KNOWLEDGE EXPECTATIONS FOR PEST CONTROL ADVISERS:
INSECT, MITES AND OTHER INVERTEBRATES

I. IDENTIFICATION

A. Names of Arthropods & Related Organisms

Be prepared to identify the listed arthropods to class, order and family when given a name, specimen or photo of adult or immature forms. Know Latin names for class, order and a combination of common and Latin name for family. You will not be required to distinguish the difference between species in the same family. For example, you do not need to recognize differences between the pear rust mite and the tomato russet mite, but you do need to know that the pear rust mite and the citrus red mite are in different families.

1. For each arthropod class and family listed, describe their
   a. mouthparts and food habits;
   b. biology and life cycle;
   c. metamorphosis;
   d. significance as a pest, natural enemy, or pollinator;
   e. damage symptoms.

*Quarantine or invasive

PHYLUM MOLLUSCA

CLASS GASTROPODA

- brown garden snail
- gray garden slug
- decollate snail

PHYLUM ARTHROPODA

CLASS MALACOSTRACA

ORDER ISOPODA—sowbugs and pillbugs

CLASS CHILOPODA—centipedes

CLASS DIPLOPODA—millipedes

CLASS SYMPHYLA

ORDER SYMPHYLA—symphylans

- garden symphylan

CLASS PARAINSECTA

ORDER COLLEMBOLA—springtails

CLASS ARACHNIDA

ORDER ARANEAE—spiders

ORDER ACARI—mites

Family Eriophyiidae—eriophyiid mites

- pear rust mite
- tomato russet mite
- citrus bud mite
- peach silver mite

Family Phytoseiidae—phytoseiid predatory mites

- western predatory mite

- *Phytoseiulus persimilis*

Family Tetranychidae—spider mites
- citrus red mite
- European red mite
- Pacific spider mite
- twospotted spider mite

CLASS INSECTA

ORDER THYSANURA—bristletails/silverfish and firebrats

ORDER ORTHOPTERA

Family Acrididae—grasshoppers

Family Gryllidae—crickets

Family Tettigoniidae—katydids

ORDER DERMAPTERA—earwigs

ORDER MANTODEA

Family Mantidae—mantids

ORDER BLATTODEA

Family Blattidae—Oriental and American cockroaches

ORDER ISOPTERA—termites

ORDER HEMIPTERA

Family Anthocoridae—minute pirate bugs

Family Coreidae—leaffooted bugs
- squash bug

Family Lygaeidae
- bigeyed bugs
- false chinch bug

Family Miridae—plant bugs
- western tarnished plant bug (lygus bug)

Family Nabidae—damsel bugs

Family Pentatomidae—stink bugs
- consperse stink bug
- redshouldered stink bug
- green stink bug

Family Reduviidae—assassin bugs

Family Tingidae—lace bugs

Family Aleyrodidae
- greenhouse whitefly
- citrus whitefly
- sweetpotato whitefly
- giant whitefly

Family Aphididae
- cabbage aphid
- green peach aphid
- pea aphid
- cotton/melon aphid
- rosy apple aphid
- potato aphid

- lettuce root aphid
- woolly apple aphid
- spotted alfalfa aphid

Family Cercopidae—spittlebugs or froghoppers
Family Cicadellidae
- glassy-winged sharpshooter
- potato leafhopper
- beet leafhopper
- western grape leafhopper
- variegated leafhopper

Family Cicadidae—cicadas
Family Coccidae—soft scales
- brown soft scale
- black scale
- citricola scale

Family Diaspididae—armored scales
- oystershell scale
- California red scale
- San Jose scale
- walnut scale

Family Margarodidae
- cottony cushion scale

Family Membracidae—treehoppers
Family Phylloxeridae
- grape phylloxera

Family Pseudococcidae
- grape mealybug
- vine mealybug*
- citrus mealybug
- obscure mealybug

