2016

Entomology 101: Introduction to Entomology

Brian Kelly

ENTO 888 Masters Project Proposal

Goal of the Project

The goal of this particular project is to create an entry-level curriculum for Entomology to present to the local university / community college. My Bachelor's Degree was obtained from the University of Colorado at Colorado Springs (UCCS). The higher institutions of learning in the city of Colorado Springs (to include Pikes Peak Community College, or PPCC, as well) lack any courses relating to Entomology. UCCS has a strong presence in the city and is growing by leaps and bounds, currently enrolling about 13,000 students and expanding its degree programs. PPCC has several campuses around town, and offers many elective courses that cannot be taken at UCCS. I have always been interested in teaching and have been told by many people that I have a natural talent of explaining and teaching. Entomology 101 would be a perfect addition for an expanding university or for a community college offering various electives. This would also be a great way to start out in the teaching world and hopefully pursue my interests in being an instructor. By teaching an introductory class to Entomology, I can pique student interest in the topic and potentially help start a program at one of the sites.

Background Information

I have done no previous work in this area, but I am extremely excited at the possibility of creating a class to both teach and excite students about Entomology. Both UCCS and PPCC offer degrees in basic Biology, so this course would be a great elective in these programs. Insects are such a huge part of nature and the forces therein, so providing information about an essential piece of the environmental puzzle would be critical in their understanding and studies. Perhaps by offering this elective, some students might realize a passion they have for studying insects and might pursue a graduate degree in Entomology, much like I did 4 years ago.

What, How, When

For this project, I plan on creating a course and most of its components from scratch. I will first begin by defining my goals of what this course should be. The purpose of this Intro to Entomology for non-majors will be to provide a basic understanding of the main topics in this field (which will be outlined below), while creating interest and capturing their attention. With this goal defined, a proposed schedule of topics will be formed and a textbook will be chosen. Several textbooks will be perused (a couple encountered in my studies thus far, and several that I have not read) for the topics I wish to cover, and the one that best matches my goal will be chosen. I am ideally looking for a textbook that covers the major areas of this field with terms that are not too technical or difficult to understand, but one that provides sufficient information. Some courses roughly follow the topics found in the textbook, while others skip around or incorporate several books. For an Intro class, I would like to tailor the lectures to follow the content found in the book for a few reasons: 1) so that students will be able to clearly follow the material, 2) to encompass and include all types of learners in the classroom, 3) offer overviews or new perspectives to those found in the text, and to 4) provide the material in as many forms as possible to ensure a sound learning and understanding. Once the topics and text have been chosen, a schedule will be drawn up and will include assignments, papers, quizzes, and exams. If this proposal is approved, I would like to have the textbook picked out and read by mid-January, and the topic list done by end of January. Papers, assignments, quizzes, and exams would be done by March, and the syllabus drawn up and finished soon after that. I would like to submit the project for final approval by May so that any required changes can be made and re-submitted by June, in time for the summer graduation in August.

Outcomes

The outcome of this project will be a ready-to-go, Introduction to Entomology, course. It will contain a syllabus, calendar, textbook, topics, assignments, papers, quizzes, and exams. I hope to take this portfolio to the local university and present the staff with this course in hopes that I might get the opportunity to teach local students about insects. The program directors will be able to flip through the portfolio and browse the topics picked for the course. If I am thorough enough, and present a knowledgeable approach to a foundational topic of Biology, hopefully I can start pursuing a life-long dream of teaching Entomology at a higher level.

Syllabus: Entomology 101
Introduction to Entomology
Fall 2016

Instructor: Brian Kelly
Email: widowman10@yahoo.com
Cell: 719-648-7413 (call or text)
Work: 719-721-7190

Course Objectives

- Gain a basic understanding of insect biology, including: anatomy, physiology, and behavior
- Explore the development, history, and classification of insect orders
- Discover the importance of insects in medical, veterinary, and forensic applications
- Understand Integrated Pest Management (IPM) techniques and importance for the future

Textbook

- The textbook for this course will be:
  "The Insects: An Outline of Entomology" by Gullan and Cranston.
  4th edition. 2010. ISBN-13: 978-1444330366
  5th edition. 2014. ISBN-13: 978-1118846155
- It can be found in the bookstore, on Amazon.com, or other online retailers for a very reasonable price.
- http://www.amazon.com/The-Insects-An-Outline-Entomology/dp/1444330365
- http://www.amazon.com/Insects-Entomology-P-J-Gullan/dp/111884615X

Class Schedule

Week	Topic	Textbook	Assignment Due
1	Importance, Diversity, and Conservation of Insects	1	
2	External Anatomy and Structure	2	Homework 1
3	Internal Anatomy and Physiology	3	Quiz 1
4	Reproduction	5	Essay 1
5	Development and Life Histories	6	Homework 2
6	Biogeography and Evolution	8	Quiz 2
7	Ground-Dwelling and Aquatic Insects	9 & 10	Homework 3
8	Insects and Plants	11	Midterm Exam
9	***Spring/Fall Break!!***		
10	Insect Societies	12	Homework 4
11	Predation and Parasitism	13	Quiz 3
12	Insect Defense	14	Essay 2
13	Medical and Veterinary Entomology	15	Homework 5
14	Pest Management and IPM	16	Quiz 4
15	Collecting, Curating, Preserving, and Identification	17	Homework 6
16	***Finals Week***		Final Exam / Paper

Homework Assignments

There will be 6 homework assignments, each worth 20 points. These are not meant to be extremely time consuming, but rather to enforce certain concepts covered during lectures and enhance learning. The format will vary and each assignment will differ in feel and application. See the “Homework Assignments Handout” for specific requirements for each assignment.

Essay Requirements

Essay 1:
1-2 pages, double-spaced, size 12, Times New Roman, 1" margins.
Pick a major subsection of chapter 4 (Sensory Systems & Behavior) and summarize.

Essay 2:
2-3 pages, double-spaced, size 12, Times New Roman, 1" margins.
Pick a “Taxobox” from the back of the book, summarizing important aspects of a particular insect order interesting to you. Include the proper way to preserve specimens and any other facts or pieces of information that make the order unique or fascinating. If you incorporate information from other sources (online or other), be sure to cite it properly.

Paper Requirements

Guidelines: 4-5 pages, double-spaced, size 12, Times New Roman, 1" margins. Make sure all information is sourced correctly (either APA or MLA) with attention to grammar. At least 1 peer-reviewed article must be used and cited.

Topic: Pick something insect-related that is interesting to you. This can include: a particular insect, aspect of behavior, ecological concept, insect interaction, etc. If you have any questions or doubts, please feel free to ask.

Assignment: Find a peer-reviewed article (either with the use of Google scholar or the resources at the library) on a topic you find interesting. Summarize the article: (please keep it to a maximum of a couple of pages) including research performed, and any conclusions the authors reached. Critique the article: explain whether you agree or disagree with their approach, methods, research, or conclusions and support your position with evidence from another peer-reviewed article. Expand: be creative and come up with any potential ideas, areas, or experiments that could be explored further regarding this topic.

Quizzes

There will be 4 short quizzes, each worth 25 points. Quizzes will cover material recently discussed (within the last 2 or 3 weeks) and will generally be true/false and multiple choice.

Exams

There will be 2 Exams, each worth 100 points (a Mid-Term and a Final). The Mid-Term exam will cover the first half of the course, with material from weeks 1-8 and textbook chapters 1-11 (excluding 4 and 7). The Final exam will cover the second half of the course, and will include material from weeks 10-15 and textbook chapters 12-17. Exams will be closed-book and may include questions or concepts from the homework assignments and quizzes. There will be true/false, multiple choice, and short answer questions.

Grading

Assignment	Point Value (555 total)	Percentage of Grade
Exams (Mid-term/Final)	200 (2 x 100)	36%
Homework assignments	120 (6 x 20)	22%
Quizzes	100 (4 x 25)	18%
Term Paper	75	14%
Essays	60 (2 x 30)	11%
Extra Credit	20	---

A+	**98-100**	**4.0**
A	**93-97**	**4.0**
A-	**90-92**	**3.67**
B+	**87-89**	**3.33**
B	**83-86**	**3.0**
B-	**80-82**	**2.67**
C+	**77-79**	**2.33**
C	**73-76**	**2.0**
C-	**70-72**	**1.67**
D	**60-69**	**1.0**
F	**0-59**	**0**

Additional Information

Academic Dishonesty:

Students are expected to conduct themselves with honesty and integrity. Please review the student code of conduct HERE and PPCC's policy on academic honesty HERE.

Pledge of Instructional Standards:

Instructor will provide students a complete syllabus meeting all standards; our classes will be based on current science and will follow published schedules and descriptions; instructor will be timely in returning grades and in responding to students.

American Disabilities Act Compliance:

Students with disabilities are encouraged to contact the instructor for a confidential discussion of their individual needs for academic accommodation. It is the policy of Pikes Peak Community College to provide flexible and individualized accommodation to students with documented disabilities that may affect their ability to fully participate in course activities or to meet course requirements. To receive accommodation services, students must be registered with the Office of

Accommodative Services and Instructional Support (OASIS), room A209 at the Centennial Campus, 719-502-3333.

ENTOMOLOGY 101

Fall 2016

Instructor: Brian Kelly

Entomology Overview

- Topics
  - What is Entomology
  - Importance of insects
  - Biodiversity
  - Naming / Classification
  - Insects in popular culture
  - Insects as food
  - Conservation

What is 'Entomology'?

- Entomology is: the study of insects
- *Entomon* = insects (or segmented), *Logia* = study of

What is 'Entomology'?

- Entomologists study, collect, observe, rear, experiment
- They study the whole range of biological disciplines
  - ecology, behavior, anatomy, physiology, biochemistry, genetics
- Entomologists work with insects for many reasons:
  - ease of culturing, rapid life cycles and development, population turnover, availability of numerous individuals
- They are employed in a wide variety of careers, with many applications (not just Orkin!)

Entomological rodeos

What is 'Entomology'?

- Hobbyists can contribute greatly to the knowledge of entomology and biology
- BugGuide.net

Charles Darwin inspecting beetles collected during the voyage of the *Beagle*. (After various sources, especially Huxley & Kettlewell 1965 and Futuyma 1986.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

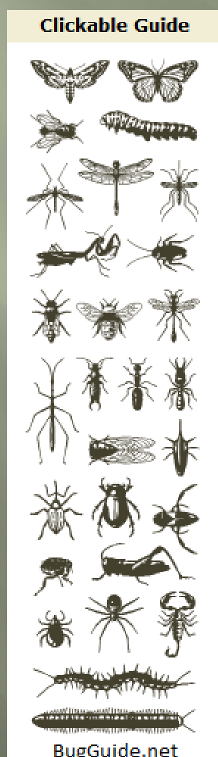
WILEY Blackwell

What is ‘Entomology’?

- Variations are astounding
  - Size-
    - Smallest insect:
      - Fairyfly - 1/8 of a mm
    - Largest insects:
      - Giant weta – weigh 70 grams
      - Titan beetle – 6.5″+ in length, powerful jaws
      - Hercules moth – 25cm wingspan
      - Meganeura (extinct) – 2.5′ wingspan!

What is 'Entomology'?

- Variations are astounding
  - Shape
  - Anatomy



Assorted Coleoptera in the University of Texas Insect Collection
Arrangement by Julia Suits; Photograph by Alex Wild
Public Domain image produced by the "Insects Unlocked" project at the University of Texas at Austin.

What is 'Entomology'?

- Variations are astounding
  - Coloration and patterning

The Importance of Insects

- Insect feeding groups are diverse and include:
  - Ingestion of detritus, rotting materials, living and dead wood, fungus, aquatic particles, herbivory, sap feeding, predation, and parasitism; non-feeding
- Inhabit all sorts of habitats:
  - Land, water, plants, animals, crude oil!
- Exhibit different lifestyles:
  - Solitary, gregarious, subsocial, highly social
- Found in various climates:
  - Hot, cold, wet, dry, windy, everything in between
- Insects can be found <u>everywhere</u>

The Importance of Insects

- Insects are essential to ecosystem functions:
  - Nutrient recycling in the form of leaf-litter and wood degradation, dispersal of fungi, disposal of animal carcasses, disposal of dung, soil turnover
  - Plant propagation: pollination and seed dispersal
  - Act as food for many vertebrates, such as birds, bats, mammals, reptiles, fish
  - Maintenance of community structure by the transmission of disease of large animals and predation of smaller ones

- "Keystone species"
  - A species that has a disproportionate effect on its environment relative to its abundance, often acting as ecosystem engineers, predators, or mutualists

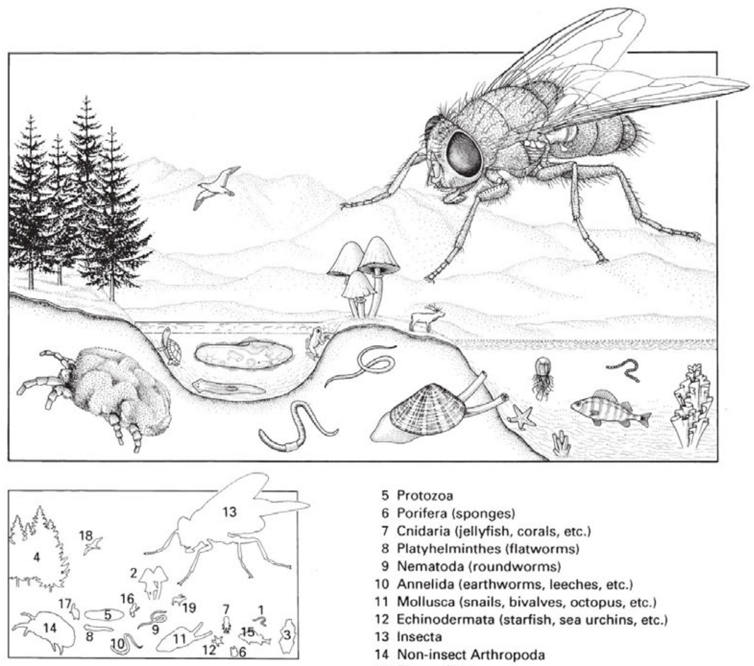
The Importance of Insects

- Benefits
  - Food
    - Honey bees provide honey, wax, and pollination at an estimated value of over $15 billion annually
    - Other insects account for over $5 billion in pollination
    - Valuable pest control by parasitism

  - Scientific Research
    - *Drosophila melanogaster*
  - Chemicals
    - Chitin (from the exoskeleton) used as a coagulant, healing agent, biodegradable plastics, pollution removal from water
    - Silk from silkworm moths used in fabric for centuries
    - Red dye from scales in food, red pens, and yes- lipstick

Biodiversity

- Across the different taxa of organisms



1 Prokaryotes
2 Fungi
3 Algae
4 Plantae (multicellular plants)
5 Protozoa
6 Porifera (sponges)
7 Cnidaria (jellyfish, corals, etc.)
8 Platyhelminthes (flatworms)
9 Nematoda (roundworms)
10 Annelida (earthworms, leeches, etc.)
11 Mollusca (snails, bivalves, octopus, etc.)
12 Echinodermata (starfish, sea urchins, etc.)
13 Insecta
14 Non-insect Arthropoda
15 Pisces (fish)
16 Amphibia (frogs, salamanders, etc.)
17 Reptilia (snakes, lizards, turtles)
18 Aves (birds)
19 Mammalia (mammals)

Fig. 1.1 Speciescape, in which the size of individual organisms is approximately proportional to the number of described species in the higher taxon that it represents. (After Wheeler 1990.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

