IPM

Integrated Pest Management

Integrated Pest Management - IPM

- **Integrated Pest Management** (IPM) is a process consisting of the balanced use of cultural, biological, and chemical procedures that are environmentally compatible, economically feasible, and socially acceptable to reduce pest populations to tolerable levels.

- **Integrated** means that many strategies are used to avoid or solve a pest problem. These strategies come from different disciplines, such as disease information from plant pathologists, weed information from agronomists, and insect information from entomologists.

- **Pests** are unwanted organisms that are a nuisance to humans or animals, that can cause injury to humans, animals, plants, structures, and possessions.

- **Management** is the process of making decisions in a systematic way to keep pests from reaching intolerable levels. Small populations of pests can often be tolerated; total eradication is often not necessary.

Video Link: Integrated Pest Management – YouTube (12min)

Total Eradication is Not the Point

- Gardens and landscapes are home to an array of organisms and only a small portion are actually pests and out of those pests are a few worth actually using pesticides on.

- The real purpose of a pest management program is not to kill pests but to give the crop plant enough protection to allow you to harvest a food product with the quantity and quality that is acceptable to you.

- All living organisms are part of the ecosystem. They have purpose to keep everything in balance. Total eradication can offset natures checks and balances .

IPM Control Strategies

1. **Cultural Control** — methods using management techniques to control pests.

2. **Biological Control** — methods using living organisms that are predators to control pests or uses naturally occurring chemicals extracted from plants.

3. **Mechanical / Physical Control** — methods using tools, equipment, or other physical means for the control of pests.

4. **Genetic Control** — methods using plant breeding and genetic engineering to manipulate plants to make them more resistant to specific pests.

5. **Chemical Control** — methods using chemicals to control pests.

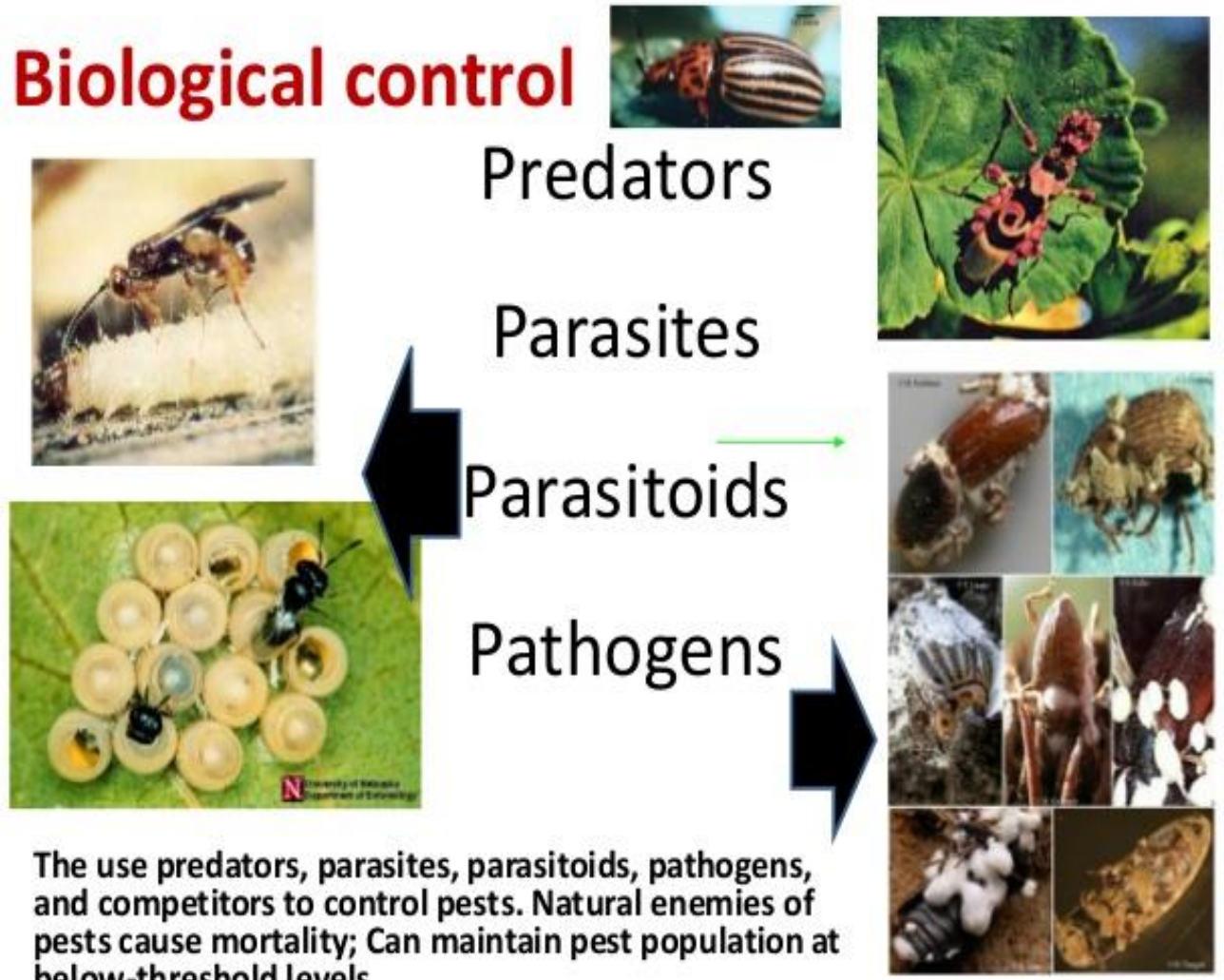
1. Cultural Controls

Cultural controls employ practices that reduce pest establishment, dispersal, reproduction and survival.

- Healthy soil
- Healthy plants
- Resistant varieties
- Crop Rotation
- Irrigation
- Fertilization
- Sanitation

2. Biological Controls

- Biological control is the use of ***natural enemies*** to control pests and their damage.
- Invertebrates, vertebrates, plant pathogens, parasites, nematodes and weeds have many natural enemies.
- Beneficial insects
  - Lady beetles
  - Lacewings
- Beneficial Bacteria
  - Rhizobium
- Plant produced chemicals, toxins and repellants
  - Pyrethrums
  - Nicotine



3. Mechanical Controls

- Mechanical and physical controls kill a pest directly, block pests out, or make the environment unsuitable for it.

- Physical controls include:
  - Plowing
  - Mowing
  - Pruning
  - Tilling /cultivation
  - Hand-picking
  - Traps
  - Temperature / Radiation

4. Genetic Controls

- Involves the use of genetically engineered / modified organisms to fight pests. (GMO's)
- Plant breeders develop varieties and hybrids that are resistant to or tolerant of pests.
  - Modification of plant enzymes target herbicidal action to render it insensitive to the herbicide

5. Chemical Controls

- Chemical control is the use of pesticides and herbicides.
- In IPM they are used only as a last resort and in combination with other approaches for more effective, long-term control.
- They are selected and applied in a way that minimizes their possible harm to people, non-target organisms, and the environment.
- With IPM you use the most selective chemical that will do the job and be the safest for other organisms, air, soil, and water quality.

Pesticides

Used to control pests:

- Insects
- Vertebrates
- Pathogens

Both organic and synthetic options are available

Herbicides

Used to control weeds

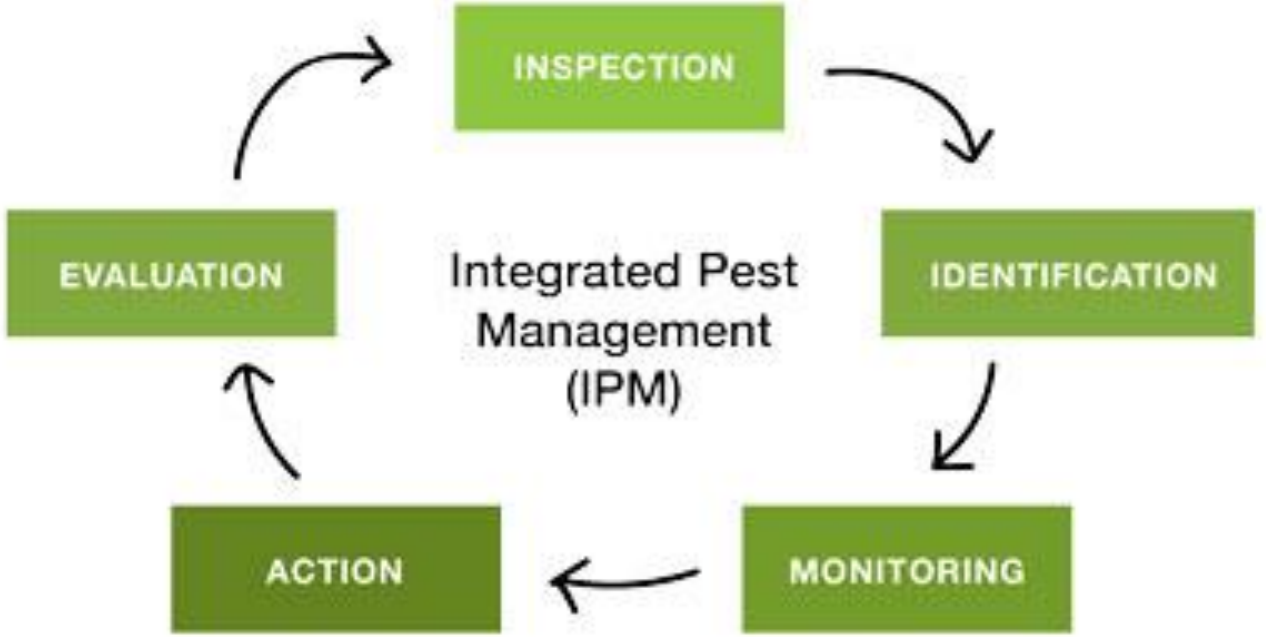
- Selective vs. non-selective
- Pre-emergents

Few organic options available

A Successful Management Plan

IPM principles and practices are combined to create IPM Plan.

- Pest identification
- Monitoring and assessing pest numbers and damage
- Guidelines for when management action is needed
- Preventing pest problems
- Using a combination of cultural , biological, physical/mechanical and chemical controls to manage pests
- After action is taken, assessing the effect of pest management



Designing an IPM Program

PLTS-Chapter 2

5 COMPONENTS OF AN IPM PROGRAM

1. IDENTIFICATION
2. PREVENTION
3. MONITORING
4. ACTION GUIDELINES AND THRESHOLDS
5. MANAGEMENT & EVALUATION

VIDEO: COMPONENTS OF AN IPM PROGRAM – YOUTUBE (16MIN)

PREVENTION

- DESIGN PROPERLY
- PREPARE SITE CORRECTLY
- PLANT SELECTION
- PROPERLY PLANT
- PROVIDE APPROPRIATE CULTURAL CARE
- EXCLUDE FOREIGN PESTS

IDENTIFICATION

- DIAGNOSE CAUSE OF PROBLEM
  - MANY LOOK SIMILAR
  - PEST, DISEASE, ABIOTIC OR COMBINATION
- PROPERLY IDENTIFY PESTS
- PROPERLY IDENTIFY NATURAL ENEMIES / BENEFICIAL INSECTS
- OBTAIN RECENT ENVIRONMENTAL & SITE CONDITIONS
- HELPFUL TOOLS
  - HAND LENS
  - REFERENCE MATERIALS
  - WEBSITES

MONITORING

- REGULAR / ROUTINE MONITORING
  - FREQUENCY AND METHOD CAN VARY WITH SEASON OR PLANT
  - SYSTEMATIC ROUTINES
- CHECK FOR:
  - PESTS
  - DAMAGE SYMPTOMS
  - EVALUATE SITE CONDITIONS
  - MANAGEMENT PRACTICES
- RECORD-KEEPING
  - PESTS, DETERMINING FACTORS, TREATMENTS, WEATHER, SOIL, ETC.
- ANALYZE AND COMPARE RESULTS
  - EFFECTIVENESS

DEGREE DAY MONITORING

- IS A TERM THAT REFERS TO THE ACCUMULATION OF HEAT UNITS ABOVE A THRESHOLD TEMPERATURE OVER TIME.
- IT IS A MEASURE OF HOW WARM OR COLD IT HAS BEEN DURING A SPECIFIC SEASON OR DATES.
- MONITORING DEGREE DAY ACCUMULATION IN YOUR SPECIFIC AREA CAN HELP YOU ESTIMATE WHEN SPECIFIC INSECT PESTS ARE LIKELY TO BE PRESENT.
- CAN HELP TO ESTIMATE WHEN THE EGGS OF A PARTICULAR PEST ARE GOING TO HATCH.

ACTION THRESHOLDS & GUIDELINES

- TOLERANCE LEVEL
  - ACCEPTABLE DAMAGE
- ACTION THRESHOLDS
  - POINT ACTION MUST BE TAKEN TO PREVENT UNACCEPTABLE DAMAGE
- AGRICULTURAL
  - ECONOMICS
  - CROP QUALITY OR YIELDS
  - PROFITS AFFECTED BY CONTROL COSTS
- LANDSCAPING
  - PRIVATE: VARIES BY HOMEOWNER
  - PUBLIC: VARIES BY VENUE, PUBLIC INVOLVEMENT, BUDGETS, ETC.
- ESTABLISH GUIDELINES
  - THRESHOLDS FOR HIGHLY VALUED PLANTS AND/OR PROBLEM PRONE PLANTS
  - CONSIDERATIONS FOR WEATHER, STAGE OF GROWTH, ETC

MANAGEMENT

- CONSIDERATIONS
  - IS ACTION NEEDED
  - WILL IT BE EFFECTIVE
  - IS IT TOO LATE FOR CONTROL
  - DOES IT THREATEN PLANT OR HUMAN HEALTH
- METHODS OF CONTROL
  - CULTURAL
  - MECHANICAL
  - PHYSICAL
  - BIOLOGICAL
  - CHEMICAL

CHEMICAL CONTROLS

- CHEMICAL CONTROL IS THE USE OF PESTICIDES AND HERBICIDES.
- IN IPM THEY ARE USED ONLY AS A LAST RESORT AND IN COMBINATION WITH OTHER APPROACHES FOR MORE EFFECTIVE, LONG-TERM CONTROL.
- THEY ARE SELECTED AND APPLIED IN A WAY THAT MINIMIZES THEIR POSSIBLE HARM TO PEOPLE, NON-TARGET ORGANISMS, AND THE ENVIRONMENT.
- WITH IPM YOU'LL USE THE MOST SELECTIVE CHEMICAL THAT WILL DO THE JOB AND BE THE SAFEST FOR OTHER ORGANISMS AND FOR AIR, SOIL, AND WATER QUALITY

- **PESTICIDES:**
- USED TO KILL, PREVENT, REPEL OR REDUCE PEST DAMAGE
- TYPES:
  - BACTERICIDES
  - INSECTICIDES
  - FUNGICIDES
  - HERBICIDES
  - MITICIDES
  - MOLLUSCICIDES
  - RODENTICIDES

MODE OF ACTION

- **SYSTEMIC POISONS**
  - FOLIAR SPRAY, SOIL DRENCH
  - TRANSLOCATED
  - INSECTS INGEST PLANT PARTS
  - KNOW TIMING OF TOXIN BREAKDOWN FOR FOOD CROPS
  - EX: ORTHENE, NEONICOTINOIDS*

  * CONTAMINATE FLOWERS AND HARM HONEYBEES AND OTHER POLLINATORS

- **CONTACT POISONS**
  - ABSORBED THROUGH EXOSKELETON
  - ATTACKS RESPIRATORY AND NERVOUS SYSTEM
  - EX: CHLORDANE

- **STOMACH POISONS**
  - CHEWING INSECTS
  - EX: ROTENONE (ORGANIC)

- **FUMIGANTS**
  - VOLATILE COMPOUNDS
  - GREENHOUSES
  - EX: METHYL BROMIDE

- **SUFFOCATION AGENTS**
  - OIL BASED COMPOUNDS
  - PLUGS SPHERICLES OF INSECTS
  - EX: DISHSOAP

- **REPELLANTS**
  - DO NOT KILL
  - EX: BORDEAUX (COPPER SULFATE)

- **FATAL ATTRACTION**
  - PHEROMONES
  - USED AS TRAPS TO ATTRACT MALE INSECTS

ACTIVE INGREDIENT CLASSIFICATION

- INORGANIC / SYNTHETIC
  - MADE FROM MINERALS
    - EX: ARSENIC, SULPHUR, COPPER
- SYNTHETIC / ORGANIC
  - ORGANIC CHEMICAL COMPOUNDS
  - ARTIFICIALLY PRODUCED
  - TOXIC TO HUMANS
  - CLASSIFICATIONS
    - CHLORINATED HYDROCARBONS
    - ORGANOPHOSPHATES: MALATHION*, DIAZINON*, ACEPHATE*
    - CARBAMATES: CARBARYL*, SEVIN*
    - PYRETHROIDS: BIFENTHRIN*, CYFLUTHRIN*, PERMETHRIN*

- NATURALLY OCCURRING
  - MADE FROM PLANTS
  - ACT AS STOMACH AND CONTACT POISONS
  - TYPICALLY NON-TOXIC TO HUMANS
  - EX:
    - PYRETHRUM (CHRYSANTHEMUM)
    - NICOTINE (TOBACCO)
    - NEEM (*AZADIRACHTA INDICA* TREE)

* LEAVE RESIDUES THAT ARE TOXIC TO HONEYBEES, BENEFICIAL PARASITES, AND PREDATORS FOR WEEKS AFTER APPLICATION

HERBICIDE CLASSIFICATIONS

- **SELECTIVE**
  - SPECIFIC: MONOCOTS OR DICOTS
- **NON-SELECTIVE**
  - DESTROY ALL VEGETATION
  - CONTACT TYPES
    - KILL ONLY PORTION OF PLANT TREATED
  - SYSTEMIC TYPES
    - EX: GLYPHOSATE (ROUND-UP)
- **TIMING OF APPLICATION**
  - STAGES OF LIFE CYCLE
    - PRE-EMERGENTS
    - POST-EMERGENTS
- **METHOD OF APPLICATION**
  - BROADCAST
  - BAND
  - SPOT
  - FOLIAR
- **CHEMISTRY**
  - ORGANIC
  - SYNTHETIC / INORGANIC
- **FORMULATIONS**
  - LIQUID
    - CONCENTRATES
    - READY TO USE (RTU)
  - DRY
    - GRANULES
    - PELLETS
    - POWDERS

HERBICIDE EFFECTIVENESS

- **PROPERLY IDENTIFY**
  - KNOW WHAT IT IS
- **ENVIRONMENTAL CONDITIONS**
  - TEMPS, WIND, RAINFALL ETC.
- **MATURITY OF CROP / WEEDS**
  - MORE EFFECTIVE ON YOUNGER PLANTS
- **SOIL CHARACTERISTICS**
  - SOILS WITH HIGH ORGANIC MATTER REQUIRE HIGH CONCENTRATIONS
- **CHEMICAL CONCENTRATION**
  - OVER DILUTED
  - UNDER DILUTED
  - SURFACTANTS
- **TIMING OF APPLICATION**
  - MUST BE ACTIVELY GROWING
- **TOTAL COVERAGE**
  - MOST EFFECTIVE
- **PROBLEMS**
  - RUN-OFF
  - DRIFT
  - EXPOSURE

PESTICIDE RESISTANCE

- OCCURS WHEN PEST POPULATION BECOMES RESISTANT TO PESTICIDES
- INSECTS, MITES, PATHOGENS, AND SOME WEEDS
- DEVELOPS THROUGH GENETIC SELECTION
- SOME ARE IMMUNE AND PASS THIS TRAIT TO THE NEXT GENERATION WHICH THEN PASSES IT ON TO THE NEXT AND SO ON
- EVENTUALLY THE PEST BECOMES PESTICIDE RESISTANT

STEPS TO AVOID **PR**

- USE BIOLOGICAL, CULTURAL, MECHANICAL, AND PHYSICAL ALTERNATIVES
- MINIMIZE AMOUNT AND FREQUENCY OF APPLICATIONS
- ROTATE / ALTERNATE WITH DIFFERENT MODES OF ACTION

PESTICIDE FORMULATIONS

- LIQUID
  - CONCENTRATES
  - READY TO USE (RTU)
  - FUMIGANTS
  - AEROSOLS
- DRY
  - DUSTS
  - WETTABLE POWDERS
  - PELLETS
  - GRANULES

GUIDELINES TO SAFE USE

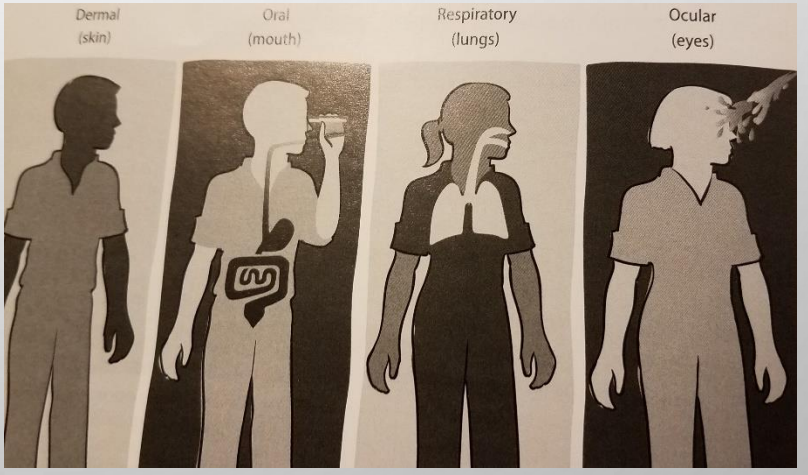
- USE ONLY APPROVED TYPES
- READ THE LABEL
- USE THE LOWEST TOXICITY
- TREAT TARGET PEST
- USE CORRECT EQUIPMENT
- USE ONLY WHEN NEEDED
- KNOW THE EMERGENCY MEASURES
- WEAR PROTECTIVE CLOTHING
  - PPE (PERSONAL PROTECTIVE EQUIPMENT)
  - MINIMUM FOR ANY USE
    - EYE PROTECTION
    - CHEMICAL RESISTANT GLOVES
    - LONG SLEEVES / PANTS
    - CLOSED TOE SHOES
- APPLY WHEN APPROPRIATE ENVIRONMENTAL CONDITIONS ARE PRESENT
- PROPERLY STORE
- PROPERLY DISPOSE OF EMPTY CONTAINERS
  - RINSE CONTAINERS 3 TIMES BEFORE DISPOSING
  - PUNCH HOLES IN EMPTY CONTAINER
  - DO NOT CLEAN IN LOCATION WHERE CONTAMINATED WATER COULD FLOW INTO WATERSHED
- HAVE SEPARATE APPLICATION EQUIPMENT FOR PESTICIDES AND HERBICIDES

KEEP PESTICIDES OUT OF WATERSHED

- DRIFT
- WEATHER CONDITIONS
- DON'T APPLY ON
  - DRIVEWAYS
  - WALKWAYS
  - GUTTERS
  - STORM DRAINS
  - SEWERS
- DON'T OVER IRRIGATE
- BE AWARE OF LOCAL BODIES OF WATER IN THE WATERSHED
  - STREAMS
  - CREEKS
  - LAKES
  - BAY
  - RIVER

TOXICITY

- ALL PESTICIDES ARE TOXIC IN SOME WAY
- CONTAMINATE WATER
  - RUN-OFF INTO WATERWAYS
  - KILLS AQUATIC LIFE
  - AFFECTS QUALITY OF DRINKING WATER
  - DO NOT SPRAY ON HARD SURFACES
  - DO NOT POUR DOWN DRAINS
  - DISPOSE OF AT HAZARDOUS WASTE COLLECTION SITES
- EXPOSURE ROUTES
  - DERMAL (SKIN)
  - ORAL (MOUTH)
  - RESPIRATORY (LUNGS)
  - OCULAR (EYES)
- TOXIC TO NATURAL ENEMIES
  - MORE SUSCEPTIBLE DUE TO THEIR HUNTING BEHAVIOR
  - DISRUPT BIOLOGICAL CONTROLS
  - RESIDUES HAVE LONG AFTERLIFE
- TOXIC TO PLANTS
  - PHYTOTOXICITY
  - EXCESSIVE APPLICATIONS
  - DRIFT
  - WEATHER



SIGNAL WORDS ON CHEMICALS

- **CAUTION –** PESTICIDE IS SLIGHTLY TOXIC
- **WARNING –** PESTICIDE IS MODERATELY TOXIC
- **DANGER -** PESTICIDE IS HIGHLY TOXIC BY AT LEAST ONE ROUTE OF EXPOSURE. IT MAY BE CORROSIVE, CAUSING IRREVERSIBLE DAMAGE TO THE SKIN OR EYES. ALTERNATIVELY, IT MAY BE HIGHLY TOXIC IF EATEN, ABSORBED THROUGH THE SKIN, OR INHALED. IF THIS IS THE CASE, THEN THE WORD "**POISON**" MUST ALSO BE INCLUDED IN RED LETTERS ON THE FRONT PANEL OF THE PRODUCT LABEL.

LD50

TABLE 1.2
Toxicity Categories Used for Human Poisons

Toxicity Category	LD50 (mg/kg)	Probable Lethal Dose for 70 kg Human Adult
Super toxic	<5	<0.35 g
Extremely toxic	5–50	0.35–3.5 g
Very toxic	50–500	3.5–35 g
Moderately toxic	500–5,000	35–350 g
Slightly toxic	5,000–15,000	350–1,050 g
Practically nontoxic	>15,000	>1,050 g

MEDIAN LETHAL DOSE

THE AMOUNT OF A SUBSTANCE REQUIRED (USUALLY PER BODY WEIGHT) TO KILL 50% OF THE TEST POPULATION.

Pests Overview

Unit 1

??? What is a Pest ???

Anything which is detrimental to plants, crops, animals or humans

- Weeds
- Nematodes
- Plant Diseases
- Vertebrate Animals
- Insects

WEEDS

Why do we hate them?

- Any unwanted plant growing out of place

- Compete with desired crop
  - Water
  - Nutrients
  - Light
  - Space

- Harbor diseases and pests

WEEDS cont'd

- **Grow with little support**
  - Warriors of neglect
- **Cultural practices can promote reproduction**
  - Cultivation can spread seeds, increase by division/separation of roots
  - Important to know life cycle:
    - Annual and Biennial = typically spread by seeds
    - Perennial = typically spread by roots
- **Noxious and beneficial types**
  - **Noxious** = Invasive types that can overwhelm native habitats
    - Bindweed, Bermuda grass, Wild Blackberry
    - The term 'Naturalized' usually indicates noxious
  - **Beneficial**
    - Helpful by holding top-soil, pulling up minerals and nutrients, providing food for microbes.
    - Deep rooted types can help breakup hard soils or access minerals in the soil:
      - Mustard, Thistle, Plantain
- **Indicators of soil types**
  - Dandelion, Stinging Nettle, Shepard's Purse thrive in sandy soils
  - Thistle, Plantain, Creeping Buttercup thrive in wet, clay soils
  - Foxglove and Daisies thrive in acidic soils
  - Mustard and Wild Carrot thrive in alkaline soils

NEMATODES

- Worm-like invertebrates
- Non-segmented
- Found in the soil
- Attack below & above ground plant parts
- Feed by penetrating root cells causing rot
- Wounds allow fungi and bacteria to enter and cause damage
- Slow moving, 12 to 30 inches per year
- Some are beneficial
  - Kill soil borne pests

Root Knot

Cyst

DISEASES

Interfere with the plants' appearance, growth, structure or function

- **Abiotic causes**
  - Nutrient deficiencies
  - Plant injury
  - Chemicals
  - Pollution
- **Biotic causes**
  - Parasites
  - Pathogens
- **Modern cultural practices**
  - Horticultural crops more susceptible
  - Mono-culture / cropping
- **Classes of diseases**
  - Fungi
  - Bacteria
  - Viruses

Fungi

- **Beneficial types**
  - Mycorrhizae
  - Penicillin
  - Mushrooms
  - Fermentation
- **Detrimental types**
  - Damping-Off
  - Downy Mildew
  - Fusarium Wilt
  - Powdery Mildew
  - Rust

Bacteria

- **Beneficial types**
  - Rhizobia
    - Symbiosis with legumes

- **Detrimental types**
  - Bacterial Canker
  - Bacterial Soft Rot
  - Bacterial Wilt
  - Common Blight
  - Crown Gall
  - Fireblight

Vertebrates

Rodents and other animals

- **Eat or damage**
  - Fruits
  - Leaves
  - Stems
  - Roots

Moles

Gophers

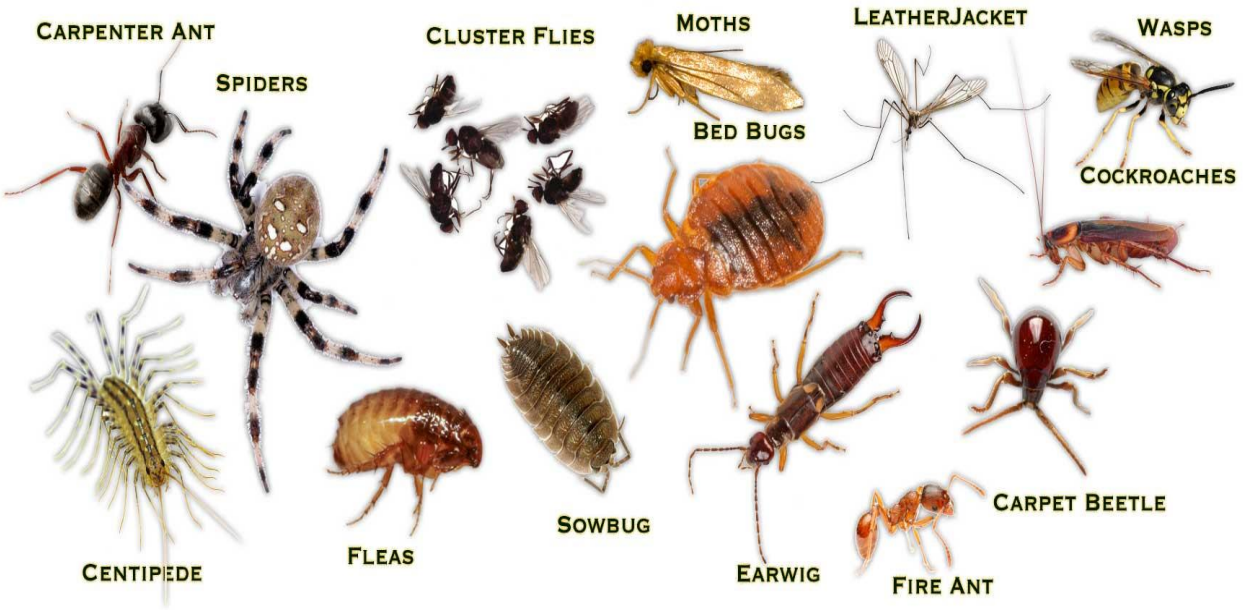
Deer

Pets

Rabbits

Insects

- Cause physical damage to plants and animals
- Spread disease in plants and animals
- Make up of 80% of all animal life on the planet
- Beneficial types
  - Pollinators
  - Biological Control



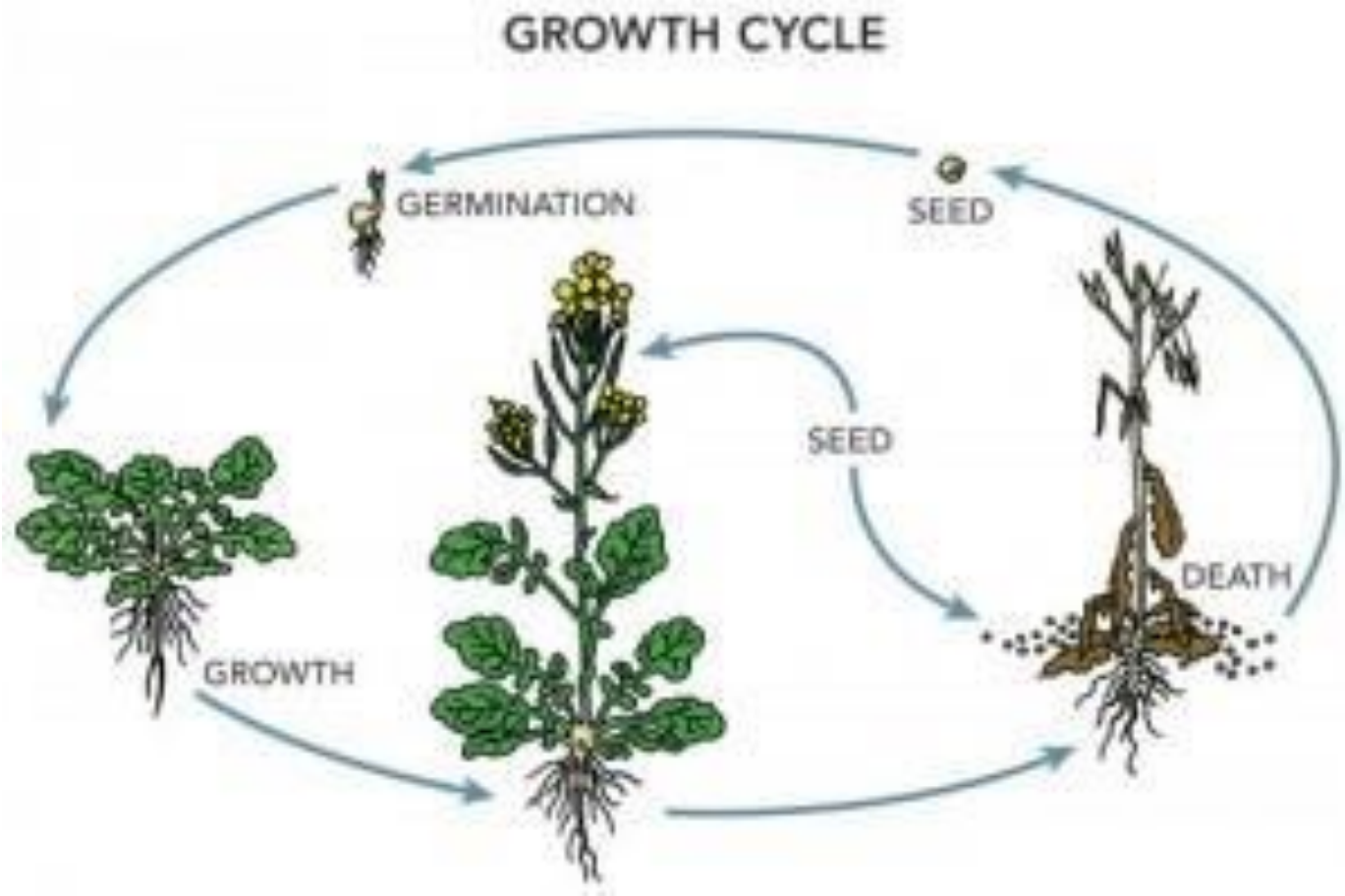
ACTIVITY

- Check out this website: http://www.differencebetween.net/science/difference-between-pest-and-insect/