Family Psyllidae—jumping plantlice (psyllids)
- Asian citrus psyllid*
- pear psylla
- potato psyllid
- blue gum psyllid

ORDER THYSANOPTERA
Family Thripidae
- citrus thrips
- western flower thrips
- greenhouse thrips
- sixspotted thrips

ORDER NEUROPTERA—lacewings
Family Chrysopidae—green lacewings
Family Hemerobiidae—brown lacewings
ORDER COLEOPTERA—beetles and weevils
Family Buprestidae—metallic wood borers

- Pacific flatheaded borer

Family Cerambycidae—longhorned beetles
- eucalyptus longhorned borer

Family Chrysomelidae—leaf beetles
- elm leaf beetle
- asparagus beetle
- western spotted cucumber beetles
- tobacco flea beetle

Family Coccinellidae—ladybird beetles
- twicestabbed lady beetle
- mealybug destroyer
- convergent lady beetle
- vedalia beetle

Family Curculionidae—weevils and snout beetles
- Egyptian alfalfa weevil
- rice water weevil
- Diaprepes root weevil*

Family Elateridae—click beetles (wireworms)

Family Scarabaeidae—scarab beetles (May or June beetles)
- white grubs
- Japanese beetle*

Family Scolytidae—bark beetles
- western pine beetle
- fir engravers
- elm bark beetle
- shothole borer

Family Tenebrionidae—darkling beetles
- confused flour beetle

ORDER HYMENOPTERA—bees, wasps, ants, sawflies, parasitoids

Family Andrenidae—miner bees—pollinators

Family Aphelinidae—parasitoid wasps
- *Aphytis melinus*
- *Encarsia formosa*

Family Aphidiidae—parasitoid wasps
- *Trioxys pallidus*

Family Apidae—honey bees, bumble bees, squash bees, sunflower bees, digger bees, carpenter bees—pollinators

Family Braconidae—braconid wasps

Family Colletidae—polyester bees—pollinators

Family Formicidae
- Argentine ant
- red imported fire ant*
- southern fire ant
- carpenter ants

Family Halictidae—sweat bees and alkali bee—pollinators

Family Ichneumonidae—ichneumon wasps

- *Hyposoter* spp.

Family Megachilidae—mason bees, leaf-cutter bees—pollinators
Family Tenthredinidae—sawflies
- California pear sawfly

Family Trichogrammatidae—trichogrammatid wasps
Family Vespidae—paper wasps and yellowjackets

ORDER LEPIDOPTERA—butterflies and moths
Family Gelechiidae—gelechiid moths
- peach twig borer
- tomato pinworm
- pink bollworm
- potato tuberworm

Family Gracillariidae
- citrus leafminer
- citrus peelminer

Family Lymantridae—tussock moths
- gypsy moth*
- western tussock moth

Family Noctuidae—noctuid moths (cutworms)
- cabbage looper
- cutworms
- tobacco budworm
- alfalfa looper
- corn earworm/tomato fruitworm/cotton bollworm
- beet armyworm
- western yellowstriped armyworm

Family Pieridae—sulfur butterflies
- alfalfa caterpillar
- imported cabbageworm

Family Pyralidae—snout moths
- navel orangeworm

Family Sesiidae—clear-winged moths
- peachtree borer
- ash borer

Family Sphingidae—sphinx moths
- tobacco/tomato hornworm

Family Tortricidae—tortricid moths (leafrollers)
- codling moth
- oriental fruit moth
- fruittree leafroller
- omnivorous leafroller
- spruce budworm
- orange tortrix

ORDER DIPTERA
Family Agromyzidae
- serpentine leafminer (*Liriomyza* sp.)