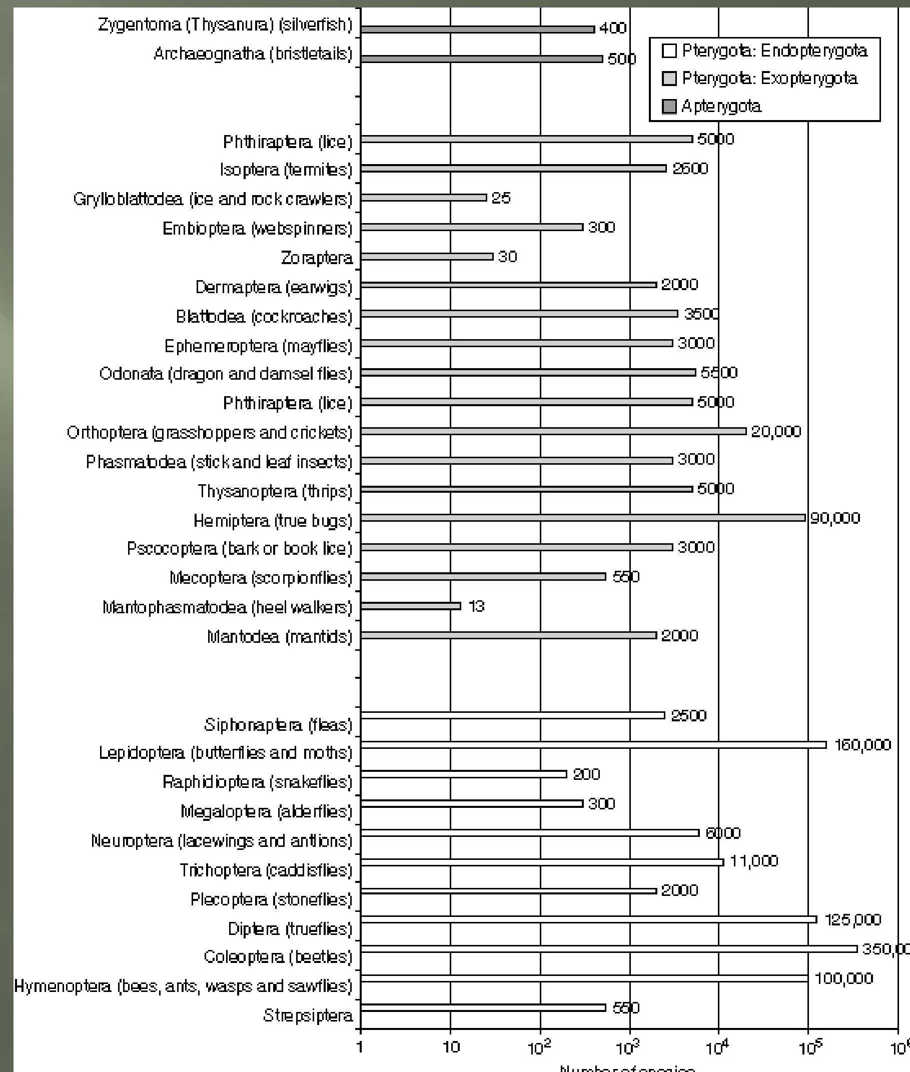
Companion Website: www.wiley.com/go/gullan/insects

WILEY Blackwell

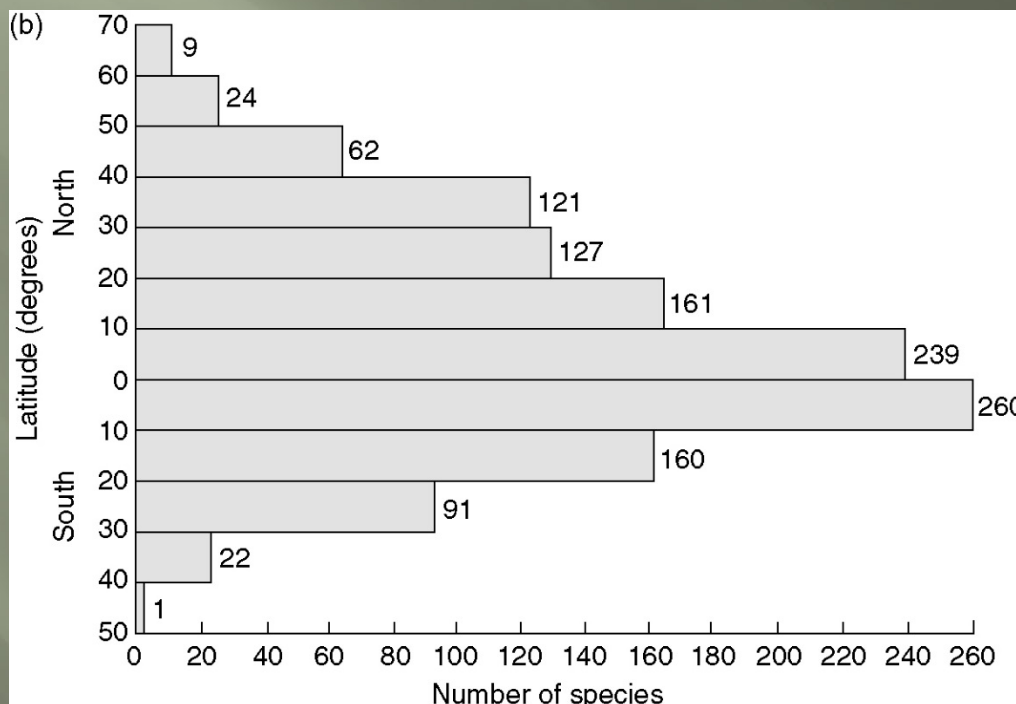
Biodiversity

- Real vs. Estimated

"Think about it, Ed.... The class Insecta contains 26 orders, almost 1,000 families, and over 750,000 described species — but I can't shake the feeling we're all just a bunch of bugs."



Biodiversity



Biodiversity

- Why so many?
  - Small size- exploit and occupy more niches; many utilize same resource
  - Genetic change between generations
  - Sexual selection

- Why so small?
  - Tracheal system limitations
  - Appearance of birds
  - Falling levels of O_2

Naming and Classification

- What's in a name?

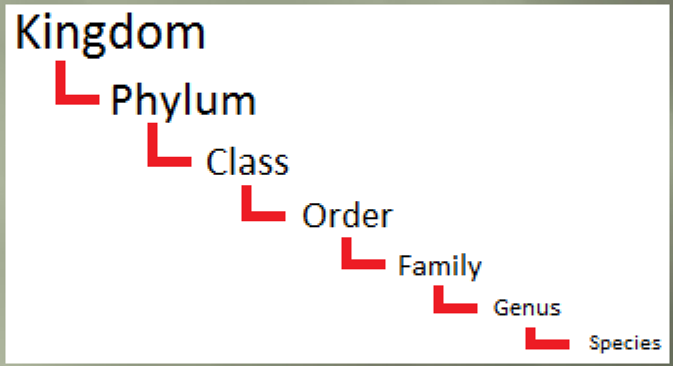


Table 1.1 Taxonomic categories (obligatory categories are shown in **bold**).

Taxon category	Standard suffix	Example
Order		Hymenoptera
Suborder		Apocrita
Superfamily	-oidea	Apoidea
Epifamily	-oidae	Apoidae
Family	-idae	Apidae
Subfamily	-inae	Apinae
Tribe	-ini	Apini
Genus		*Apis*
Subgenus		
Species		*A. mellifera*
Subspecies		*A. m. mellifera*

- Scientific names
  - Italicized, *Upper lower,* or underlined
  - Needed because of confusion
  - Example: *Dasymutilla occidentalis* -or- <u>Dasymutilla occidentalis</u>

- 'Lumpers' and 'Splitters'

Naming and Classification

- Species: *aegypti*
- Genus: *Aedes* – includes many other similar mosquitos
- Family: Culicidae – contains all of the mosquito species
- Order: Diptera – has common flies, crane flies, mosquitos, midges, fruit flies, gnats
- Class: Insecta – encompasses grasshoppers, bees, butterflies, beetles, etc.
- Phylum: Arthropoda – consists of spiders, crabs, centipedes, insects
- Kingdom: Animilia – tigers, dolphins, birds, insects, all other animals

Insects in Popular Culture

Insects in Popular Culture

- Ancient cultures
  - Egypt
    - Scarabs
  - China
    - Cicadas
  - Australia
    - Totems
  - Europe
    - Symbolism
  - Japan
    - Caged pets, and “Cri-Kee”

- Current cultures
  - USA
    - Butterfly farms and insect zoos, caddisfly jewelry, fashion shows
  - Japan
    - Video games, collections, ‘Beetlemania’
  - Malaysia
    - Praying mantises

Insects as Food

- Entomophagy: the practice of eating insects
- Prominent in: Africa, Asia, Australia, Latin America, and rising in other parts of the world
- Repugnance in the USA
- Taste: nutty, citrus
- Big Bang Theory

Insects as Food

- Values and benefits
  - Rich source of nutrients
  - Twice the protein of beef
  - Better animal feed for domesticated animals
  - Less environmental damage
  - Diet diversification

Nutritional Value of Various Insects per 100 grams

Data collected from *The Food Insects Newsletter*, July 1996 (Vol. 9, No. 2, ed. by , Montana State University) and *Bugs In the System*, by

Insect	Protein (g)	Fat (g)	Carbohydrate	Calcium (mg)	Iron (mg)
Giant Water Beetle	19.8	8.3	2.1	43.5	13.6
Red Ant	13.9	3.5	2.9	47.8	5.7
Silk Worm Pupae	9.6	5.6	2.3	41.7	1.8
Dung Beetle	17.2	4.3	.2	30.9	7.7
Cricket	12.9	5.5	5.1	75.8	9.5
Small Grasshopper	20.6	6.1	3.9	35.2	5.0
Large Grasshopper	14.3	3.3	2.2	27.5	3.0
June Beetle	13.4	1.4	2.9	22.6	6.0
Caterpillar	6.7	N/A	N/A	N/A	13.1
Termite	14.2	N/A	N/A	N/A	35.5
Weevil	6.7	N/A	N/A	N/A	13.1
Beef (Lean Ground)	27.4	N/A	N/A	N/A	3.5
Fish (Broiled Cod)	28.5	N/A	N/A	N/A	1.0

Insects as Food

- Examples
  - Central Africa
  - Philippines
  - Early North America
  - Australia

- Do not eat!
  - Distasteful or toxic
  - Allergies

Conservation

- Conservation can be difficult
- Typical programs
- ‘Flagship species’ and the ‘umbrella effect’
- Monarch Butterfly reserves

Conservation

- Cause of extinctions
  - Habitat loss
  - Fragmentation
- Program focus
  - Too many insect species
- CITES
  - Stands for: "Convention on International Trade in Endangered Species"
  - Ensures that trade of animals does not threaten their survival

Conservation

- Community benefits
  - Income for societies that struggle for cash
  - Leads locals to realize the importance of their habitat

- Success stories and examples
  - Lord Howe Island stick insect
  - New Zealand weta
  - Phengaris butterflies

Pictures by Slide

no modifications were made to any pictures on any of the slides

1. (no picture)
2. (no picture)
3. (no picture)
4. The Far Side Gallery 5 by Gary Larson, 1995, page 107
5. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Charles Darwin inspecting beetles, page 1
6. Weta and Titan Beetle
   - Flickr user: abodftyh: https://www.flickr.com/photos/117032936@N08/12796109234
   - https://commons.wikimedia.org/wiki/File:Titan_beetle_%28Titanus_giganteus%29_found_by_Jean_NICOLAS_%2810331669783%29.jpg
7. Diversity:
   - https://commons.wikimedia.org/wiki/File:Assorted_Coleoptera_in_the_University_of_Texas_Insect_Collection.jpg
   - BugGuide.net "Clickable Guide" (permission granted)
8. https://commons.wikimedia.org/wiki/File:A_butterfly_collection.jpg
9. (no pictures)
10. https://commons.wikimedia.org/wiki/File:Cathedral_Termite_Mound_-_brewbooks.jpg
11. https://commons.wikimedia.org/wiki/File:Pollinationn.jpg
12. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 1.1
13. Biodiversity
    1. The Far Side Gallery 3 by Gary Larson, 1988, page 123
    2. Wiley Blackwell: The Ecology of Insects: Concepts and Applications, 2nd edition – Figure 1.5
14. Wiley Blackwell: The Ecology of Insects: Concepts and Applications, 2nd edition – Figure 9.8b
15. https://commons.wikimedia.org/wiki/File:Tarantula_1955.jpg
16. Naming:
    - (my drawing)
    - Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Table 1.1
17. http://www.freestockphotos.biz/stockphoto/16744
18. https://en.wikipedia.org/wiki/File:Comic-Con_Ant-Man_Poster.jpg
19. https://commons.wikimedia.org/wiki/File:Egyptian_-_Scarab_of_Hatshepsut_-_Walters_4260_-_Top.jpg
20. https://commons.wikimedia.org/wiki/File:Insect_food_stall.JPG
21. ***The Food Insects Newsletter, July 1996 (Vol. 9, No. 2, ed. by University) and Bugs in the System
22. https://commons.wikimedia.org/wiki/File:Monarch_In_May.jpg
23. https://commons.wikimedia.org/wiki/File:Monarch-butterflies-pacific-grove.jpg
24. https://commons.wikimedia.org/wiki/File:Indiana_Dunes_Habitat_Fragmentation.jpg
25. https://commons.wikimedia.org/wiki/File:Lord_Howe_Island_stick_insect_Dryococelus_australis_10June2011_PalmNursery.jpg

Questions?

Permission

Widowman10 <bkspiderman@gmail.com> Jan 11 (11 days ago)

to John

Thank you sir!! I (and hopefully my students!) appreciate it very much.

...

On Mon, Jan 11, 2016 at 4:19 PM, VanDyk, John K [ENT] <jvandyk@iastate.edu> wrote:

> Go right ahead!
>
> John
>
> > On Jan 11, 2016, at 4:26 PM, Widowman10 <bkspiderman@gmail.com> wrote:
> >
> > Hey John, I'm teaching an Intro to Entomology at a local university here in Colorado Springs. I was wondering if I could use a snapshot of the "Clickable Guide" for a powerpoint presentation, assuming of course I credit BugGuide?

ENTOMOLOGY 101

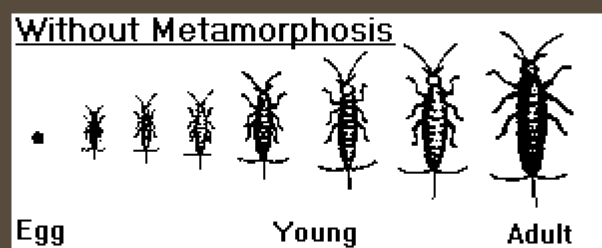
External Anatomy

External Anatomy

- Topics
  - Cuticle
  - Segmentation
  - Head
  - Thorax
  - Abdomen

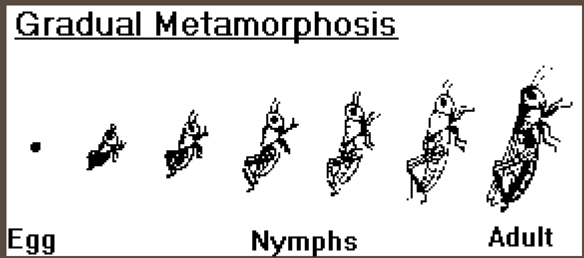
External Anatomy

- Types of Metamorphosis - Ametabolous
  - aka “no metamorphosis”
  - Only difference between the immature and adult is the maturation of sex organs
  - Example: Silverfish



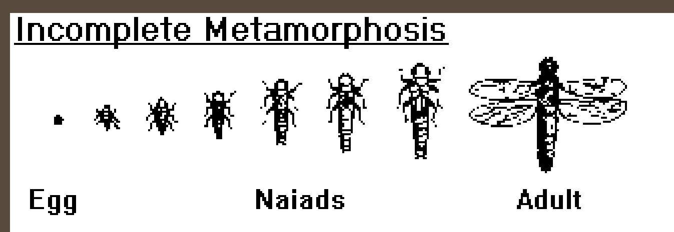
External Anatomy

- Types of Metamorphosis - Paurometabolous
  - aka “gradual metamorphosis”
  - Nymphs resemble the adults except for body proportions
  - Example: Grasshoppers, Milkweed bugs



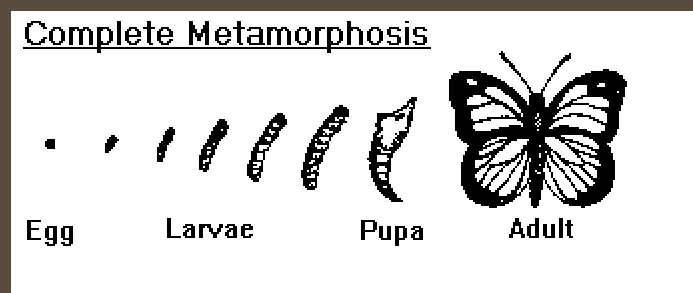
External Anatomy

- Types of Metamorphosis - Hemimetabolous
  - aka “incomplete metamorphosis”
  - Naiad very different from adult in appearance and behavior
  - All are aquatic
  - Example: Dragonflies, Mayflies