- Answer the following questions:
    1. What is an insect?
    2. What is an insect pest?
    3. Are all insects pests?
    4. Are all pests insects?
    5. Name 3 examples of beneficial insects:
    6. Name 3 examples of detrimental insects:
    7. Are all insects controlled with pesticides?
    8. Name 2 examples of insect controls:

Weed Management

Chapter 7



Weeds and Control

- Weeds can be defined as any plant growing where it is not desired
- Compete with crops (aka….Weed Pressure)
  - Water
  - Nutrients
  - Light
  - Space
- Harbor diseases
- Attract pests
- Some are invasive
- Some are beneficial

Before Planting Steps

1. Assess the site
2. Prepare the site
3. Design / Redesign the site
4. Avoid introducing weeds
5. Exclude invasive plants
6. Encourage rapid establishment of desired plants

Assessing the Site

- Identify, monitor, and remedy adverse site conditions
  - Weeds
    - Abundance
    - Types
      - Annual
      - Perennial
      - Biennial
      - Invasive
  - Evaluate soil conditions
    - Compaction & Water infiltration
  - Sun / shade exposures
  - Elevation changes
  - Drainage

Keep Good Records

- Good records include:
  - Weeds
    - Species
    - Age (pg 254, fg 7-1)
    - Location
    - Density
  - Time of year they emerge
  - What action taken with date
  - Location & size of area treated
  - Compare & evaluate monitoring results
    - Are problems increasing, decreasing or remaining the same
    - Effectiveness of management
    - Is control action needed or just modified
    - Landscape Maps/ Plot Plans are helpful (pg 255, fg 7-2)

Preparing the Site

- Eliminate established / future weeds before
  - Grading
  - Irrigation
  - Planting
- Cultivation
  - Cut, uproot or bury
  - Water, wait, cultivate (repeat)
  - Do not till more than 2” deep
  - Effective on annuals and some perennials
- Sheet mulching
  - Mow low, cover with cardboard, then cover with arbor chips
- Soil solarization
  - Cover prepared (bare) soil with clear plastic for 4-6 weeks
  - Avoid cultivation after treatment

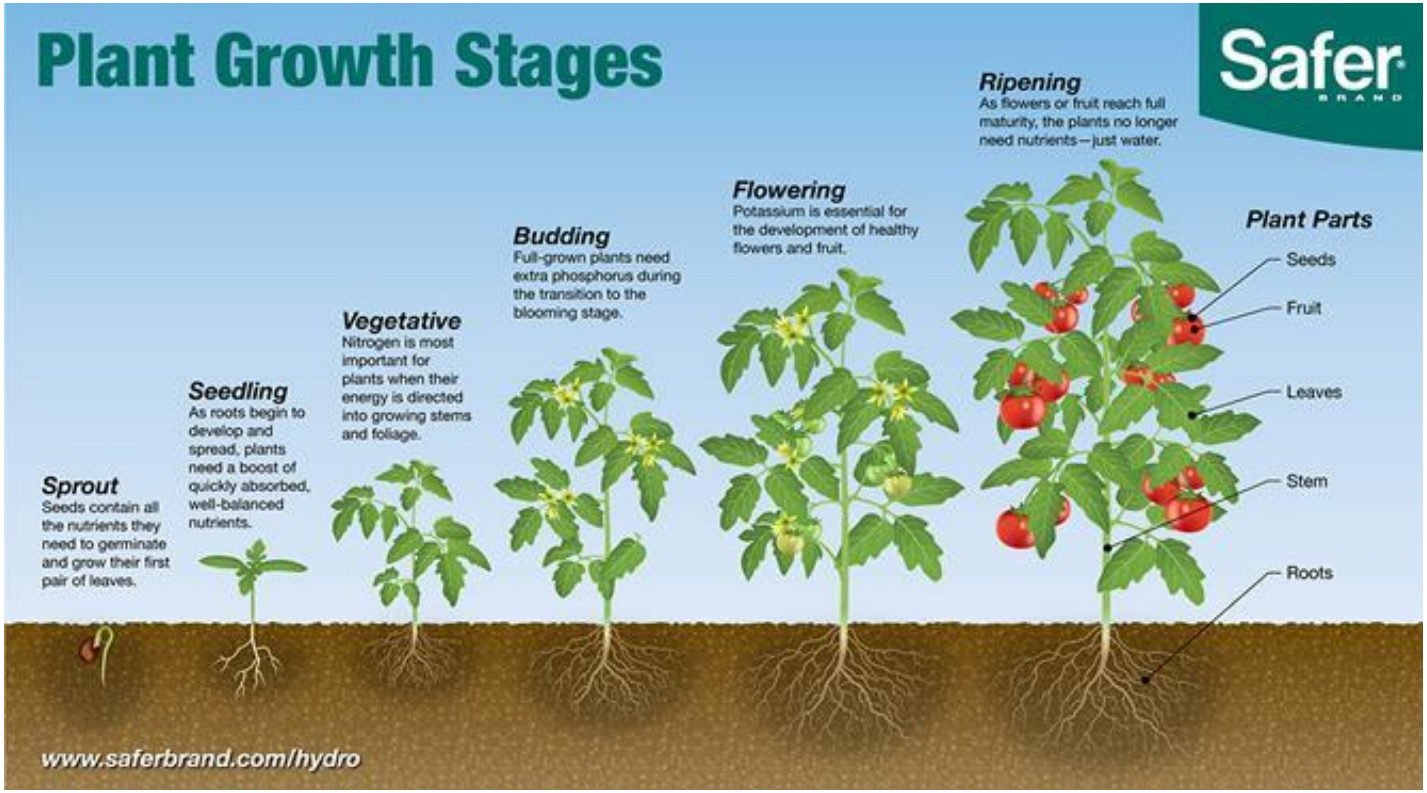
Design / Redesign Plantings

- Grow species adapted to local climate
  - Light, moisture, soil and temperatures
- Choose species/cultivars resistant to pests
- Group (cluster) plants with compatible cultural requirements
- Avoid planting invasive types or incompatible growth habits
- Plant in larger clusters/groups
- Plant low growing types under taller grower types
- Plant densely to shade/cover the soil
  - Allow enough space for plants to mature
- Leave space for maintenance access
- Edging / Headers to reduce weed encroachment
- Choose drip irrigation
  - Waters at root zone minimizing weeds
- Mulch

- **Prevent Weed Introductions**
  - — Inspect new plants for weeds
  - — Are mulches, manures, soil amendments pasteurized ?
  - — Steam, heat treated or composted properly
- **Establish Desired Plants**
  - – Provide optimal cultural care and growing conditions
  - – Prevent weeds while establishing
- **Exclude invasive plants**
  - – Don’t plant a pest
    - Broom, pampas grass, vinca, ivy
  - – Use recommended alternatives
    - Cal-ipc.org
    - Plantright.org
  - – Buy from reputable sources
  - – Do not bring fruit, plants, seeds, or soil into California unless certified to be pest free

Stages of Growth

- Sprouting
- Seedling
- Vegetative
- Budding
- Flowering
- Ripening



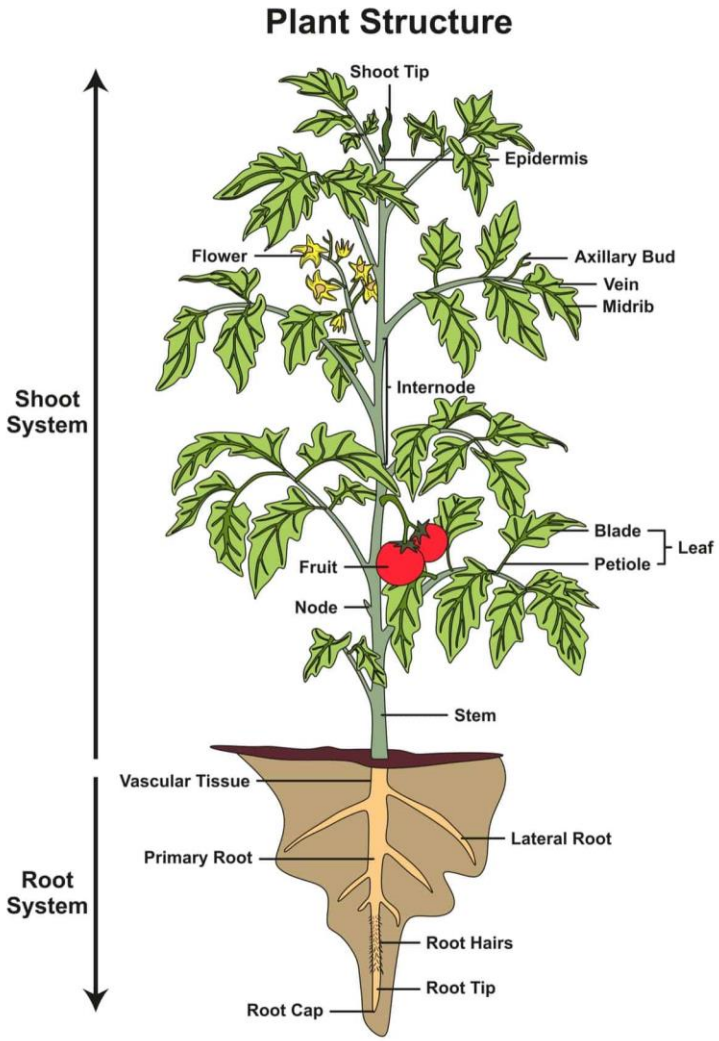
Life Cycles

- **Annuals**
  - Complete entire life cycle in one year or one season
  - Warm season or Cool season
  - Coastal climates anytime
- **Biennials**
  - Complete life cycle in two years or two seasons
  - Vegetative growth first season, reproductive growth second season
- **Perennials**
  - Can live for more than 2 years
  - Include trees and woody shrubs
  - Reproduce mostly from vegetative parts
    - Stems, stolons, rhizomes, roots

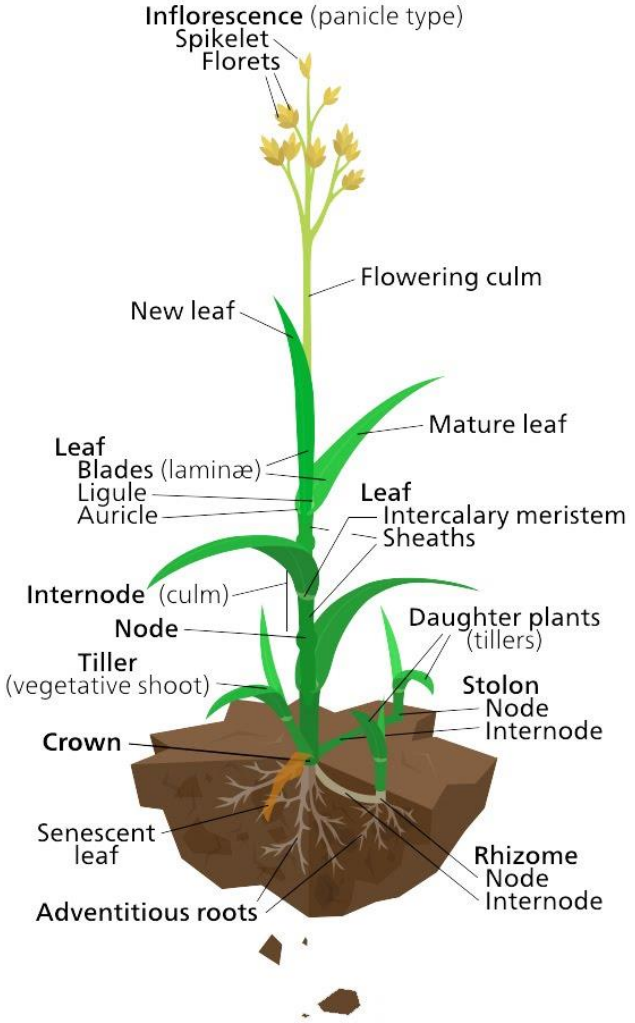
- **Stages of growth**
  - sprout, seedling, vegetative, budding, flowering, ripening

Identification

- Broadleaf types



- Grassy types

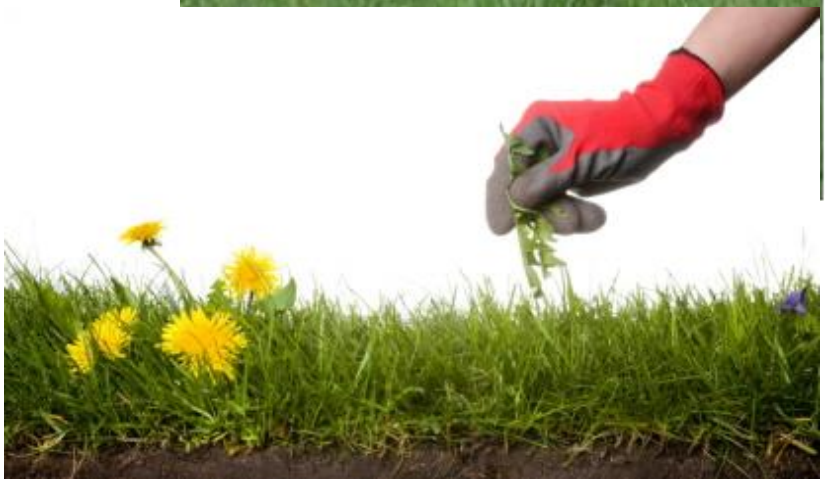


Weed Removal Techniques

- Hand-pulling
- Hoeing
- Cultivation
- Mowers
- String trimmers (weed whackers)
- Flamers
- Steam / hot water
- Mulch

HAND-PULLING

- The most time consuming method but the safest way to remove weeds growing close to your plants.
- Using hand tools such as an asparagus fork, trowel or cultivator can help by loosening the soil around the weeds making it easier to pull them.
- You want to be sure to remove the roots.
- Tip: irrigate soil 1 -2 days before pulling



HOEING

- Works best on large patches of densely growing weeds.
- You remove lots of weeds with each hoe stroke but you are not necessarily getting the all roots so the weeds may grow back.
- Also if you are not careful you can easily damage the desired plants.
- There are several types of hoes available, long and short handles, wide, oscillating, and angular bladed types.
- Tip: do not loosen or dig no deeper than ½ inch to reduce injury to roots of desired plants. It also limits exposing seeds to the surface for germination

CULTIVATION:

Method of plowing weeds under and into the soil rather than removing them. Weeds will decay and add organic matter back into the soil but many of these weeds will regrow. Perennial types from roots and stems and exposes seeds for germination. This method can be accomplished with tools or mechanical roto-tillers.

Mowers & String Trimmers

- Effective for annual broadleaf types (before forming seeds)
- Not effective for most perennial types
- Most annual grass types regrow from rhizomes just below the surface
- Prevent wounding trunks and root crowns by using tree guards

Flame Torching

- Used on herbaceous types
- Broadleaf annuals and seedlings
- Only torch the basal stem area of the plant
- It kills the cells and the plant dies
- Best done early morning or late evening
- Fire is a serious hazard
- Keep fire prevention equipment ready

Steam / Heat

- Effective on annual types and seedlings
- Not effective on grasses and established perennial types
- Does not kill seeds
- Used mostly on big farms
- Takes longer exposure than flaming to be effective

Mulches

- Thick layers of bark or stone which limit weed growth by depriving the weed seeds from sunlight to germinate
- Bonus: Conserves moisture
- Organic types
  - Bark, greenwaste, compost, leaves, lawn clippings
  - Advantages they build soil as they breakdown and improve water penetration
- Synthetic types
  - Stone, plastic, geotextiles
  - Can heat up root zones of plants
  - Require under layer to keep in place

Mulch cont'd

- Particle sizes
  - Larger mulch particles require greater depth effectively block sunlight
  - Large: 1½ " at 4 inch depth
  - Medium: ½ - 1" at 3-4 inch depth
  - Small: ¼ - ½ " at 2-3 inch depth
- Keep mulch 6 inches away from trunks of plants
- Pest & Weed free
- Mushrooms can grow from decaying mulch
  - Can be beneficial
  - Dog vomit fungus
- Problems
  - Can harbor root diseases
  - Avoid mulches with bad odor
    - Smells like vinegar or rotten eggs
    - Can injure plants
  - Avoid black plastic
    - It breaks down quickly

Biological Controls

- Goats, Chickens or Sheep

Herbicides: Post Emergents

- Plant killing chemicals when used properly are effective and time saving
- They are applied by spraying on the foliage of the weeds
- Risks:
  - Drift can kill plants you wish to keep
  - Can leach or run-off polluting water
  - Toxic to living organisms

Herbicides: Pre-Emergents

- Kills weeds before they germinate from seeds therefore never emerging from the ground.
- Applying pre-emergent does not kill weeds or plants* that are already growing.
- Also prevents all other types of seeds from germinating.
- Once applied creates a barrier within the soil. This can be broken when walked on.

* There are some exceptions. Check label before applying

Herbicides cont'd

- **Mode of Action**
  - How it kills
  - Systemic or foliar
- **Selectivity**
  - Monocots or Dicots
- **Resistance**
  - Repeated applications can build up tolerances
  - Failure may be due to incorrect application
- **Formulations**
  - Liquid
  - Dry
    - Granules
    - Powders
- **Organic types**
  - Vinegar
  - Botanical oils
  - Salt
  - Corn gluten meal
- **Safety**
  - Read and follow all instructions
  - Environmental hazards
  - Proper PPE
  - Storage and disposal
- **Application tips:**
  - Mow/cutback taller weeds before applying herbicide
  - Apply mulch after treatment to suppress seeds from germinating

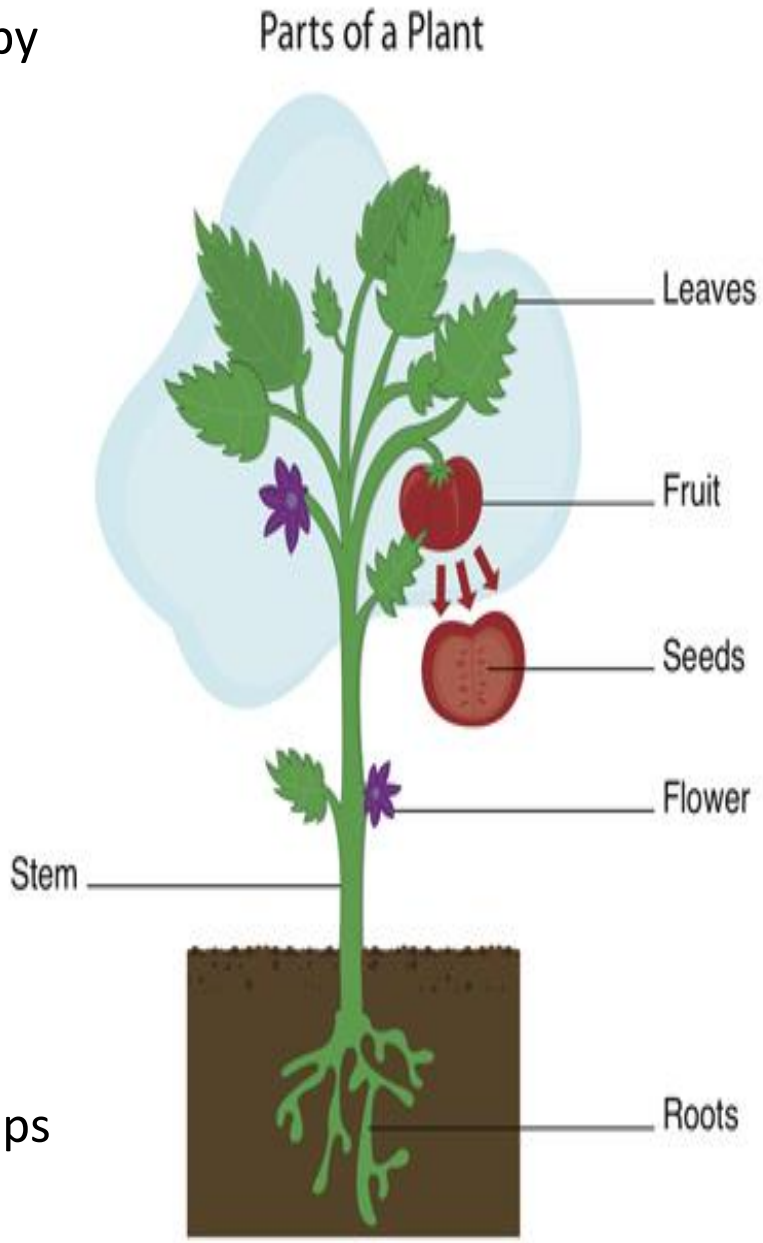
Videos to Watch

- Introduction to Weed Management in a Small Scale Organic Production System HD – YouTube (17min)

- Principles of Weed Control - Part 1 of 5 – YouTube (5min)
- Principles of Weed Control - Part 2 of 5 – YouTube (9min)
- Principles of Weed Control - Part 3 of 5 – YouTube (3min)
- Principles of Weed Control - Part 4 of 5 – YouTube (8min)
- Principles of Weed Control - Part 5 of 5 – YouTube (4min)

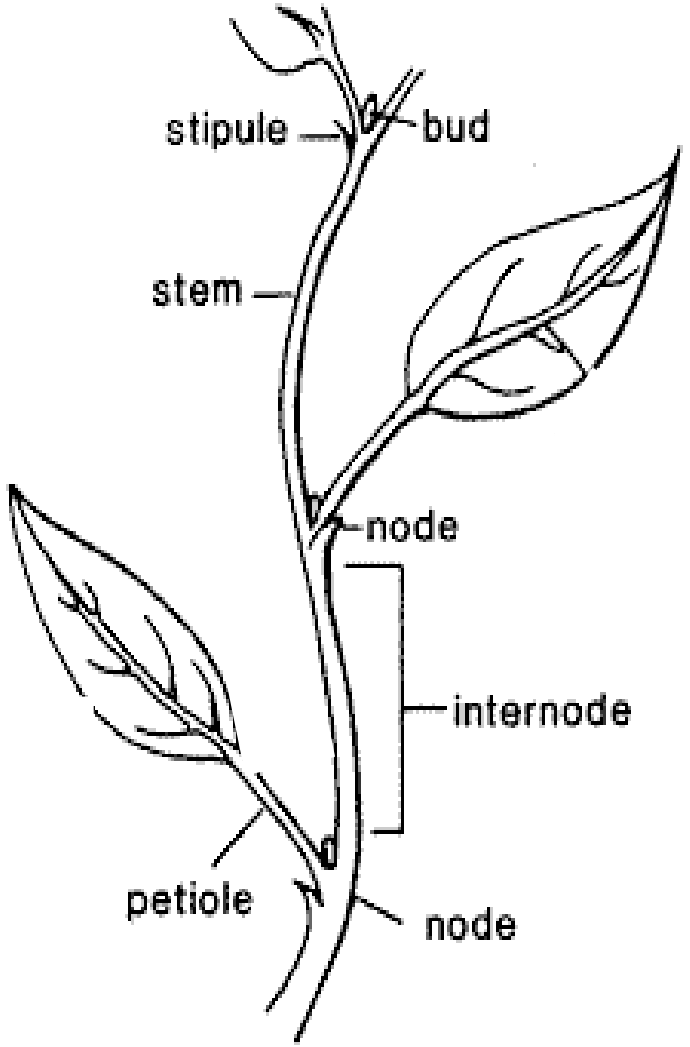
BROADLEAF WEEDS (dicotyledons) MORPHOLOGY

- **Leaves:** function primarily in food manufacture & oxygen by photosynthesis
- **Fruit:** seed carrying structure
- **Seed:** produces new plants through sexual reproduction
- **Flowers:** Attracts insects, animals and birds for pollination
- **Stem:** the main body of the plant; act as a support for branches and contains passages for food and water movement
- **Roots:** Anchors the plant; helps in water and nutrient absorption; and food storage



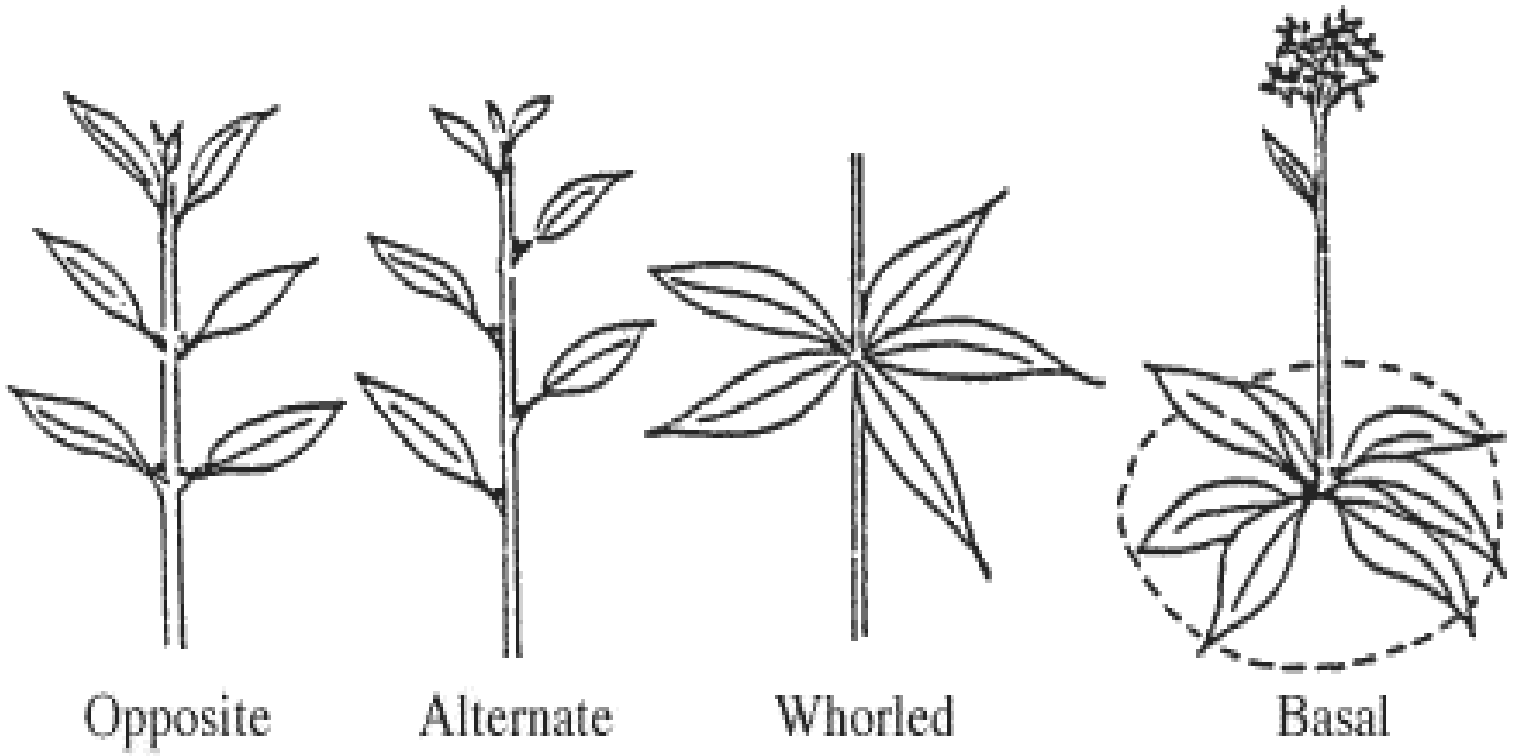
Parts of a Stem:

- **BUD:** undeveloped flower, leaf or stem.
- **INTERNODE:** section of stem between two nodes.
- **NODE:** point on a stem where one or more leaves, branches or flowers are attached.
- **PETIOLE:** leaf stalk or leaf stem.
- **STIPULE**: small leaf like appendages at the base of the petiole. They are protective coverings for the unborn leaf and shed soon after it opens.



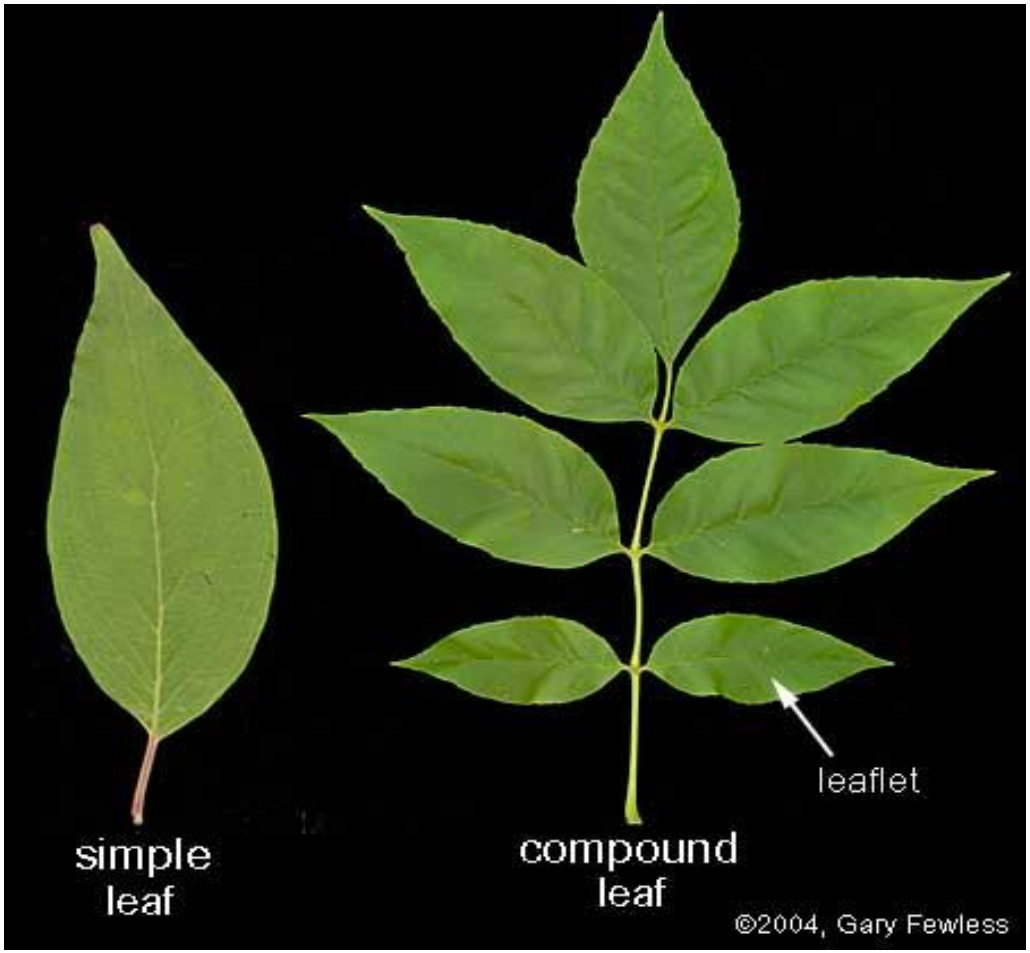
Leaf Arrangement: position of leaves on the stem

- **OPPOSITE**
  two leaves per node
- **ALTERNATE**
  one leaf per node
- **WHORLED**
  three or more leaves per node
- **BASAL / ROSETTE**
  leaves form at base of stem



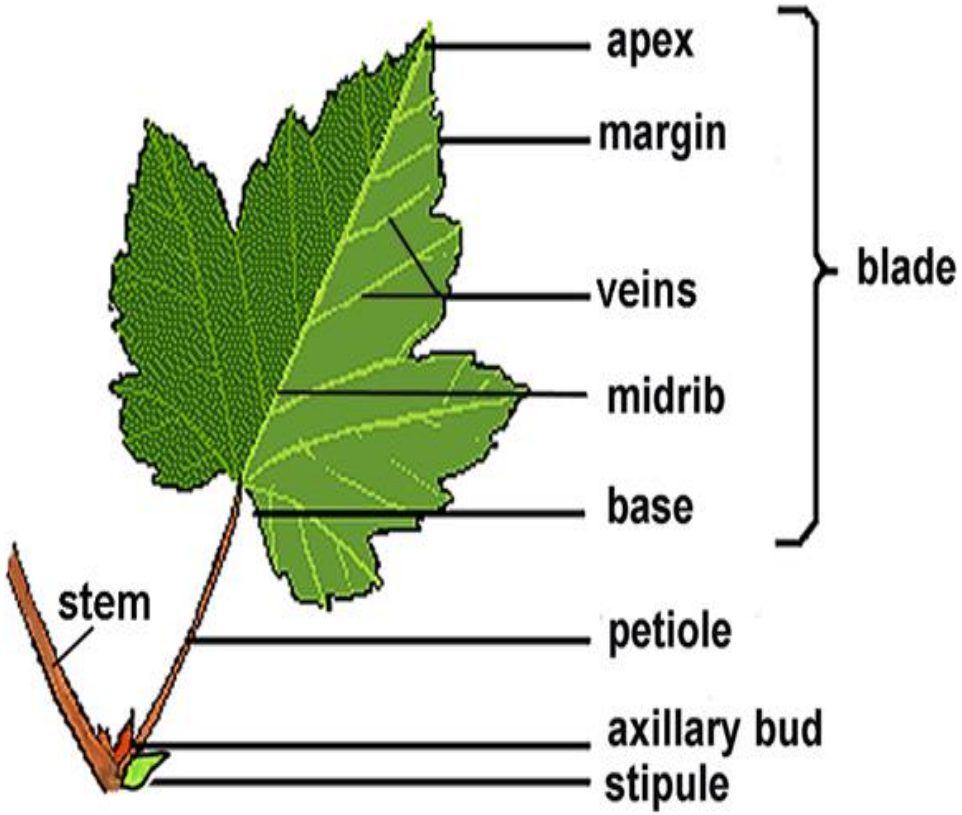
Video:
https://www.youtube.com/watch?v=Kka3YEH4E64

Leaf Complexity:
Simple or Compound



Videos:
https://www.youtube.com/watch?v=cAG8KQQluZE
https://www.youtube.com/watch?v=GHzlUjeZIQI

Simple Leaf



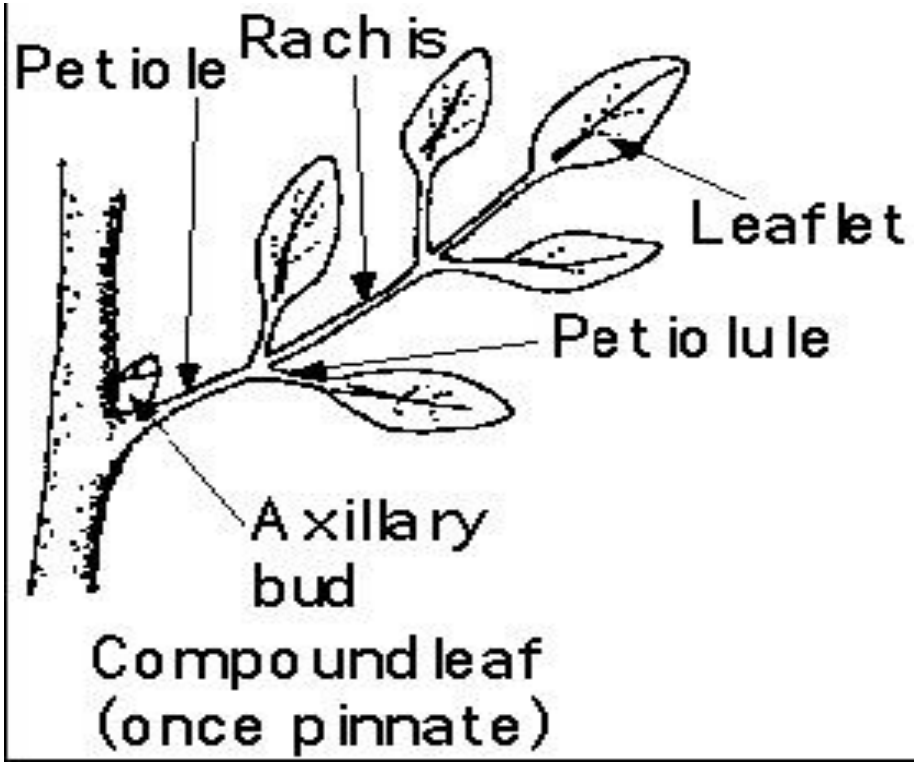
- **APEX**: the tip of a leaf.
- **AXILLARY BUD**: a bud borne on the side of a stem, from a leaf axil. Leaves, flowers, or new stems form from these.
- **BASE:** is the lowest part of a blade that is attached to the petiole.
- **BLADE:** the broad flattened part of a leaf.
- **MID-RIB:** the center or primary (main) vein of a leaf or leaflet, usually runs down the center of the leaf, extending the leaf stalk, or petiole.
- **MARGIN**: edge or border of a leaf.
- **PETIOLE**: the leaf stalk / stem.
- **STEM**: the point where the leaf petiole attaches; supports the leaf, flowers and fruit.
- **STIPULE**: small leaf like appendages at the base of the petiole. They are protective coverings for the unborn leaf and shed soon after it opens.
- **VEINS:** secondary or lateral veins branching from the main vein (midrib) of a leaf.