Family Anthomyiidae—root maggot flies
- cabbage maggot
- seedcorn maggot

Family Cecidomyiidae—gall midges/predaceous midges
- Aphidoletes

Family Culicidae—mosquitoes
Family Muscidae—house fly
Family Syrphidae—syrphid or flower flies
Family Tachinidae—tachinid flies
Family Tephritidae—fruit flies
- apple maggot
- walnut husk fly
- Mediterranean fruit fly*
- olive fruit fly

*Quarantine or Invasive Species

B. Morphological characteristics of importance

1. List and describe the different types of mouthparts of insects.
2. List several insect orders that have
    a. chewing mouthparts;
    b. piercing-sucking mouthparts.
3. Describe how piercing-sucking mouthparts are different from chewing mouthparts.
4. List the main body regions of adult
    a. insects;
    b. spiders;
    c. mites.
5. Recognize the following body parts on various groups of insects:
    a. head;
    b. antenna;
    c. compound eye;
    d. ocellus;
    e. clypeus;
    f. mandibles;
    g. palps,
    h. labrum;
    i. prothorax;
    j. mesothorax;
    k. metathorax
    l. spiracle;
    m. forewings;
    n. hindwings;
    o. trochanter;
    p. coxa;
    q. femur;
    r. tibia;
    s. tarsus;

t. abdomen;
u. ovipositor.

6. Identify and give examples of the following larval body types:
    a. caterpillarlike (eruciform);
    b. grublike (scarabaeiform);
    c. maggotlike (vermiform).
7. Be able to identify and give insect examples with the following wing types:
    a. haltere
    b. tegmina
    c. hemelytra
    d. elytra
    e. scales

II. ARTHROPOD BIOLOGY

A. Physiology

1. List the major sections of the insect gut and name the basic functions of each.
2. Describe how respiration in insect larvae and adults takes place.
3. Describe the insect circulatory system.
4. Describe the insect nervous system and how nerve impulses travel down axons and across synapses. Describe a reflex reaction.
5. Describe the reproduction process most frequently observed in insects. (sexual reproduction)
6. Define parthenogenesis and give an example of an insect that reproduces by parthenogenesis.
7. List the exoskeleton's key functions.
8. Describe the molting process (apolysis and ecdysis) in arthropods.
9. Describe the functions of the following insect hormones:
    a. ecdysone;
    b. juvenile hormone.

B. Life History

1. Describe and give an example of insects
    a. without metamorphosis;
    b. with gradual/incomplete metamorphosis;
    c. with complete metamorphosis.
2. Compare nymphs vs. larvae.
3. Compare the life cycle and stages of mites and insects.
4. Define and give an example of
    a. aestivation;
    b. diapause.
5. Define
    a. allomones;
    b. degree-days;
    c. instar;
    d. invertebrate biofix date;
    e. pheromones;

f. semiochemicals.

6. List insects for which phenology (degree-day) models are useful in management programs, and describe how they are used.
7. Describe and give examples of two ways in which pheromones are used in an IPM program.
8. Define and give an example of a
    a. polyphagous insect;
    b. monophagous insect.
9. Describe the mechanisms of dispersal and movement used by various arthropod species.
10. List and give examples of the different ways that insects overwinter (stages and strategies).

III. ARTHROPOD ECOLOGY

A. Population Dynamics

1. Describe mortality factors and give examples of their impact on population dynamics.
2. List various factors that can limit insect
    a. development;
    b. reproduction.
3. Describe the role of nutrition on insect development.
4. Describe the role of temperature and humidity on insect development.
5. Describe how reproduction affects population growth and dynamics.
6. Define the term *carrying capacity*.
7. Explain population regulation.

B. Biotic Factors

1. Define
    a. trophic structure;
    b. host specificity.
2. Describe host range.
3. Describe the relationship of surrounding vegetation on pest populations.
4. Explain the importance of recognizing the different feeding habits in immature and adult stages and give examples.
5. Explain the role of alternate hosts in relation to
    a. pest problems;
    b. biological control;
    c. honey bees and native pollinators;
    d. virus vectors.
6. Describe the influence of nutrition on host quality.
7. Define and give an example of a
    a. parasite;
    b. parasitoid;
    c. predator;
    d. pathogen.
8. Explain the importance to biological control of knowing the

a. specificity of natural enemies;
b. broad host (prey) range of natural enemies.