External Anatomy

- Types of Metamorphosis - Holometabolous
  - aka “complete metamorphosis”
  - Classic or ‘standard’ insect development, found in many orders
  - Example: Butterflies, Beetles, Flies, Bees

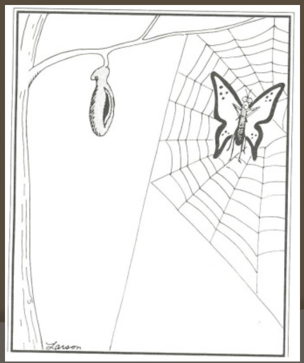


The Cuticle

- Much like skin and bones, all in one
- Key contributor to the success of insects
  - Protects against water loss / dessication
  - Acts as a barrier to keep water out
  - Repels pathogens and other disease-causing agents
  - Surface for muscle attachment
  - Sensory interface with the environment

The Cuticle

- Molting, or "Ecdysis"



The Cuticle

- Forms:

- Structure & Function of the various layers of the cuticle:

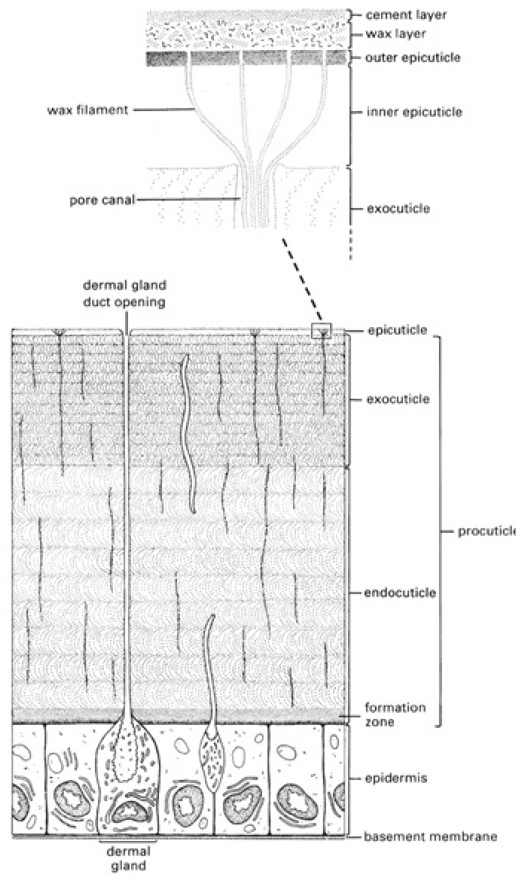


Fig. 2.1 The general structure of insect cuticle; the enlargement above shows details of the epicuticle. (After Hepburn 1985; Hadley 1986; Binnington 1993.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

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The Cuticle

- Chitin
  - Key supporting element in exoskeletons and extracellular structures
  - Gives the cuticle rigidity and strength
  - One of the most important biopolymers in nature
  - Mainly produced by fungi, arthropods, and nematodes
- Arthrodial membrane
  - Up to 20-fold expansion

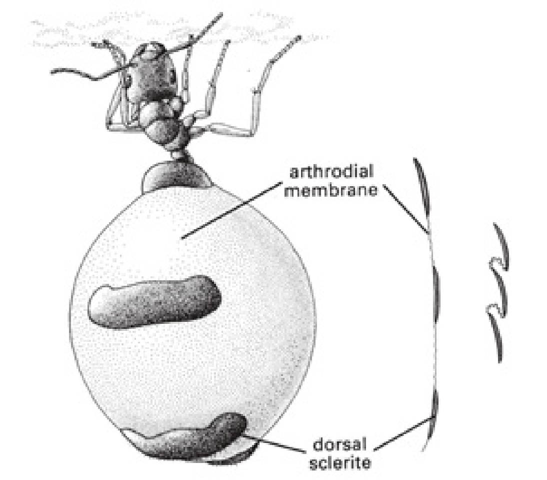
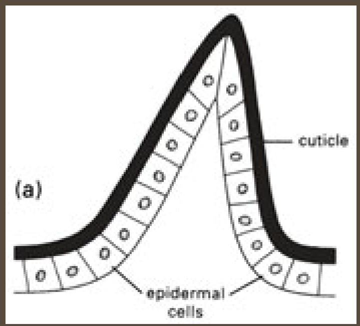


Fig. 2.4 A specialized worker, or replete, of the honeypot ant, *Camponotus inflatus* (Hymenoptera: Formicidae), which holds honey in its distensible abdomen and acts as a food store for the colony. The arthrodial membrane between tergal plates is depicted to the right in its unfolded and folded conditions. (After Hadley 1986; Devitt 1989.)

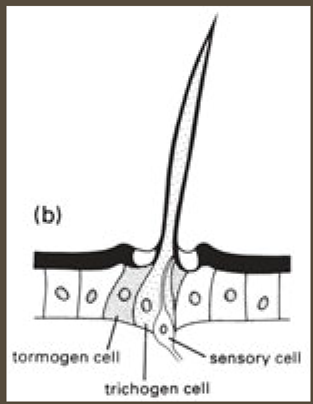
The Cuticle

- Cuticular extensions – Spines



The Cuticle

- Cuticular extensions – Setae
- Help the insect sense:
  - Sound
  - Touch
  - Humidity
  - Light
  - Wind direction
- Cockroaches



The Cuticle

- Cuticular extensions – Setae

The Cuticle

- Colors - Produced by different means (or a combination)
  - Physical: scattering, interference, diffraction
  - Chemical: by pigments in three ways
    - Insect's metabolism
    - Sequestration from plant source
    - Microbial endosymbionts

  - “Blue Moon Cicada”
    - Insectoverdin: green pigment produced by mixture of tetrapyrrole (blue) and carotenoid (yellow) compounds. If carotenoids are missing, blue cicadas occur

Segmentation & Tagmosis

- 3 distinct regions:
  - Head
    - Composed of 6 segments
    - Fused into rigid capsule
  - Thorax
    - Composed of 3 segments
    - Contains attachment sites for leg / wing muscles
  - Abdomen
    - Composed of 11 segments
    - Typically not rigid, somewhat flexible or soft

Segmentation & Tagmosis

- Bilateral symmetry
- Orientation

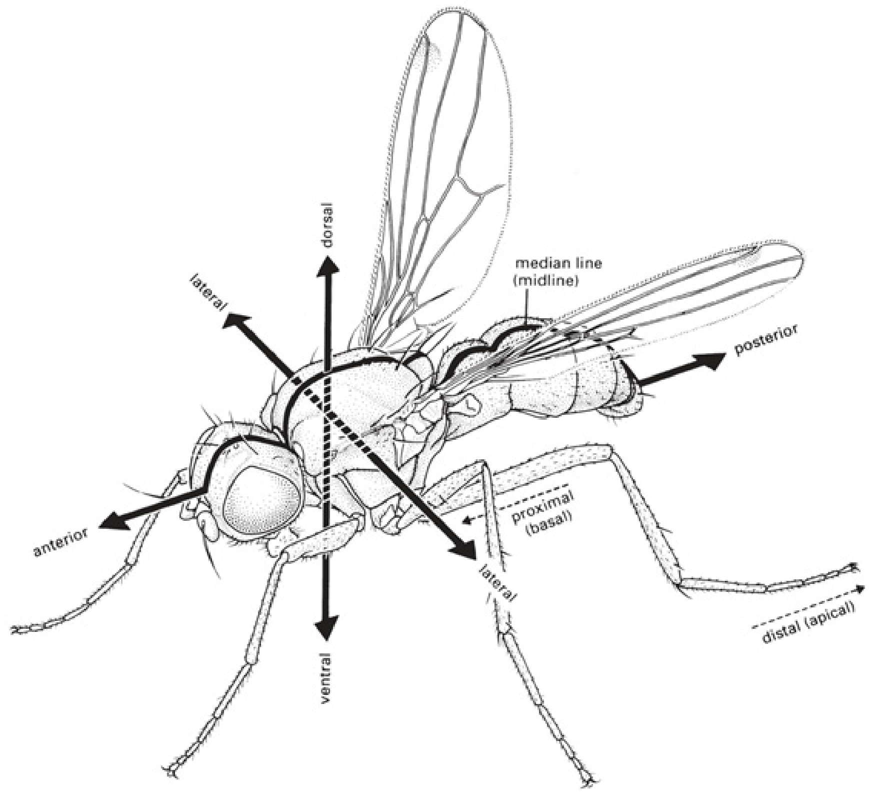


Fig. 2.8 The major body axes and the relationship of parts of the appendages to the body, shown for a sepsid fly. (After McAlpine 1987.)

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The Head

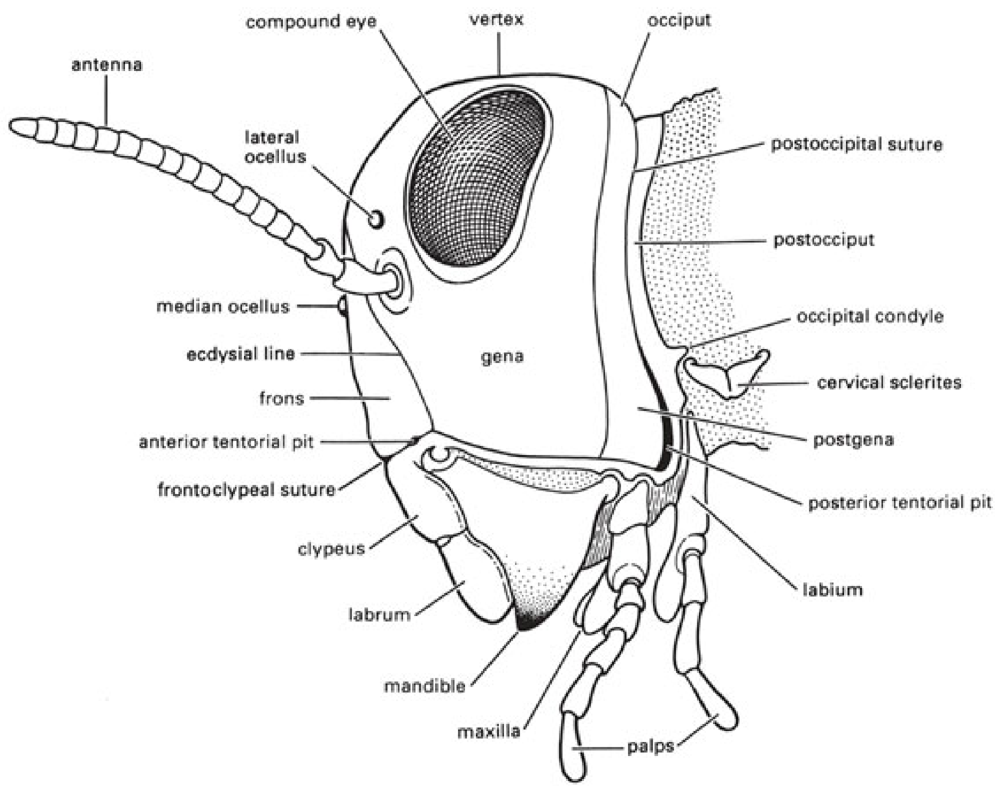

Fig. 2.9 Lateral view of the head of a generalized pterygote insect. (After Snodgrass 1935.)
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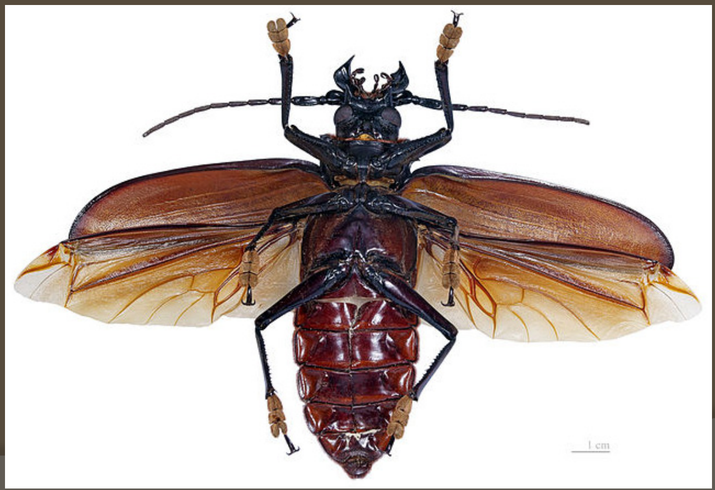
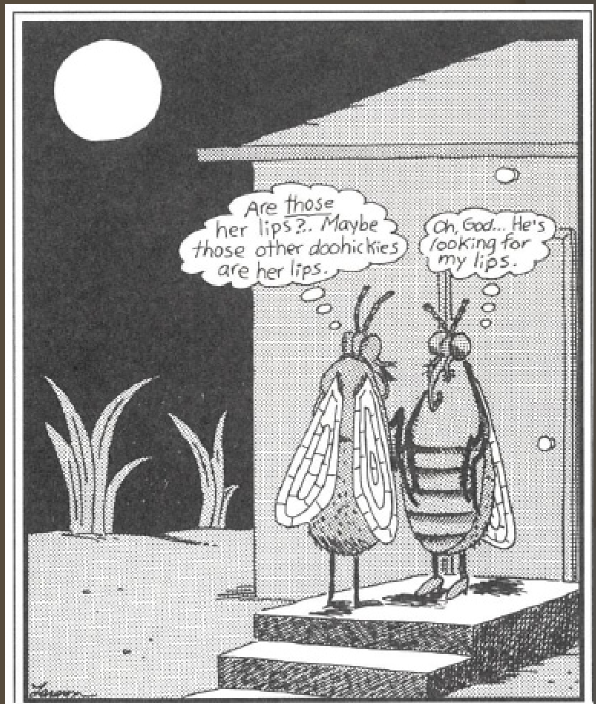
The Head

- Mouthparts
  - Important for classification and taxonomy
  - 5 basic components of mouthparts
    1. Labrum - the ‘upper lip’
    2. Hypopharynx - divides mouth cavity
    3. Mandibles - cut/crush food; defense
    4. Maxillae - assist in processing food
    5. Labium - the ‘lower lip’
  - Many different types





Fly dates

The Head

- Common types of mouthparts
  1. Chewing
     - Beetles, Hoppers, Caterpillars
  2. Piercing/Sucking
     - True bugs, Mosquitos
  3. Siphoning
     - Butterflies
  4. Sponging
     - Flies
  5. Other types

- Positioning of mouthparts

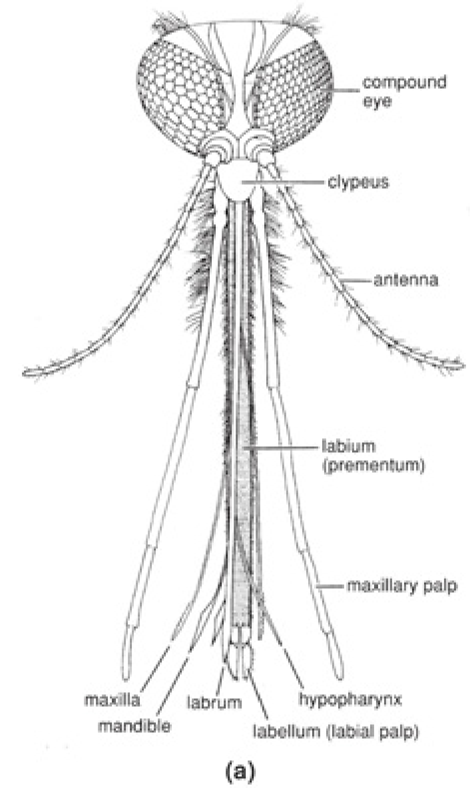


Fig. 2.13 Mouthparts of female mosquito in: (a) frontal view; (b) transverse section. ((a) After Freeman & Bracegirdle 1971; (b) after Jobling 1976.)
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The Head

- Antennae types

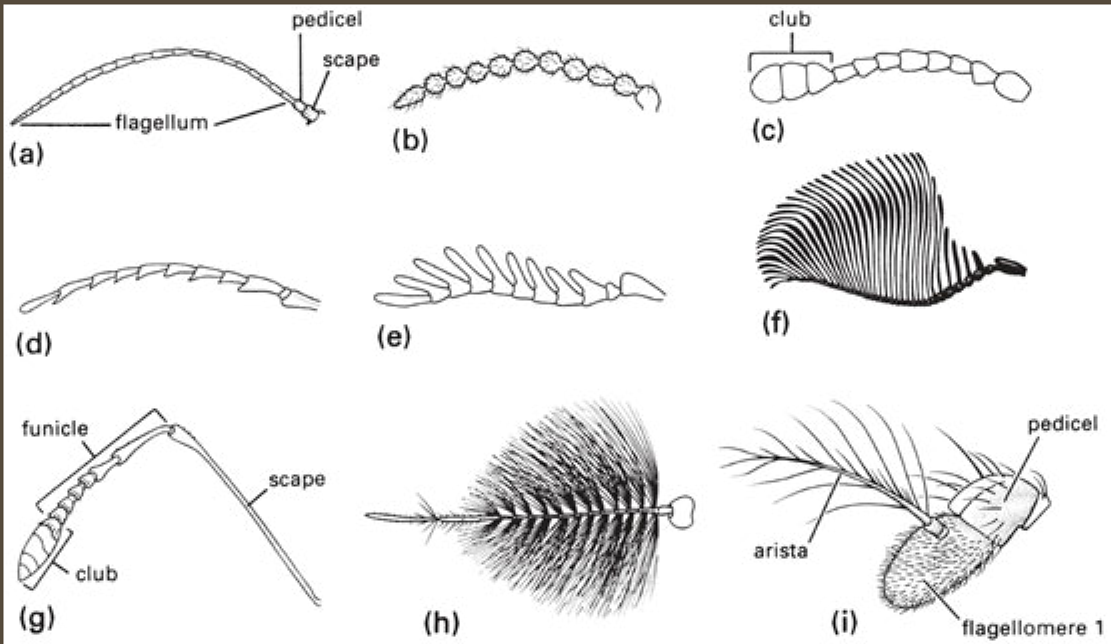

Fig. 2.19 Some types of insect antennae: (a) filiform – linear and slender; (b) moniliform – like a string of beads; (c) clavate or capitate – distinctly clubbed; (d) serrate – saw-like; (e) pectinate – comb-like; (f) flabellate – fan-shaped; (g) geniculate – elbowed; (h) plumose – bearing whorls of setae; and (i) aristate – with enlarged third segment bearing a bristle.