Compound Leaf:

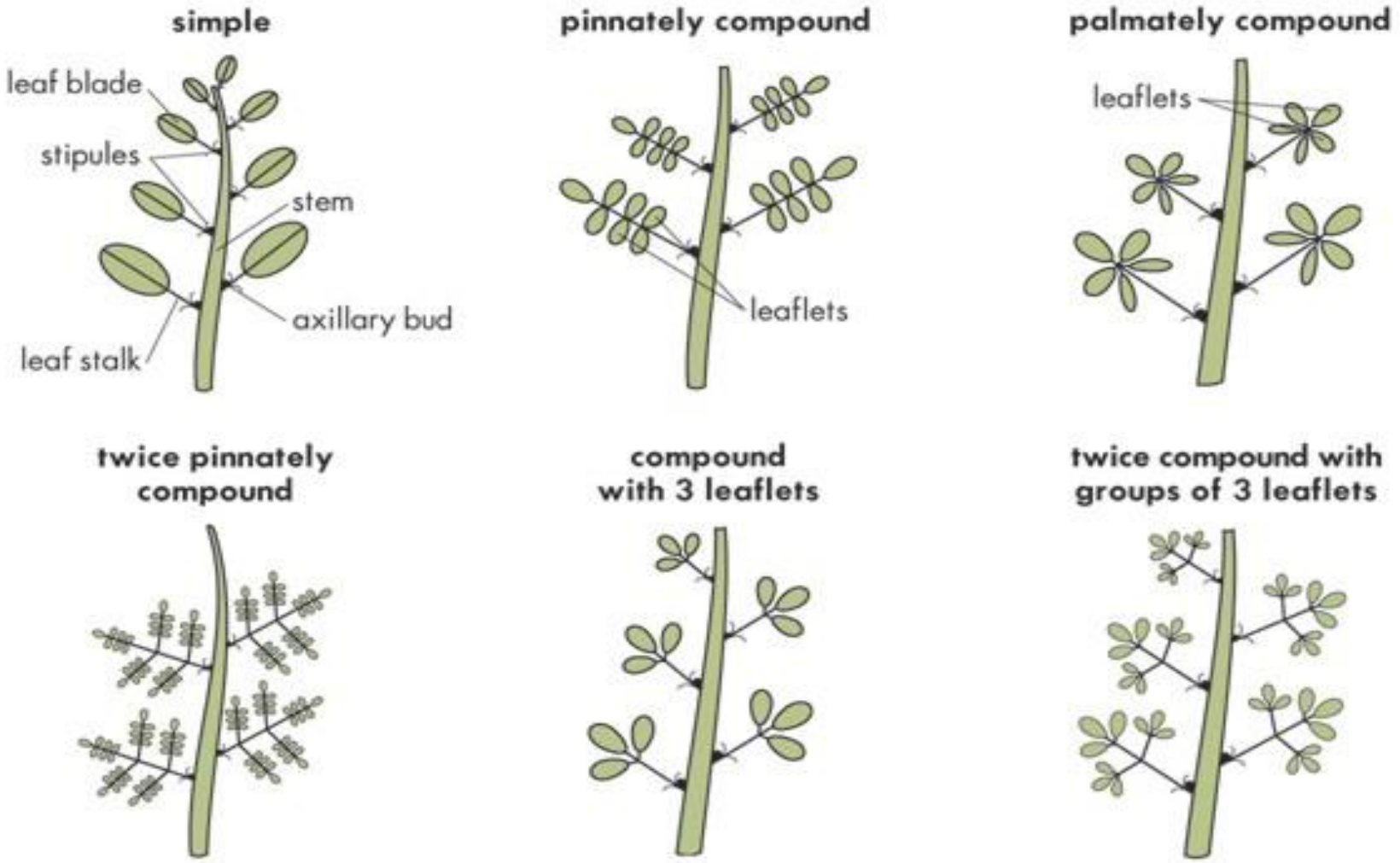
leaf is divided into two or more separate leaflets

Compound leaves have all the same parts as a simple leaf but have these additional parts:

- **RACHIS:** the main stem of a compound leaf, it is an extension of the petiole or leaf stalk.
- **PETIOLULE:** the stalk of an individual leaflet
- **LEAFLET:** a leaf on a compound leaf



Types of Compound Leaves



Stems: Round, Square or Triangular

LEAF SHAPES

Elliptic (football)

Dissected (deeply cut)

Cordate (heart)

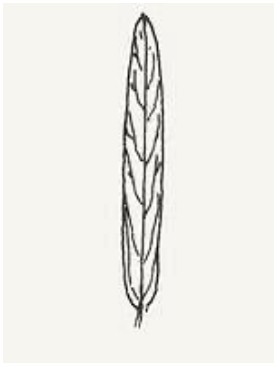
Orbicular (round)

Hastate (arrow)

Reniform (kidney)

Cuneiform (wedge)

Lanceolate (sword)



Linear (narrow)

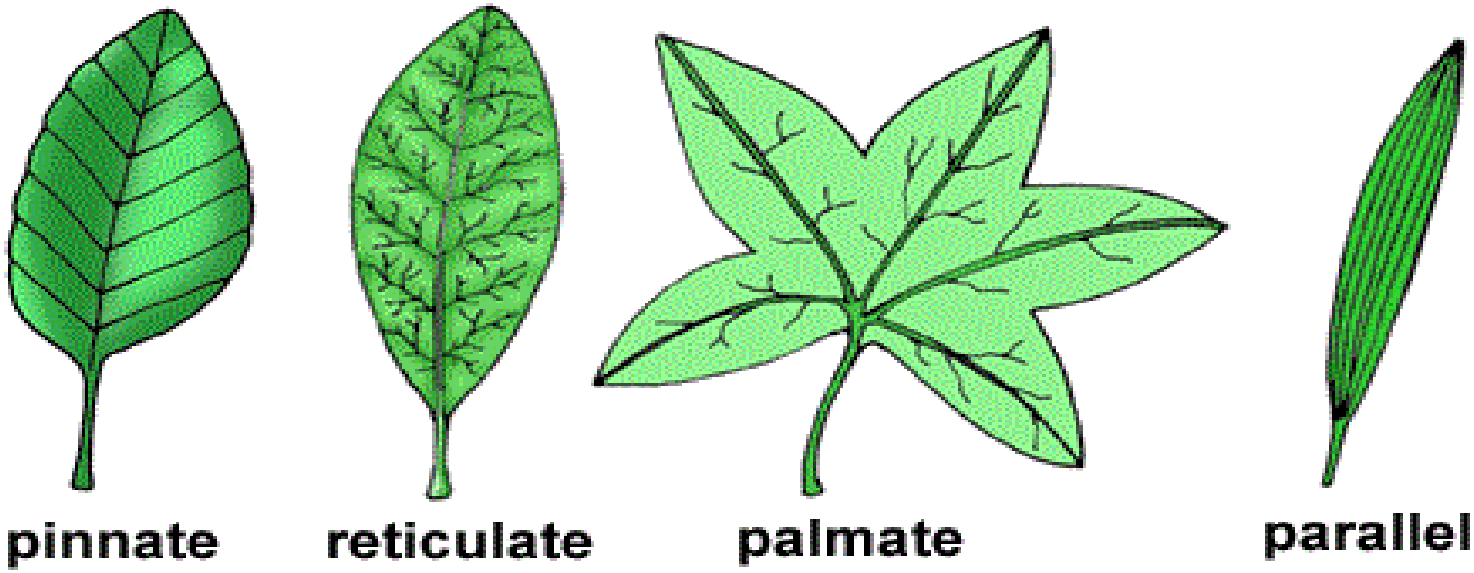
Oblong

Obovate (upside down egg)

Ovate (egg)

Leaf Venation

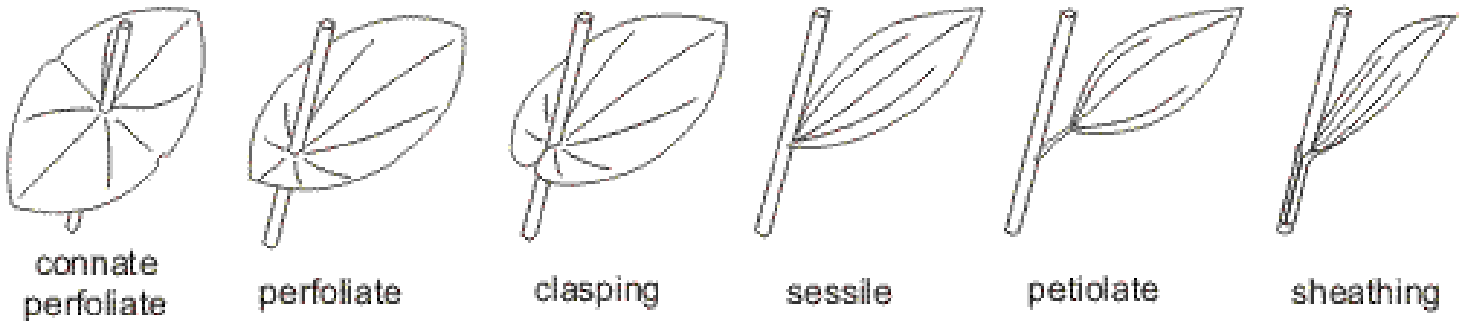
the pattern in which leaf veins are organized



- **Pinnate:** veins branching off from the mid-rib vein
- **Reticulated or Netted**: veins forming a netted pattern
- **Palmate:** veins originating from a single central point
- **Parallel:** veins running parallel to each other

Video:
https://www.youtube.com/watch?v=XhQ2Z4u5upw

Leaf Petioles



- **clasping** a sessile leaf with free bases partly or entirely surrounding the stem.

- **connate-perfoliate** - with bases of opposite leaves fused around the stem, which appear to go through the leaf.

- **perfoliate** - with the bases of a single leaf fused around the stem, which appear to go through the leaf blade.

- **petiolate** - a leaf attached to the stem by a petiole.

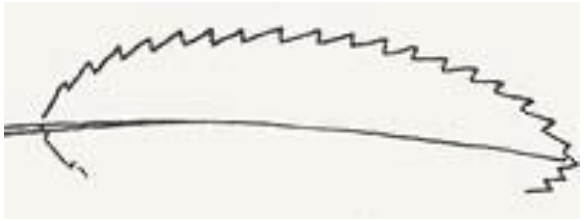
- **sessile** - a leaf whose blade is attached directly to the stem, lacking a petiole.

- **sheathing** - with a tubular portion of the leaf blade surrounding the stem below the base.

Leaf Margins (edges)

Smooth

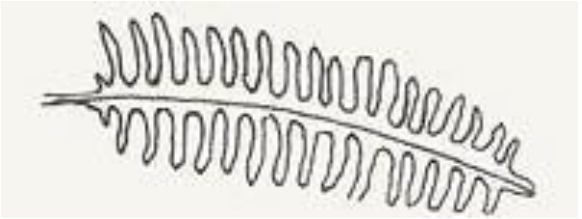
Toothed



Rounded / Scalloped

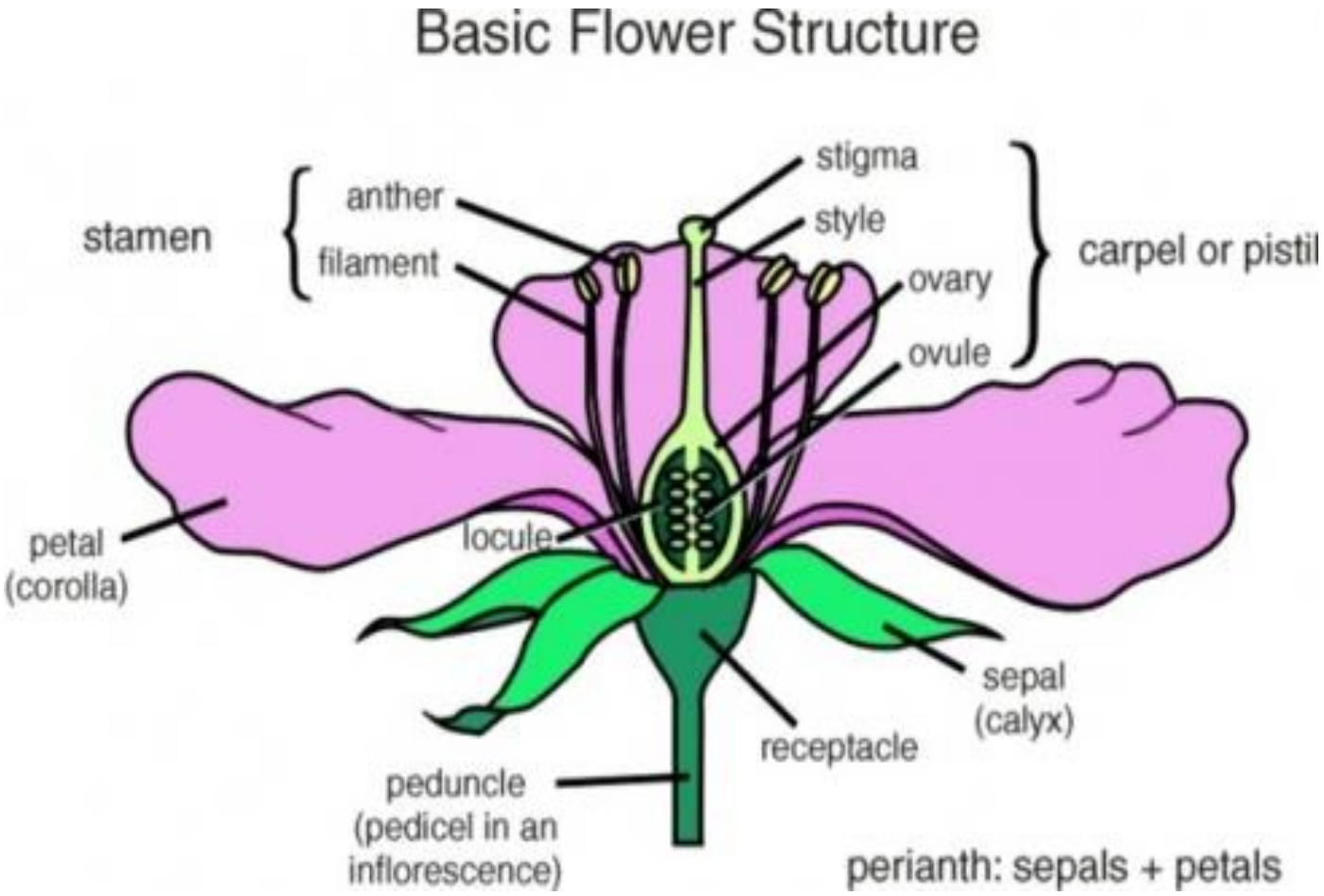
Lobed

Parted



Video:
https://www.youtube.com/watch?v=jkMjYJCdmF0&t=7s

Flowers


Basic Flower Structure
stamen
anther
filament
stigma
style
ovary
ovule
carpel or pistil
petal
(corolla)
locule
sepal
(calyx)
receptacle
peduncle
(pedicel in an
inflorescence)
perianth: sepals + petals

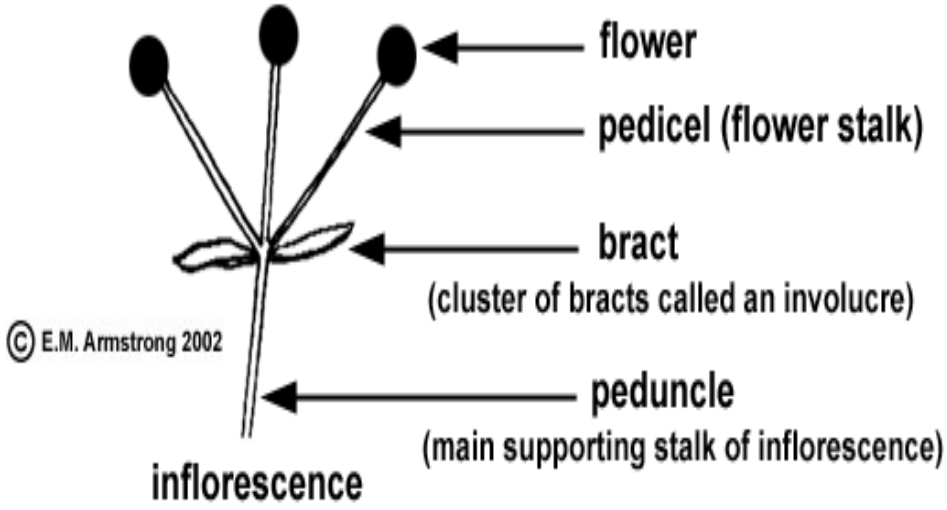
Flower Types

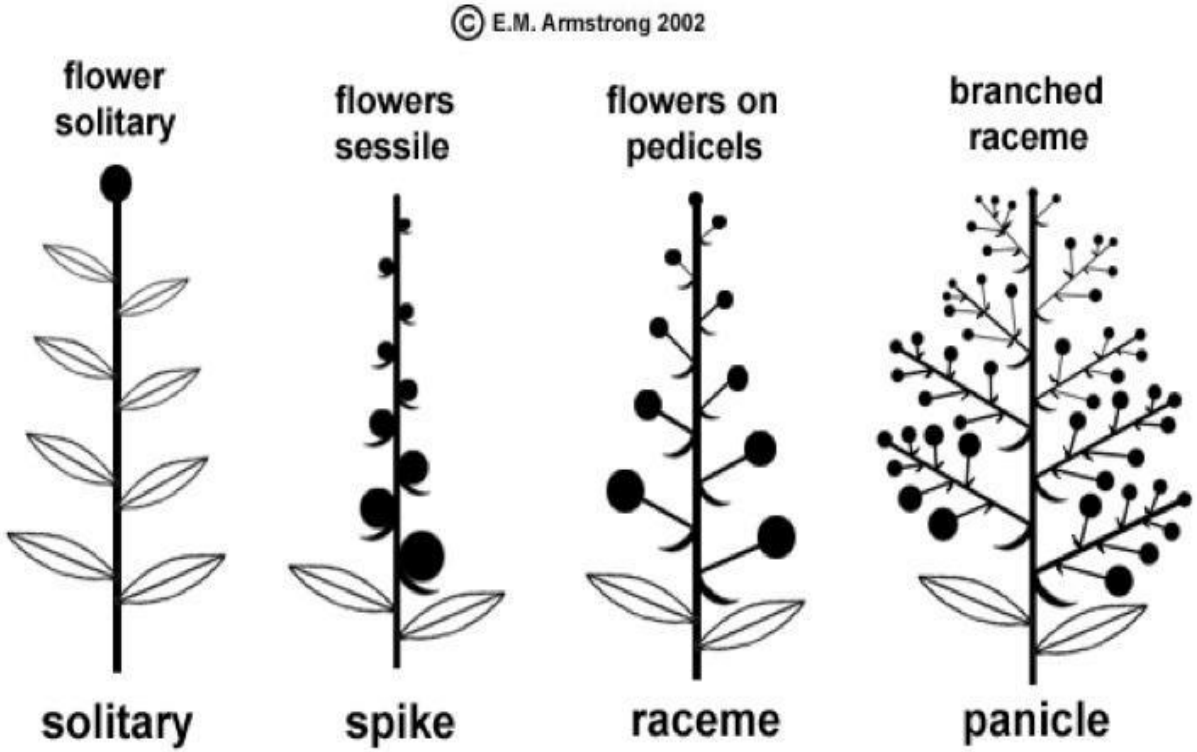
- **Radial Flower**
  - Individual parts of a set are all identical in size, shape and color.
  - Can be divided in half at any point and it will have mirror images

- **Bi-Lateral**
  - Some of the individual parts of a set are different.
  - Cannot be divided in half at any point and have mirror images

Inflorescences:

a group or cluster of flowers arranged on a stem that is composed of a main branch or a complicated arrangement of branches





Fruit: seed bearing organ of a plant

Seed: an embryonic plant

Dicots

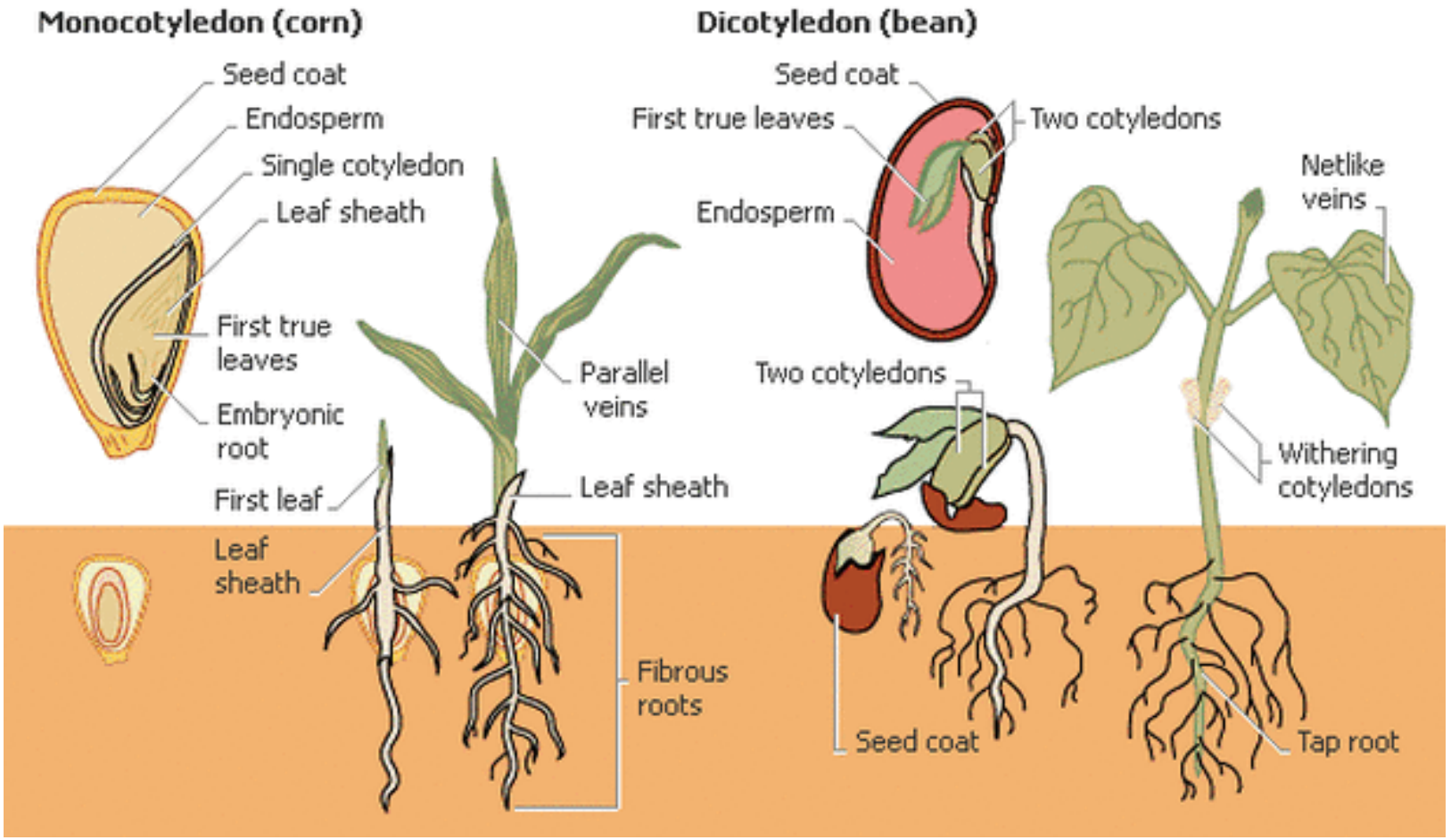
BROAD-LEAVED PLANTS

Monocots

GRASSY-LEAVED PLANTS

	Seed	Root	Vascular	Leaf	Flower
Monocot					
	One cotyledon	Fibrous roots	Scattered	Parallel veins	Multiples of 3
Dicot					
	Two cotyledon	Tap roots	Ringed	Net-like veins	4 or 5

Seedlings: Monocots & Dicots



MORPHOLOGY of GRASS WEED PESTS

Videos:

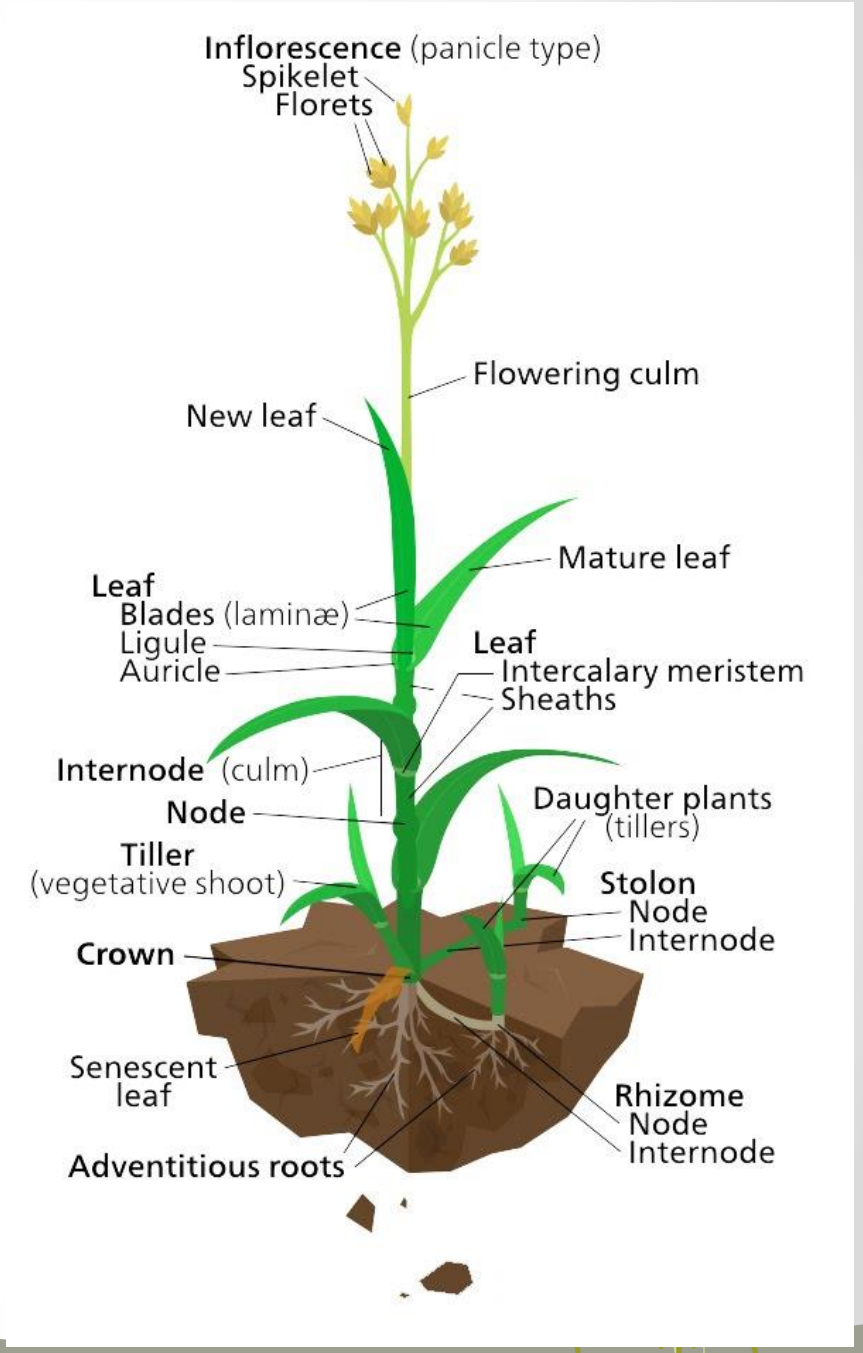
Classes for Grasses Episode 1 - Grass Structure and Anatomy – YouTube (26min)

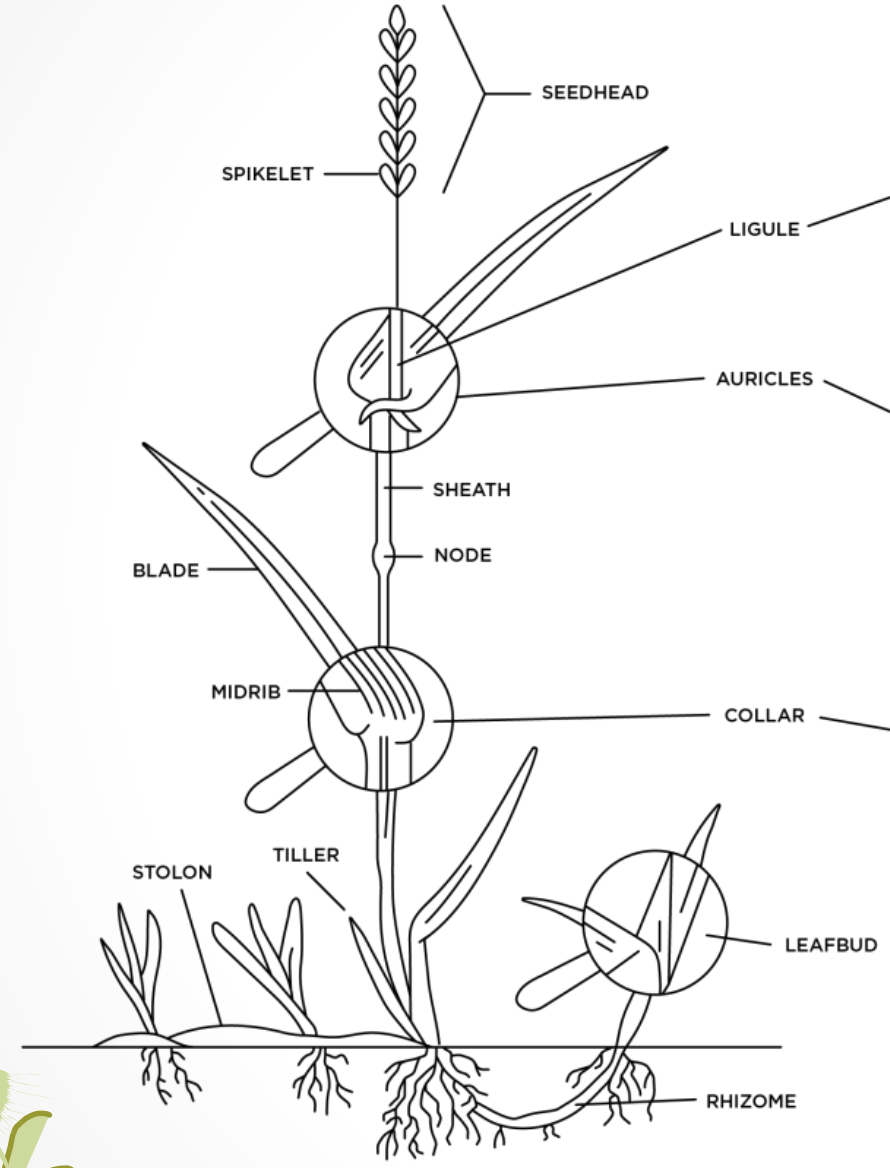
How to Identify Grasses - Part 1: I.D. Characteristics – YouTube (4min)

Website: https://forages.oregonstate.edu/regrowth/how-does-grass-grow/grass-structures

Grass Anatomy & Nomenclature

- **auricle:** short, often claw-like appendages at the base of the leaf blade which tend to clasp the sheath at the culm internode. The various shapes can be useful for identifying certain grasses.
- **crown:** basal zone of the shoot, the origin of which was tissue during the seedling stage. The crown is essential for the perennial growth of the plant as this zone is comprised of over-wintering tissues (basal internodes, rhizomes, stolons, corms) which produce new shoots the following spring. *Annual grasses do not develop a crown*.
- **culm:** central axis of the mature grass shoot, comprised of nodes and internodes; each node bearing a leaf.
- **culm node:** solid region on the culm which gives rise to a leaf sheath. On certain grass species, lower culm nodes may bear adventitious buds capable of producing new tillers.
- **flag(new)leaf:** uppermost leaf of the culm, enclosing the seed head.
- **Leaf (lamina/blade):** part of the leaf above the sheath, also known as the lamina.
- **leaf sheath:** lower section of a grass, enclosing its associated culm internode.
- **ligule:** a variously modified extension of the sheath lying at the base of the blade; often a vertical membrane, and in certain cases, mere bristles.
- **meristem:** the cells capable of growth.
- **peduncle:** upper most culm segment supporting the seed head.
- **rhizome:** a prostrate subterranean stem, capable of rooting at the nodes and becoming erect at the apex; a means of vegetative reproduction.
- **stolon:** a prostrate or creeping, above-ground stem, rooting at the nodes; a means of vegetative reproduction.
- **tiller:** a daughter plant, a shoot capable of producing a new plant.