C. Abiotic factors

1. Describe how the following abiotic factors can affect arthropod growth and development:
    a. water stress;
    b. nutrient availability;
    c. dust;
    d. weather;
    e. soil type.

IV. DAMAGE AND LOSS

A. Types of Damage

1. Compare the type of damage inflicted by insects with chewing mouthparts vs. piercing-sucking mouthparts.
2. Give some examples of arthropod species responsible for
    a. direct injury;
    b. indirect injury;
    c. damage that provides access for pathogen entry;
    d. damage as vectors of pathogens
    e. honeydew damage.
3. Describe the influence of the following factors on damage to the plant host and loss of economic or aesthetic value:
    a. plant compensation;
    b. pest stage;
    c. host stage;
    d. induced resistance;
    e. abiotic factors;
    f. natural enemies;
    g. relationship to plant pathogens;
    h. markets.

B. Injury Levels

1. Describe
    a. economic injury levels;
    b. aesthetic injury levels;
    c. treatment thresholds;
    d. economic thresholds.
2. Explain how economic injury levels are developed.
3. List various resources available to keep PCAs abreast of changes in injury levels.

C. Sampling and Monitoring

1. List three patterns of distribution common to insect populations.
2. Describe how to determine the sampling method from the insect distribution.
3. Explain how sampling statistics help to determine

a. sampling efficiency;
b. sampling accuracy.

4. Describe how the following factors influence choice of a sampling method:
    a. the pest species;
    b. the host;
    c. pest distribution patterns;
    d. the cost of sampling;
    e. crop value;
    f. sampling tool.
5. Compare the use of absolute and relative sampling techniques.
6. Describe
    a. presence–absence sampling;
    b. sequential sampling.
7. Identify the following sampling tools and give an example of an arthropod pest typically monitored using
    a. D-Vac vacuum devices;
    b. knockdown (beat sheet);
    c. leaf counts;
    d. light traps;
    e. non-pheromone sticky traps;
    f. pheromone traps;
    g. sweep net.
8. Describe and assess the value of clues such as plant damage, frass, and honeydew for indicating pest population presence and damage potential.

V. MANAGEMENT

A. General Approaches

1. Define and give an example of the appropriate use of the following pest management strategies:
    a. IPM;
    b. organic;
    c. quarantine;
    d. eradication/total population management.

B. Invasive Species

1. Define what an invasive species is, be able to list examples, and understand the types of effects they have. [An invasive species is non-native to the ecosystem and whose introduction is likely to cause human health, environmental, or economic, harm. Detrimental effects of invasive species include crop damage, vectoring of crop pathogens, disruption of cultural and management activities (e.g., ant mounds get in the way of tractors), interruptions of IPM programs (e.g., to control invasive need to apply a pesticide that disrupts biological control), export impacts such as quarantines or pesticide changes may affect maximum residue levels (MRLs).]
2. Know where to get current information about California's invasive species. [California Department of Food and Agriculture Invasive Pests and Diseases Web site: www.cdfa.ca.gov/invasives]

C. Host Plant Resistance

1. Define host plant resistance.
2. List examples of arthropod pests managed using host plant resistance.
3. Describe the use and give some examples of transgenic (genetically modified—GM) plants used for the control of arthropod pests.
4. Describe the limitations of transgenic plants in the management of arthropod pests.
5. Define biotypes and give an example of why they are problematic.