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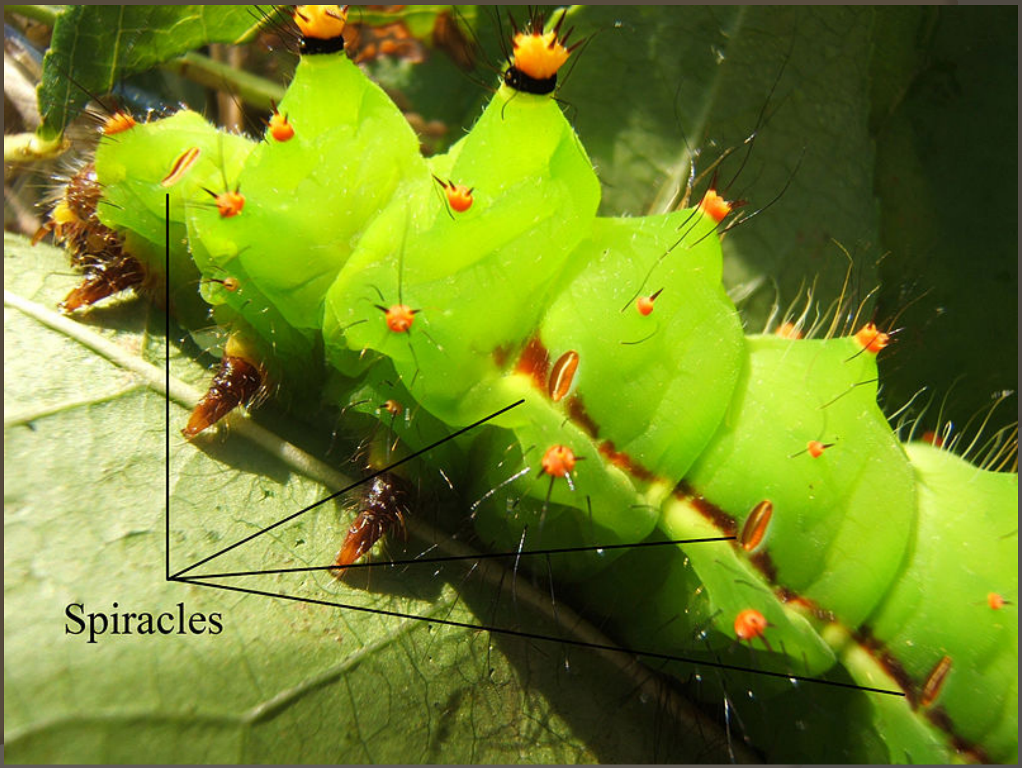
The Thorax

- Composed of 3 segments
  - Prothorax
  - Mesothorax
  - Metathorax
- Spiracles



The Thorax

- Legs
  - Segments

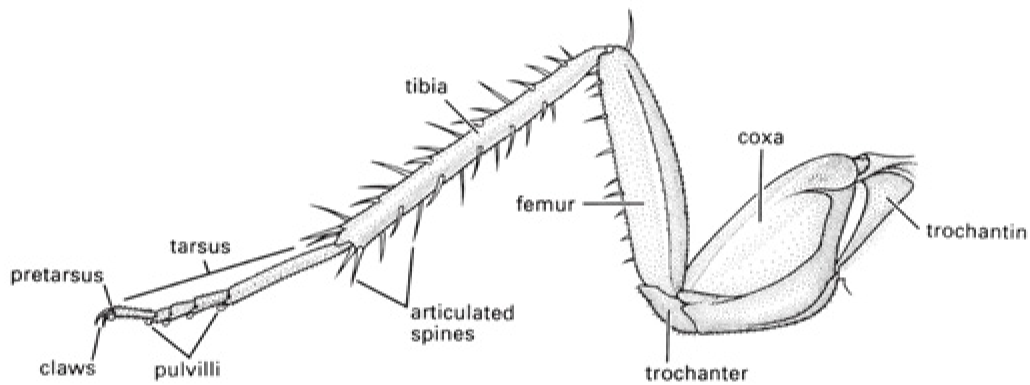


Fig. 2.21 The hind leg of a cockroach, *Periplaneta americana* (Blattodea: Blattidae), with enlargement showing ventral surface of pretarsus and last tarsomere. (After Cornwell 1968; enlargement after Snodgrass 1935.)
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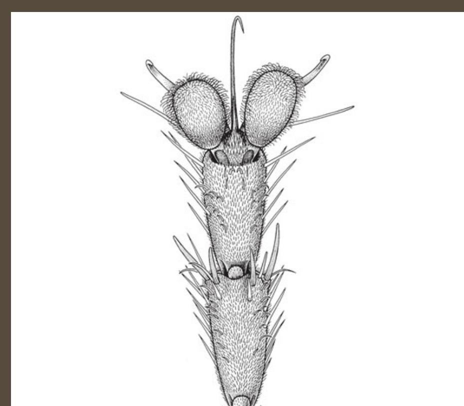
The Thorax

- Legs
  - Tarsomeres

  - Pulvilli



"Feet" of leaf beetle (left) and bush fly (right). (From scanning electron micrographs by C.A.M. Reid and A.C. Stewart.)
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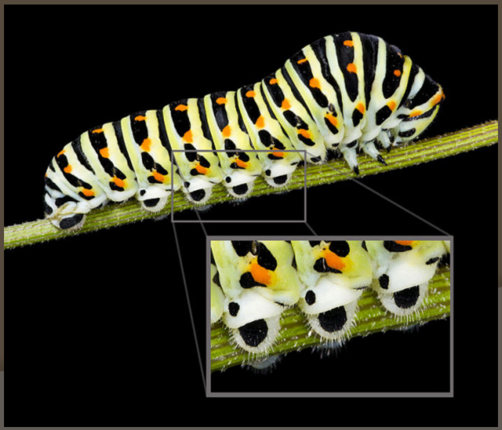
"So once they started talking, I just remained motionless, taking in very word. Of course, it was just pure luck I happened to be a fly on the wall."

The Thorax

- Legs
  - -orial leg adaptations

  - Prolegs



The Thorax

- Wings
  - As a general rule, fully developed wings are found only in adult insects- the only exception being the mayfly
  - Basic wing venation, shared by most orders

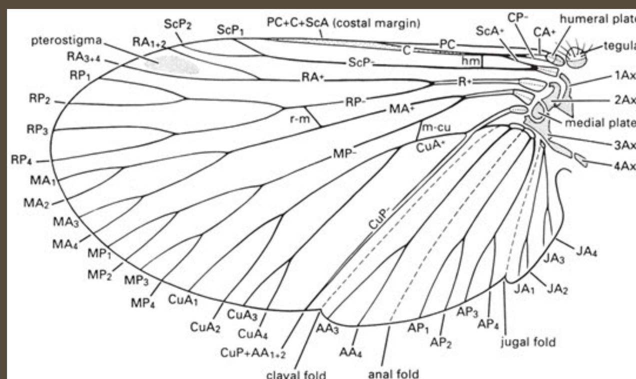


Fig. 2.23 A generalized wing of a neopteran insect (any living, winged insect, other than Ephemeroptera and Odonata), showing the articulation and the Kukalová-Peck nomenclatural scheme of wing venation. Notation is as follows: AA, anal anterior; AP, anal posterior; Ax, axillary sclerite; C, costa; CA, costa anterior; CP, costa posterior; CuA, cubitus anterior; CuP, cubitus posterior; hm, humeral vein; JA, jugal anterior; MA, media anterior; m-cu, cross-vein between medial and cubital areas; MP, media posterior; PC, precosta; R, radius; RA, radius anterior; r-m, cross-vein between radial and median areas; RP, radius posterior; ScA, subcosta anterior; ScP, subcosta posterior. Branches of the anterior and posterior sector of each vein are numbered, e.g. CuA_{1-4}. (After CSIRO 1991.)
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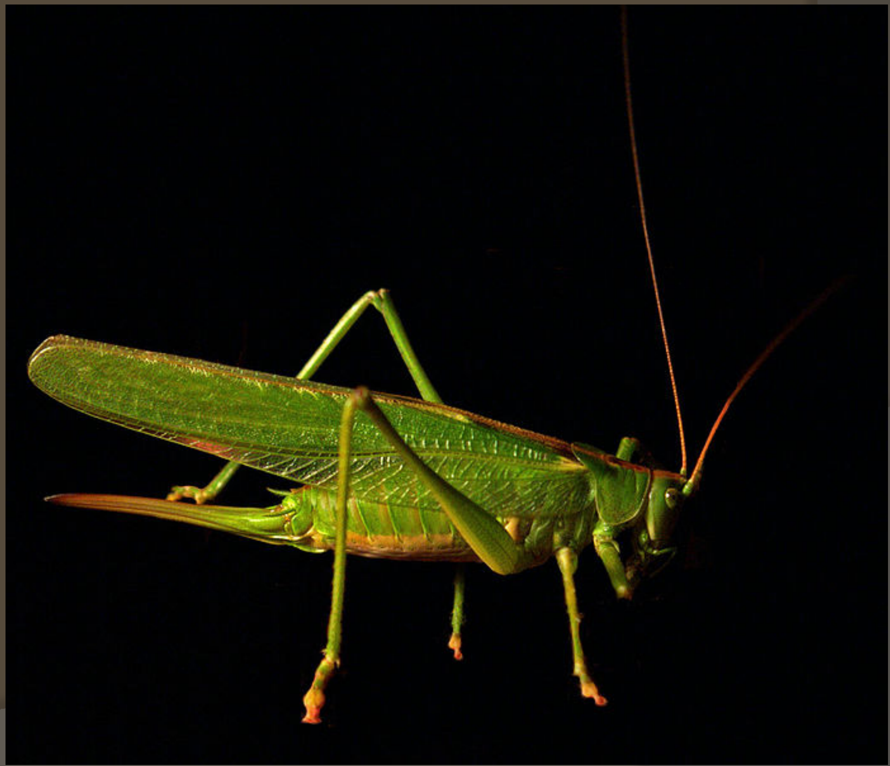
  - Open / closed cells

The Thorax

- Wings
  - Fore / hind wings
    - Coupled together in most orders
  - Forewing modification
    - Elytra, tegmina, etc.
  - Hindwing modification
    - Halteres

The Abdomen

- 11 segments
- Ovipositor
  - Modified as sting
- Cerci
- Identification
  - Examination needed



Pictures by Slide

no modifications were made to any pictures on any of the slides

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2. (no picture)
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    1. Cicada: https://commons.wikimedia.org/wiki/File:An_adult_periodical_cicada_emerges_from_its_17-year_nymph_stage,_molts_and_arises_as_a_winged_adult.jpg
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21. https://commons.wikimedia.org/wiki/File:Actias_selene_5th_instar_spiracles_sjh.jpg
22. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 2.21
23. Legs
    1. Tarsomeres: https://commons.wikimedia.org/wiki/File:Tillus_elongatus_tarsus.jpg
    2. Pulvilli: Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Chapter 2 vignette
    3. The Far Side Gallery 4 by Gary Larson, 1993, page 154
24. Legs
    1. Mole cricket: https://en.wikipedia.org/wiki/File:Gryllotalpa_2009_G5.jpg
    2. Prolegs: https://commons.wikimedia.org/wiki/File:Chenille_de_Grand_porte_queue_%28macaon%29_Fausses_pattes.jpg
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26. Wings
    1. Beetle: https://commons.wikimedia.org/wiki/File:Maybug.jpg
    2. Crane fly: https://commons.wikimedia.org/wiki/File:Crane_fly_halteres.jpg
27. https://commons.wikimedia.org/wiki/File:Tettigonia_viridissima_AB.jpg

Questions?

Permission

On Friday, January 15, 2016 3:40 PM, B K <widowman10@yahoo.com> wrote:

Thank you sir, I appreciate it greatly!!

On Friday, January 15, 2016 3:38 PM, "Newton, Blake L" <blaken@uky.edu> wrote:

No problem!
Sent from Outlook Mobile

On Fri, Jan 15, 2016 at 2:23 PM -0800, "B K" <widowman10@yahoo.com> wrote:

Hello, I hope I've reached the right folks for this email. I'm teaching an Intro to Entomology course at a local university here in Colorado Springs. I was wondering if I could use a snapshot of the metamorphosis types from this page (https://www.uky.edu/Ag/Entomology/ythfacts/4h/unit2/metavari.htm), assuming of course I credit the University of Kentucky and cite the URL?

ENTOMOLOGY 101

Internal Anatomy & Physiology

Internal Anatomy

- Topics
  - Muscular system & Locomotion
  - Nervous system
  - Endocrine system
  - Circulatory system
  - Tracheal system
  - Digestive system
  - Excretory system
  - Reproductive system

Internal Anatomy

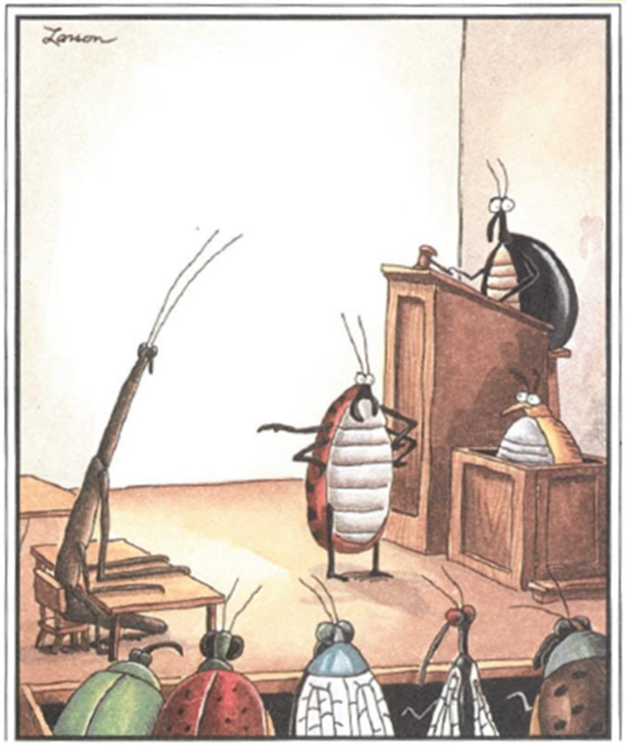
- Hemocoel
- Hemolymph
  - Copper-based proteins vs iron-based proteins (blue vs red)

Muscles & Locomotion

- Muscles & Attachment
  - Power/mass ratio increases as body size decreases
  - Muscles attach to the exoskeleton
    - Tonofibrillae act as attachment sites
  - Strength of ants

Muscles & Locomotion

- Ground locomotion
  - Wriggling
    - Maggots – waves of contraction from head-to-tail
    - Caterpillars – contractions from tail-to-head
  - Walking
    - Tripod
    - Stability
    - Variations
  - Jumping
    - Mechanisms
  - Swimming
  - Water-walking



"Most interesting, ma'am—you've identified the defendant as the one you saw running from the scene. I take it, then, that you're unaware that my client is a *walking* stick?"