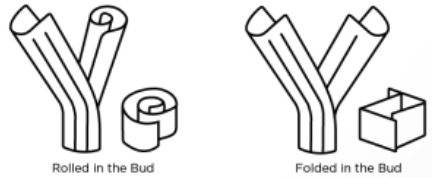


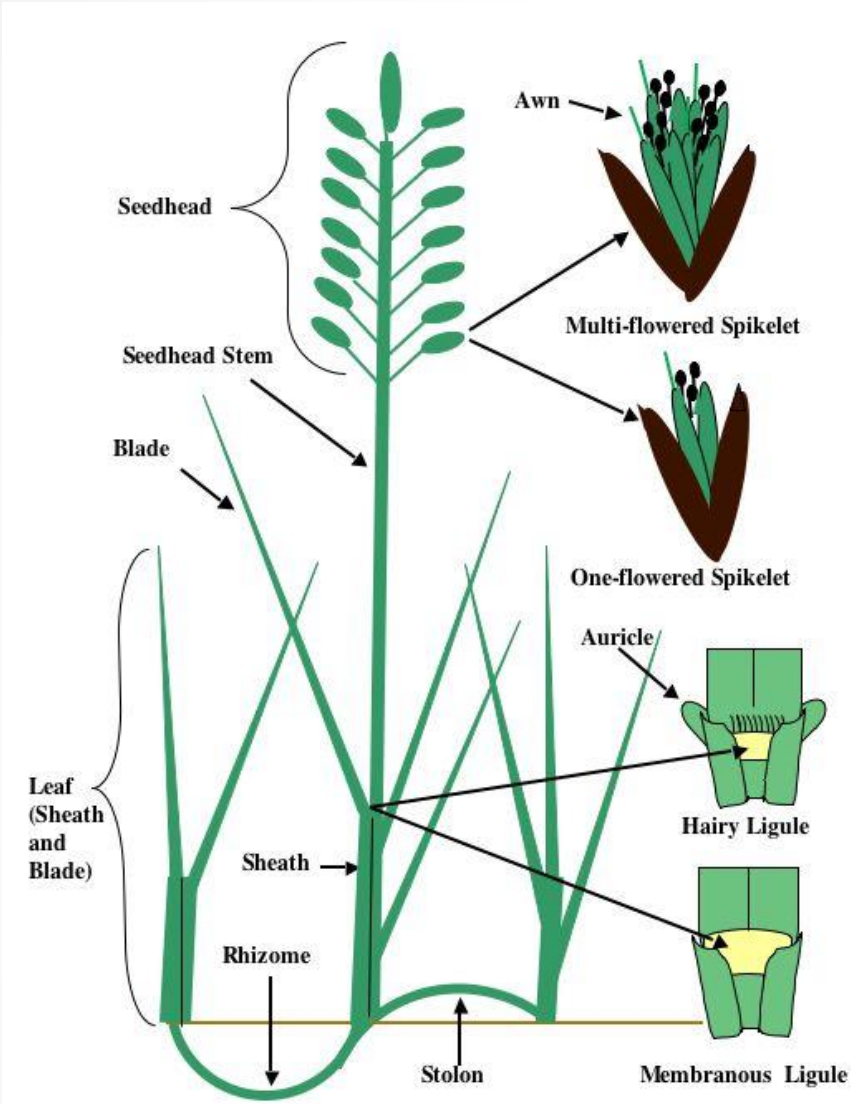
LIGULES MAY BE

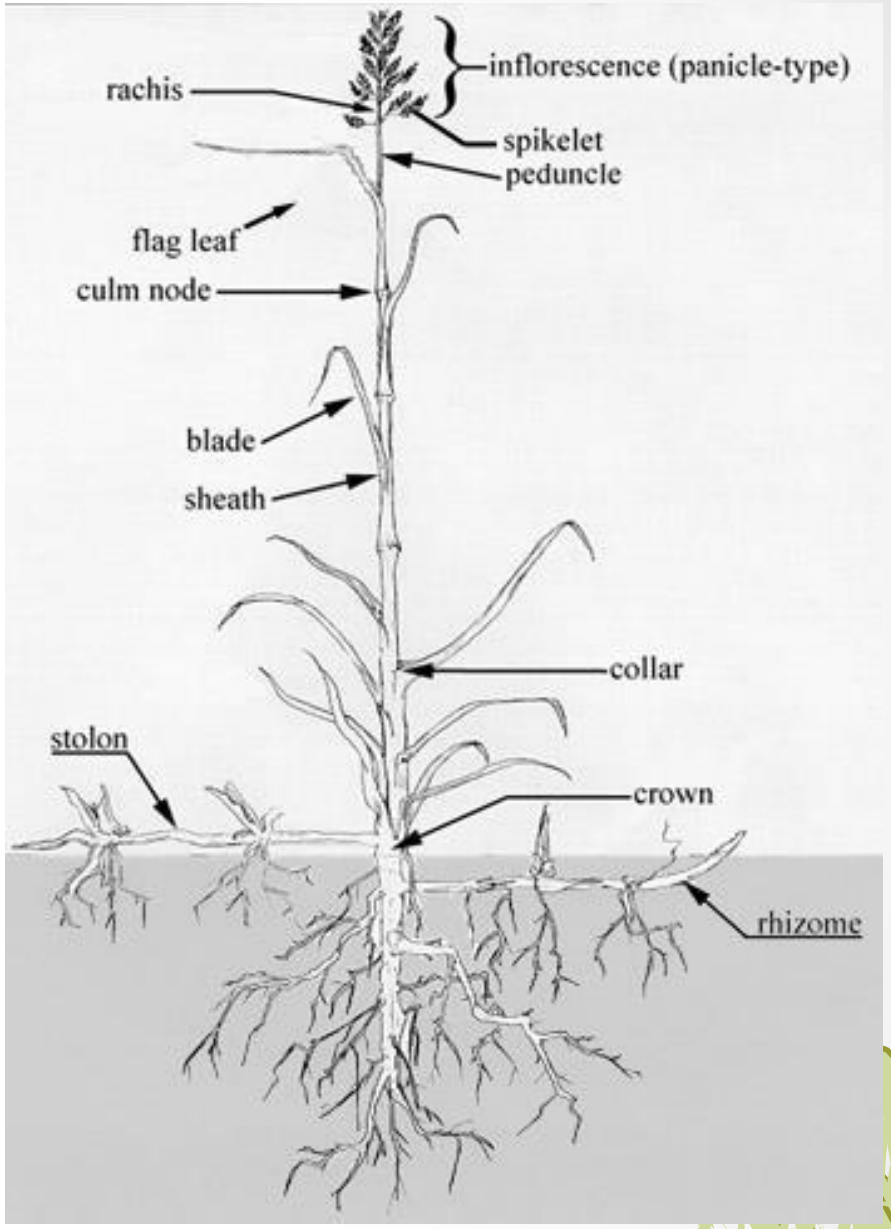
AURICLES MAY BE

COLLARS MAY BE

LEAFBUDS MAY BE




Awn
Seedhead
Multi-flowered Spikelet
Seedhead Stem
Blade
One-flowered Spikelet
Auricle
Leaf
(Sheath
and
Blade)
Hairy Ligule
Sheath
Rhizome
Stolon
Membranous Ligule


inflorescence (panicle-type)
rachis
spikelet
peduncle
flag leaf
culm node
blade
sheath
collar
stolon
crown
rhizome

Collar Region

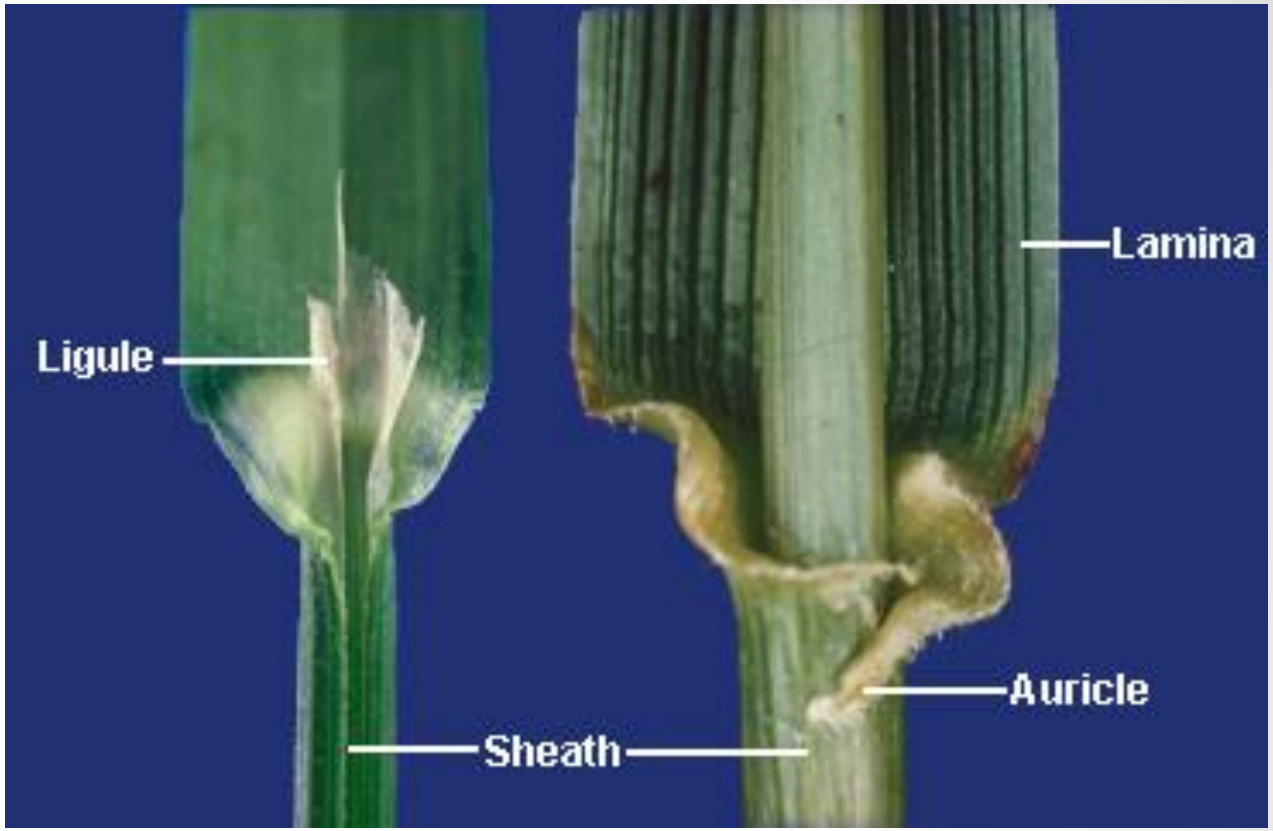
The collar region of the leaf is the most useful area for identifying vegetative-stage grasses.

The collar is a narrow band of ntercalary meristem (tissue capable of growth) which accounts for blade growth. With immature blades, this meristem provides for further blade growth following defoliation.

The collar region consists of the leaf blade, the leaf sheath wrapping around the stem, auricles (if present), a ligule, and connective tissue called the collar.

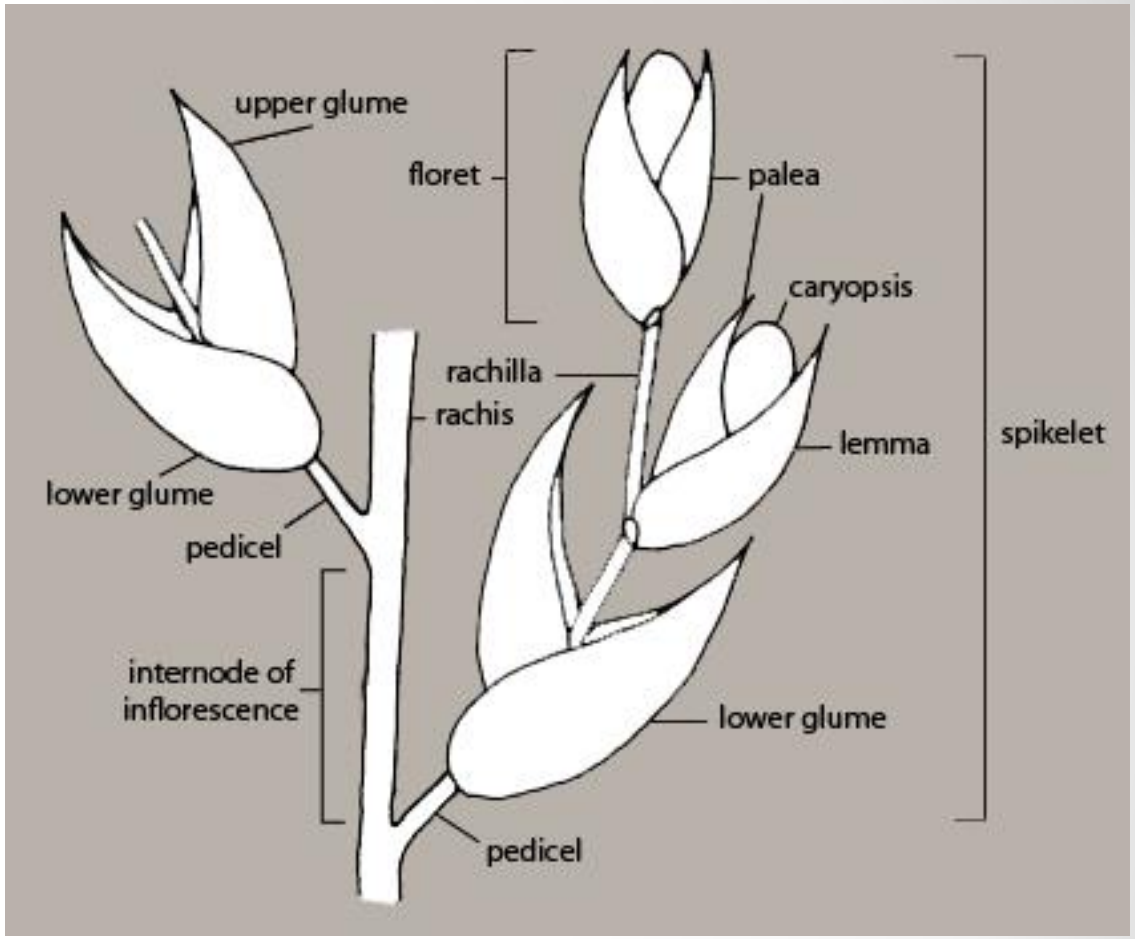
Each species is unique with respect to the presence, size, and shape of the auricles and ligules in this leaf zone.

After seed head emergence, floral structures can provide a more obvious means of identification.



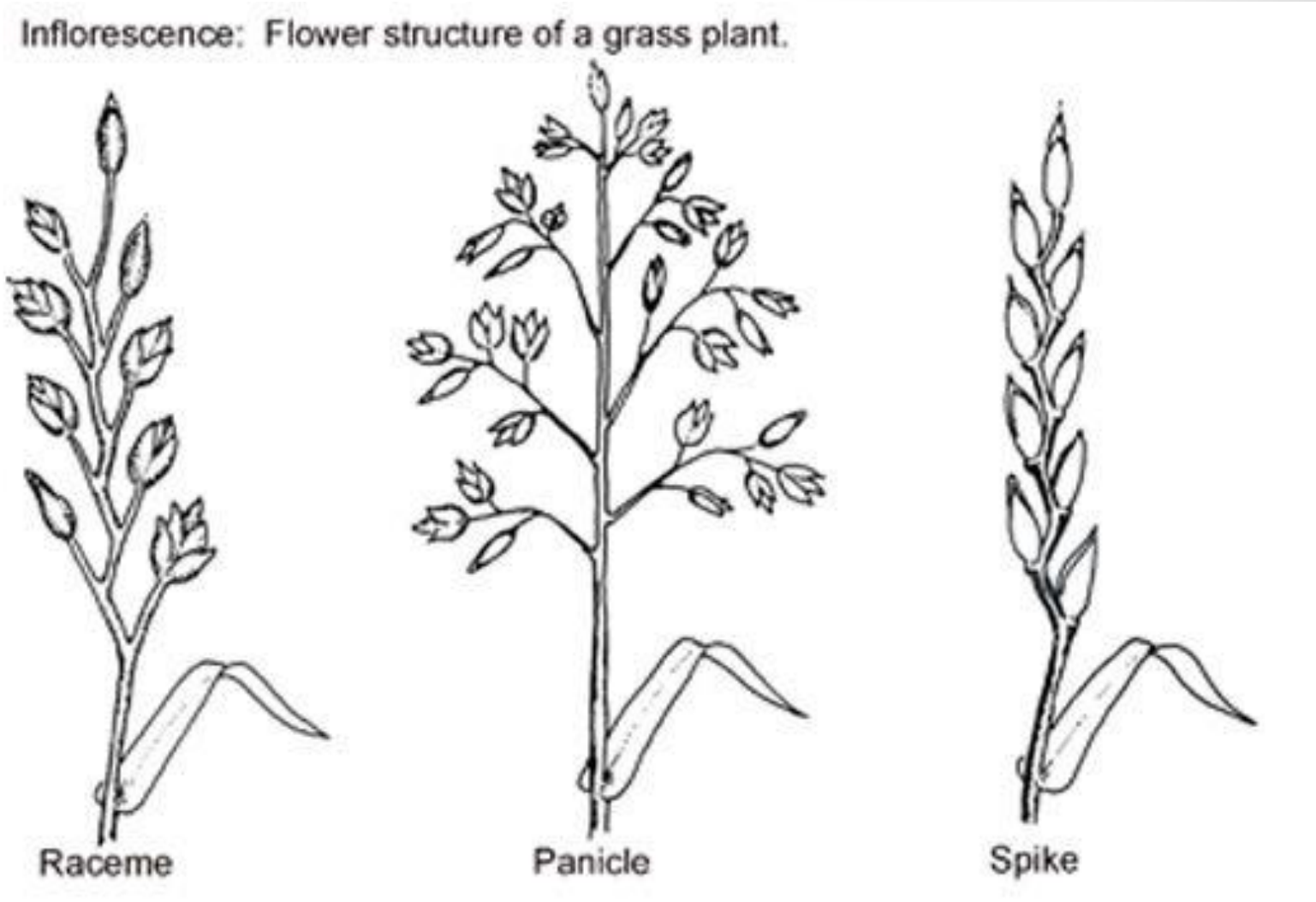
Grass Flowers

- **awn:** a fibrous bristle (often called a beard) which is an extension of the lemma. It may arise from the tip of the lemma or from the abaxial (outer) surface below the tip.
- **floret:** small flower; the reproductive unit of a grass spikelet consisting of a lemma and palea and the small flower they contain (see spikelet).
- **glume(s):** bracts which enclose the floret(s). A spikelet can be described as a pair of glumes with the enclosed floret(s). The outer (lower) glume is always the largest of the pair.
- **lemma:** the larger, outer, bract which, along with the palea, serves to contain the floret(s) held within. The lemma and palea provide a protective covering for the developing floret as well as for the seed after ripening.
- **palea:** the shorter, upper, bract which, along with the lemma, serves to contain the floret(s) held within (see lemma).
- **pedicel:** in grasses, a short stem segment supporting a spikelet
- **rachis:** central axis of seed head.
- **rachilla:** the segmented central axis of a spikelet is prominent in spikelets which bear two or more fertile florets. Each rachilla segment bears a floret, thus in threshed form, a single seed usually retains a rachilla segment or joint. The presence or absence of a rachilla segment provides a means of recognizing many seeds.
- **spikelet:** a flowering unit comprised of one or more florets enclosed by two glumes (bracts). When the spikelets are attached directly to the rachis the inflorescence is called a spike (wheat, rye, barley, ryegrass). When the spikelets are attached to the rachis with short pedicels, the inflorescence is termed as raceme. When the spikelets are attached by means of a branch the inflorescence is said to be a **panicle**.

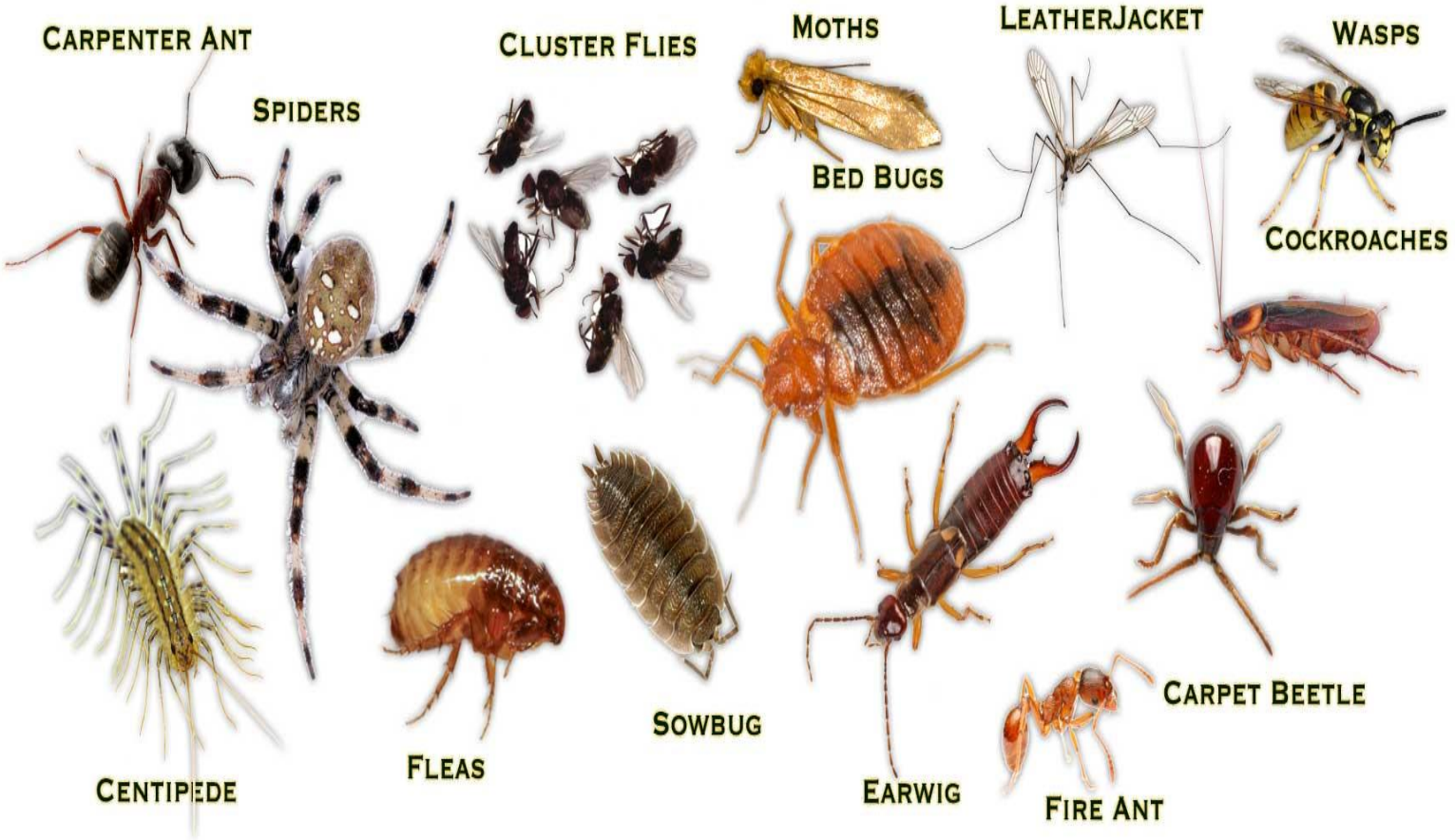


Inflorescences

- Flower head terminating the stem, consisting of a collection of flowers arranged on a common axis.
- There are three main grass inflorescence types:
  - **Raceme**
  - **Panicle**
  - **Spike**



Insects


CARPENTER ANT
SPIDERS
CLUSTER FLIES
MOTHS
BED BUGS
LEATHERJACKET
WASPS
COCKROACHES
CENTIPEDE
FLEAS
SOWBUG
EARWIG
FIRE ANT
CARPET BEETLE

Insect Ecology

- Insects play many important roles in nature. They aid bacteria, fungi, and other organisms in the decomposition of organic matter and in soil formation.
- The decay of carrion, for example, brought about mainly by bacteria, is accelerated by the maggots of flesh flies and blowflies.
- The activities of these larvae, which distribute and consume bacteria, are followed by those of moths and beetles, which break down hair and feathers.
- Insects and flowers have evolved together. Many plants depend on insects for pollination.
- Some insects are predators of others

Website: https://www.britannica.com/animal/insect

- It has long been recognized and documented that insects are the most diverse group of organisms, meaning that the numbers of species of insects are more than any other group.

- In the world, some 1.2 million different kinds of insects are known.

- This representation approximates 90 percent of the world's insect species.

- In the United States, the number of described species is approximately 100,000.

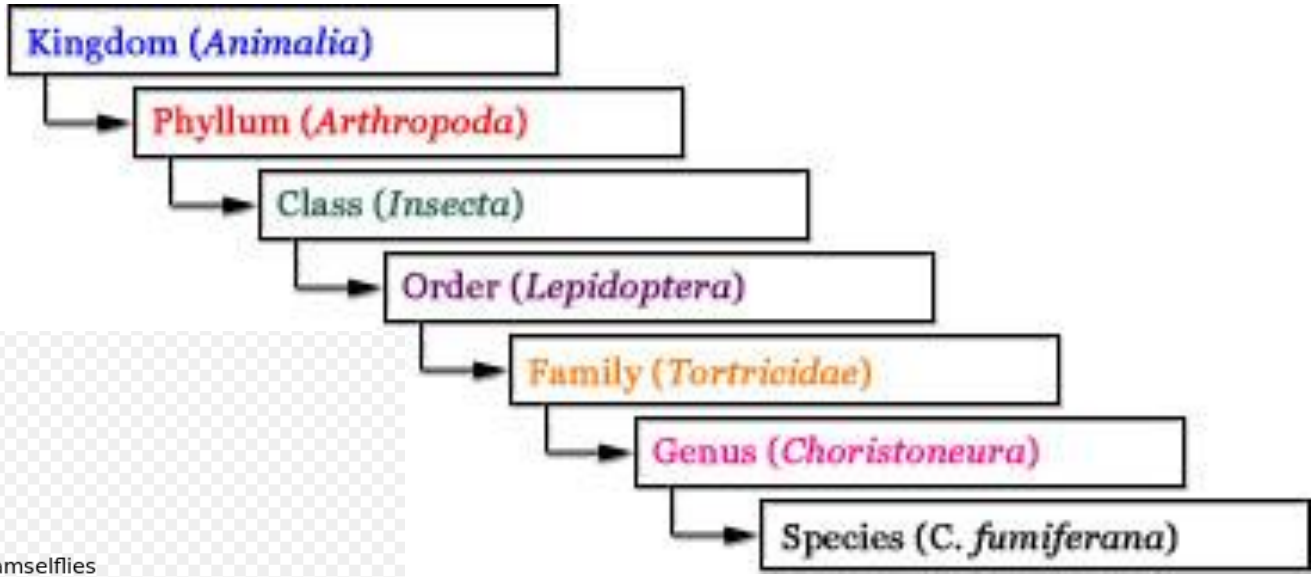
- The largest numbers of described species in the U.S. fall into four insect Orders: Coleoptera (beetles) at 23,700, Diptera (flies) at 19,600, Hymenoptera (ants, bees, wasps) at 17,500, and Lepidoptera (moths and butterflies) at 11,500.

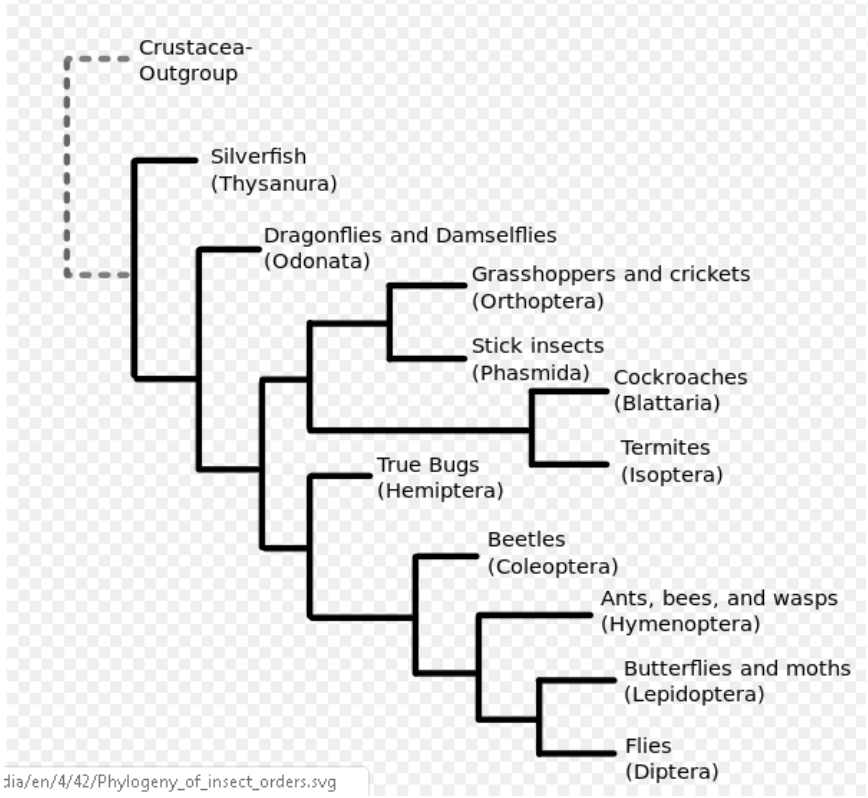
Website: https://www.si.edu/spotlight/buginfo/bugnos

Insect Management

- Most of the insect populations in and around your garden are either neutral or beneficial.
- Anytime you treat with an insecticide you are having a negative impact on insect populations.
- Chewing insects and sucking/rasping mouthparts are the insects of most interest to us. They damage, stunt and can even kill plants.
- Sucking insects are more prone to spreading diseases.
- Some species do harm during larval phase and others in adult phase.