D. Biological Control

1. Define and give an example of
    a. classical biological control;
    b. conservation and enhancement biological control;
    c. augmentative biological control.
2. Identify common pest organisms attacked by the following natural enemies:
    a. convergent lady beetle;
    b. green lacewing;
    c. *Aphytis melinus*;
    d. *Hyposoter* spp.;
    e. syrphid fly larvae;
    f. assassin bugs;
    g. bigeyed bugs;
    h. *Trichogramma* spp.;
    i. mealybug destroyer;
    j. *Encarsia formosa*;
    k. western predatory mite;
    l. *Phytoseiulus persimilis*;
    m. vedalia beetle.
3. Compare the life cycle of a parasitoid vs. a predator.
4. Describe the following successful biological control introductions in California:
    a. vedalia beetle;
    b. *Trioxys pallidus* (walnut aphid parasite);
5. Understand the limitations of establishing a successful biological control agent and concerns about biological control introductions.
6. Describe how the following techniques can be used to conserve natural enemies:
    a. alternate hosts;
    b. ant control;
    c. border harvesting;
    d. selective pesticides;
    e. spot treatments with pesticides;
    f. strip cropping.

E. Cultural Control

1. Describe the following cultural control techniques and give an example of an arthropod pest that each aids in controlling:
    a. fruit removal;

b. plow down;
c. host-free period;
d. early harvest;
e. planting date;
f. water management;
g. fertilizer management.

F. Mechanical/Physical Control

1. Describe the use of the following mechanical/physical control techniques and give an example of a pest each method aids in controlling:
    a. sticky traps;
    b. mass trapping;
    c. flooding; [wireworm and garden symphylan]
    d. row covers; [leafminer and flea beetle]
    e. reflective mulches;
    f. greenhouse vent screening; [scale, whitefly, and leafminer]
    g. discing/cultivation.

G. Sterile Insect Techniques

1. Describe the basis for effective use of sterile insect techniques.
2. Give examples of successful sterile insect technique programs.

H. Pesticides

1. Define the following terms. Describe how they relate to the toxicity and effectiveness of insecticides and acaricides:
    a. hormoligosis or reproductive stimulant;
    b. mode of action;
    c. persistence;
    d. selectivity;
    e. synergism;
    f. uptake in plant (systemics).
2. Compare contact vs. ingested insecticides and acaricides.
3. Describe several nontarget hazards of insecticides/acaricides.
4. Define Toxicity Categories as they apply to insecticides and acaricides.
5. Describe various secondary effects associated with insecticide/acaricide use.
6. For the two groups of pesticides identify the:
    a. mechanism of toxicity on target organisms;
    b. impact on nontarget organisms including honey bees and native pollinators
    c. potential impact on humans;
    d. persistence and movement through the environment;
    e. effective period of action against the pest:
        i. organophosphates;
        ii. carbamates;
7. Identify the mechanism of toxicity on target organisms for pyrethroids, neonicotinoids, avermectins, insect growth regulators, botanicals, oils and soaps, inorganics, and fumigants.

8. Identify the impact of pyrethroids, neonicotinoids, avermectins, spinosyns, insect growth regulators, botanicals, and oils and soaps on nontarget organisms including honey bees and native pollinators.
9. Understand how the following techniques can be used to conserve honey bees and native pollinators:
    a. selective pesticides;
    b. spot treatments;
    c. applying pesticides when bees and pollinators are not foraging.

I. Pesticide Resistance

1. Define
    a. pesticide resistance;
    b. cross resistance.
2. List various factors that affect the rate at which pesticide resistance develops.
3. Describe the role of selection pressure in the development of pesticide resistance.
4. Describe the role of genetic variability in the development of pesticide resistance.
5. Describe ways to detect pesticide resistance in the field.
6. Understand ways to manage the development of resistance.

J. Application Methods

1. Explain the importance of coverage in a pesticide application and give some examples of how to achieve effective coverage.
2. Describe the importance of placement in pesticide applications and give some examples of different methods of placement.
3. Describe the following selective application methods and give an example of a pest situation in which each might be appropriately used:
    a. spot treatments;
    b. alternate rows;
    c. outside coverage; [pesticide application to the outside parts of the tree only—best for pests found on the tree's periphery]
    d. baits;
    e. band treatments.