Muscles & Locomotion

- Aerial locomotion (flight)
  - Benefits
    - Greater mobility (food, resources, mating)
    - New environments
    - Predator evasion
  - Wing beat: 5-1000 times / second
  - Sensory information (eyes, antennae, halteres)
  - Takeoff and landing

Muscles & Locomotion

- Aerial locomotion (flight)
  - Muscle-powered flight
    - Direct flight muscles
    - Indirect system
  - The “click” point

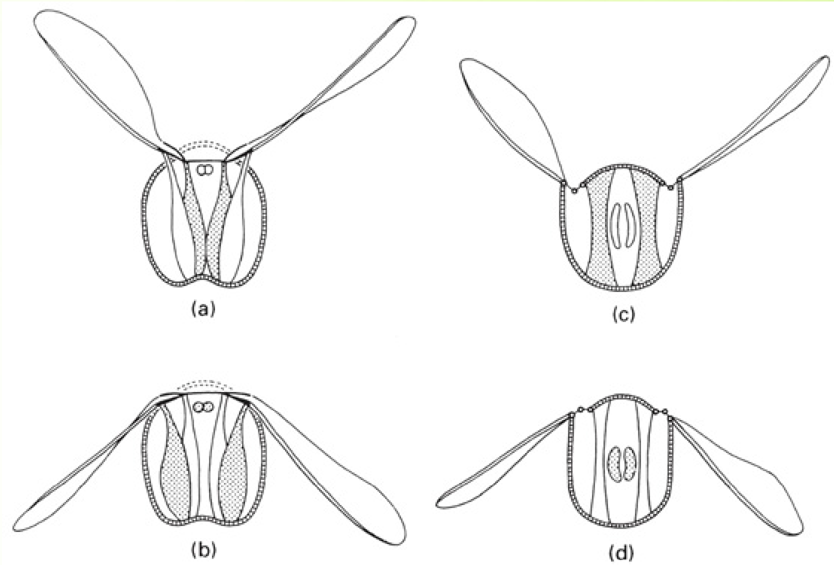
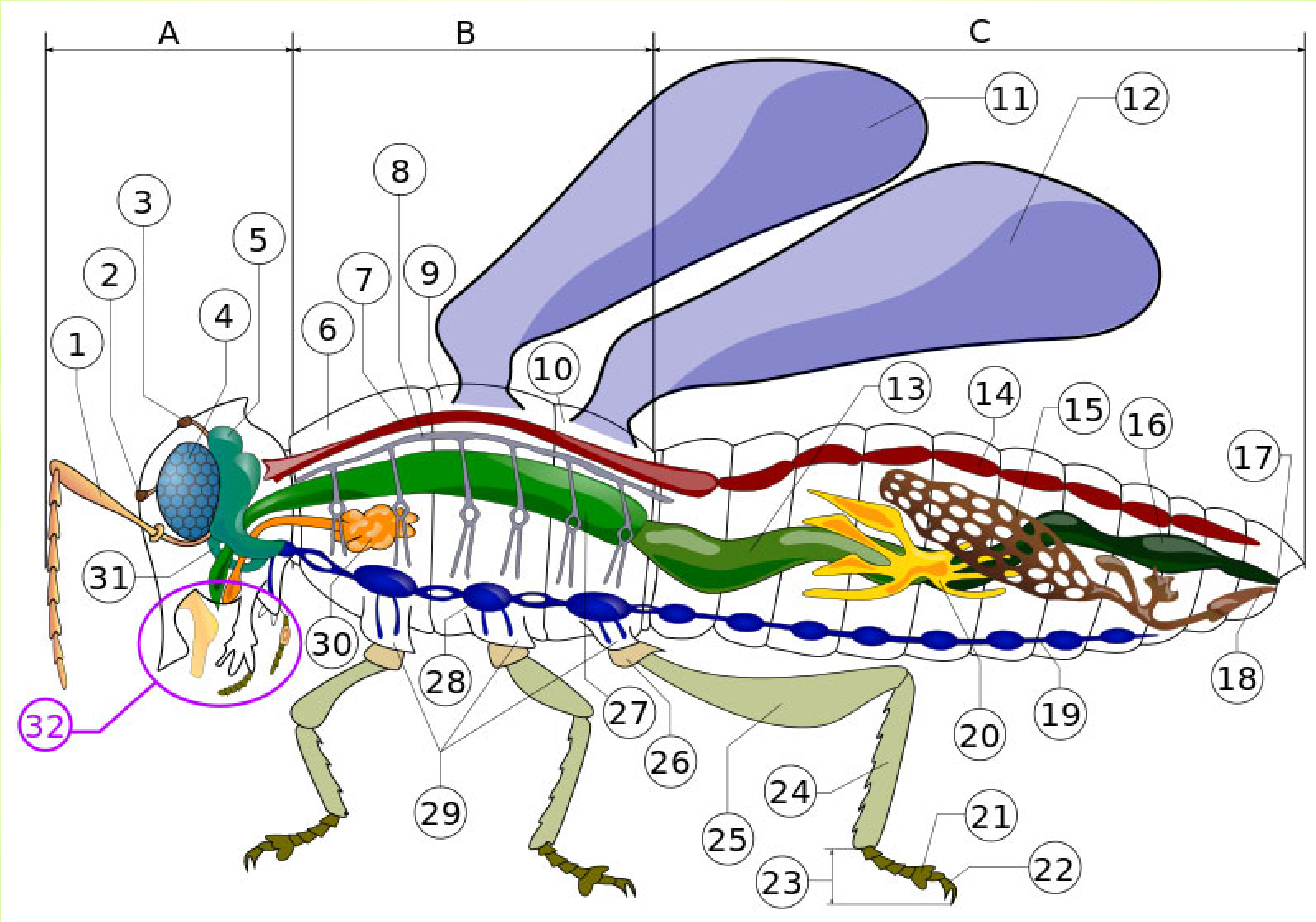


Fig. 3.4 Direct flight mechanisms: thorax during (a) upstroke and (b) downstroke of the wings. Indirect flight mechanisms: thorax during (c) upstroke and (d) downstroke of the wings. Stippled muscles are those contracting in each illustration. (After Blaney 1976.)

Nervous System

- Neuron: nerve cell
- Ganglia: a dense cluster of interconnected neurons that process sensory information or control major outputs
- Ventral nerve cord
- Insect brain
  - Protocerebrum: associated with eyes, optic lobes
  - Deutocerebrum: innervates the antennae
  - Tritocerebrum: handles signals from the body

Nervous System



Endocrine System

- Hormones play a critical role in molting and development
- Neurosecretory cells produce most of the hormones in the insect
- Hormones reach their target via transport in the hemolymph
- Tobacco hornworm

Endocrine System

- Endocrine centers and hormones
  - Prothoracic glands
    - Secrete ecdysteroids
      - Any steroid with molt-promoting activity
      - Ecdysterone
  - Corpora allata
    - Secrete juvenile hormone
      - Controls metamorphosis
      - Regulates reproductive development
  - Corpora cardiaca
    - Secrete neurohormones
      - Control many aspects (largest class of hormones)
      - Prothoracicotropic hormone (PTTH)

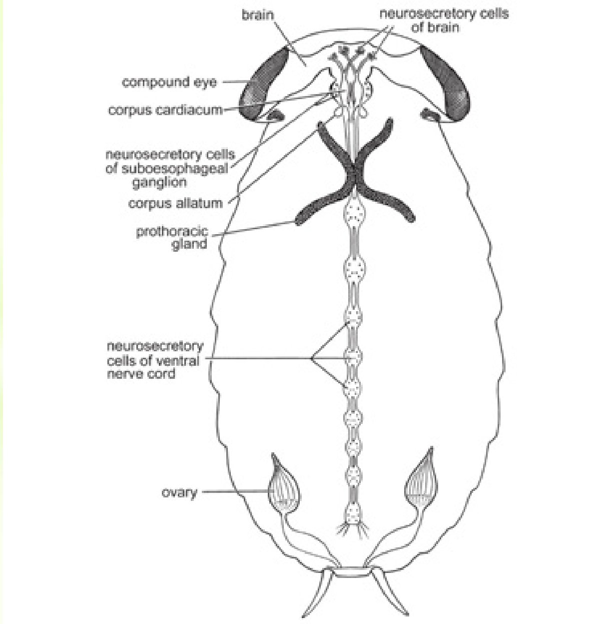


Fig. 3.8 The main endocrine centres in a generalized insect. (After Novak 1975.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

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Circulatory System

- Hemolymph
  - All chemical exchanges mediated via hemolymph
    - Hormones transported
    - Nutrients distributed
    - Wastes removed
  - Color
  - Difference between vertebrate/invertebrate blood
  - Protection / defense
    - Physical injury (clotting)
    - Protects against pathogens (immune responses)
    - Protection against predators (chemical deterrents)

Circulatory System

- Circulation
  - Open circulatory system
  - Dorsal blood vessel
  - Direction of blood flow
  - Ostia
  - Accessory pulsatile organs

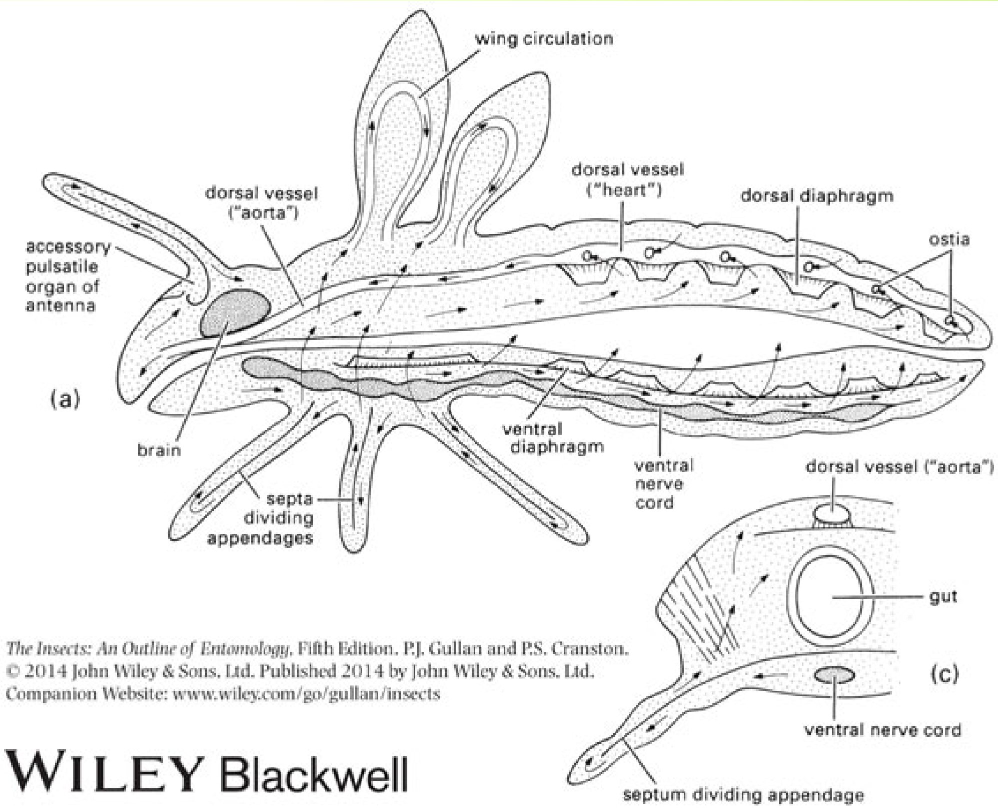

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Fig. 3.9 Schematic diagram of awell-developed circulatory system: (a) longitudinal section through body; (b) transverse section of the abdomen; (c) transverse section of the thorax. Arrows indicate directions of haemolymph flow. (After Wigglesworth 1972.)

Tracheal System

- "Open tracheal system"
  - Gas exchange
  - Trachea
  - Tracheole
  - Molting
  - Size

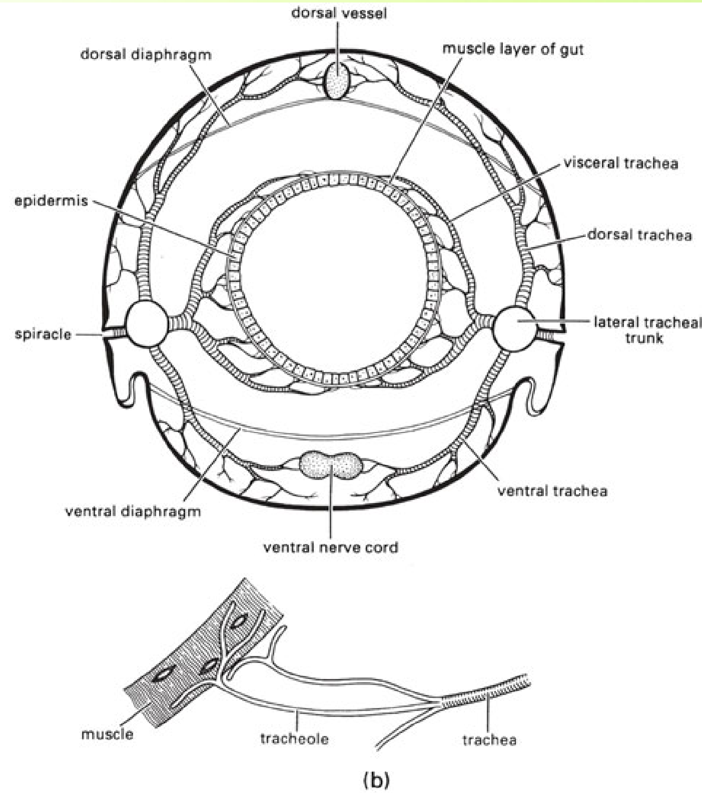

Fig. 3.10 Schematic diagram of a generalized tracheal system seen in a transverse section of the body at the level of a pair of abdominal spiracles. Enlargements show: (a) an atriate spiracle with closing valve at inner end of atrium; (b) tracheoles running to a muscle fibre. (After Snodgrass 1935.)

Tracheal System

- "Open tracheal system"
  - Atrium
  - Valve
  - Pesticides

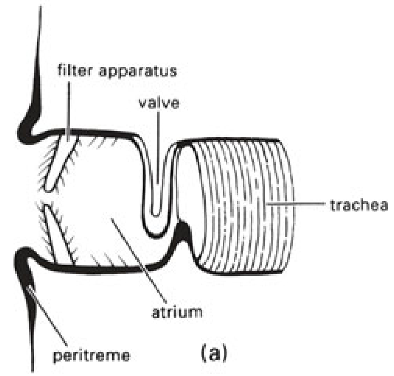

Fig. 3.10 Schematic diagram of a generalized tracheal system seen in a transverse section of the body at the level of a pair of abdominal spiracles. Enlargements show: (a) an atriate spiracle with closing valve at inner end of atrium; (b) tracheoles running to a muscle fibre. (After Snodgrass 1935.)

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- "Closed tracheal system"
  - Lack spiracles
  - Types & examples

Tracheal System

- Diffusion
- Discontinuous gas exchange
- Water loss / Oxygen tradeoff
- Xeric environments
    - Small spiracles
    - Deep atria
    - Cuticular projections
- Why are big insects long and thin?