Insect Orders





Video:
https://www.youtube.com/watch?v=TZdAfk1Pafk&list=PL1Ci3ehW5a_v8G6HFCKxiIIwoviRFOzdB&index=2Common (10min)
Insect Orders – YouTube (9min)

True Insects

Phylum: Arthropoda
Class: Insecta

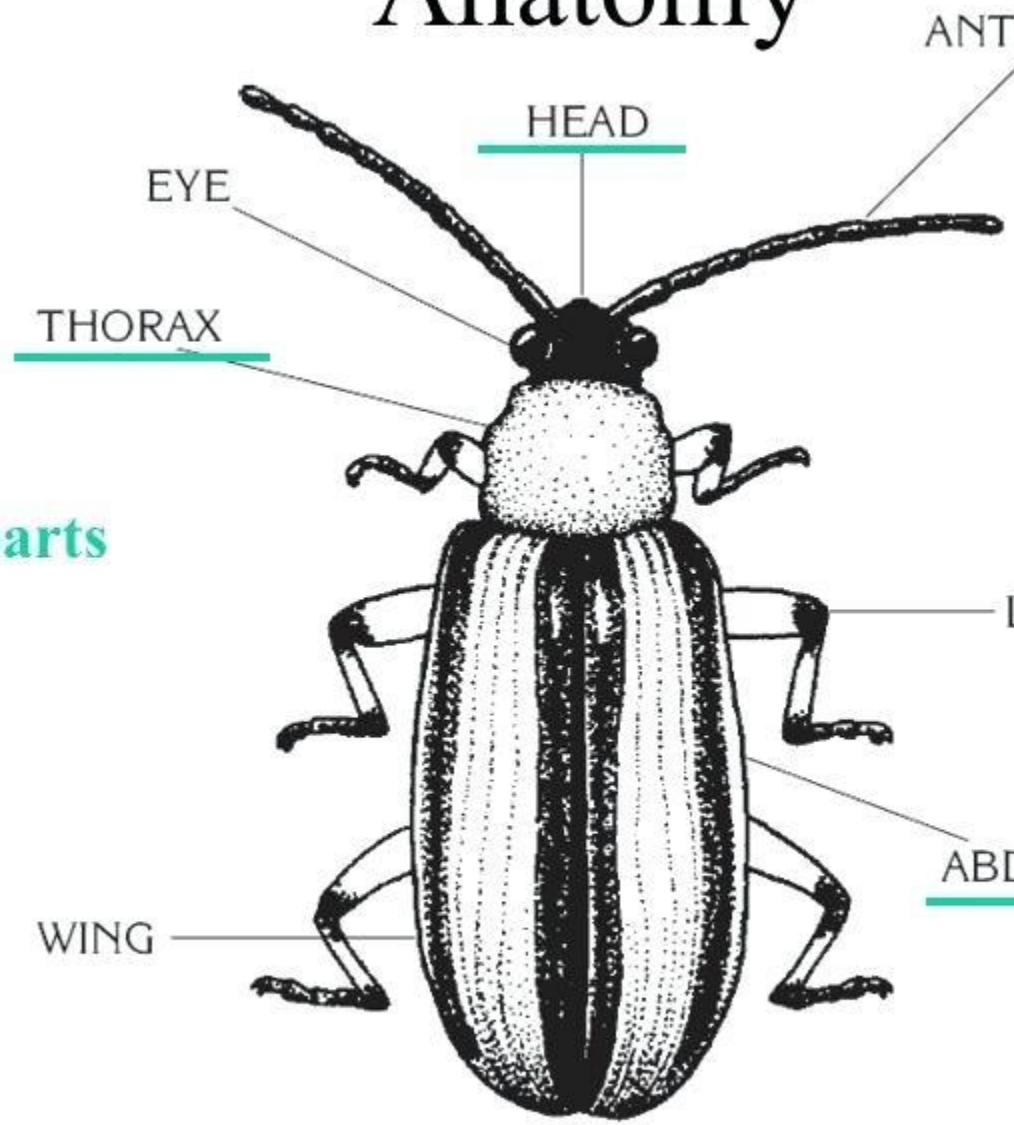
- Have 3 distinct body parts

1. Head
    - Eyes
    - Antennae
    - Mouthparts
2. Thorax
    - Composed of 3 segments
        - Prothorax
        - Mesothorax
        - Metathorax
    - Wings
    - Legs
3. Abdomen

- Outer layer is called **Exoskeleton**
- Have 3 pairs of segmented legs
- Have none, one or two pairs of wings
- Have antennae
- Any deviation is classified as an '**Insect Related Pest**'
- Most cause physical damage to plants or spread disease in plants
- Make up of 80% of all animal life on the planet
- Beneficial types
    - Pollinators
    - Biological controls

https://www.youtube.com/watch?v=iZvCmDJsfIs&list=PLH8okQGmTdonZ8JWMk4yB4AfFMtX-A8hQ&index=12 (10min)
https://www.youtube.com/watch?v=wO1nQRqA63Q&list=PLH8okQGmTdonZ8JWMk4yB4AfFMtX-A8hQ&index=13 (3min)

Anatomy



3 Body parts

3 pairs=6 legs

STRIPED CUCUMBER BEETLE

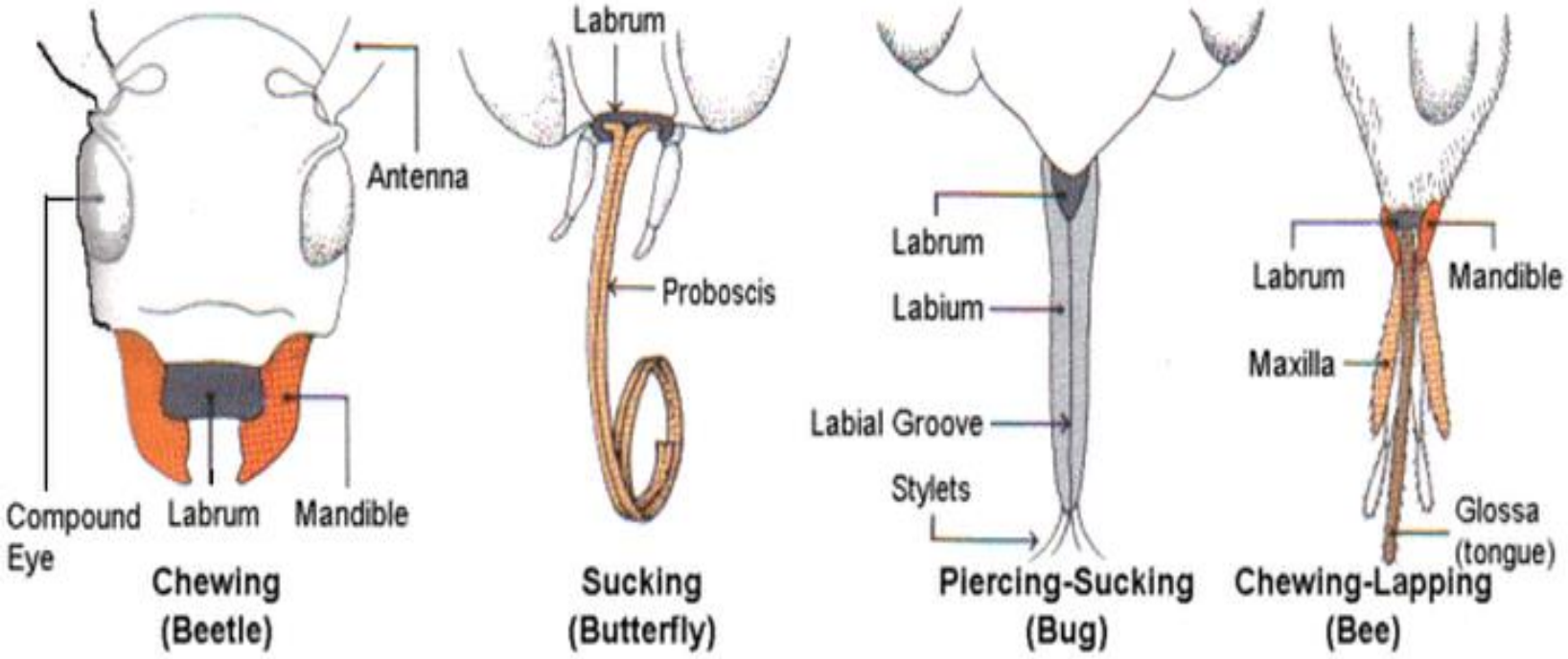
Classification by Feeding Habits

Chewing

- Use mandibles for chewing , tearing, grinding plant parts

Piercing / Sucking

- Use labrum to pierce the leaf/stems to suck plant juices

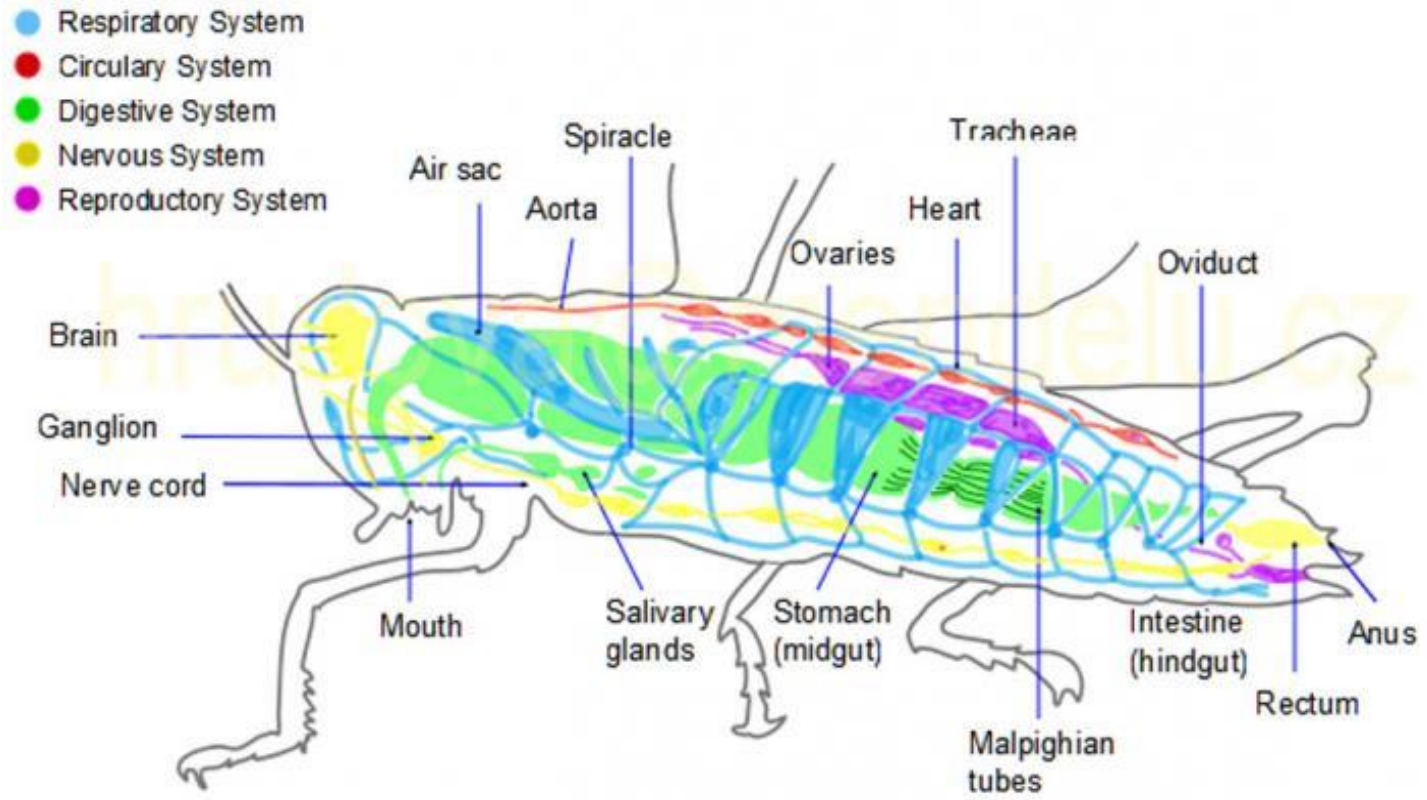


Video: A simple way to tell insects apart - Anika Hazra – YouTube (5min)

Internal Anatomy of Insects

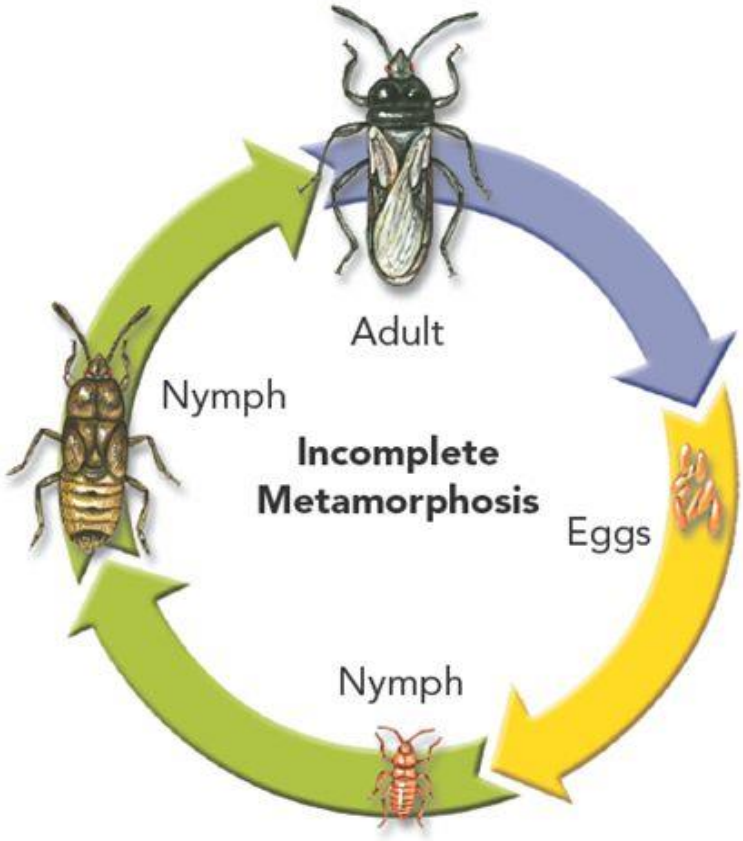
- **Circulatory system**
  - No veins, blood fills cavities, circulated through a tube in upper back
  - Pumping part of tube located in abdomen
- **Respiratory system**
  - Has no lungs
  - Breathes through tiny pores called '**Spiracles**' located in abdomen
- **Reproductive system**
  - Reproduce sexually (most)
  - Organs located in abdomen
- **Nervous system**
  - Brain has 2 cords that run thru thorax and abdomen
    - 1 controls the mouth parts
    - 1 controls the body
  - Nerve cluster called '**Ganglia**' work can work without the brain
- **Digestive system**
  - Tube from mouth to anus
  - Divided into 3 sections
    - Foregut
    - Midgut / stomach
    - Hindgut / intestine

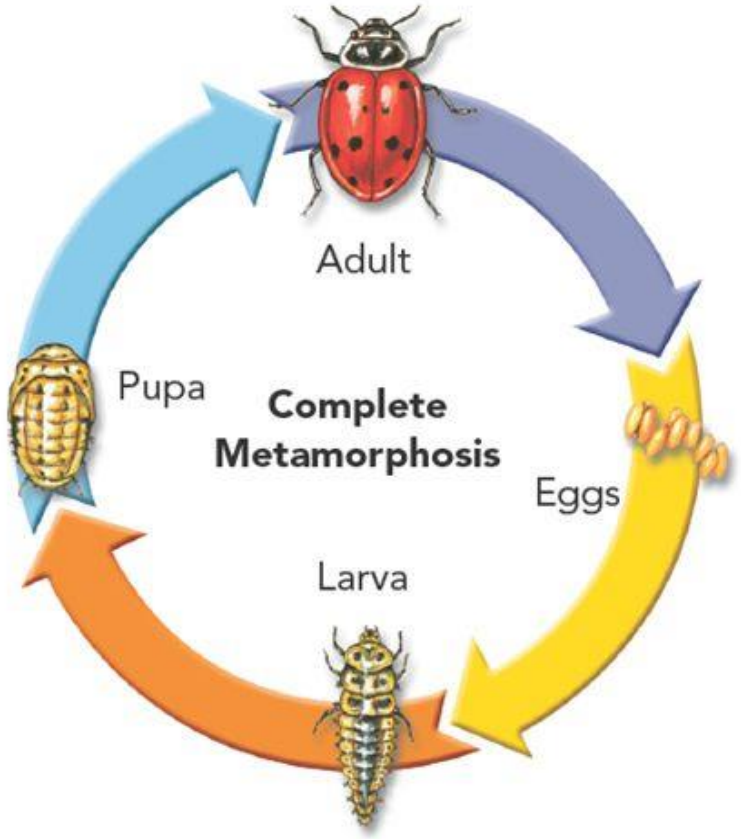
Internal anatomy of insect



https://www.youtube.com/watch?v=hbERzvUDreE&list=PLH8okQGmTdonZ8JWMk4yB4AfFMtX-A8hQ&index=14 (10min)
https://www.youtube.com/watch?v=Hl29bwxKDIw&list=PL1Ci3ehW5a_ugYOdbJjJFIMjc_zBRCOMm&index=5 (11min)

Complete vs. Incomplete Metamorphosis





https://www.youtube.com/watch?v=hrd40JQQI8A&list=PL1Ci3ehW5a_smx_lNK7klTEZfKl3Evo6C&index=68&t=18s (9min)

- **Complete (complex) Metamorphosis**

  Instead of developing in several small stages, these insects undergo major physiological change in the pupa stage.

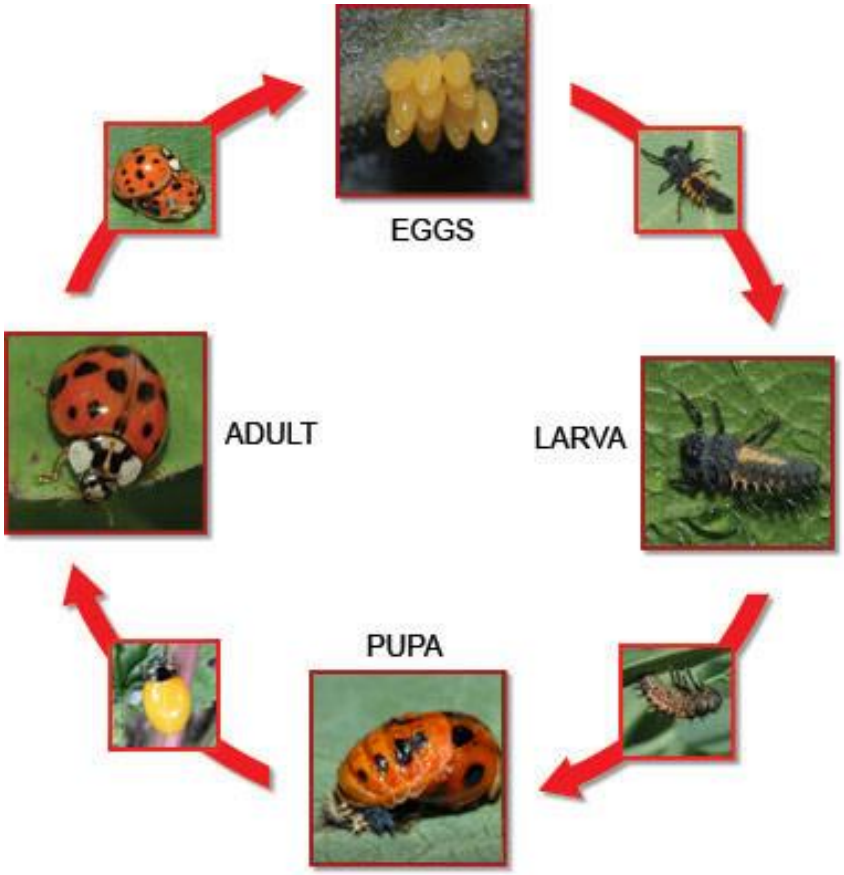
  - 4 stage process:

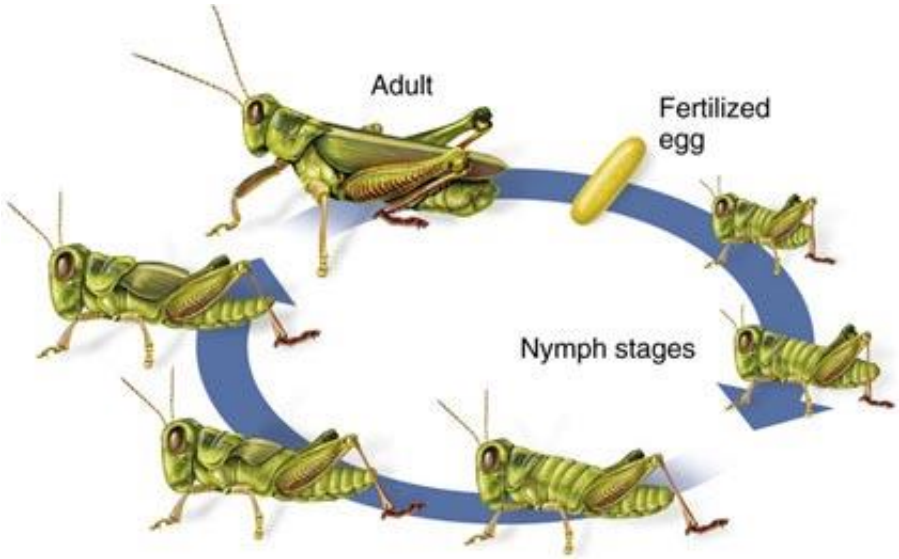
    1. Egg
    2. Larva
    3. Pupa
    4. Adult

  - Mating and reproduction is the primary purpose in the adult stage.

- **Incomplete (simple) Metamorphosis**
  - 3 stage process: egg to nymph to adult.
  - The nymphs look like small adults but with underdeveloped wings. .
  - As they grow, they periodically shed their exoskeleton in a process known as 'Molting'.
  - As the insect molts, it slowly grows into a winged adult.
  - These types of insects may molt several times before reaching adulthood.

Lady Beetles & Grasshoppers





Insect Related Arthropods

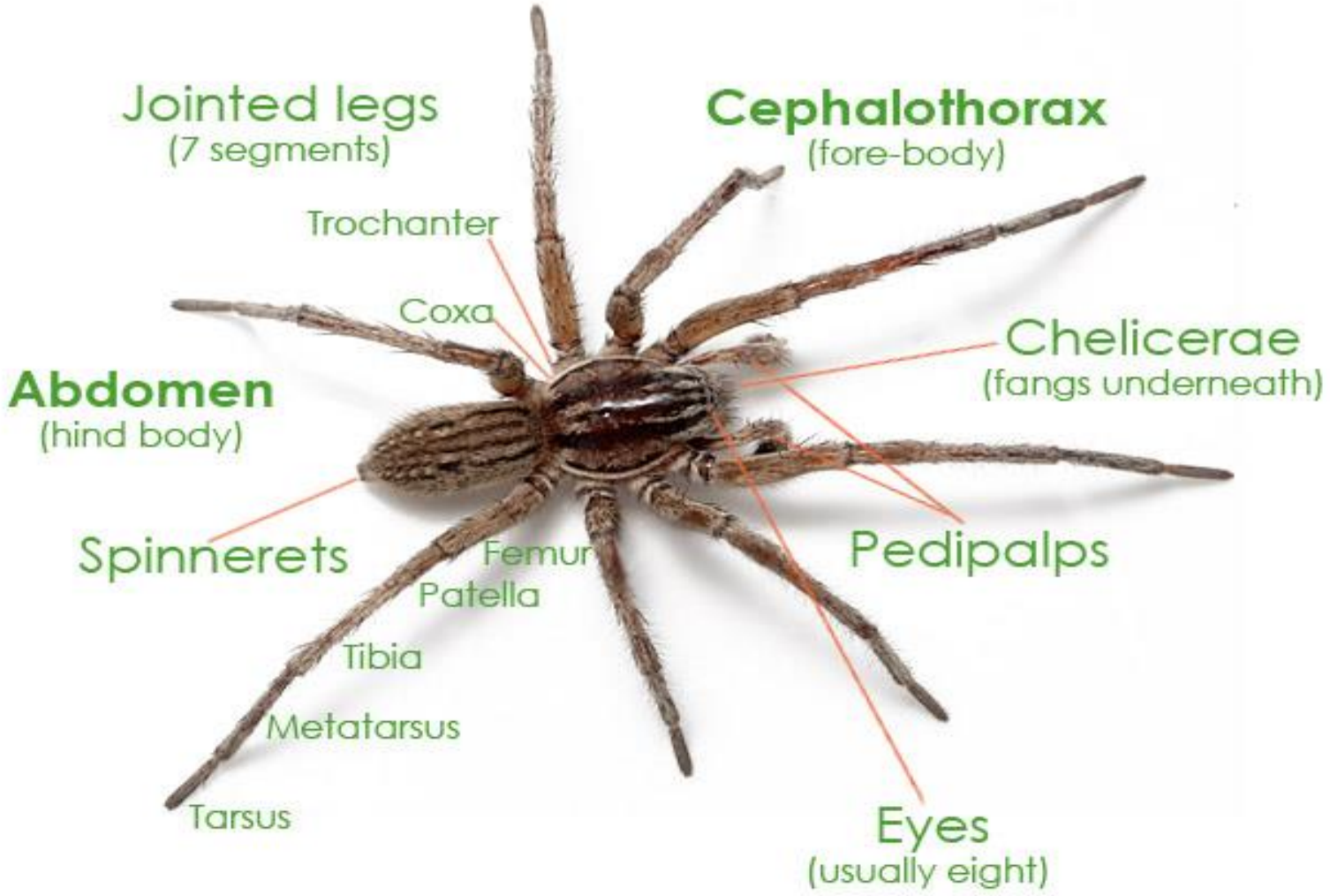
Phyllum: Arthropoda **Class:** Arachnida

Order: Araneae (spiders) & Acari (mites)

- Spiders, Mites and Ticks
  - Phylum: Arthropoda
  - Class: Arachnida
- 2 body parts
  - Cephalothorax
  - Abdomen
- 4 pairs of segmented legs
- No antennae
- Have spinnerets for making webs
- Mouthparts are fangs capable of injecting venom
- Considered beneficial, though they are not selective

- Mites and Ticks are pests

Spider anatomy



Genitalia

- Bug genitalia can be complicated including:
  - Hooks
  - Claspers
  - Levers
  - Pliers
  - Syringes

- Spiders have one pair of mouth parts (**pedipalps**) that serves as the male sex organs.

Other Insect Related Arthropods

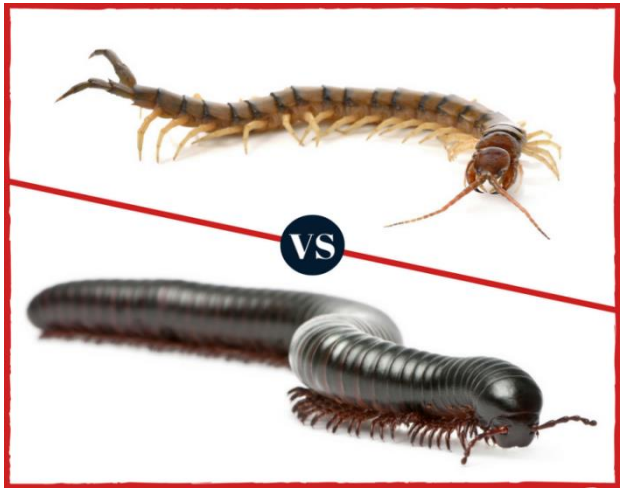
Phylum: Arthropoda

Class: Malacostraceae **Order:** Isopoda

- Pill Bug (rolls up) / Sowbug (no roll up)
  - Has 7 pairs of legs
  - Prefers to feed on decaying organic matter
  - Prefers dark, damp habitat

Phylum: Arthropoda, **Class:** Chilopoda, **Orders**: Scutigeromorpha, Scolopendromorpha, Lithobiomorpha & Geophilomorpha

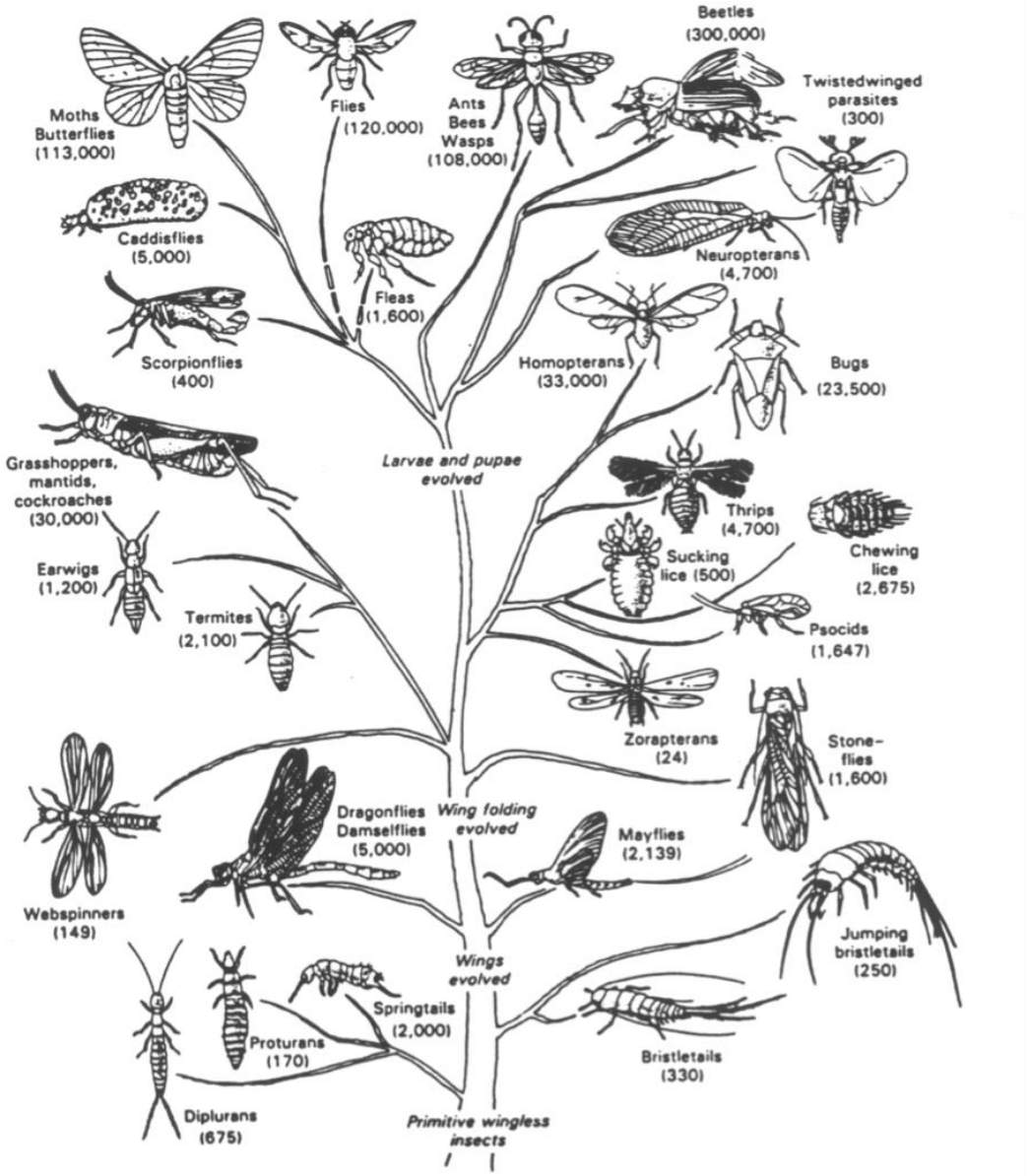
- Centipedes
  - Flat body with 15 pairs of legs
  - Fast running
  - Feeds on insects, spiders & other arthropods
  - Jaws contain poison to subdue its victim
  - Jaws are too weak to bite through human skin



Phylum: Arthropoda, **Class:** Diplopoda, **Orders**: 16 total

- Millipedes
  - Round body with up to 200 pairs of legs
  - Slow moving
  - Prefers to feed on decaying organic matter
  - Prefers dark, damp habitat

Orders of Insects



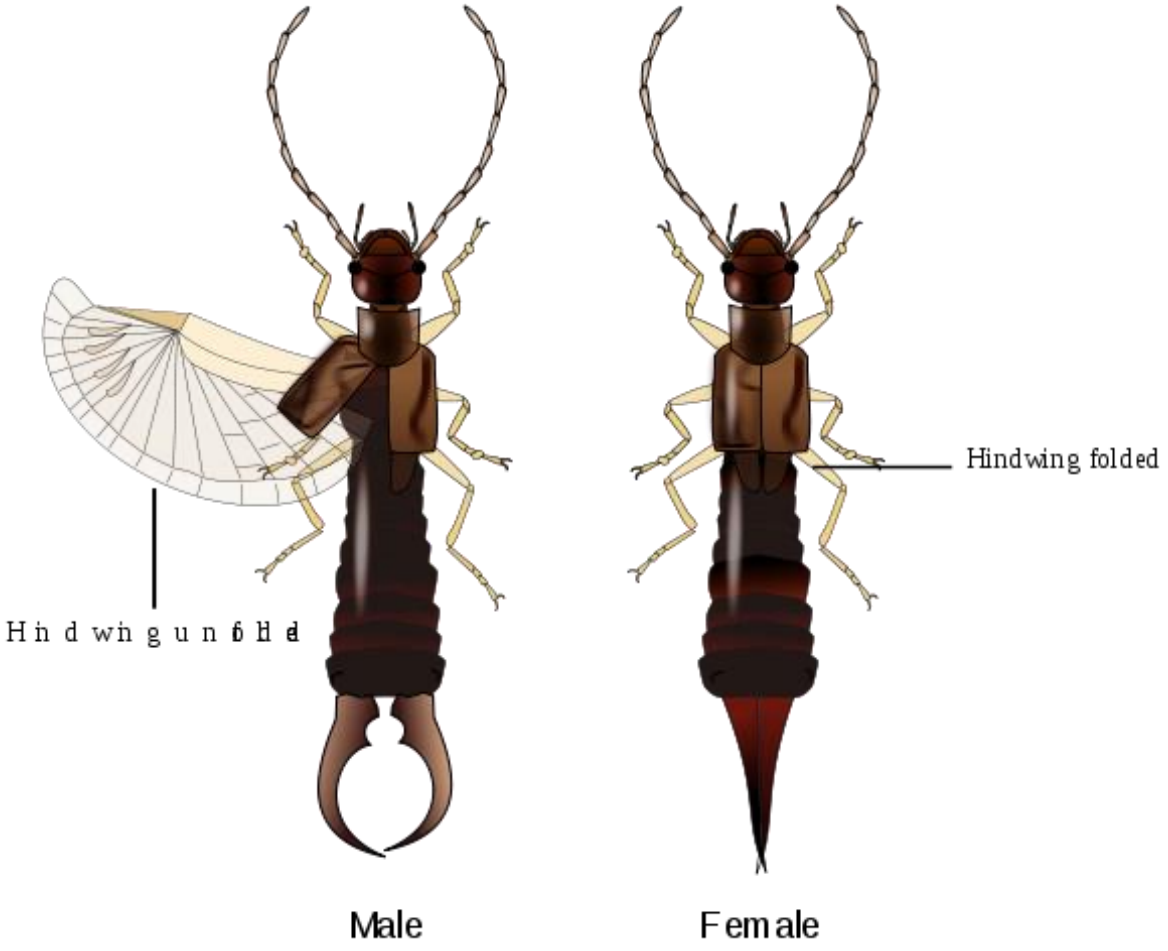
https://www.youtube.com/watch?v=pHWywkt8pco&list=PL1Ci3ehW5a_v8G6HFCKxiIIwoviRFOzdB&index=6 (13min)

Coleoptera (Sheath Wings)

Beetles

Dermaptera (Skin Wings)

Earwigs



Diptera
(Two Wings)

Flies and
Mosquitos

Hemiptera
(Half Wings, True Bugs)

Box Elder Bug

Stink Bug

Homoptera
(Same Wings)

Aphids, Mealybug, Scale

Hymenoptera
(Membrane Wings)

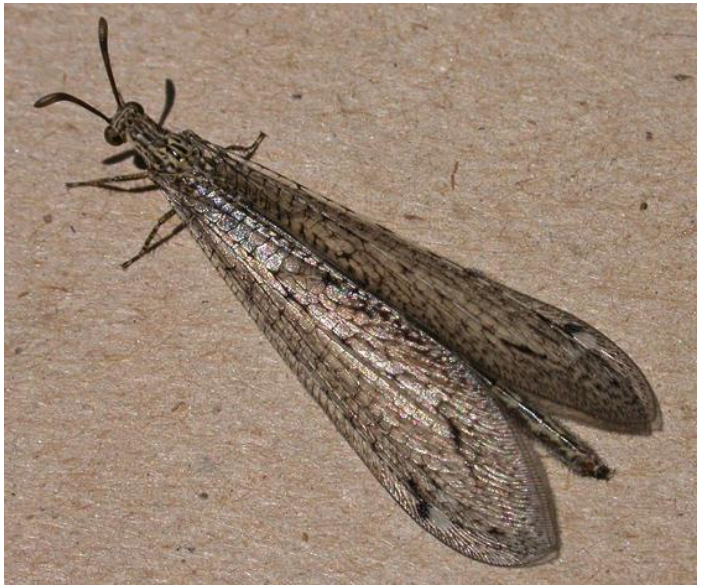
Ants, Bees, Wasps

Lepidoptera
(Scale Wings)

Butterflies, Moths

Neuroptera
(Nerve Wings)

Lace Wings, Ant Lions

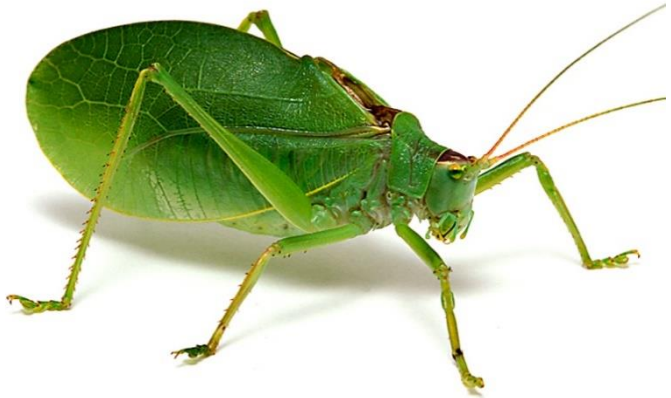


Odonata
(Toothed)

Dragonflies, Damsel Flies

Orthoptera
(Straight Wings)

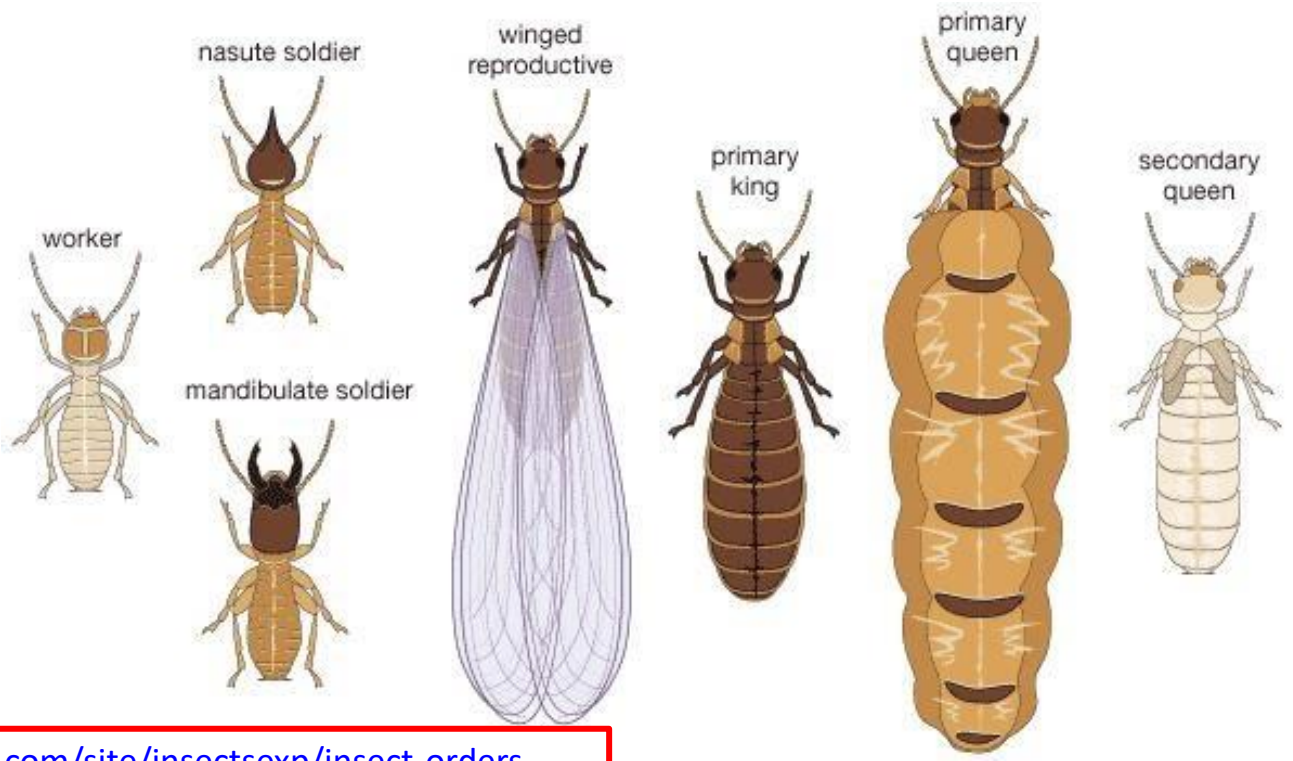
Grasshoppers, Crickets, Katydids



Isoptera-Termites

Identifying Features

- Termites workers are small white insects without wings.
- Antennae are moniliform, not elbowed, with 10+ segments, and chewing mouthparts.
- Thorax is broadly joined to the abdomen.
- Reproductive parts are winged and sclerotized.
- Forewings and hindwings are of similar size, and are held flat over the abdomen at rest.



