenses that are always present regardless of herbivory
- **Induced plant defenses :** Defenses that are only produced when there is feeding by an herbivore

Physical Defenses

• Modified plant structure that interfere physically with the insects locomotory behaviour, feeding or reproductive function

a) Colour: Insects can be attracted to certain colour while stay away from other, thus decreased susceptibility to feeding.

Aphids : Attracted to yellow-green leaves, less attracted to dark green plants.

Ball weevil: Infect green varieties more than the red cotton varieties

Cabbage butterfly : Prefer green cabbage variety for oviposition than the red variety

b) Shape: Plants have evolved shape similar to other plants, hence confuse the insect (mimicry)

***Heliconius* butterfly:** Feeds on passion vine plant.

Leaves of certain vine plants resemble those of passion vine plant, but are inedible

The passion vine plant have developed leaves of various shapes that makes *Heliconius* to locate the same.

c) Thickened cell wall: More thick the cell wall, more resistant to tearing action of insects.

d) Stem characteristics: Especially affect insects residing in the stem

Solid stem – resistant to mustard fly than hollow stem

Thick cortex in stem of tomato - prevents the aphid *Myzus persicae* from reaching the vascular tissue

e) Trichomes and glandular secretion

- Cellular, hairlike outgrowths of plant epidermis, which may occur on leaves, shoots and roots.
- Important for water conservation of the plant
- Mechanical effects of trichomes depends on : density, erectness, length and shape
- Some trichomes secrete secondary plant metabolites, some secret glue like sticky substance

Non-Glandular hairs are non-poisonous but cause irritation. E.g. *Capsicum pubescens*

Glandular hairs are seen in *Cannabis sp.*

Mechanism of defense:

Pubescent surface (those with high densities of trichomes) - prevent sucking insects to feed as the stylets will not reach the epidermis.

If eggs are laid, they dehydrate

If eggs hatch, the larvae have to feed trichomes first to reach the larvae.

If the larvae still survive, their gut walls damaged due to spike like trichomes

f) **Silica:** Some plants notably grasses, take up silicon from the soil and deposit it in their tissues in form of solid slilca phytoliths. These meachnically reduce the digestibility of plant tissue causing rapid wear to insect mandibles.

g) Wax: Cuticle of most vascular plants are covered in wax, act as protection against insect attack

Chemical Defenses

• Plants contain **thousands of chemicals** which are by products in the synthesis of primary metabolites and are stored by the plants

• These **secondary metabolites** are used by plants as chemical defense and are known **as allelomones**

• These are **chemical substances** produced and released by plants which affect the **behavior of insects**

• They can act as repellents, feeding deterrents, toxins , growth regulators and may impair digestion

Chemical Defenses

• Grouped into four major categories:

a) **Nitrogen compounds**: Alkaloids serve as toxins as defense against insects

Family solanaceae is well known to produce alkaloids

Green parts of potato *Solanum tuberosum* – solanine

Nicotiana spp -- nicotine

Deadly nightshade *Atropa belladona* – produce atropine

Only few insects such as colorado potato beetle, *Leptinotarsa decelimneata* and tobacco and tomato hookworms are able to overcome these defenses.

b) **Terpenoids**: Biologically important classes of natural plant products

They act as attractants for pollinators but feeding deterrents and toxins for others

Chrysanthemum contains **pyrethroids** (toxic monoterpenes) **-** used as insecticides

Sesquiterpenoid- **gossypol** – makes cotton plant resistant against cotton bollworm

Triterpenoids – **cucurbitacins** – impart bitter taste to plant serve as potent feeding deterrents to several insects

Triterpenoid – **Azadirachtin** – from Neem tree serves a powerful feeding deterrent.

c) **Phenolics**: Non-nitrogenous compounds that contain one or more hydroxyl groups attached to benzene ring.

Rotenone: has a bitter taste comercially available insecticide

Tannins: Polyphenolic compound, with protein adsorbing property known to reduce fecundity of insects

Proanthocyanidins / condensed tannins: Reduce feeding as well protein digestion

d) **Proteinase inhibitors:** Inhibit activity of digestive proteinases thus provide protection

e) **Insect growth regulators:** Plant chemical which mimic insect hormones namely juvenile hormone (Balsam Fir) and moulting hormone (Bracken fern).

Induced Plant Defenses Against Insects

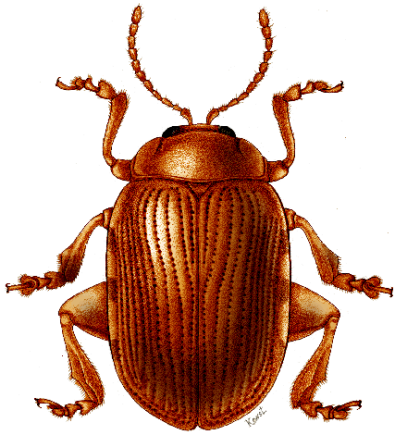
Defenses produced only when needed, in presence of herbivore insects

Responses may be in terms of

a) Increased production of secondary metabolites (alkaloids, terpenoids –toxins)

b) Increased production of defensive proteins (proteinase inhibitors)

Bersera squirts toxic resin when fed upon -- terpenes under pressure



Blepharida has evolved a behavior to overcome this defense

Response of Insects to Chemical defenses

- Plants defend themselves from insect herbivores with a vast array of chemical defences, yet insects have evolved several mechanisms for detoxifying these and even sequestering them for their own use.
- Most herbivorous insect species subsist on a small number of related host plants or one or two plant families that employ the same types of chemical defences, and reliably detoxifying them.
- Some insects may even use these compounds **as oviposition and feeding stimulants.**
- Some may deploy the chemicals for the **insects own defense**