Digestive System

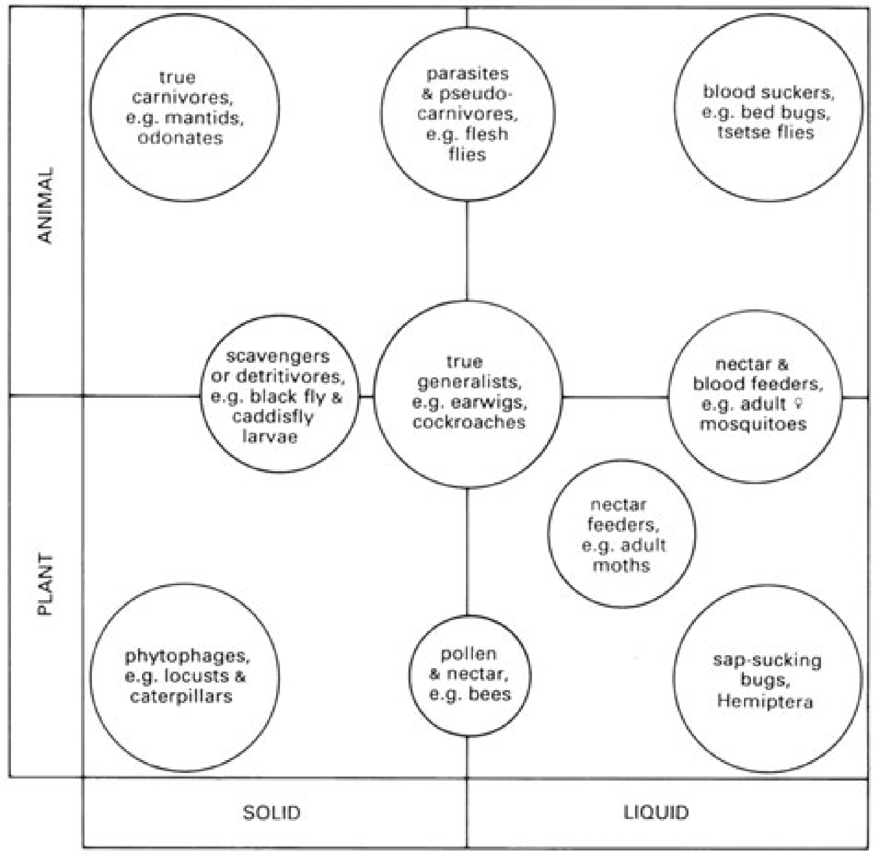

Fig. 3.12 The four major categories of insect-feeding specialization. Many insects are typical of one category, but others cross two categories (or more, as in generalist cockroaches). (After Dow 1986.)
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Digestive System

- Insect gut (or alimentary canal)
  - 3 sections
    - Foregut – ingestion, storage, grinding, transport
    - Midgut – enzymes produced, digestion occurs
    - Hindgut – absorption of valuable molecules
  - Cuticular lining
  - Salivary glands

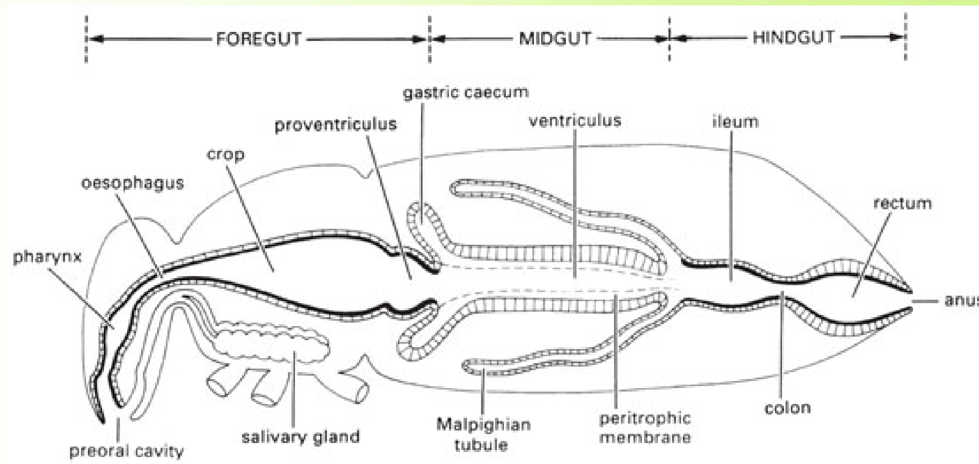


Fig. 3.13 Generalized insect alimentary canal showing division into three regions. The cuticular lining of the foregut and hindgut are indicated by thicker black lines. (After Dow 1986.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Digestive System

- Saliva
  - Aids insects in digestion
  - Can contain:
    - Digestive enzymes
    - Anticoagulants & thinning agents
  - Disease transmission
  - Spittlebugs

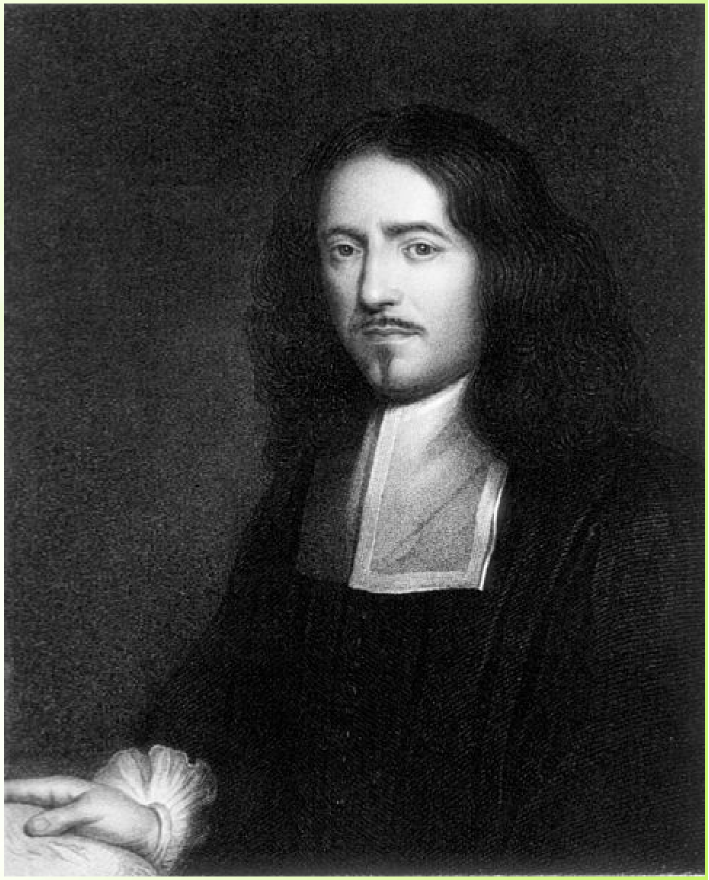
Digestive System

- Symbionts
  - Insects cannot synthesize sterols / carotenoids
  - Sterol, vitamin, carbohydrate, amino acid synthesis
  - Bacteria, yeast, fungi, protist
  - Transmission to other individuals
  - Termites: 12% of natural methane production
  - Fungus gardens

Excretory System

- Comprised of 2 related processes
  - Excretion – elimination of metabolic wastes in an insoluble form
  - Osmoregulation – the regulation of water balance

- Malpighian tubules play important role



Excretory System

- Malpighian tubules
  - Wave freely in the hemolymph
  - Filter out solutes
- Three sections of the hindgut:
  - Ileum
  - Colon
  - Rectum
- Nitrogen excretion & uric acid

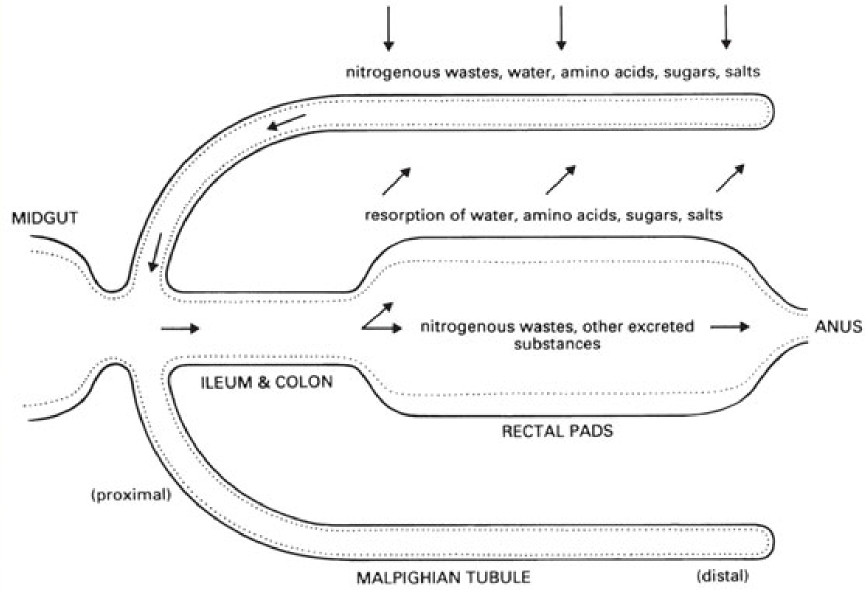


Fig. 3.17 Schematic diagram of a generalized excretory system showing the path of elimination of wastes. (After Daly *et al.* 1978.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Reproductive System

- Female system
  - 2 main functions:
    - Egg production
    - Spermatozoa storage
  - Main components & function
    - Ovaries
    - Oviduct
    - Vulva
    - Spermatheca
    - Ovarioles
    - Etc.
  - Accessory glands

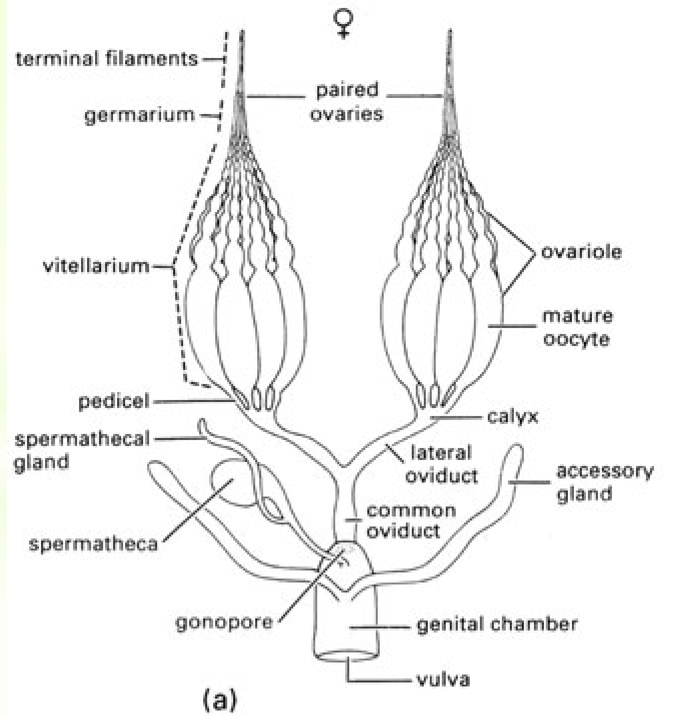


Fig. 3.20 Comparison of generalized: (a) female reproductive system: (After Snodgrass 1935.)

Reproductive System

- Male system
  - 2 main functions:
    - Production/storage of spermatozoa
    - Transport in a viable state
  - Main components & function
    - Testes
    - Vas deferens
    - Ejaculatory duct
    - Gonopore
    - Accessory glands
  - Spermatophore

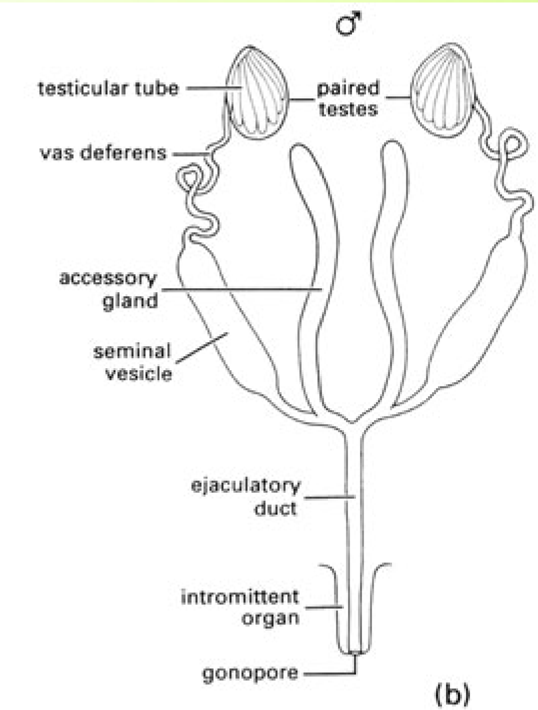


Fig. 3.20 Comparison of generalized: (b) male reproductive system. (After Snodgrass 1935.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Reproductive System

- Male system
  - Spermatophore

Pictures by Slide

no modifications were made to any pictures on any of the slides

1. (no picture)
2. (no picture)
3. (no picture)
4. https://commons.wikimedia.org/wiki/File:Cicindela_chinensis_japonica_0s1.JPG
5. The Far Side Gallery 5 by Gary Larson, 1995, page 35
6. http://www.gorskikotar.com/genious/slike/0727-killafly.jpg (permission granted)
7. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.4
8. (no picture)
9. https://commons.wikimedia.org/wiki/File:Insect_anatomy_diagram.svg
10. https://commons.wikimedia.org/wiki/File:Tobacco_Hornworm_1.jpg
11. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.8
12. https://commons.wikimedia.org/wiki/File:Canibalism_-_Reflex_bleeding_%282106637702%29.jpg
13. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.9
14. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.10
15. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.10
16. https://commons.wikimedia.org/wiki/File:Large,_brown,_live_specimen_of_a_New_Zealand_stick_insect.JPG
17. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.12
18. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.13
19. https://commons.wikimedia.org/wiki/File:Cuckoo_Spit.jpg
20. https://commons.wikimedia.org/wiki/File:White_Ants_%28Termites%29147.jpg
21. https://commons.wikimedia.org/wiki/File:MarcelloMalphigiMiall.jpg
22. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.17
23. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.20
24. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 3.20
25. Permission from George Carnell on Arachnoboards.com – pic # 10 in link
    https://onedrive.live.com/redir?resid=77B173E999776998!10851&authkey=!ABnv0JVMeUk0r3k&ithint=folder%2cJPG

Questions?

Permission

"how to kill a fly" image re-use request (3)

Peopl

B K <widowman10@yahoo.com>

To Chris Glass

Today at 1:20 PM

Thank you!!

Hide original message

On Friday, January 22, 2016 1:16 PM, Chris Glass <csglass@gmail.com> wrote:

Sure, go for it.