Website: https://sites.google.com/site/insectsexp/insect-orders

Blattodea - Cockroaches

Identifying Features

- Cockroaches are medium-sized to large insects, with a broad and flattened body. The hindwings are large and membranous, folded beneath leathery smaller forewings at rest. They are running insects with chewing mouthparts.

Website: https://sites.google.com/site/insectsexp/insect-orders

Mantodea - Praying Mantis

- Praying mantids are large, with an enlongated prothorax, and grasping forelegs. They are predators and have chewing mouthparts.

https://sites.google.com/site/insectsexp/insect-orders

Phasmatodea-Walkingsticks

Identifying Features

- Walkingsticks are large insects, herbivores, with very elongate bodies.

- They have chewing mouthparts, and the wings are either reduced or absent.

Website: https://sites.google.com/site/insectsexp/insect-orders


INSECT PEST
MANAGEMENT

Why Should We Tolerate Insects ?

- Food sources for birds & other wildlife
- Most are innocuous or beneficial
- Many are valuable parasites or predators
- Many breakdown organic matter
- Many are pollinators
- Few are destructive

Damage from Insect Pests

- Chewing Types
  - Leave identifiable holes in external plant parts
  - Root feeders
  - Tissue feeders
    - Cause discolored or wilted foliage
    - Damage can mimic pathogen, nutrient or cultural problems
  - Boring types feed inside of trunks and limbs/branches
- Sucking Types
  - Feed on plant fluids
  - Cause buds, fruit, or leaves to discolor, distort, die-back, or drop
  - Some excrete sticky honeydew or spread bacteria and viruses

Exotic Pests

- From other states & countries
- Brought in by contaminated fruit, plants, soil, and firewood
- Argentine ants, mealybug, psyllid, thrips, whitefly to name a few

- **Prevention**
  - Don't bring unless inspected by US Ag officials
  - Buy pest-free plants from reputable sources
  - Purchase firewood near to where you plan to burn it
  - Don't move plants across county lines without consulting Ag dept.
  - Identify unknown pests from-UC Cooperative Extension.
  - Call: 800-491-1899

Life Cycles

- Insect Metamorphosis
  - Complete
    - Egg, Larva, Pupa, Adult
  - Incomplete
    - Egg, Nymph/Naiad, Adult
      - Molting
- Mites
  - Egg, Larva (6-leg), Nymph, Adult (8-leg)
- Damage varies on stage of development

Control Action Guidelines / Thresholds

- No established quantitative thresholds
  - Lack of research
  - Variation in tolerance
  - Economics
  - Aesthetics
- Can develop over long term monitoring
- Usually no effective control once damage is obvious
  - Many instances require waiting for insect to develop to a stage vulnerable to control

Monitoring & Diagnosing

- Identify pest
- Learn their biology
- Learn potential damage
- Management options
- Is it tolerable?
  - Without threatening plant health

Video: Integrated Pest Management: Monitoring – YouTube (6 min)

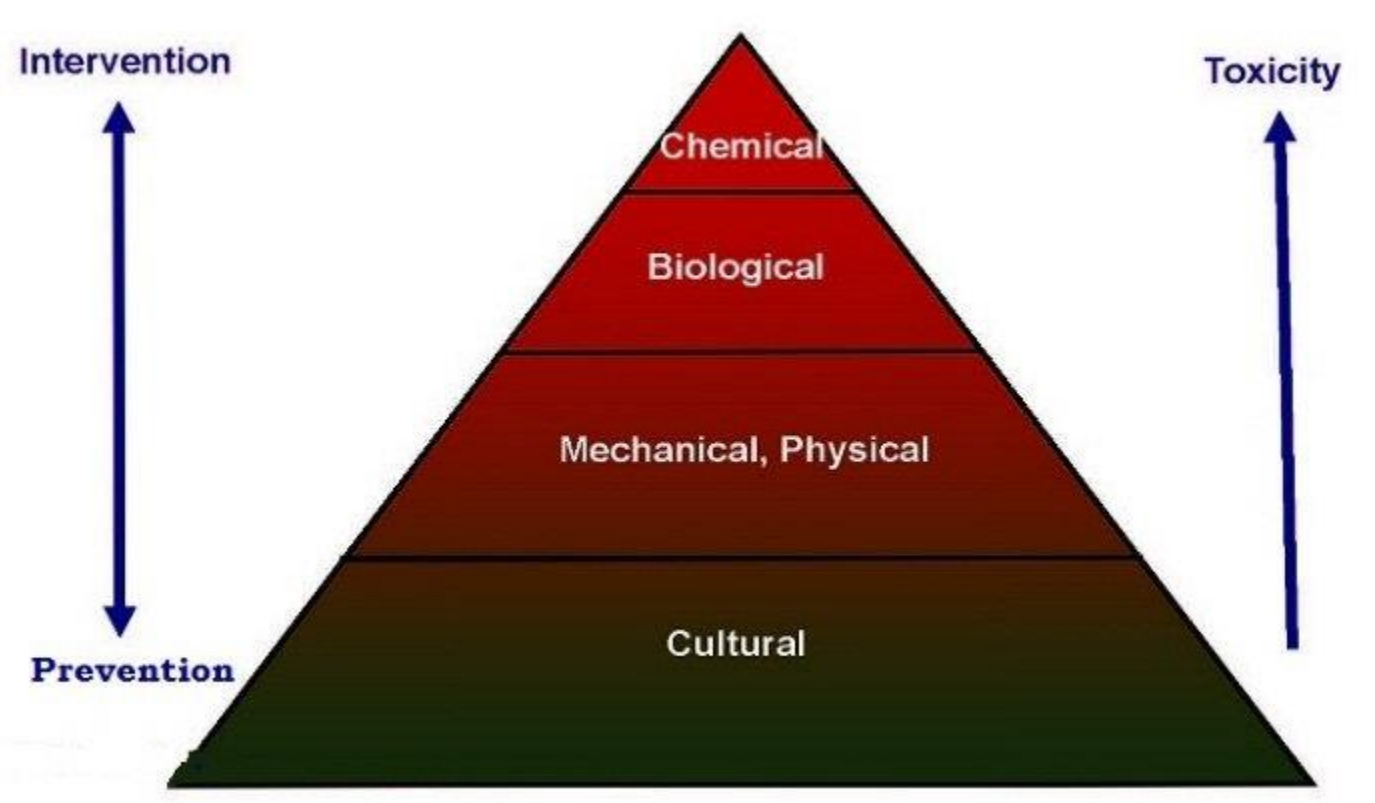
- Monitoring Methods
  (table 6-1, pg 127)
  - Visual of plant parts
  - Branch beating
  - Sticky traps & tapes
  - Trunk wraps
  - Trap boards
  - Pheromone traps (mating disruption)
  - Pitfall traps
  - Honeydew / frass
  - Degree-day monitoring

Sampling

- Quantitative monitoring
- Presence or absence of pests
- Per plant / plant part
- Counts and comparisons
  - Increasing, decreasing, or same
  - Is management needed
  - When / where to implement controls
  - Effectiveness of management actions
- Method description
- Sample same way each time
- Record:
  - Dates
  - Weather / phenology
  - Specific location
  - Host plant
  - Pests sampled
  - Who sampled
  - Results from samples
  - Management action and date

IPM: strategies for preventing and minimizing pest damage in ways to reduce risks to human health, beneficial and non-target organisms, and the environment.

- Cultural Control
- Mechanical Control
- Physical Control
- Biological Control
- Chemical Control



Cultural Controls

- Plant selection
  - Right plant, right place
  - Proper plant spacing
  - Companion planting
- Adapted to location
  - Natives
  - Ornamentals
  - Alternatives
- Meet cultural needs
  - Sun exposure
  - Appropriate watering
- Proper care and maintenance
  - Weeding
  - Pruning
  - Fertilizing

Videos:
IPM: Proper Planting and Spacing – YouTube (7:19) plant spacing
IPM: Companion Planting and Trap Crops – YouTube (7:18)
IPM: Sanitation – YouTube (5:32)
IPM: Native Plants – YouTube (4:18)
IPM: Right Place, Right Plant – YouTube (5:14)

Mechanical Controls

- Use labor and non-pesticidal materials
- Copper bands repel snails & slugs
- Chip/grind branches from on-site to use as mulch
- Hand-pick
- Traps
  - Boards, pits, rolled paper, saucers of liquids
- Small infestations
  - remove infested parts of plants (do not compost)
- Sticky barriers:
  - Encircle trunk with band of sticky material such as Tanglefoot
  - Exclude ants, flightless invertebrates, juvenile scale, snails
  - 2-6 inch wide bands
  - Check every 1 -2 weeks for pests, plant damage
  - Replace as necessary

Physical Controls

- Alter environmental conditions of light, humidity, and temperature
  - Thinning canopies increases sun & heat exposure to kill scale insects
  - Solarize wood to control wood boring insects
  - Apply white interior latex paint (diluted with 50% water) to prevent sunscald and deter boring type insects
- Spray foliage with forceful stream of water to dislodge aphids and whiteflies
- Wet undersides of foliage during hot weather to decrease spider mite populations
  - This method also improves the reproduction of predatory mites

Video: IPM - Mechanical and Physical Pest Control – YouTube **(11:34)**

Biological Controls

- Control pests and reduce damage with natural enemies:
  - Parasites
  - Parasitoids
  - Predators
  - Pathogens
  - Competitors
- Safe?
- Conservation
- Pesticides

- Tactics for using natural enemies:
  - Importation (Classical Biological Control)
  - Conservation and Enhancement
  - Augmentation
    - Innoculation
    - Inundation

Videos:
IPM: Natural Enemies – YouTube (10min)
IPM: Beneficial Fungal Pathogens – YouTube **(2min)**

Importation (Classical Biological Control)

- Import, release and establishment of exotic natural enemies
- Treat introduced exotic species (table 6-2, pg 132)
- Universities and government agencies research and introduce to the public
- Biological controls are relatively safe for human health and the environment

- Negative impacts have occurred from imported species
  - Cane Toad
    - Australia- imported in 1960 from S. America to control beetles affecting sugar cane crops. Now many native species / habitat are threatened
  - Asian Mongoose
    - Hawaii imported 1883 from India to control rodents in sugar cane fields. Many native species of ground nesting birds have disappeared
  - Mosquito Fish
    - Introduced to control mosquito larvae but have outcompeted native species for resources

Videos:
Biological Control of Pests – YouTube (15min)

Conservation and Enhancement

- Preservation of naturally occurring beneficial organisms
- Use of cultural, mechanical, or selective chemical controls that do not interfere with beneficial species
- Grow nectar and pollen rich plants that attract and provide habitat for beneficials year-round (fig 6-4, pg 133)
- Some parasitoids lay their eggs on new growth. Prune judiciously and leave trimmings as mulch so the eggs can hatch.

- **Pesticide Management**
  - Kill more beneficials because of their searching behaviors
  - Residues persist killing migratory beneficials
  - Increases damaging pest populations with less predators
  - Systemics translocate into blossoms exposing pollinators
  - Choose selective insecticides over broad-spectrum types (table 6-3, pg 133)
  - Carbamates, organophosphates, and pyrethroids are toxic to natural enemies

Augmentation

- Purchase and release of existing beneficial species
- Inoculative releases
  - Low numbers released
  - Allowing offspring of existing to thrive
  - Usually once over a growing season
- Inundative releases
  - Large numbers released
  - Several times over a growing season

- Effectiveness
  - Identify pest and its life stage
  - Know its biology and natural enemies
  - Release natural enemy when target pest is at its most vulnerable and with large infestation
  - Release during at night or early morning
  - Avoid introducing non-selective predators such as Praying Mantids

Video: IPM: Biological Control - Augmentation – YouTube (10:32)

Natural Enemies

- **Parasitoids** (insect parasites)
  - Feeds in or on larger hosts
  - Most from Diptera (flies) & Hymenoptera (wasps) orders
- **Pathogens**
  - Microorganisms that infect and kill the host
  - Nematodes, bacteria, fungi, and viruses
- **Competitors**

  Birds, Vertebrates & Reptiles
  - Insects important food source
  - Provide habitat to encourage establishment
  - Dead, decaying trees also provide habitat

- **Predators** (insects)
  - Assassin Bugs
  - Lacewings / Dustywings
  - Lady Beetles
  - Minute Pirate Bugs
  - Predacious Flies
  - Predacious Ground Beetles
  - Soldier Beetles
  - Predacious Mites
  - Spiders

Lab – Activity

Microbial/Biological & Botanical Insecticides
Naturally Occurring Pathogens

- **Microbial/Biologicals**
  - Derived from bacteria that have little or no effect on humans but are detrimental to certain pests:
- **Abamectin** (derived soil bacteria)
  - Affects nervous system
  - Leaf miners, mites, & thrips
- **Bacillus thuringiensis (Bt)**
  - Kills larvae of moths, butterfly, mosquito, blackfly & fungus gnats
- **Entomopathogenic Nematodes**
  - Kills root & soil dwelling weevils, grubs, & wireworms
- **Botanicals**
  - Derived from plants
  - Break down quickly
  - Effective thru contact
- **Inorganics**
  - Derived from minerals
  - Diatomaceous earth, Sulphur, phosphates, boric acid
- **Insecticidal Soaps / Oils**
  - Derived from plant oils
  - Effective on soft bodied insects such aphids, mealybugs
- **Carbomates / Organophosphates**
  - Sevin & Malathion
  - Derived from petroleum
  - Very toxic to natural enemies & pollinators
- **Neonicotinoids**
  - Systemic, translocates thru plant
  - Very toxic to natural enemies & pollinators
- **Spinosad – fermatated bacteria**
  - Kills caterpillars, flies & thrips thru contact/eating

Group-Activity

1. Describe their physical description: size, color, etc.
2. Life stage they are predators
3. What is their target pest?
4. How do they kill their target pest?

Assassin Bugs

Lacewings / Dustywings

Predacious Flies

Minute Pirate Bugs

Soldier Beetles

Predacious Mites

Lady Beetles

Predacious Flies

INSECT ORDERS

ORDER Name, Order Common Name, and Example	CHARACTERISTICS of ADULTS	MOUTHPARTS	METAMORPHOSIS	BENEFICIAL or DETRIMENTAL
COLEOPTERA (Sheath Wings) Beetles	2 pair of wings; front wings modified into thick, horned wing covers; hind wings are membraneous folded under front wings when at rest; some species are wingless	Chewing	Complete	Benefical & Detrimental
DERMAPTERA (Skin Wings) Earwigs	wingless or 2 pairs of wings; front wings short and leathery; hind wings large and membranous, folded under when at rest; forceps on abdomen	Chewing	Incomplete	Detrimental
DIPTERA (Two Wings) Flies, Midges, Mosquitoes	transparent front wings; hind wings replaced by short, knobbed structures called 'Halters', which serve as balancers; large eyes	Piercing / Sucking Sponging	Complete	Detrimental
HEMIPTERA (True Bugs, Half Wing) Assasin Bug, Stink Bug	2 pair of wings; base of front wings thick and leathery, membranous, fold under front wings when at rest; some species are wingless	Piercing / Sucking	Incomplete	Detrimental
HOMOPTERA (Same Wings) Aphids, Cicadas, Scale	wingless or one or two pair of membranous wings; roofed over body when at rest; some species wingless	Piercing / Sucking	Incomplete	Detrimental
HYMENOPTERA (Membrane Wings) Ants, Bees, Sawflies, Wasps	2 pair of small, stiff membranous wings that interlock in flight; front wings larger than hind wings; worker ants and some others are wingless; most species are solitary; some have social behavior.	Chewing / Lapping	Complete	Benefical & Detrimental

INSECT ORDERS

LEPIDOPTERA (Scale Wings) Moths and Butterflies	Sucking mouth parts shaped like a coiled tube when not in use; 2 pair of scaly, usually broad wings; front wings usually larger than hind wings; long antennae; large eyes	Chewing (larvae), Sucking (adult)	Complete	Benefical
NEUROPTERA (Nerve Wings) Ant Lions, Lacewings	2 pair of similar membranous wings covered with numerous veins; wings roofed over body at rest; long slender antennae; larvae and adults are predatory	Chewing	Complete	Beneficial
ODONATA (Toothed Wings) Dragon Flies, Damsel Flies	2 pairs of equal-sized, transparent membraneous wings that cannot be folded; very small antennae; huge eyes; strong fliers; cannot walk; legs can catch prey in air; mate in flight; juvenile stage they are called **'Naiads'** not Nymphs because they live in the water	Chewing	Incomplete	Beneficial
ORTHOPTERA (Straight Wings) Crickets, Grasshoppers, Roaches	two pair of wings; front wings short and leathery; hind wings large and membranous, folded under front wings when at rest; medium to long antennae; some species wingless; some species make sounds by stridulating	Chewing	Incomplete	Detrimental

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Establishing Integrated Pest Management Policies and Programs: *A Guide for Public Agencies*

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INTRODUCTION

As a result of growing concerns about health and environmental problems associated with pesticides, public agencies are facing increasing demands from their employees, their clientele, and the general public to explain and justify their use of these materials. Agencies must be able to respond with careful, thoughtful answers. Managing insects, plant pathogens, weeds, rodents, and other organisms that become pests is a complex science; applying pesticides safely and effectively in public areas requires substantial expertise and skill. Responses to the public's questions must communicate an understanding of this complexity and a genuine concern for health and environmental problems.

Adoption of a written policy and procedures for making pest management decisions provides an agency with an effective way to respond to the questioning public and at the same time improves the agency's internal decision-making process, resulting in more efficient, more effective, and safer resolution of pest problems. Involving the public and employees in the development and evolution of a pest management policy can help educate everyone on the potential hazards and benefits of pest management practices.

What Is Integrated Pest Management?

Integrated pest management (IPM) is a pest management strategy that focuses on long-term prevention or suppression of pest problems with minimum impact on human health, the environment, and nontarget organisms. Preferred pest management techniques include encouraging naturally occurring biological control; using alternate plant species or varieties that resist pests; selecting pesticides with a lower toxicity to humans or nontarget organisms; adopting cultivating, pruning, fertilizing, or irrigation practices that reduce pest problems; and changing the habitat to make it incompatible with pest development. Pesticides are used as a last resort when careful monitoring indicates that they are needed according to preestablished guidelines. When treatments are necessary, the least toxic and most target-specific pesticides are chosen. Implementing an integrated pest management program requires a thorough understanding of pests, their life histories, environmental requirements, and natural enemies, as well as establishment of a regular, systematic program for surveying pests, their damage, and other evidence of their presence.

What Are Special Issues for Public Agencies?

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For many years, integrated pest management programs have been implemented in agricultural cropping systems. IPM programs in schools, parks, and other public places have been a bit slower to be adopted. Public agencies face infrastructure complexities and public relations issues that are not a concern for individual farmers making pest management decisions.

Pest management programs in public agencies rely on the coordinated activities of many individuals. Often, several different departments and supervisors are involved in activities that affect pest problems and their management. There may be different supervisors for janitorial staff, pesticide application staff, plant maintenance staff, landscape maintenance staff, and landscape design staff—yet all have critical roles in a pest management program. Each group may have different priorities and a different way of doing business; there may not be effective communication between departments. However, these divisional barriers must be broken down and all employees must be enlisted in a program that shares common goals and approaches to achieve success.

In addition, public agencies must be accountable and responsive to the public. People in the community often want justification for the use of certain types of pesticides and at the same time may demand to know why the agency isn't doing a better job of controlling organisms that they consider pests. A written IPM policy enhances an agency's ability to respond to public concerns and coordinate activities within its bureaucracy.

What Will an Integrated Pest Management Policy Do for Your Agency?

Although the initial reason for developing an integrated pest management policy may be to explain and justify your agency's use or nonuse of pesticides, it will provide many other benefits as well. For instance, a written policy provides procedural guidelines for the agency. There are many federal, state, and local regulations that must be followed when storing, transporting, applying, and disposing of pesticides, and there are specific laws regarding who can recommend pesticides and how applicators must be trained in California. Specific safety equipment and procedures are required for the use of many pesticides. A written policy assures that these laws and regulations are adhered to each time a pesticide is used and helps you document that proper procedures were followed.

Developing and establishing a set policy educates applicators, administrators, other employees, and the general public about when and why pesticides are used and when alternative methods might be adopted. It also helps employees gain a better understanding of their jobs. An IPM policy may reduce your agency's reliance on pesticides, protect the environment, and protect applicators, coworkers, their families, and the public. If problems do arise, the policy provides procedures for immediately handling the problem and helps you to document that your agency acted responsibly.

SETTING POLICY GOALS

The first step in establishing an integrated pest management policy is to determine the goals of your pest management program. Policy goals give your agency a framework on which to base individual decisions. All goals may not be met with each and every decision, but established goals will give your agency a set of priorities to work from. *Goals will vary considerably from agency to agency* according to the function of the agency, public and wildlife access to agency grounds, employee concerns, and political priorities. The overall goal for many agencies would be "to establish a more effective and safe pest management program"; however, this type of general goal is not specific enough to guide decision making. More specific goals might be divided into two categories: political, educational, and public relations goals for policy makers; and operational goals for basing individual pest control decisions.

Goals should be set with input from employees and the general public. Establishing goals is one of the most productive ways that people without technical expertise can participate in the policy-making process. Involving various factions of the community in policy development is a good way to garner widespread support for the program and policy later on. Pest management policy goals differ with the function of different agencies; examples of possible goals follow.

Examples of Political-Educational Goals

- Encourage employees to first consider alternatives to pesticides.
- Keep citizen complaints at or below current levels through effective practices and public education.

Examples of Operational Goals

- Design a written plan for implementing IPM procedures throughout the facility and for individual pests.
- Ensure that the public agency's governing board (supervisors, trustees, directors) is kept informed as to the progress of the IPM program. The board's support and encouragement can assure the program's presence and fiscal health.
- Establish procedures (e.g., through a technical review committee and periodic reevaluations) for assuring that the latest information is incorporated into pest management decisions.
- Develop procedures for allowing public input without disruption of the overall program.
- Make information accessible to the public and employees regarding pesticides used and areas treated.
- Ensure that applicators are educated regarding current pesticides, their hazards, and applications.
- Educate employees and the public about pest management problems and solutions.
- Develop protocols for plant inventory and pest problem survey.
- Establish monitoring programs and evaluative criteria to measure control success.
- Maintain pests at levels that prevent them from becoming a health hazard.
- Eliminate fire hazards (such as tall dry grass or dead trees) in a timely manner.
- Reduce or eliminate all use of pesticides in CDFA category I, II, or III (agency choice).
- Establish and maintain pesticide use reporting and recordkeeping.
- Provide employees with pest management training, including diagnostic skills and use of alternative pest control methods.
- Establish and maintain records of pest occurrence and levels at which they become a problem.
- Identify and evaluate cultural and environmental conditions on the grounds that seem to encourage pest problems.
- Use the safest effective practices whenever economically feasible.

PROCEDURES FOR DESIGNING AN IPM PROGRAM

Once policy goals are set, persons with pest management expertise within (and perhaps also outside) your agency must establish reasonable procedures for meeting these goals. At first, some operating guidelines will be crude, but you can refine them with time as your experience grows. However, it is important to have established procedures so you can document and measure their success and improve them with time. The procedures listed below are intentionally generic because of the great variety of pest management situations. Pest control procedures must be developed on a pest-by-pest basis, and procedures will change and evolve over time. You can get help by consulting the resources at the end of this publication, talking with University of California Cooperative Extension staff, consulting private pest management consultants, or talking with other agencies with similar problems. Remember to keep your policy goals in the forefront and to regularly document and reevaluate your program. Keep up with new ideas and practices through continuing education and professional publications.

The success and sophistication of your IPM program will depend on the experience, skill, education, and enthusiasm of your employees. Take these factors into account when establishing procedures. Don't expect employees to perform new tasks without encouragement and training. You may need to bring in outside expertise to assist in the first season of a new program. Expect to implement change over time, incorporating a few major component at a time.

Step-by-Step Procedures for Developing an IPM Program

1. Identify all potential pests (including all life stages) in the system. Verify damage symptoms associated with pests and identify natural enemies. For plant pests, this will require identifying plant species in the management area and developing pest lists for each host. Train all pest management personnel to accurately identify beneficials as well as major pests and their damage, and to seek help when they can't make a conclusive identification. Have materials (e.g., a field manual or identification texts such as those listed in the resources on p.11) and tools (e.g., a dissecting microscope and hand lens) available to assist in pest identification. Make provision for identifying new pests as they are observed (see step 9).

2. For each pest, establish monitoring guidelines. These may be crude at first but can be improved with experience. Monitoring methods vary from pest to pest (for more information, see the resources on p.11), but all involve regular (e.g., weekly) checking, visually or with traps, for pests or damage symptoms, or other evidence of pest presence (e.g., feces); methods also involve some way of quantifying observations. Also provide for monitoring of beneficials and natural enemies. Overall, the objectives of a monitoring program are to pinpoint precisely when and where pest problems may become intolerable and to determine the effectiveness of treatment actions. To determine the need for treatment, the objectives must be used with action thresholds, as discussed in step 3.

3. Establish injury levels and action thresholds for each individual pest species before making any treatment. An injury level is the pest population size (e.g., 10 aphids per leaf or 2 cockroaches per trap) that is associated with intolerable damage. Action thresholds are the set of conditions required to trigger a control action—usually a pesticide application.

Determine the infestation levels that will be intolerable to people or to structures or that will cause unacceptable damage at various times of the year, plant growth stages, situations, and so on. At the same time, devise a monitoring plan for detecting these pest levels and determining when to treat. Over time you will refine the injury levels and action thresholds; however, treatment is usually required when

- a regular monitoring program indicates that the pest population will reach the injury level if left untreated; and
- biological or environmental factors cannot be expected to reduce the pest problem within a reasonable time; and
- treatment cost and health and environmental hazards are considered less than the potential pest damage.

4. Establish a recordkeeping system. Good records are essential for evaluating and improving your IPM program and for reference when the public wants to know how you handle certain types of pests. Any recordkeeping system should include observations such as

- identity of the pest (to species if possible) and how the identification was made
- the size (density) of the pest infestation
- the geographic distribution of the pest problem in the managed area (a map of your facility can be useful for this)
- complete information on how you treated the problem, including what, how much, where, when, who, cost, application difficulties, and the effectiveness of treatment in solving the pest problem (short-term and long-term)
- the side effects of the treatment on nontarget species
- public complaints or other problems that arise, and positive feedback

5. Develop a list of acceptable management strategies for each pest. The preferred methods in an IPM program *prevent* pest problems and therefore eliminate the need for pesticide applications. These methods might include modifying structures or landscaping to be less conducive to pest survival, using pest-tolerant or pest-resistant cultivars, using cultural practices (such as mulches or mowing and the use of pruning and planting times that discourage pests), and educating the public to be more tolerant of pests. Encouragement of naturally occurring biological controls can be very important; in some cases, barriers, traps, or mechanical removal can be effective. Develop a list of pesticides that are effective against each pest but are least disruptive to the environment—for instance, soap sprays, microbials, botanicals, oils, and synthetic pesticides with low LD-50 and short persistence. Investigate and document the potential for using low rates, spot treatments, and other selective ways to integrate pesticides into an IPM program that is least disruptive to biological control agents and nontarget organisms. For instance, using bait stations or other formulations that reduce exposure to humans or nontarget organisms is an important way to reduce potential risks.

6. Develop specific criteria for selection of pest management methods. Make the criteria known to employees and the public. Although all criteria may not be met in every case, choices should meet the majority of the following requirements:

- least disruptive of natural controls
- least hazardous to human health
- least toxic to nontarget organisms and least damaging to the general environment
- most likely to produce permanent reduction of the pest
- easiest to carry out effectively
- most cost-effective in the short- and long-term

For instance, avoid the common practice of regularly scheduled perimeter sprays to keep invading species such as ants, beetles, spiders, or earwigs out of buildings. This strategy does not provide a long-term solution to a problem and may kill beneficials and promote pesticide resistance. Structural changes, habitat reduction around buildings, and the use of baits can provide long-term control in many cases.

7. Develop guidelines to be followed each time a pesticide is used. Prepare a checklist to be used each time an application is made. Important items on the checklist should include:

- choosing the safest material that is effective
- considering label signal words, persistence, impact on nontargets, and potential chronic human health effects
- considering the potential for treating only the most seriously infested areas (i.e., spot treatments) to allow for survival of natural enemies (this works for some insects and mites only)
- making sure the pesticide is registered in California for the situation and that you are aware of all laws regarding its use
- if required, making sure you have in hand a written recommendation for using the pesticide made by a licensed pest control adviser
- checking the pesticide label to make sure all precautions and legal requirements are being carefully adhered to
- making sure all safety equipment and clothing are used
- verifying that the person doing the application is certified and qualified to handle the equipment and material chosen and that the person has been adequately trained
- after the application, monitoring the pest population to see if the treatment was effective
- keeping written records
- obtaining the Material Safety Data Sheet (MSDS) for the pesticide from the manufacturer
- making sure your application equipment is appropriate for the job and calibrated
- being prepared for all emergencies and knowing whom to call for help and interim measures to take before help arrives

8. Designate a person to be responsible for each step along the way. These are the people (e.g., job titles) who will be responsible for making decisions, carrying out the various pest management and emergency operations described in your policy, and regularly evaluating the effectiveness of the program.

9. Develop a list of resources. Know where you can go when information or outside help is needed. Include resources for pest identification, pesticide recommendations, and information about pesticides, pest management, and handling emergencies. Build a library and have employees participate in training and continuing education programs on a regular basis. (See the resources on p.11.)

10. Consider your IPM policy to be a "living document" that changes as you acquire experience and new information. Establish an oversight committee that includes persons with toxicological and pest management expertise to assist with initial review of procedures and future changes in the policy. Review the program regularly (e.g., annually). Involve environmental organizations, worker health advocates, and other interested members of the public or employee representatives from your facility in the development and revision of the IPM policy.

Outside Contractors

Some agencies have no staff or limited staff to devote to pest management activities. Some do not have staff with expertise or appropriate licenses to carry out certain pest management activities. In these cases, agencies will want to hire outside contractors for pest management services.

Contractors differ in their skills and experience, and it is important to hire a company that is reliable and knowledgeable about IPM practices and the goals of your IPM program. Performing appropriate preventive and monitoring activities may take extra time, so the lowest bidder may not always be the best company for your job. Be sure to specify needed IPM practices clearly in your contract and formalize a good communication system. Hire contractors who have appropriate pesticide application and pest control adviser licenses and training and who also have experience in IPM in situations such as yours. Ask them to provide you with their license number.