On Fri, Jan 22, 2016 at 3:06 PM, B K <widowman10@yahoo.com> wrote:

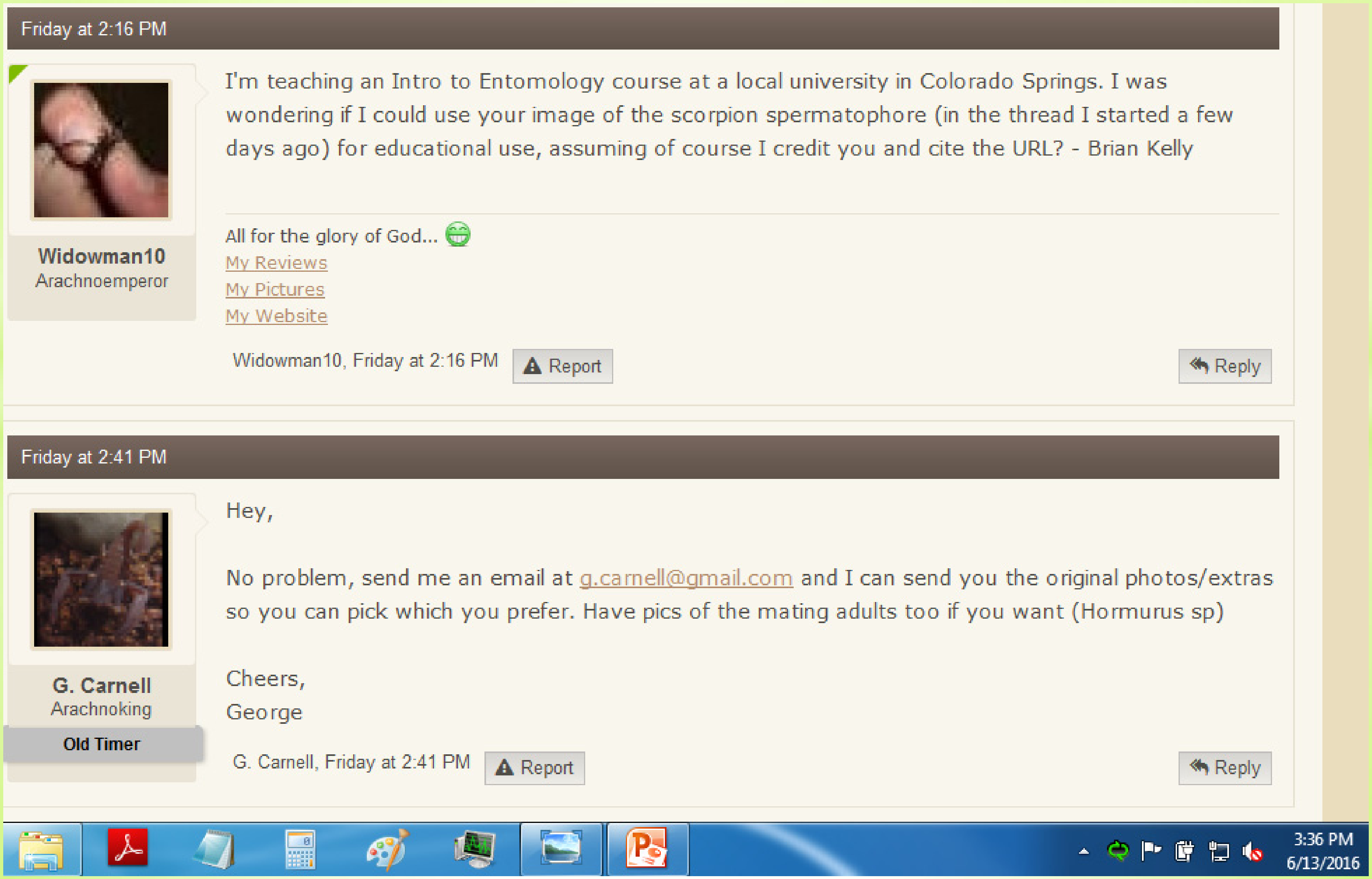
> Hey Chris, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image from this page, assuming of course I credit you and cite the URL?
>
> http://glass.typepad.com/journal/2005/07/how_to_kill_a_f.html
>
> How to kill a fly without a flyswatter

How to kill a fly without a flyswatter

July 27, 2005 How to kill a fly without a flyswatter In three easy steps 1.) Position your hands a few inches above the fly as if you were about to clap. 2.) Clap. ...

View on glass.typepad.com Preview by Yahoo

Permission



Friday at 2:16 PM

I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image of the scorpion spermatophore (in the thread I started a few days ago) for educational use, assuming of course I credit you and cite the URL? - Brian Kelly

All for the glory of God...

My Reviews

My Pictures

My Website

Widowman10
Arachnoemperor

Widowman10, Friday at 2:16 PM Report Reply

Friday at 2:41 PM

Hey,

No problem, send me an email at g.carnell@gmail.com and I can send you the original photos/extras so you can pick which you prefer. Have pics of the mating adults too if you want (Hormurus sp)

Cheers,
George

G. Carnell
Arachnoking
Old Timer

G. Carnell, Friday at 2:41 PM Report Reply

3:36 PM
6/13/2016

ENTOMOLOGY 101

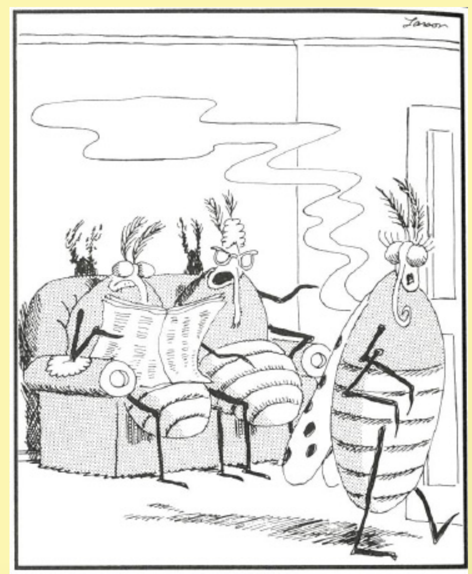
Reproduction

Reproduction

- Topics
  - Attracting a Mate
  - Courtship
  - Sexual Selection
  - Copulation
  - Genitalic Morphology
  - Sperm
  - Sperm Competition
  - Egg-laying (Oviparity)
  - Ovoviviparity & Viviparity
  - Atypical Reproduction
  - Physiological Control

Attracting a Mate

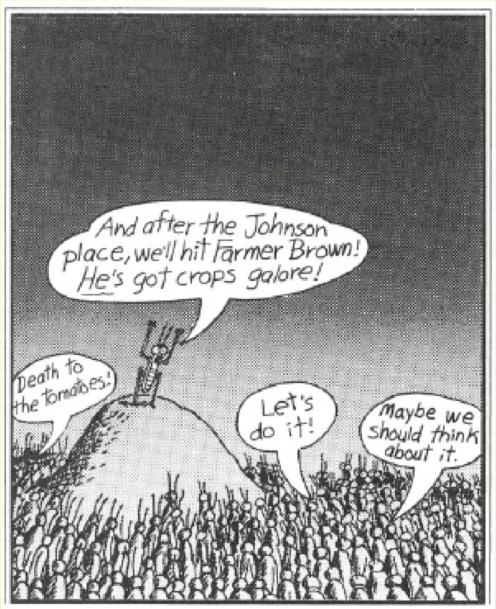
- Long range broadcasting and detection
- Crickets, fireflies, cicadas
- Beneficial, but can backfire (predation; firefly mimics)
- Pheromone: a chemical used in communication between individuals of the same species, designed to elicit some behavior
- Sex pheromones
  - Beetle aggregations
  - Testing with moths
  - Use in pest control



"Hold it right there, young lady! Before you go out, you take off some of that makeup and wash off that gallon of pheromones!"

Attracting a Mate

- Swarming: an aerial aggregation of insects for mating purposes
  - Can be female, but predominantly male
  - Midges
  - Locusts



How locusts are incited to swarm

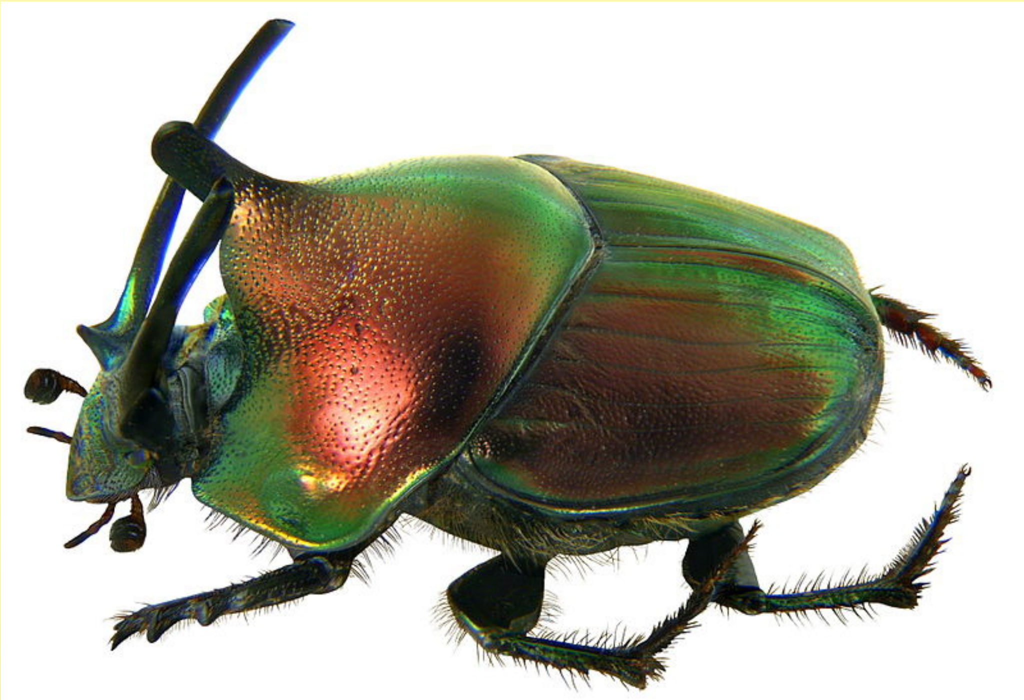
- Lek mating system
  - Male mating aggregation with a defended territory
  - Fruit flies

Courtship

- Still an excess of potential partners
- Courtship is close-range and discriminatory
- Includes visual, tactile, and/or acoustic
- If all goes well, it proceeds to mating

Sexual Selection

- Courtship is competitive
- Female beetles preferentially select males with larger horns
  - Benefits of doing so include: better defensive capabilities to protect the food source, their mate, and their young
- Males 'pay for' their large horns, however



Sexual Selection

- Sneaky small-horned beetles
- “Survival of the sneakiest”
  - Noisy males
  - Sneaky males
  - Vulnerability

Sexual Selection

- Other features
  - Eye stalks
  - ‘Antlers’

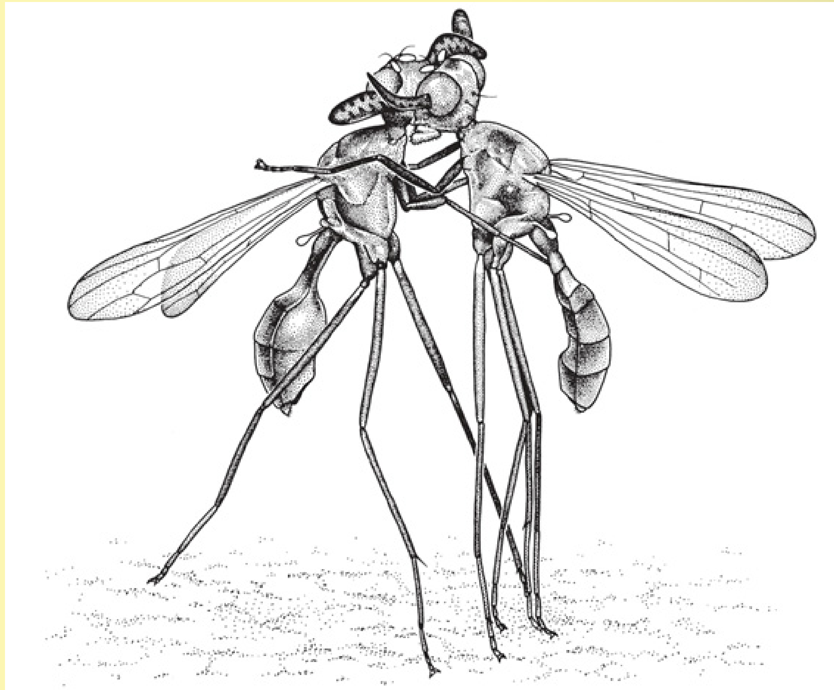


Fig. 5.3 Two males of *Phytalmia mouldsi* (Diptera: Tephritidae) fighting over access to the oviposition site at the larval substrate visited by females. These tropical rainforest flies thus have a resource-defence mating system. (After Dodson 1989, 1997.)

Copulation

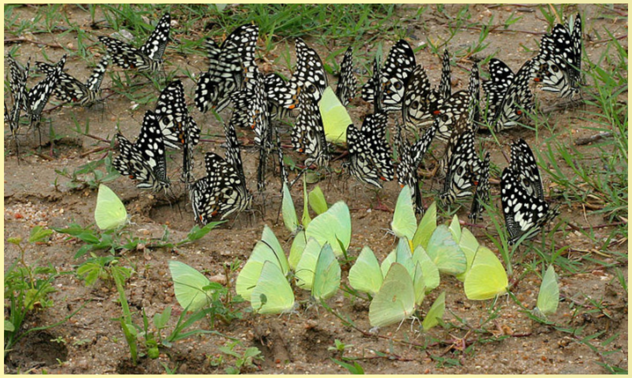
- Spermatophore: an encapsulated package of spermatozoa
- Means of sperm transfer in most insect orders
- Modified locking claspers

Copulation

- Nuptial gifts
  - Male locates prey item
  - Presents to female
  - Size and duration correlated
    - If she rejects = no copulation
    - If prey is small = rejection or incomplete passage by male
    - If prey is large = sufficient time for male to pass complete ejaculate
  - Evolved independently in many insect groups
  - Females benefit from offerings
  - Males parental investment

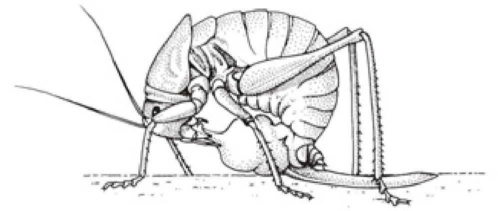
Copulation

- Nuptial gifts
  - Takes 1 of 3 forms:



1. Nourishment from food from male
   - "Puddling" butterflies

2. Ingestion of spermatophore
   - Mormon crickets
   - Multiple benefits



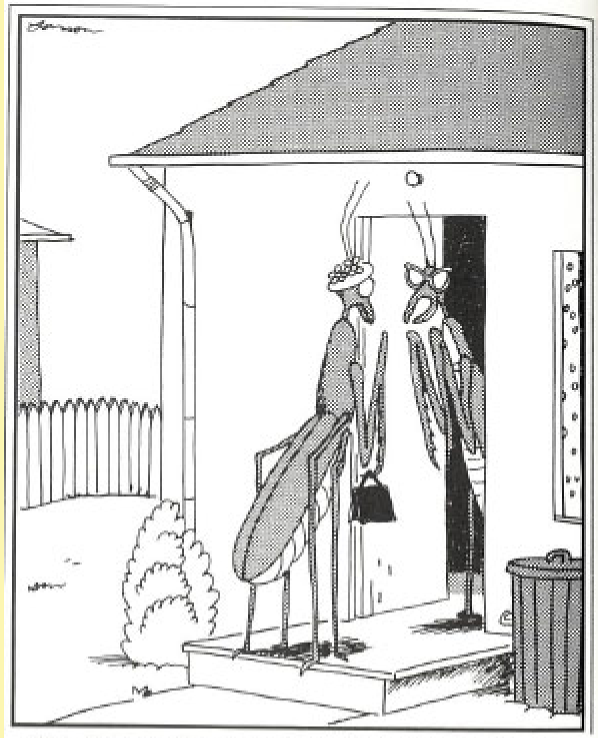
Box 5.2 Mating in katydids and crickets
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Copulation

- Nuptial gifts
  - Takes 1 of 3 forms:

    3. Cannibalization of male
       - Mantids

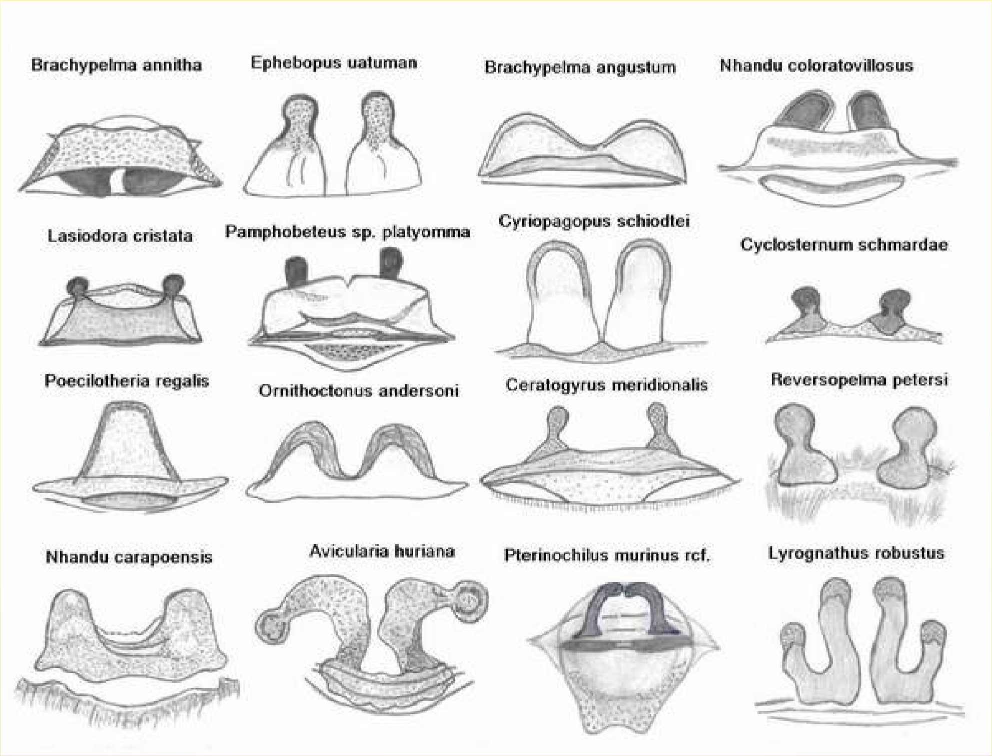


"I don't know what you're insinuating, Jane, but I haven't seen your Harold all day — besides, surely you know I would only devour my *own* husband!"