The first step in hiring a contractor is to prepare a request for qualifications (RFQ) that will allow you to prescreen and ensure that only qualified contractors submit proposals for the bid process. Next, prepare a request for proposals (RFP) that details the terms of your IPM policy. Evaluate the responses to the RFP according to the contractor's ability to meet the goals of your program. As part of the pest management contract, develop a quality assurance form (QAF). The QAF is filled out by the contractor each time a service is provided. It should detail information on pest sightings, sanitation and structural concerns, pesticides applied, traps or monitoring stations installed, pesticide use or other regulatory forms filed, and any additional pest management concerns.

BUILDING SUPPORT FOR YOUR IPM PROGRAM WITHIN AND OUTSIDE YOUR AGENCY

Once an IPM policy has been adopted by a city council, school board, or other policy-making body, it falls to agency staff or pest control contractors to implement the policy. Change never comes easily. There are a number of predictable obstacles within an agency—both psychological and institutional—to be overcome when initiating IPM programs. At the same time, even if the public has been involved with development of a policy, there are likely to be occasional complaints and controversies, especially as pests, pest control practices, and public concerns change.

Psychological Barriers to IPM Adoption

Psychological resistance to change

The problem: When pest control personnel are asked to make pest management decisions in a new way and to use new methods, they may feel that there is a negative implication regarding their past performance.

How to address it: Many factors contribute to the need to change pest management practices. Most of these factors are beyond the control of the individual pest manager. They include loss of effectiveness of many pesticides as pests develop genetic resistance; increased availability of less-toxic products or techniques; increased requirements for documentation, licensing, certification, and continuing education; and public concern about adverse health and environmental effects of pesticides. Adoption of IPM methods enables pest control professionals to respond to these forces for change and at the same time achieve cost-effective control of pests.

Loss of authority

The problem: Adopting an IPM approach may engender fear of many kinds of losses, including loss of personal authority or supervisory authority. In the first case, individuals may fear that their experience in the field will become devalued, particularly if their expertise has been in pesticide application. In the second case, supervisors may fear that the system will become more efficient and they will lose positions.

How to address it: Successful IPM implementation enhances both personal and supervisory authority. Many of the new, less-toxic pest control materials such as pheromones, microbial and botanical pesticides, insect growth regulators, and biological controls require application skills and equipment that are similar to conventional pesticides, and workers can readily learn necessary modifications to conventional practices. Mastery of IPM monitoring skills enhances the professionalization of pest management and can lead to upgrading job classifications. In terms of supervisory authority, IPM programs provide managers with greater decision-making responsibilities and an increase in the flexibility of staff assignments. For example, by emphasizing monitoring rather than prophylactic pesticide applications, staff time previously spent spraying can be redirected to other tasks, increasing overall productivity within a department.

Imagined difficulty in learning new technology

The problem: The techniques used in IPM may initially appear to require conceptual and operational skills beyond those of current staff.

How to address it: This fear can be overcome by building staff training into the IPM implementation program and by establishing a transition period during which pest management personnel experiment with and fine-tune IPM methods. Transition new practices in a step-by-step fashion so that not all changes are made at once.

Fear of IPM program failure

The problem: Supervisory personnel may believe that the IPM program will not work for them even though it has been successful for a nearby agency.

How to address it: IPM programs are specifically designed for the particular circumstances of each location, such as the plants and pests involved, microclimates at the site, and management history. While the IPM decision-making process remains the same no matter what the pest or site, the tactics and products used may vary greatly from one location or circumstance to another. This flexibility usually assures an appropriate solution to the pest problem.

Institutional Barriers to IPM Adoption

Fear that IPM means no access to pesticides

The problem: Some people think that IPM means never using chemical controls.

How to address it: While IPM definitely encourages alternatives to pesticides when feasible, chemical controls are used when necessary. However, in an IPM program, pesticides that are least disruptive, most selective to specific pests, and rapidly biodegradable are preferred over common, broad-spectrum materials. For instance, the microbial insecticide *Bacillus thuringiensis*, a naturally occurring bacteria that kills only certain groups of pest insects, is an example of the type of pesticide preferred for use in IPM programs. When chemical controls are used in an IPM program, every effort is made to reduce human and nontarget exposure, for instance, by putting materials in bait stations or within walls or by "spot-treating" specific areas rather than broadcast spraying.

Fear that IPM is more expensive than traditional pest control

The problem: Until agencies have experience with IPM, they may expect that it will cost more than their current program.

How to address it: While there are short-term start-up costs for any new technology, in the long run IPM has often proven to be more cost-effective than a strictly chemical control program. When possible, IPM programs substitute information gathering (monitoring) in place of other pest control activities. This can be very cost-effective. For example, by monitoring the 1,100 elm trees in their city rather than prophylactically spraying them against elm leaf beetles, the city of San Rafael, California, found that only a small portion of the trees required treatment. As a result, the city saved $1,400 (including costs of monitoring) in the first year of its IPM program compared to the previous year when all trees were sprayed.

Also, IPM methods emphasize reducing the source of pest problems (e.g., eliminating pest habitat and food sources) rather than treating the pests themselves (e.g., spraying). This type of pest prevention program is more cost-effective than a continuing program of pest reduction that does not address the underlying cause of the infestation. For example, by permanently reducing habitats for rats (i.e., by filling rat holes with concrete, changing the design of garbage cans, and increasing frequency of garbage pickup), the National Park Service was able to permanently reduce rat populations in certain parks. Previous rat control programs that had relied on poison baits had not been successful despite large expenditures of labor and money.

Lack of in-house IPM expertise

The problem: Agency staff may be unfamiliar with IPM and not know where to go for information.

How to address it: While it is true that IPM education and training resources are not as widely available as those for chemical controls alone, good resources can be found in any community. Many agencies have found it feasible to hire an IPM specialist to work as a consultant to in-house pest control staff during the initial year or two of IPM implementation, or to create an IPM coordinator position and recruit nationwide. Increasingly, cooperative extension advisors or agents, college horticultural or entomological faculty, pest control advisers, and a nationwide network of nonprofit organizations involved in pest management, sustainable agriculture, and environmental protection are able to provide IPM information and advice. Periodicals and Web sites providing practical technical advice on IPM methods for specific pest problems are increasingly available. The resources at the end of this publication will assist anyone attempting to implement IPM programs.

SOME FINAL HINTS FOR IMPLEMENTING AN IPM PROGRAM

The following suggestions will help overcome barriers and smooth the transition to IPM implementation.

Mandate staff training in IPM. When writing the IPM policy document, include a requirement for the continuing education of pest management personnel. Ensure that budgetary allocations are made to assist them in obtaining the information, skills, and equipment they need to carry out the policy.

Start small. Begin IPM implementation in one location (e.g., one lawn in one park; one kitchen in one school) and include short-term objectives. For example, when dealing with a number of pest problems, identify one of the pests likely to respond quickly to an IPM approach so that a short-term objective can be realized. Test the IPM methods and fine-tune them. When the program is working successfully in one area or against one pest, expand the program.

Don't change everything at once. To the maximum degree possible, retain communication and accountability procedures already in use. Tailor new recordkeeping and reporting forms to fit existing agency formats. Recycle existing equipment to uses consistent with IPM methods rather than immediately eliminating the equipment.

Share the process. Involve all pest management personnel in the day-to-day IPM program process as early as possible so that they will understand and support the program during the sometimes difficult transition period.

Emphasize communication and plan for future training. During the IPM transition period, keep all personnel informed about what is planned, what is happening now, the expected outcome, and what will happen next. Prepare written records and visual aids that will remain in the agency when persons associated with development of the IPM program are no longer there.

Build in a reward system. Identify benchmark objectives (e.g., testing of mechanical weed control methods in one park during a 3-month period or a 10 percent reduction in pesticide use in the first year). Encourage staff to achieve objectives (e.g., a letter of commendation from agency head, recognition at an awards ceremony, an article in an agency bulletin, merit pay increase).

Publicize the program. Develop good rapport with agency public relations personnel and with the local news media. Include field and management staff at photo and interview sessions about the IPM program.

Involve the community. Form an IPM advisory committee composed of interested organizations, members of the public, and pest control professionals. They can help make IPM implementation a budgetary priority in the agency, can donate or locate resources that may not otherwise be available to the agency, and may add needed expertise and experience to the process.

RESOURCES FOR AGENCIES DEVELOPING IPM POLICIES

General Information

In addition to the resources listed in this section, other agencies that deal with problems similar to yours, as well as pest management consultants, can be valuable sources of general information.

The University of California County Cooperative Extension offices are a valuable resource. In California, check your phone book under University of California or Cooperative Extension; or, see the University of California Agriculture and Natural Resources Web site, http://ucanr.org/.

Professional Organizations

- Association of Applied IPM Ecologists (AAIE) http://aaie.net/
- California Agricultural Production Consultants Association (CAPCA) http://www.capca.com/
- California Weed Science Society (CWSS) http://www.cwss.org/
- Pesticide Applicators Professional Association (PAPA) http://www.papaseminars.com/

Web Sites

The University of California Statewide IPM Program Web site at http://www.ipm.ucdavis.edu has information on managing and identifying pests of landscape, structures, agricultural crops, and pests of medical importance. There are links to pages related to pesticide toxicity, water quality, and other related resources.

The California Department of Pesticide Regulation IPM for Schools Web page at http://www.schoolipm.info/ has complete information on California's IPM in Schools Program as well as links to other information relating to managing pests in public buildings and landscapes.

The U.S. EPA Region 9 has an IPM manual for schools, *Integrated Pest Management for Schools: A How-to Manual* on its Web site http://www.epa.gov/region09/toxic/pest/school/. The manual includes appendixes that include IPM contract performance specifications and sample monitoring forms.

Many (but not all) pesticide Material Safety Data Sheets (MSDS) and labels are available at the Crop Data Management Systems Web site: http://www.cdms.net/manuf/manuf.asp

Other useful Web sites related to pesticides include:

- National Pesticide Information Center http://npic.orst.edu/links.htm
- Extoxnet (Extension Toxicology Network) http://ace.orst.edu/info/extoxnet/ghindex.html
- U.S. EPA Reregistration Fact Sheets http://www.epa.gov/pesticides/

Books and Other Literature

A free catalog is available from University of California Agriculture and Natural Resources Communication Services (6701 San Pablo Avenue, Oakland, CA 94608-1239; http://anrcatalog.ucdavis.edu; phone 1-800-994-8849/510-642-2431) that lists many publications of value in managing pests, including those listed below as University of California ANR publications.

Dreistadt, S. H. 1994. Pests of landscape trees and shrubs: An integrated pest management guide. University of California ANR Publication 3359.

Flint, M. L. 1998. Pests of the garden and small farm: A grower's guide to using less pesticides. 2nd ed. University of California ANR Publication 3332.

Flint, M. L., and P. Gouveia. 2001. IPM in practice: Principles and methods of integrated pest management. University of California ANR Publication 3418.

Mallis, A. 1997. Handbook of pest control. 8th ed. Cleveland, OH: Mallis Handbook and Technical Training Company.

Marer, P. J. 1991. Residential, industrial, and institutional pest control. University of California ANR Publication 3334.

O'Connor-Marer, P. J. 2001. The safe and effective use of pesticides. 2nd ed. University of California ANR Publication 3324.

Salmon, T. P., and R. E. Lickliter. 1984. Wildlife pest control around gardens and homes. University of California ANR Publication 21385.

Whitson, T. D., L. C. Burrill, S. A. Dewey, D. W. Cudney, B. E. Nelson, R. D. Lee, and R. Parker. 2001. Weeds of the west. 9th ed. Western Society of Weed Science. Available from UC ANR Communication Services as Publication 3350.

Zavala, M. 1991. The illustrated guide to pesticide safety/ Guía ilustrada para el uso seguro de pesticidas. Instructor's Edition. University of California ANR Publication 21489.

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Glossary

A

abdomen
The posterior body portion of an arthropod.

abiotic disorder
Disease caused by factors other than pathogens, such as inappropriate cultural practices or adverse environmental conditions including nutrient deficiencies and pesticide phytotoxicity.

acaricide
A pesticide for mites. Also called a miticide.

achene
A simple, one-seeded fruit in which the seed is attached to the ovary wall at only one point, such as the "seed" on the surface of a strawberry.

acid equivalent (a.e.)
The acid portion of an active ingredient. A measure of pesticide potency used for herbicides (e.g., glyphosate) for which the amount of active ingredient is not a good measure of the amount of weed-killing ingredients; because the pesticide is formulated varying ways (e.g., an amine, ester, or salt), the amount of active ingredient can differ without changing the amount of the weed-killing component (the acid portion of the pesticide).

action threshold
The point at which a given pest is numerous enough that a management action (usually a pesticide application) is necessary to prevent economic loss or unacceptable damage. May also be called *aesthetic threshold*, *economic threshold*, or *treatment threshold*.

active ingredient (a.i.)
The component of a pesticide formulation that affects or kills the target pest or performs the pesticide's function.

acute effect
An effect (e.g., illness or injury) that becomes apparent soon after an organism is exposed to the causal factor or substance, such as a pesticide.

adjuvant
A substance added to a pesticide to improve pesticide handling, performance, or safety, such as the mixing qualities or on-target coverage.

adventitious
Arising from an unusual place, as in the case of roots growing from leaves or stems ("*adventitious* roots").

aestivation
A state of inactivity of an animal during dry or hot periods, typically during summer months. Also called *estivation*.

aggregation pheromone
A *pheromone* that attracts individuals of a given species for mating, defense, or other purposes. Aggregation pheromones are sometimes used to monitor or manage insect pests.

agricultural commissioner
The official in each California county responsible for enforcing federal and state pesticide regulations and issuing permits for restricted-use pesticides.

albedo
The white, spongy inner part of citrus fruit rind.

alkaline
Basic, having a high pH or pH greater than 7.

allelopathy
The ability of a plant species to produce substances that are toxic to certain other plants.

allowable depletion
The proportion of available water in soil that can be used before irrigation is needed.

anemometer
An instrument for measuring wind speed.

annual
A plant that normally completes its life cycle of seed germination, vegetative growth, reproduction, and death in a single year.

antagonist
An organism that releases toxins or otherwise changes conditions in a way that reduces the activity or growth of other organisms (especially pests).

antenna (plural: antennae)
The paired, segmented, sensory organs on each side of the head of certain arthropods, such as insects.

anther
The pollen-producing organ of flowers.

anticoagulant
A substance commonly used in rodenticides that prevents blood clotting, resulting in internal hemorrhaging.

apical dominance
Growth of the bud at the apex of a stem or tuber while growth of all other buds on the stem or tuber is inhibited.

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apothecium (plural: apothecia)
Cup-shaped, spore-bearing structure produced by some fungi (e.g., *Sclerotinia* species) and lichens.

aquifer
An underground formation of gravel, porous rock, or sand that contains water (groundwater).

arthropod
An animal with jointed appendages and an external skeleton, such as a crab, insect, mite, or spider.

ascospore
A spore produced within the saclike cell of the sexual state of a fungus.

auricles
The earlike projections at the base of leaves of some grasses that may be used to identify grass species.

available water
The amount of water held in the soil that can be extracted by plants.

avicide
A pesticide for pest birds.

awn
A slender, bristlelike organ usually at the apex of a plant structure.

axil
The upper (narrow) angle between a branch or leaf stalk and the stem from which it is growing.

axillary bud
An undeveloped branch or flower (bud) located in an axil.

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B

Bt
Abbreviation for *Bacillus thuringiensis.*

Bacillus thuringiensis (Bt)
A group of bacteria that causes disease in certain insects. Formulations of several subspecies of *Bacillus thuringiensis* are used as insecticides, most commonly for caterpillars but for other pests as well (e.g., mosquito larvae).

bacterium (plural: bacteria)
A single-celled, microscopic organism that lacks a nucleus. Some bacteria cause animal or plant diseases.

bait station

A box or container designed to hold a mixture of attractive bait and pesticide to kill insects, rodents, or other pests and including baffles, small openings, or other design features to prevent access to the bait by nontarget animals.

band application
An application in which a material such as fertilizer or pesticide is applied in strips, usually to the planting bed or seed row.

basin
A portion of a crop field bounded by levees.

biennial
A plant that completes its life cycle in two years and usually does not flower until the second growing season.

binomial sampling or presence/absence sampling
A sampling or monitoring method that involves recording only the presence or absence of a given organism (e.g., an insect pest) on a sample unit (e.g., a leaf), rather than counting the number of individuals.

biodegradation
The breaking down of a substance (e.g., a pesticide) by organisms (commonly microorganisms) in the environment.

biofix
An identifiable event that signals when to begin *degree-day* accumulation.

biological control or biocontrol
The reduction of an organism's abundance or damage due to a *natural enemy*, such as a predator consuming (killing) prey. Biological control may occur naturally in the field or result from introduction or manipulation of natural enemies by people.

biotic disease
An unhealthy condition caused by a pathogen, such as a *bacterium*, *fungus*, *phytoplasma*, or *virus*.

biotype
A strain of a species that has certain biological characteristics distinguishing it from other individuals of that species. For example, certain populations of horseweed have genetic characters that make them resistant to the herbicide glyphosate; those are glyphosate-resistant biotypes.

blank
A nut with no kernel, which consists of only the collapsed pellicle (skin).

blanking
Producing no grain or seed (e.g., individual florets of the rice *panicle* may be *blanking*).

blight
A disease characterized by general and rapid death of plants or parts, such as branches, flowers, or leaves.

blind node

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The first node formed on a strawberry runner that usually does not form a *daughter plant*.

bolt
To initiate the growth of flower structures.

boot
A bulge in the upper leaf sheath caused by the expansion of the developing *panicle*.

Bordeaux mixture
A pesticide made of **a mixture of copper sulfate and hydrated lime** (http://www.ipm.ucanr.edu/PMG/PESTNOTES/pn7481.html) primarily used as a fungicide.

border harvesting
A harvesting method that leaves a strip of uncut hay along every other border. During the next harvest, these borders are mowed and the alternate borders are left standing.

borrow pits
Depressions on either side of a levee created when soil is removed from the field to build the levee.

botanical
Derived from plants or plant parts.

bract
A modified leaf at the base of a flower.

broad-spectrum pesticide
A pesticide that kills a wide variety of unrelated species.

broadcast application
The application of a substance (e.g., fertilizer or pesticide) to an entire area (e.g., field or orchard).

broadleaf
A flowering vascular plant (angiosperm) in the *dicot* group, characterized by leaves that are usually broader than needles or grass leaves, with a network of intersecting veins instead of parallel veins. Broadleaf plants include many herbaceous species and nonconiferous shrubs and trees.

bud
A small protrusion on the stem of a vascular plant that will later develop into a flower, leaf, or shoot. For example, a terminal bud is the primary growing point of a plant.

buffering capacity
The ability of soil or water to resist change in acidity (pH).

bulb
An underground storage organ of plants, composed chiefly of enlarged, fleshy leaf bases.

button
The circular, cupped portion of a fruit where the stem connects or was previously connected.

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C

calcareous soil
Soil containing a high proportion of calcium carbonate.

calibrate
To correct or standardize measuring devices. To properly adjust a sprayer's output.

calyx
An outer structure of a flower consisting of the sepals.

cambium
A thin layer of undifferentiated, actively dividing cells that produces new bark (*phloem*) on the outside and new wood (*xylem*) on the inside.

canker
A dead, discolored, often sunken area (*lesion*) on a branch, root, stem, or trunk.

canopy
The leafy parts of plants or the outer layer of leaves.

carcinogen
A substance or agent capable of causing cancer.

caterpillar
The immature stage (larva) of a butterfly or moth (Lepidoptera).

catfacing
Disfigurement or malformation of fruit, such as catfaced strawberries caused by lygus bug feeding or low temperatures.

catkin
A spikelike cluster of unisexual flowers, such as the male flowers of walnut.

cauda
An appendage resembling a tail on some insects (e.g., adult snakeflies) and other arthropods.

certified seed or planting stock
Seeds, tubers or young plants certified by a recognized authority to be free of specified pests or to contain less than a minimum number of specified pathogens or other pests.

certified transplants
Transplants (e.g., strawberry) that have received a certification tag from the California Department of Food and Agriculture. Production practices for these transplants must meet standards to be free of specified pests, such as viruses.

check
The part of a rice field between two levees.

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chilling
Exposure to temperatures low enough to induce biological processes that produce the consumed crop. Some crops must undergo specific chilling periods in order to produce vegetative growth or floral structures.

chlamydospore
A thick-walled *spore* formed from the cell of a fungal hypha.

chlorophyll
The green pigment of plants that captures the energy from sunlight, which is necessary for *photosynthesis*.

chlorosis
Bleaching or yellowing of normally green plant tissue.

chorion
The outer membrane of an insect egg.

chronic
Occurring frequently or over a long duration. Caused by frequent occurrence or long duration of a given condition (e.g., pesticide exposure and *chronic toxicity*).

chronic toxicity
The potential for a substance (e.g., a pesticide) to cause harm after multiple exposures (typically smaller amounts) over an extended period of time.

circulative virus
A virus that systemically infects its vector (e.g., an insect) and generally is transmitted for the remainder of the vector's life. Also called *persistent virus*.

cocoon
A sheath, such as a covering of silk, formed by an insect larva as a chamber for pupation.

cohort
A group consisting of individuals that all have a common characteristic, typically consisting of individuals who are the same age.

cole crop
A crop within the crucifer family (Brassicaceae) harvested for either its leaves or head. *Cole crops* typically refers to different subspecies of *Brassica oleracea* (including broccoli, Brussels sprouts, cabbage, and cauliflower). Other *Brassica,* such as *B. rapa* (bok choy, tatsoi, and turnip), may also be considered cole crops.

coleoptile
A sheathlike structure enclosing the young shoot tip of a grass seedling.

collar region
In grasses, the region where the leaf blade and sheath meet; used in identifying species. In shrubs and trees, the trunk area at the soil line.

companion planting

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The practice of planting certain plant species (e.g., herbs) in close association with other crop plants as an effort to repel pests or otherwise favor plant growth.

competitive exclusion agent
An organism capable of out competing other organisms to such an extent that it excludes the other organisms from the environment.

complete metamorphosis
A type of development in which there are four main life stages (egg, larva, pupa, and adult) and the larvae generally look distinctly different than the adults.

conidium (plural: conidia)
An asexual fungal spore formed by budding or fragmentation at the tip of a specialized hypha.

cornicle
One of two tubular structures projecting from the top rear of an aphid's abdomen.

cortex
The tissue between the *phloem* and the *epidermis* in roots and stems.

cotyledon
A leaf formed within the seed and present on a seedling at germination. Also called a *seed leaf*. Cotyledons typically have a different appearance than *true leaves*.

cover crops
Crops that are primarily grown to improve the production system for a primary crop. Examples include grasses or legumes maintained in orchards or vineyards and legumes or other crops grown during the winter season to improve soil conditions.

crawler
The mobile first instar of certain types of insects, such as mealybugs, scales, and whiteflies.

crochets
Tiny hooks on the *prolegs* of caterpillars.

crop rotation
The practice of purposefully alternating crop species grown on the same plot of land, typically to improve soil conditions or manage pests.

cross resistance
A condition in which a pest population that has developed *resistance* to one type or group of pesticides is also resistant to another type or group of pesticides, even in the absence of exposure to the latter pesticides.

crown
In trees or shrubs, may either mean the place where the main stem (trunk) and roots join at the soil line or the topmost limbs on a tree or shrub (the latter definition is commonly used in forestry). In strawberry, the shortened stem of a strawberry plant, from which fruit, leaves, and roots arise. The crown may also mean all the aboveground parts of the plant in some contexts.

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culm
The aboveground stem of grasses and sedges.

cultivar
An identifiable strain within a plant species that is specifically bred for particular properties; sometimes used synonymously with *variety*.

curing
Holding tubers under warm, humid conditions that favor wound healing. The process of drying a crop, such as to improve its storage.

cuticle
The outer protective covering of arthropods and plants, which helps prevent moisture loss.

cutout
In cotton, a period of reduced growth and square production following a fruiting cycle.

D

damping-off
Death of seedlings caused by one or more pathogens that weaken the stem or root.

daughter plants
Vegetative progeny of plants that reproduce via rhizomes, stolons, tubers, or other structures. In strawberry, daughter plants develop along the runners produced by the original strawberry plant (called the *mother plant*).

day-neutral
The term applied to cultivars, such as of strawberry, that produce flower buds more or less independently of day length.

degree-day (DD)
A unit combining temperature and time used in monitoring growth and development of organisms. May also be called a *heat unit.*

dehiscence
Opening naturally and regularly along lines of weakness. In fruits, opening along sutures to release seeds.

delayed dormancy
The period in tree fruit and nut crops that begins when buds begin to swell and continues until the beginning of green tip development or just before the emergence of new leaves.

determinate
Having stems and branches that stop growing at a certain point, usually after producing flowers. In cotton, this term is applied to varieties with a distinct interruption in growth following fruit set. In tomato, this term applies to varieties that grow into compact, bush-type forms and for which fruit ripens all at once.

developmental threshold

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The lowest temperature at which growth occurs in a given species.

diapause
A period of physiologically controlled dormancy or inactivity in insects or other invertebrates.

dicot
A plant that has two *cotyledons*, or embryonic leaves, which are the first leaves to appear from a germinating seed.

disease
An unhealthy condition (e.g., that caused by a pathogenic bacteria, fungus, or virus) that impairs the function or performance of an organism. In the case of crops, disease impairs a plant's economic value.

dormancy
A period of inactivity or slowed function, such as that seasonally or during periods of adverse environmental conditions. For many tree fruit and nut crops, dormancy occurs during the winter.

dough stage
A stage in grain (seed) development when the grain turns from a liquid to a soft doughy consistency before hardening.

drag off
The practice of removing soil from the tops of potato hills before sprout emergence.

drift
The aerial dispersal of a substance, such as a pesticide, beyond the intended application area.

dwarfing
Stunting of plant growth, such as smaller-than-normal leaves and stems.

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E

economic threshold
The point at which a pest has become numerous or damaging enough to require a management action (e.g., pesticide application) to prevent intolerable economic loss. The point at which the damage caused by a pest exceeds the cost of taking a management action to reduce the pest's abundance or subsequent damage. May also be called *action threshold* or *treatment threshold*.

ectoparasite
A parasite that lives on the outside of its host.

endoparasite
A parasite that lives inside its host.

endosperm
The tissue containing stored food in a seed that surrounds the embryo and is eventually digested by the embryo as it grows.

entomopathogenic nematodes
Nematodes that infect and, in combination with symbiotic bacteria, kill insects.

epicotyl
The part of an embryo or seedling above the attachment point of the *cotyledon(s)*.

epidermis
The outermost layer of living cells on the surface of an animal or plant.

estivation
A state of inactivity during the summer months or dry or hot weather. Also called *aestivation*.

evapotranspiration
The loss of soil moisture due to the combination of evaporation from the soil surface and transpiration by plants.

everbearing
In strawberries, producing flowers and fruit throughout year as long as temperatures are favorable.

exclusion
The act of keeping pests away from crops, structures, or other areas, commonly by using barriers such as fencing, row covers, or screens.

extrafloral nectary
A nectary located outside the flower.

eye
In potato, a collection of buds on the surface of the tuber that can sprout and form a new stem when conditions are favorable.

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F

fallow
Allowing cultivated land to lie dormant, with no crops growing on it, for an extended time period, such as during one growing season.

feeder roots
The youngest roots with root hairs, which are most important in the absorption of nutrients and water.

field capacity
The amount of moisture left in the soil after saturation and excess water has drained away via infiltration, percolation, and runoff.

flag leaf
The terminal leaf of a grass plant. The last emerging leaf below the grain head.

flavedo
Outer part of the rind of citrus fruit, bearing oil glands and pigments.

flight
The period of flying activity of moths or other adult insects of a given generation.

floret
In grasses, an individual flower in a grass spikelet. In head-forming cole crops, one of the flowering stems making up the head of broccoli or cabbage. In plants in the sunflower family (Asteraceae), one of the small flowers within the inflorescence.

flower bud
A bud in which flower parts are contained.

foliage
The leaves of a plant.

frass
The feces of insects.

fruiting bodies
In fungi, reproductive structures that produce *spores*.

fumigation
Treatment with a pesticide that either is a gas or becomes a gas after it is applied.

fungicide
A pesticide for fungi.

fungus (plural: fungi)
A multicellular organism (e.g., mildew, mold, rust, or smut) that lacks chlorophyll and derives its nutrients from other organisms. The fungal body generally consists of filamentous strands called mycelium.

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G

gall
Localized swelling or outgrowth of plant tissue, often formed by a plant in response to the action of an insect, pathogen, or other organism.

girdle (v.)
To damage or kill a ring of tissue around a root or stem in a way that interrupts the transport of nutrients and water and commonly results in the death of plant parts above or below the girdle or even the entire plant.

glume
Each of two membranous bracts (leaflike structures) below a grass spikelet or the single bract surrounding the florets of a sedge.

glycoalkaloid
A bitter-tasting plant compound that can be present at potentially toxic concentrations in the foliage of plants in the Solanaceae family and in the epidermis of potatoes.

gossypol
A substance poisonous to many animals, produced by numerous small glands in most cotton varieties.

graft union
Place where the rootstock joins the scion, or top part of grafted trees, shrubs, or vines.

ground cover
Any of various low- and dense-growing, spreading plants, such as ivy and pachysandra. Plants used for covering the ground, such as substitutes for turfgrass.

H

head
The inflorescence of certain plants, such as cole crops, grasses, small grains, and sunflowers.

heat unit
See *degree-day*.

herbicide
A pesticide for undesirable vegetation (weeds).

hibernaculum (plural: hibernacula)
A shelter occupied during the winter by a dormant insect, notably peach twig borer, or other animal.

honeydew
An excretion from insects, such as aphids, mealybugs, soft scales, and whiteflies, consisting of modified plant sap and composed mostly of sugars and water.

hormoligosis
An increase in the reproduction of an organism that can occur after sublethal exposure to certain pesticides.

horticultural oils
Highly refined petroleum (or seed-derived) oils that are manufactured specifically to manage (e.g., kill or repel) pests on plants.

host
An animal, plant, or other organism that provides sustenance for a parasite or pathogen.

host resistance
The ability of a host plant or animal to ward off or resist attack by pests or to be able to tolerate damage from pests.

hypha (plural: hyphae)
A filament that is the vegetative, structural unit (mycelium) of a *fungus*.

hypocotyl

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The portion of an embryo or seedling between the *cotyledons* and the developing root.
The stem of a germinating seedling.

I

immune
Unable to become diseased or infected by a given pathogen.

incomplete metamorphosis
A type of arthropod development that consists of three life stages (egg, nymph, and adult) and has nymphs that commonly resemble the adults.

incorporate
To move a substance, such as an herbicide or plant matter, into the soil, commonly by cultivation or irrigation.

indeterminate
Having a growth pattern in which stems continue growing indefinitely. For flower clusters, this term means that the lower flowers of the cluster open first, and the terminal ones open last.

indexing
Testing a plant for a pathogen infection (commonly viruses) by grafting tissue from it onto another plant (an indicator plant) that readily develops characteristic symptoms if the pathogen is present.

infection
The entry into a host and establishment of a pathogen.

infestation
The presence of pests in a field or other area or on a given host.

inflorescence
A flower cluster.

inner bark
In older trees, the living part of the bark; the *phloem*.

inoculum
Any part or stage of a pathogen that can infect a host, such as *spores* or *virus* particles.

inorganic
Containing no carbon. Generally used to describe substances (e.g., pesticides) that are of mineral origin.

instar
One of the larval or nymph stages of an immature insect between successive molts. For example, the first instar is between hatching and the first molt.

integrated pest management (IPM)
A **pest management strategy** (https://www2.ipm.ucanr.edu/What-is-IPM/) that focuses on long-term prevention or suppression of pests or their damage through a combination of

techniques, such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines if available, and treatments are made with the goal of removing only the target organism or preventing its damage. Pesticides are selected and applied in a manner that minimizes risks to human health, nontarget organisms, and the environment.

internode
The portion of a stem between two nodes.

invertebrate
An animal having no spine or internal skeleton, such as an earthworm or insect.

J

jointing
The elongation of rice internodes before flowering.

juvenile
An immature form of a nematode, insect, or other animal.

K

L

larva (plural: larvae)
The immature form of an insect that hatches from an egg, feeds, and then enters a pupal stage. The first-stage immature of mites is also called a larva, although mites do not develop a pupal stage.

label
The information and directions for use, storage, and disposal of a pesticide, typically found on a pesticide container. The pesticide label is a legal document that users must follow.

latent
Producing no visible symptoms (generally refers to an infection or a pathogen).

latent period
The time between when a vector acquires a pathogen and when the vector becomes able to transmit the pathogen to a new host. The time between infection of a host plant and production of inoculum by the pathogen.

layby application
An application, such as of fertilizer or herbicide, after the crop is well established. An application at the latest time in the season when it is still possible to pass through the field with a tractor.

leaching fraction
The proportion of applied irrigation water that is added to meet the crop's *leaching requirement*. A measure of the excess water that is applied during an irrigation event.

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leaching requirement
The amount of water in excess of a crop's evapotranspiration requirement that is needed to maintain maximum yield by moving (leaching) harmful salts down below the root zone.

leaf area index
A measure of how much foliage there is. The ratio between the total leaf surface area of a plant and the surface area of ground that is covered by the plant's leaves.

leaf margin
The outer edge of the leaf.

lenticels
Natural openings in the surface of a stem or tuber, which can open and close and allow gas exchange, similar to leaf stomata.

lepidopterous
Of or pertaining to butterflies and moths (order Lepidoptera).

lesion
Localized area of diseased or discolored tissue.

ligule
In many grasses, a short membranous projection on the inner side of the leaf blade at the junction where the leaf blade and leaf sheath meet.

locule
One of the seed chambers in a plant *ovary* or cotton boll.

lodging
The toppling of plants (e.g., a grain or leaves of a bulb crop) before harvest, which can be caused by rain, wildlife, or wind.

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M

mandibles
Jaws. The forward-most pair of mouthparts of an insect.

meconium
The fecal pellet excreted by a larva before pupation.

meristem
The collection of cells at a growing point of a plant that are capable of cell division.

metamorphosis
A change in form that takes place during development (typically for insects) from an immature to an adult.

microbial pesticides
Bacteria, fungi, viruses, or other microorganisms that are commercially produced to kill or otherwise reduce the abundance or damage of pests, such as invertebrates, plant pathogens, or weeds.

microorganism
An organism of microscopic size, such as a *bacterium, phytoplasma*, or *virus*.

micropropagation
Generation of new, disease-free plants from tiny pieces of *meristem* tissue.

microsclerotia (singular: microsclerotium)
Very small *sclerotia*, such as those produced by Verticillium wilt fungi.

milk stage
The early stage of grain development when the grain is filled with a milky liquid.

mineral oils
Highly refined petroleum (or seed-derived) oils that are manufactured specifically to manage (e.g., kill or repel) pests on plants. Synonymous with *horticultural oils*.

minituber
A small tuber produced under greenhouse conditions on a small potato plant generated by *micropropagation*.

miticide
A pesticide for mites. Also called acaricide.

molluscicide
A pesticide for pest mollusks, such as slugs and snails.

molt
In insects and other arthropods, the forming of a new cuticle (skin) that precedes shedding (ecdysis) of the old skin. Molting is a part of the process of development into a larger and older instar, or *metamorphosis* into the next life stage.

monitoring
Carefully gathering and recording information on the abundance, development, and growth of organisms (typically pests or crops) or other factors (e.g., crop damage), often utilizing very specific procedures and commonly on a regular basis over a period of time.

monocot
A plant that has one *cotyledon* when it germinates from the seed.

mulch
A layer of material placed on the soil surface to prevent weed growth and improve the health of a crop or other desirable plants.

mummy
An unharvested nut remaining on the tree. For aphids, psyllids, and some other insects, the crusty skin remaining after the inside of the insect has been consumed by a parasite.

mutation
A change in the genetic code of a cell or an organism. A change in the structure of a gene.

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mycelium (plural: mycelia)
The vegetative structure of a *fungus*, consisting of a mass of slender filaments called hyphae.

mycoplasma
A living organism smaller than a *bacterium* that has a unit membrane but no cell wall. The newer generally accepted term is *phytoplasma.*

mycorrhiza (plural: mycorrhizae)
A *fungus* that grows in a symbiotic association with the roots of a plant, generally in a way that is beneficial to the plant.

N

narrow-range oil
A highly refined petroleum or seed-derived oil that is manufactured specifically to manage (e.g., kill or repel) pests on plants. Also called horticultural, superior, or supreme oil.

natural enemy
An organism (e.g., a parasite, pathogen, or predator) that attacks and kills one or more pests. These organisms provide *biological control.*

necrosis
Death of tissue accompanied by dark discoloration.

nectary
A gland that secretes nectar.

nematicide
A pesticide for nematodes.

node
The slightly enlarged part of a stem where buds are formed and flowers, leaves, and stems originate.

nonpersistent virus
A virus that is carried on the mouthparts of its vector (e.g., an insect) and is lost after the vector feeds once or a few times. A stylet-borne virus.

nymph
The immature stage of insects (e.g., aphids and grasshoppers) that develop through *incomplete metamorphosis*. The juveniles that hatch from eggs and develop into adults through a series of molts without passing through a pupal stage.

O

organic
Relating to or derived from living matter (as in decaying plant material in a field). For substances (e.g., pesticides or decaying plant matter), this term also means that the substance contains carbon and hydrogen atoms. For agriculture (*organic* agriculture), *organic* describes a process in which animals or plants are raised or grown without the

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use of synthetic fertilizers, synthetic pesticides, or genetic engineering. For animals, *organic* means the animals are managed without antibiotics, added growth hormones, or animal products, as well as other specifications.

ovary
The portion of the flower that contains the ovules, which later develop into seeds. The ovary later matures into the fruit.

oviposit
To lay or deposit eggs.

oviposition
The act of laying or depositing of eggs.

ovisac
A capsule or covering that contains a group of eggs, excreted by the ovipositing female.

P

packing tissue
In walnut, the firm, membranous tissue lining the nut shell and separating the kernel halves.

panicle
A branching cluster of flowers held on a stem, such as the flowering parts of most grasses.

pappus
The modified calyx of flowers in the sunflower family (Asteraceae, formerly Compositae), which usually takes the form of awns, bristles, or scales.

parasite
An organism that derives its food from the body of another organism without killing the host directly. In integrated pest management, this term also encompasses *parasitoid*s.

parasitoid
An insect that spends its immature stages feeding on or inside of the body of a host insect, ultimately killing its host over the course of its development.

parthenogenesis
A form of asexual reproduction. Development of an egg without fertilization.

pathogen
A disease-causing organism.

peduncle
The stem of an individual flower or fruit.

pellicle
The covering (skin) that encloses the kernel.

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perennial
A plant that can live three or more years and flower at least twice.

periderm
Several layers of corky cells located on the outside of the epidermis of a potato tuber and containing high amounts of *suberin*.

perithecium (plural: perithecia)
A globular to flask-shaped fruiting body with an apical pore through which spores (ascospores) are released.

persistent virus
A virus that systemically infects its vector (e.g., an insect) and generally is transmitted for the remainder of the vector's life.

pest
An organism that interferes with the availability, quality, use, or value of a crop, other desirable plant, or managed environment or resource. An organism that creates a nuisance or otherwise is undesirable.

pest resurgence
The rapid rebound of pest abundance after the numbers were reduced by management action.

pesticide
Any substance or mixture intended for destroying, killing, preventing, or repelling a pest (including fungi, insects, nematodes, rodents, or weeds) or mitigating problems pests cause. Also includes any substance or mixture intended for use as a defoliant, desiccant, or plant growth regulator.

pesticide resistance
A result of genetic selection in which a pest population is able to survive or resist the effects of a pesticide or group of pesticides that formerly controlled the pest, ultimately resulting in the pesticide being less effective or no longer effective.

pesticide rotation
The practice of alternating pesticides of different modes of action in order to prevent the development of *pesticide resistance*.

petiole
The stalk connecting a leaf to a stem.

pH
A value used to express the relative acidity or alkalinity (basic) of a substance (e.g., soil or pesticide mixture). The hydrogen ion concentration of a substance as expressed in a negative logarithmic scale ranging from 0 to 14. Lower numbers indicate acidity; higher numbers indicate alkalinity.

phenoxy herbicides
A group of herbicides for broadleaf plants derived from phenoxy-acetic acid. These herbicides include 2,4-D; 2,4-DB; and MCPA.

pheromone

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A substance secreted by an organism to affect the behavior or development of other members of the same species. Pheromones used to monitor or manage insect pests include sex pheromones and aggregation pheromones.

phloem
The vascular tissue of a plant that transports sugars and other photosynthesis products from the leaves, such as downward to roots.

phloem-feeding
An organism that withdraws nutrients from the food-conducting tissue (*phloem*) of a plant's vascular system.

photosynthate
The products of *photosynthesis*, used to support plant fruit production, growth, and respiration.

photosynthesis
The process by which plants convert sunlight, carbon dioxide, and water into sugars and other compounds needed to support development, growth, and reproduction.

physiological disorder
An unhealthy condition caused by factors other than a pathogen. An *abiotic disorder*.

phytoplasma
A living organism smaller than a bacterium, formerly called mycoplasma or mycoplasma-like organism. Phytoplasmas have a unit membrane but no cell wall.

phytotoxic
Substances that are injurious to plants.

pistil
Female part of the flower, usually consisting of ovules, ovary, style, and stigma.

pollinator
An organism that transfers pollen, commonly bees and other insects.

pollenizer
A plant that provides pollen. The variety used as a source of pollen for cross-pollination.

pome fruit
A simple fleshy fruit that has a core of several small seeds surrounded by a thin, tough layer. Examples are apples and pears.

postemergence herbicide
An herbicide applied after weeds emerge.

predator
Any animal (including insects and mites) that attacks and kills other animals (prey) and then feeds on them, usually consuming many prey during its lifetime.

preemergence herbicide
An herbicide applied before weeds emerge.

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presence/absence sampling
A sampling or monitoring method that involves recording only the presence or absence of a given organism (e.g., an insect pest) on a sample unit (e.g., a leaf), rather than counting the numbers of individuals. Also called *binomial sampling*.

primary bloom
The first production of flowers on a potato plant, occurring after 8 to 12 leaves have been formed on the mainstem and generally coinciding with the beginning of the tuber growth phase.

primary inoculum
The initial source of a pathogen that starts disease development in a given location.

primary roots
The central, first-formed, or main roots of a plant. In strawberry, roots that develop from the crown of the plant.

proleg
A fleshy, unsegmented, leglike appendage on the abdomen of certain insect larvae (e.g., caterpillars and sawflies).

pronotum
A prominent, platelike structure that covers a portion or all of at least the upper surface (dorsum) of the first thoracic segment of an insect.

propagule
Any part of an organism from which a new organism can grow. For plants, this includes bulbs, seeds, and tubers. For fungi, this includes sclerotia and spores.

protectant fungicide
A fungicide that prevents a plant from being infected by a fungal pathogen. A fungicide that prevents the development of a fungal infection.

protective coverings
Any cloth, screen, plastic or other material placed over growing plants to prevent damage by pests or harsh weather.

prothorax
The first (front) segment of the insect *thorax*.

pupa (plural: pupae)
The nonfeeding, relatively inactive stage between larva and adult in insects that undergo *complete metamorphosis*.

pupate
To develop into a *pupa*.

pustule
A small, blisterlike elevation of epidermis from which spores emerge.

pycnidium (plural: pycnidia)

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A small, spherical or flask-shaped structure formed by certain types of fungi, inside which spores are produced.

Q

quadrant
One of four equal parts into which a field can be divided for monitoring.

quarantine
A period of enforced isolation and restricted movement that is imposed to prevent the spread of pests. The legal enforcement of measures aimed to prevent a pest from spreading or establishing in new areas.

R

random sample
A method of sampling in which the selection of the sample area is based on chance, and in which all parts of a given area have equal chance of being selected for sampling. Locations for samples are not predetermined either by previous sampling in that field, the relationship of one sample location to another, or other patterns.

rat-tail bloom
A secondary bloom in apples or pears that results when terminal buds form and open on the current season's growth.

receptacle
The apex of the flower stem that bears the organs of the flower.

regrowth bud
The buds on alfalfa crowns that become new stems.

reproductive bud
The buds on alfalfa stems that become flowers.

reservoir
The site where a pest can survive in the absence of a host crop, and that can facilitate an infestation in a crop.

residue management
Management (including incorporation and decomposition) of crop or weed matter that remains in the field or other area after harvest.

respiration
In cells, the process by which nutrients are metabolized to provide energy needed for cellular activity. In animals, the production of energy, typically with the intake of oxygen and the release of carbon dioxide from the digestion of complex organic substances.

rhizome
A horizontal, underground stem that forms roots at the nodes to produce new plants.

rogue

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To remove weeds or damaged crop plants.

rolling
Mechanical crushing of potato vines to hasten vine death, sometimes used synonymously with vine-killing.

rootstock
The lower portion of a graft that consists of the root system. The cultivar or variety used for that part of a graft.

rosette
A cluster of leaves arranged in a compact circular pattern, often on young plants, at a shoot tip, or on a shortened stem.

rosetted bloom
A flower with petals that have been tied together with silk by a pink bollworm larva.

rosetting
Abnormal growth caused by certain pathogens in which new foliage is stunted and tightly bunched.

row cover
Any fabric or covering placed over rows of plants to protect them from pest damage or harsh weather.

rugose
In leaves, rough in appearance with sunken veins and raised interveinal tissue. A rough appearance generally caused by virus infection.

ruminant
Any of the hoofed mammals (including cattle, deer, and sheep) that chew cud.

runner
In strawberry, a stolon from which a daughter plant may develop. In cucurbits, a vine.

russeting
In various crops (e.g., apples, pears, red potatoes, tomatoes), damage that consists of brown discoloration and rougher texture. In russet potato varieties, thickening of the *periderm* on tubers that occurs after vine senescence.

S

sanitation
Activity that reduces the spread of pathogen inoculum, especially the removal and destruction of infected plant parts and cleaning of equipment and tools. The practice of removing crop debris and weeds from growing areas.

scion
The portion of a graft that consists of the top part of the plant, such as the branches, trunk, and tree top. The cultivar or variety used for the top part of a graft.

sclerotium (plural: sclerotia)

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A compact mass of hardened *mycelia* that serves as a dormant stage in some fungi. A fungal survival structure.

secondary bloom
A second production of flowers on a potato plant that occurs at the end of the main stem of an indeterminate cultivar or at the leaf axils along the main stem of a determinate cultivar.

secondary infection
An additional infection facilitated or enabled either by a previous infection caused by another pathogen or a previous injury.

secondary pest outbreak
An increase in or infestation of a pest (the secondary pest) following a management action (generally a pesticide application) taken to control a different pest, caused either by the destruction of natural enemies that normally control the secondary pest or elimination of the secondary pest's competitors.

secondary roots
The network of fine roots that develops from the primary roots of a plant. Roots that branch off of one or more primary roots.

secondary spread
The spread of a pathogen within a field after the initial or primary infection.

sedge
A grasslike, herbaceous plant that, unlike grasses, has unjointed stems. Sedge stems are commonly solid and triangular in cross-section.

seed leaf
A leaf formed in a seed and present on a seedling at germination. Also called a *cotyledon*.

seed piece
Portion of a potato tuber containing at least one eye that is planted to produce a new potato plant.

seed cotton
Raw, harvested cotton that is still attached to seeds before ginning.

selective pesticide
A pesticide that is toxic to a relatively small number of species, including the target pest and closely related species.

self-fruitful
The ability to set fruit with pollen from the same flower or plant.

senescence
The condition or gradual process of deterioration with age.

sepal
One of the outermost structures of the flower that make up the calyx, commonly arranged in a whorl, which usually encloses the other flower parts.

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sequential sampling
A sampling method in which the number of samples is not fixed in advance; the number of samples taken depends on the results of the previously taken samples.

sessile
Permanently attached. Incapable of moving from place to place. On plants (e.g., flowers), attached directly at the base, not raised on a stalk or stem.

seta (plural: setae)
A bristle or hair.

sex pheromone
A substance secreted by an individual to attract individuals of the same species for mating. Sex pheromones are commonly emitted by female insects to attract males.

sheath
The part of a grass leaf that encloses the stem below the *collar region*.

short-day
In strawberry (a subset of *June-bearing* cultivars), requiring a period of time with day length shorter than a minimum (about 14 hours) to induce flower buds.

sidedressing
Fertilizer or other material added to the soil around a growing crop. The most common use is sidedressing nitrogen to induce nutrient uptake and rapid growth.

sieve tubes
The elongated living cells of the *phloem*, which are the conduits of sugars produced during *photosynthesis*.

sign
Physical evidence of a pest's presence that can be seen on a host or its surroundings. For example in plant pathogens, signs can include fruiting bodies and spores.

skeletonize
To remove leaf tissue between the veins, leaving the network of veins intact.

soil profile
The characteristics and differences of soil at different depths. The arrangement of soil into layers.

solarization
The practice of heating soil to levels lethal to pests using solar energy by laying clear plastic on soil surfaces for 4 to 6 weeks during warm, sunny weather.

sooty mold
Fungi that form a dark coating on foliage, fruit, or other surfaces on which *honeydew* has been deposited by *phloem*-sucking insects (e.g., aphids and whiteflies).

sp.
The abbreviation for a single species.

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species (abbreviation: sp. if singular, spp. if plural)
A group of individual organisms consisting of similar individuals that can interbreed in nature to produce fertile offspring.

specific gravity
The ratio of the density of a substance to the density of pure water. In potato, often used to quantify the dry matter content of potato tubers.

spike
An elongated, relatively tall inflorescence in which individual flowers are attached tightly against the main stem. Commonly the flower arrangement is unbranched and the newest flowers are at the tip.

spiracle
An external opening in the body of an insect or other arthropod that allows air to enter the respiratory system.

sporangium (plural: sporangia)
A structure in which asexual spores are contained.

spore
A reproductive structure produced by fungi and other organisms that develops into a new individual under proper conditions.

sporulation
The production of spores.

spp.
Abbreviation for multiple species.

sprout
A young, germinated seedling. A new stem formed from the eye of a potato tuber.

sprout inhibitor
A substance applied to potato vines or stored tubers to prevent sprouting.

spur
On fruit trees, a short, woody shoot on which flowers and fruit develop.

square
A cotton flower bud.

ssp.
Abbreviation for subspecies.

stamen
A male flower structure comprised of the pollen-bearing anther and a stalk or filament.

stand decline
The gradual (over a period of 3 to 5 years) debilitation of an alfalfa field due to the combined effects of pests and unfavorable environmental conditions.

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stele
The central cylinder inside the cortex of the roots and stems of vascular plants, which contains the conducting or vascular tissue.

stipe
A stalk or stem, especially of a fungus but may also pertain to plants.

stolon
A trailing, aboveground stem or shoot, often rooting at the nodes and forming new plants.

stoma (plural: stomata)
A natural opening in a leaf surface that allows for gas exchange and water evaporation and that opens or closes in response to environmental conditions.

stroma
A compact structure formed from fungal mycelium on the surface of a host, which generally is spore-producing.

stub cotton
A cotton crop in which the stalks are cut down after harvest, but the crown and rootstock are left in the ground to regrow the following season.

stylet-borne virus
A virus that is carried on the mouthparts of its insect vector and is lost after the vector feeds once or a few times. A *nonpersistent virus*.

suberin
A waxy substance that is resistant to microbial attack and is formed in the corky cells of *periderm* layers, such as in potatoes.

suberization
The formation of *periderm* layers on the cut surfaces or wounds (e.g., of potato tubers).

sucker
A shoot arising from the roots or lower part of the stem or trunk of a plant.

sun checking
Breaking or cracking of whole kernels of grain due to alternating conditions of dew, sun, and water stress.

suture
The visible seam on a nut hull.

symptom
An outward expression or change in appearance indicating that an organism is unhealthy. In plants, symptoms include chlorosis, necrosis, and wilting.

systemic
Capable of moving throughout a plant or other organism, usually via the vascular system.

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T

tailwater
Irrigation water that has drained from a field.

taproot
A large primary root that grows vertically downward, with small lateral roots growing from it.

target pest
The pest that a management action (e.g., a pesticide application) is intended to destroy or manage.

teliospore
A thick-walled, dark spore of rust and smut fungi that is able to survive adverse conditions.

tensiometer
A device for measuring soil moisture, such as that consisting of a buried tube of water that develops a partial vacuum as surrounding soil dries out.

terminal spikelet stage
The stage in the development of the wheat spike when the primordia (cells that will develop into florets or spikelets) of the terminal are formed.

thorax
The second of three major body divisions of an insect. The segments bearing the legs and wings (if present).

tiller
A stem or shoot of grass that grows after the initial shoot has grown from the seed.

tolerance
In pests, the ability to endure a pesticide without experiencing adverse effects. In crops, the ability of a plant to grow in spite of a pest infestation. In pesticide regulation, the maximum amount of pesticide residue that is permitted on a given agricultural product. In seed certification, the maximum percentage of the crop infested with a pathogen or other pest that is allowed during field inspections for certification of a seed lot.

top crop
Fruit produced in the second fruiting cycle of cotton, mainly on upper branches.

topwork
To change the cultivar of an established tree by pruning off part or all of the existing *scion* and subsequently budding or grafting a new *scion* onto either the rootstock or the remaining *scion*.

toxin
A poisonous substance produced by an organism, commonly through metabolic processes.

translocated pesticide

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A pesticide that is able to move throughout a plant, such as to roots after being applied to leaf surfaces. A *systemic* pesticide.

transpiration
The evaporation of water from plants, commonly through tiny leaf openings (*stomata*).

trap crop
A crop or portion of a crop intended to attract pests so they can be destroyed by treating a relatively small area or by destroying the trap crop and the pests together.

treatment threshold
The point at which a given pest is numerous enough that a management action (e.g., a pesticide application) is necessary to prevent economic loss or unacceptable damage. May also be called *action threshold* and *economic threshold*.

true leaf
Any leaf produced after the *cotyledons*.

tuber
An enlarged, fleshy, underground stem with buds capable of producing new plants.

tuberization
The formation of tubers at the ends of stolons. *Tuber* production.

U

urediospore
Spore produced by a rust fungus that can spread the fungus to infect other hosts.

V

variety
In plants, an identifiable variant or strain within a species, generally occurring naturally as opposed to a cultivar, which is specifically bred for particular properties. Sometimes used synonymously with *cultivar*.

vascular system
The system of plant tissues consisting of the *phloem* and *xylem* that transports nutrients, photosynthesis products, and water through the plant.

vascular tissue
Plant tissue that transports nutrients, photosynthesis products, and water throughout the plant.

vector
An organism that transports and transmits a pathogen to a host.

vegetative growth
The growth of leaves, roots, and stems. Does not include the growth of reproductive structures (e.g., flowers and fruits).

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véraison
In viticulture, the beginning of fruit ripening, characterized by the softening of the berries and beginning of pigmentation in black or red varieties.

vigor
Plant health or hardiness. The capacity of a plant to grow.

viroid
A tiny, infectious particle that is smaller than a virus, consisting of single-stranded, ribonucleic acid and not enclosed in a protein coat.

virulent
Capable of causing a severe disease. Strongly pathogenic.

virus
A tiny, infectious particle consisting of nucleic acid and a protein coat, which can reproduce only within the cells of a living host.

volunteer
A self-seeded, previously planted crop that has emerged at a time when it is not desired.

W

windowpane
A type of plant damage in which the epidermal (green) tissue is removed while the leaf cuticle is left intact, leaving small segments of clear tissue.

wing
An extension of the nut shell at the suture line.

X

xylem
The vascular tissue that transports nutrients and water from the roots upward through the plant.

Y

Z

zonate
Marked with zones or bands. Striped.

zoospore
A motile spore.

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A Few Entomological Terms Defined

Term	Definition	Applies to:
abdomen	The posterior and usually longest of the 3 principal body segments	General
anal lobe	Lobe in the posterior basal part of wing	Wing
anal vein	Longitudinal unbranched veins extending from base of wing to outer margin below the cubitus	Wing
antenna	Pair of segmented appendages located on the head above mouthparts, below and between eyes; plural = antennae	Head
antenodal crossvein	Small cross veins along the basal portion of the front edge of wings	Odonata
anterior	In front; before	General
arculus	Small crossvein near base of wing	Odonata
arista	Large bristle, usually dorsally located, on apical antennal segment	Diptera
aristate	Last segment enlarged and bearing a conspicuous dorsal bristle	Antennal forms
arolium	A cushion-like pad on the tarsi of many insects, one of the lobes of the pulvillus	General
arolium	The terminal pad between the claws	Orthoptera
auct., auctorum	Of authors	Latin Abbreviations
basitarsus	Basal (1st) segment of tarsus; segment connecting to tibia	Leg
beak	The jointed structure or rostrum covering the maxilla or trophi in Hemiptera	Hemiptera
book gills	Respiratory apparatus consisting of leaflike folds	Xiphosura (Horseshoe crab)
c., circa	About, near	Latin Abbreviations
calypter	One or two small lobes at base of wing, just above haltere	Diptera

Term	Definition	Applies to:
caudal	Refers to tip of abdomen, toward the tail, posterior end of body	General
cenchrus	Pl. cenchri; minute, often white marks or membranous spaces on the metanotum of some Hymenoptera	Hymenoptera
cercus	Segmented paired appendages located at tip of abdomen (plural = cerci)	General
cf., cfr.,	Compare	Latin Abbreviations
clavate	Clublike, enlarged at tip (e.g. clavate antennae)	General
clavus	Oblong or triangular anal portion of front wing	Hemiptera, Homoptera
claw	A hollow, sharp organ, generally paired, at the end of the insect leg	General
clubbed	Segments increasing in diameter distally	Antennal forms
clubbed - (capitate)	Terminal segments abruptly enlarged to form a club	Antennal forms
clubbed - (clavate)	Gradual increase in diameter of segments	Antennal forms
clubbed - (lamellate)	Terminal segments expanded laterally to form rounded or oval platelike lobes	Antennal forms
clypeus	Plate on face above mouthparts, between labrum and frons	Head
collophore	Tubelike sturcture located on ventral side of 1st abdominal segment	Collembola
compound eye	Composed of many elements or ommatidia	General
corbicula	A concave, smooth space, edged by a fringe of hairs arising from the margins of the posterior tibia in bees, forming pollen basket	Hymenoptera
corium	Elongate, usually thickened, basal portion of front wing	Hemiptera
cornicle	Tubelike structure located dorsally on abdomen	Aphids

Term	Definition	Applies to:
costa	Longitudinal wing vein, usually enlarged and along the leading (anterior) edge of the wing	Wing
coxa	Basal segment of leg (plural = coxae)	Leg
cubitus vein	The 5th longitudinal vein of the wing, extending from wing base and usually 2-branched before reaching outer wing margin	Wing
cuneus	Small triangular area at end of embolium of hemelytra	Hemiptera
distal	Near or toward the free end of any appendage; that part of segment farthest from the body	General
dorsum	Top surface of body	General
elytron	Thickened front pair of wings	Coleoptera, Dermaptera, Hemiptera
embolium	Narrow sclerite extending along anterior margin of hemelytra, from base to cuneus or membrane	Hemiptera
embolium	Narrow piece of corium, along costal margin	Hemiptera
empodium	Padlike or bristlelike structure at tip of last tarsal segment between claws	Diptera
epi-	Prefix, above	General
epimeron	Area of thoracic pleuron posterior to pleural suture	General
epiphysis	A lappet-like process covering an excavation on the foretibia of many Lepidoptera	Lepidoptera
epiproct	Supra-anal plate; pygidium	General
epistomal sulcus	The frontoclypeal furrow	Head
f., forma	Form, shape	Latin Abbreviations
femur	Large leg segment located near base of leg; the 3rd leg segment, located between trochanter and tibia	Leg
filiform	Threadlike, segments nearly uniform in diameter, elongate, usually cylindrical	Antennal forms
filiform	Threadlike, hairlike (see also antennae)	General

Term	Definition	Applies to:
flagellomere	Segment of flagellum	General
flagellum	Distal segments of antenna after pedicel	Antenna
fontanelle	Small, depressed pale spot on front of head between eyes	Isoptera
frenulum	Bristle or group of bristles at humeral angle of hind wing	Lepidoptera
frons	Front of head between epistomal suture and frontal sutures, includes median ocellus	Head
furcula	Forked springing apparatus	Collembola
gen. nov., g.n., genus novum	New genus	Latin Abbreviations
gena	Lateral portion of head below and behind eyes, the "cheek"	Head
geniculate	Elbowed; first segment long, following segments smaller, going off at an angle from the first	Antennal forms
genitalia	All of the genital structures collectively	General
haltere	Modified wing; usually a small knobbed structure on 3rd thoracic segment (Diptera) or modified front wing in Strepsiptera	Diptera, Strepsiptera
head	Most anterior body region; with eyes, antennae, mouthparts	General
hemelytron	Front pair of wings in Hemiptera, usually with a thickened basal region	Hemiptera
humeral angle	Basal anterior angle of or portion of the wing	General
humerus	Shoulder, anterior lateral angle of elytra	Coleoptera
hypognathous	With head and mouthparts located ventrally when viewed from above	Head
hypopleuron	Plate on thorax above hind coxae	Diptera
hypostoma	Portion of the head included between the antennae, eyes and mouth	Diptera
id., idem	The same	Latin Abbreviations

Term	Definition	Applies to:
in litt., in letteris	In correspondence or letter	Latin Abbreviations
jugum	Sclerite of the head	Hemiptera, Homoptera
jugum	Lobelike process at base of front wing, overlaps hind wing	Lepidoptera
labial	Referring to labium, mouthpart similar to lower lip of vertebrates	Head
labium	Mouthpart, lower lip	Head
labrum	Upper lip, below clypeus	Head
lamellate	Containing some enlarged, flattened segments	General
lateral	Relating, pertaining, or attached to the side	General
loc. cit., loco citato	Work cited (includes page references)	Latin Abbreviations
mandible	Jaw, anterior pair of mouthparts	Head
maxilla	Paired mouthparts posterior to mandibles	Head
media vein	Fourth of the longitudinal veins, extending from base through approx. middle of wing, not more than 4-branched	Wing
medial	Referring to, or at the middle	General
mesonotum	Dorsal portion of second thoracic segment	Thorax
mesopleuron	Lateral plate of mesonotum (dorsal region of second thoracic segment)	Thorax
moniliform	Like a string of beads	Antennal forms
moniliform	Beadlike, with rounded segment (see also antennae)	General
mystax	A patch of hair or bristles above the mouth, on the lower part of the hypostoma above the vibrissae	Diptera
n.g., nov. gen., novum genus	New genus	Latin Abbreviations
n.s., n.sp., nova species	New species	Latin Abbreviations
nasutiform	Head narrowing anteriorly into a snout-like projection	Isoptera
nodus	Strong cross vein near middle of costal border of wing	Odonata

Term	Definition	Applies to:
notopleuron	Area on thoracic dorsum, at lateral end of transverse suture	Diptera
occiput	That part of the head behind the vertex	Head
ocellus	A simple eye of insects or other arthropods; appearing to be small raised spots on top of head	Head
op. cit., op. c., opere citato	Work cited (not page reference)	Latin Abbreviations
palp	Small segmented appendages associated with mouthparts (maxillae or labium)	Head
paraproct	A pair of lobes bordering the anus laterally	General
parapsidae	Small sclerites on each side of the scutellum in Chalcids	Hymenoptera
parapsidal furrows	Longitudinal grooves on each side of the mesoscutum of Proctytrypiae separating the parapsides from the middle lobe	Hymenoptera
parapsidal grooves	Grooves or furrows on each side of the Chalcid scutellum	Hymenoptera
parapsides	Lateral pieces of meso-scutum, separated from mesal portion by parapsidal furrows	Hymenoptera
parapteron	Small sclerites, articulated to the dorsal extremity of the episternum, just below the wings; absent on thorax; = tegulae in Hymenoptera, patagia in Lepidoptera	General
pectinate	Comblike; most segments with long, slender processes	Antennal forms
pectinate	With branches like the teeth of a comb (see also antennae, claws)	General
pedicel	Second antennal segment	Antenna
pedicel	Stem of the abdomen, between thorax and gaster (ants)	Hymenoptera
pedicel	Greatly narrowed or restricted apparent 1st abdominal segment which connects the propodeum with the gaster in Hymenoptera	Hymenoptera

Term	Definition	Applies to:
pedunculated	Set on a stalk or peduncle; attached by a slender stalk or neck	General
petiole	Stalk or stemlike constriction of the abdomen to form attachment to thorax	Hymenoptera
pleural membrane	Membrane of the lateral pleurites	General
pleural suture	A suture on a thoracic pleuron extending from base of wing to base of coxa	General
pleuron	Lateral area of a thoracic segment	General
plumose	Feathery	Antennal forms
post-vertical bristles	In Diptera, in the middle of the upper part of the occiput	Diptera
posterior	Hinder, or hindmost; opposed to anterior	General
prepectus	Chitinized sclerite separating the pronotum from the tegulae	Hymenoptera
pretarsus	The terminal limb segment; in insects, comprising usually a pair of lateral claws and reduced median parts (arolium)	General
primaries	The anterior or forewings	Wing
pronotum	The dorsal section of prothorax; 1st segment of thorax	Thorax
propodeum	That part of thorax just above insertion of abdomen, really the first abdominal segment	Hymenoptera
propodium	Posterior portion of thorax, actaully the 1st abdominal segment united with thorax	Hymenoptera
prothorax	First or anterior thoracic segment	Thorax
proximal	That part of an appendage nearest the body	General
ptilinal	Refers to ptilinum, a bladderlike structure that everts from top of head during emergence of adult flies	Diptera
radius vein	Third of the longitudinal veins caudad of subcosta, starting from base, no more than 5 branches	Wing

Term	Definition	Applies to:
reticulate	Like a network, sculptured	General
s.l., s. lat., sens. lat., sensu lato	In a broad sense	Latin Abbreviations
s.s., s. str., sens. str., sensu stricto	In the strict sense	Latin Abbreviations
scape	Basal segment of antenna	Antenna
scutellum	A triangular plate on back between bases of wings	Coleoptera, Hemiptera, Homoptera
serrate	Sawlike, segments in distal half triangular in shape	Antennal forms
setaceous	Bristlelike, segments becoming more slender distally	Antennal forms
setaceous	Bristlelike (see also antennae)	General
sp. nov., sp. n., species nova	New species	Latin Abbreviations
sp., species,	Species, singular	Latin Abbreviations
spiracle	External opening of the breathing system, usually round or oval in shape	General
spp., species	Plural of species	Latin Abbreviations
spurious	False or incomplete	Diptera
spurious vein	Certain folds or thickenings in the wing surface which resemble a vein so nearly as to be readily mistaken for a vein	Diptera
squama	A small scale above the halteres in Diptera	Diptera
sterna	Plural of sternum	General
sternal	Referring to sternum or ventral regions	General
stigma	A dense, often discolored portion of the costal margin of a wing, usually at the end of the radius	Wing
stylate	Last segment bearing an elongate terminal fingerlike process	Antennal forms
stylus	Short, slender, fingerlike process	Thysanura
sub. gen.	Subgenus	Latin Abbreviations
subcosta vein	Generally unbranched, longitudinal vein extending parallel to the costa, reaching the outer margin before the costa	Wing

Term	Definition	Applies to:
subsp.	Subspecies	Latin Abbreviations
supr. cit., supra citato	Cited above	Latin Abbreviations
tarsal formula	Number of segments in pro-, meso-, and metatarsi (expressed as 5-5-5)	Coleoptera
tarsomere	Tarsal segment	General
tarsus	Distal or apical portion of leg, bearing claws (1-5 segments)	Leg
tegmen	Thickened or leathery front wing (plural = tegmina)	Orthoptera
tegula	Small scalelike structure overlapping base of front wing	Hymenoptera
tegulae	Small, more or less cup-like scales at the base of primaries in many insects, specifically Hymenoptera	Hymenoptera
tenaculum	Minute structure on ventral side of 3rd abdominal segment that serves as a clasp for furcula	Collembola
tergum	Plate on dorsal surface of abdomen	General
thorax	Second of 3 body regions, bearing legs and wings	General
tibia	4th segment of leg, between femur and tarsus	Leg
trachea	Tubular breathing system of insects, marked externally by a circular opening or spiracle	General
trochanter	2nd segment of leg, between coxa and femur	Leg
tympanum	Vibrating membrane; auditory membrane or eardrum	Orthoptera, Diptera, Coleoptera, Mantodea
ventral	Bottom surface of body	General
vertex	Top of head, anterior to occipital suture	General
vibrissae	Curved bristles or hairs in some Diptera, situated between the mystax and antennae	Diptera
wing pads	External expression of wing in immature insects, before eclosion	General