- Trickery!

Genitalic Morphology

- Diverse in otherwise similar species
- “Lock-and-key” hypothesis
- Selects against hybridization
- Interspecific breeding can result in damage (ex: *Carabus* beetles)

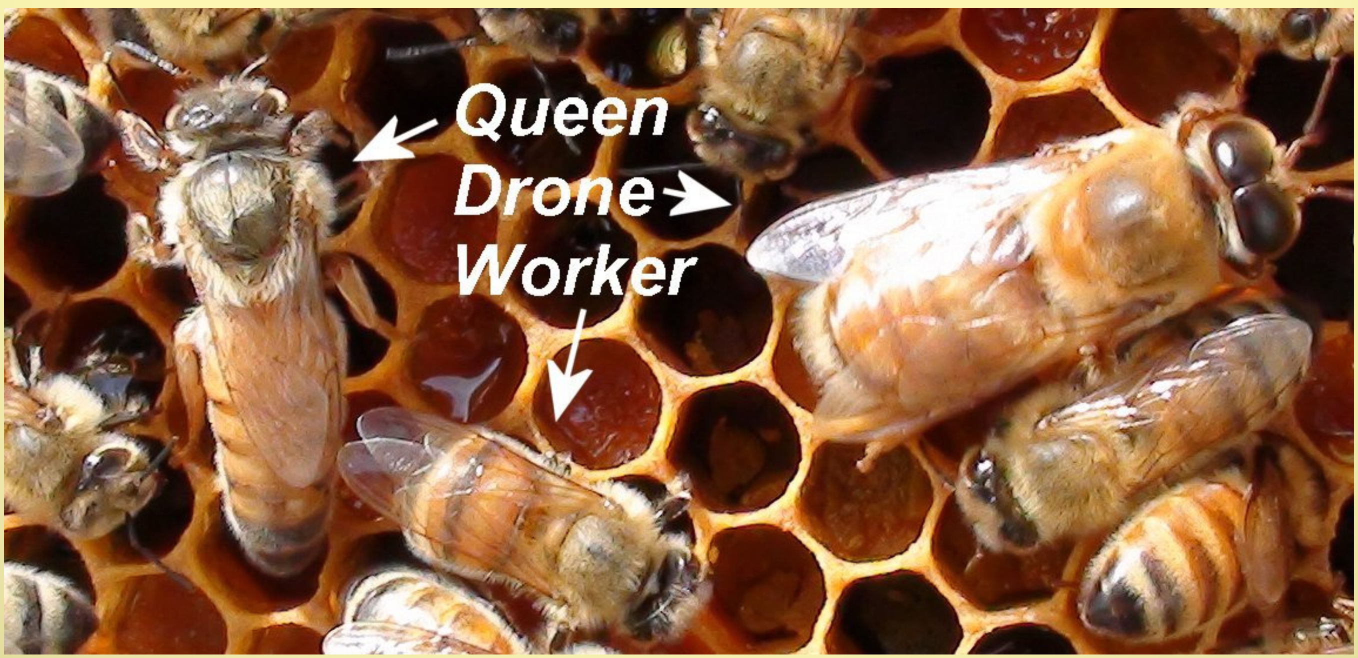


Genitalic Morphology

- Species-specific genital morphology
  1. Pleiotropy
  2. Genetalic recognition
  3. Female choice
  4. Intersexual conflict
  5. Male-male competition
- Female choice of fertilization
- Males overcome these barriers (ex: traumatic insemination)

Sperm

- Spermatheca
- Sperm can stay viable for years
- Sex determination
  - Fertilized = female; unfertilized = male (ex: honey bees)
- Environmental factors



Sperm Competition

- Multiple matings are common (ex: butterflies)
- Sperm competition: combination of internal fertilization, sperm storage, multiple matings, and overlap of ejaculates
- Occurs within the reproductive tract at time of oviposition

Sperm Competition

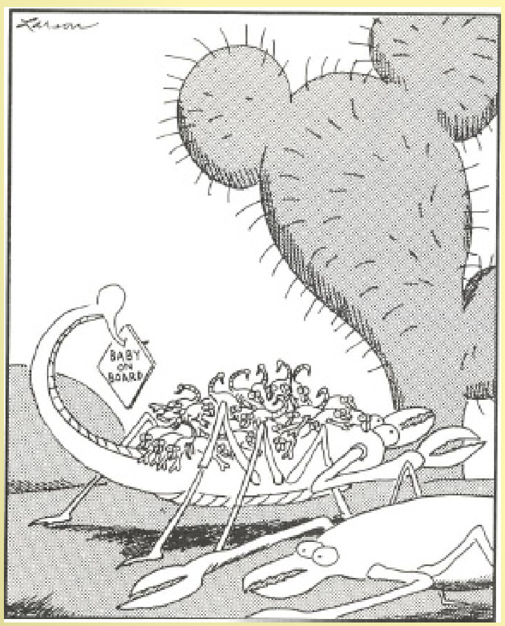
- 2 adaptations in males that increase the odds of paternity
  1. Sperm precedence
     - Damselflies
  2. Lowering competitors' odds
     - Mating plugs
     - Prolonged copulation
     - Guarding of females

Egg-laying (Oviparity)

- Majority are oviparous
- Oviposition
  - Digging, probing, dropping
  - Deposited on or near offspring food source
- Care of eggs ranges

Egg-laying (Oviparity)

- Egg-tending is rare by insects, even more rare by male insects
- Giant water bugs
- Paternal protection as an adaptation for large size
- "Back-brooding"



Egg-laying (Oviparity)

- Egg structure

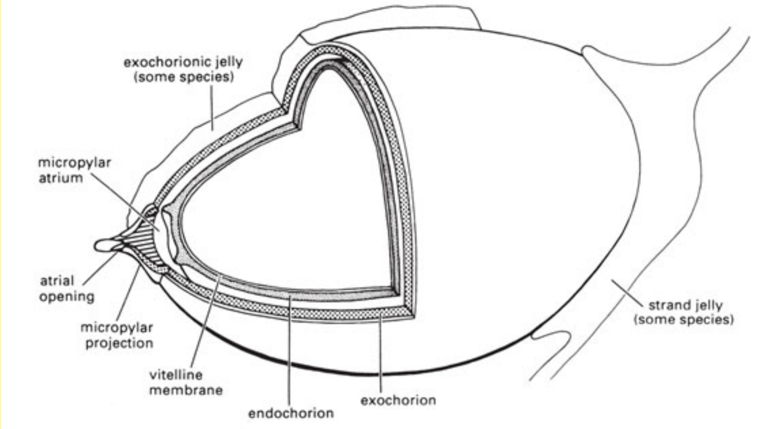


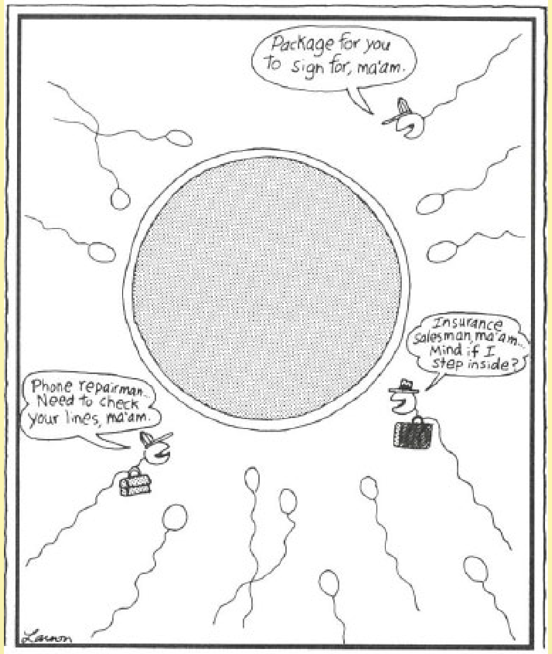
Fig. 5.10 The generalized structure of a libelluloid dragonfly egg (Odonata: Corduliidae, Libellulidae). Libelluloid dragonflies oviposit into freshwater but always exophytically (i.e. outside of plant tissues). The endochorionic and exochorionic layers of the eggshell are separated by a distinct gap in some species. A gelatinous matrix may be present on the exochorion or as connecting strands between eggs. (After Trueman 1991.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

- Vitelline membrane
- Chorion

Egg-laying (Oviparity)

- Function of the eggshell
  - Elasticity for oviposition
  - Protection from environmental factors
  - Infection avoidance
  - Allows selective entry of the sperm



How the human egg is often deceived.

Egg-laying (Oviparity)

- Ovipositor modifications
  - Parasitic wasps; bees
- Egg secretions / cement
- Ootheca

Ovoviviparity & Viviparity

- Viviparity
  - Mother's body provides necessary nourishment
  - Young develop inside mother
  - Live young
  - Example: Tsetse flies

- Ovoviviparity
  - Midway between oviparity and viviparity
  - Appears to be viviparous on the outside
  - Egg created with enough nourishment
  - Hatch immediately prior to, or after, being laid
  - Example: Tachinidae flies

Atypical Reproduction

- Alternating sexual/asexual reproduction
- Parthenogenesis: development from unfertilized eggs
- Obligatory vs. faculatative
- Thelytokous parthenogenesis: female only (aphids)
- Arrhenotokous parthenogenesis: male only (honey bees)
- Amphitokous parthenogenesis: both
- Larval pedogenesis

Physiological Control

- Reproductive events may start or stop due to:
  - Temperature
  - Humidity
  - Photoperiod
  - Availability of food
  - Suitable egg-laying site
- May also be modified by internal events such as:
  - Nutritional condition
  - Maturation of oocytes
- Hormones
  - Juvenile Hormone- triggers functioning of certain organs
  - Ecdysteroids- influence morphogenesis and gonad functions
  - Neuropeptides- regulate endocrine function

Pictures by Slide

no modifications were made to any pictures on any of the slides

1. (no picture)
2. (no picture)
3. http://www.news.cornell.edu/sites/chronicle.cornell/files/fireflyeatingmale.72.JPEG / The Far Side Gallery 4 by Gary Larson, 1993, page 74
4. Attracting a mate
   - https://commons.wikimedia.org/wiki/File:Kanizsa.jpg
   - The Far Side Gallery 2 by Gary Larson, 1986, page 135
5. https://commons.wikimedia.org/wiki/File:MalePeacockSpider.jpg
6. https://commons.wikimedia.org/wiki/File:Proagoderus_%28%3DOnthophagus%29_nigricornis_Fairmaire,_1887_male_%283232050794%29.jpg
7. https://commons.wikimedia.org/wiki/File:Gryllus_bimaculatus_02.jpg
8. Other features:
   1. https://en.wikipedia.org/wiki/File:Teleopsis_dalmanni.jpg
   2. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 5.3
9. https://commons.wikimedia.org/wiki/File:Mating_Small_Milkweed_bugs_Lygaeus_kalmii.jpg
10. https://commons.wikimedia.org/wiki/File:Zygaena_filipendula_240503.jpg
11. Nuptial gifts:
    1. Butterfly: https://commons.wikimedia.org/wiki/File:Common_Emigrant_%28Catopsilia_pomona%29_%26_Lime_Butterfly_%28Papilio_demoleus%29_mud-puddling_W_IMG_0283.jpg
    2. Cricket: Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Box 5.2
12. Nuptial gifts:
    1. Mantis: https://commons.wikimedia.org/wiki/File:Praying_Mantis_Sexual_Cannibalism_European-26.jpg
    2. The Far Side Gallery 3 by Gary Larson, 1988, page 114
13. http://tarantulas.tropica.ru/files/images/spermatheca_2.jpg (see permission)
14. https://commons.wikimedia.org/wiki/File:Traumatic_insemination_1_edit1.jpg
15. http://1.bp.blogspot.com/_qz9aE02ggbw/TGATWpwgHVI/AAAAAAAAB-4/EMrc8ay5bPc/s1600/Caste.jpg
16. (no picture)
17. https://commons.wikimedia.org/wiki/File:Common_blue_damselflies_%28Enallagma_cyathigerum%29_female_dull_green_form_mating_wheel.jpg
18. https://commons.wikimedia.org/wiki/File:Dolichomitus_imperator_Eiablage-02-R_Bartz.jpg
19. https://commons.wikimedia.org/wiki/File:Toe-Biter.jpg / The Far Side Gallery 3 by Gary Larson, 1988, page 166
20. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 5.10
21. The Far Side Gallery 4 by Gary Larson, 1993, page 15
22. https://commons.wikimedia.org/wiki/File:Mantis_laying_ootheca.jpg
23. http://www.warrenphotographic.co.uk/06910-tsetse-fly-female-laying-larva
24. Atypical Reproduction:
    - https://commons.wikimedia.org/wiki/File:Aphid-giving-birth.jpg
    - https://commons.wikimedia.org/wiki/File:Mycocepurus_smithii_CASENT0173989_1.jpg
25. (no picture)

Questions?

Permission

Honey bee caste:
called 217-427-2678 on 2/4/16 @ 8:11am MST and gained permission

On Thursday, February 4, 2016 10:19 AM, Steven Philip Gattine <spg65@cornell.edu> wrote:

Hi Brian,

Feel free to use the image. Thanks for contacting us.

Steve Gattine
Web Editor
Cornell Chronicle
(607) 254-1165

From: Steven Philip Gattine <cunews@cornell.edu> on behalf of Brian Kelly <widowman10@yahoo.com>
Date: Thursday, February 4, 2016 at 12:10 PM
To: Steven Philip Gattine <cunews@cornell.edu>
Subject: Contact us

Submitted on Thursday, February 4, 2016 - 12:10
Submitted by anonymous user: [134.223.230.154]
Submitted values are:
Name Brian Kelly
Email widowman10@yahoo.com
Message
Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image found on the page below, assuming of course I credit you and cite the URL?

http://www.news.cornell.edu/stories/1997/09/cornell-biologists-report-mimicry-and-murder-night
The results of this submission may be viewed at:
http://www.news.cornell.edu/node/11730/submission/12146

Mikhail F. Bagaturov <bbigmojo@mail.ru> Feb 14 at 1:36 AM
To B K

Hello!

You can use my pictures please, no problems.
Just list me as source.

Good luck!

=====
All the best, Dr. Mikhail F. Bagaturov

IUCN/SSC Amphibian SG and SSC Conservation Breeding SG,
Academic Member of Athens Institute For Education & Research (http://atiner.gr)

Author of Theraphosids of the World: http://tarantulas.tropica.ru

WP06910 use for college class? (3) People

B K <widowman10@yahoo.com> Today at 9:05 AM
To info@warrenphotographic.co.uk

9:34 AM
2/4/2016

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image, assuming of course I credit you and cite the URL?

Tsetse Fly female laying larva photo

Tsetse Fly female laying larva photo
orsitans) female giving birth to fully developed larva. Warren Photograph
View on www.warrenphotogr... Preview by Yahoo

WP06910 use for college class? (3) People

Warren Photographic <info@warrenphotographic.co.uk> Today at 9:18 AM
To B K

Hello,

Yes, that's fine. Please can you link to us if you have a website, and like and share us on Facebook if you have a Facebook page. Thank you.

Best wishes,
Mark

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Warren House, Albury Heath,
Guildford, GU5 9DB.
Tel +44 (0) 1483 203354
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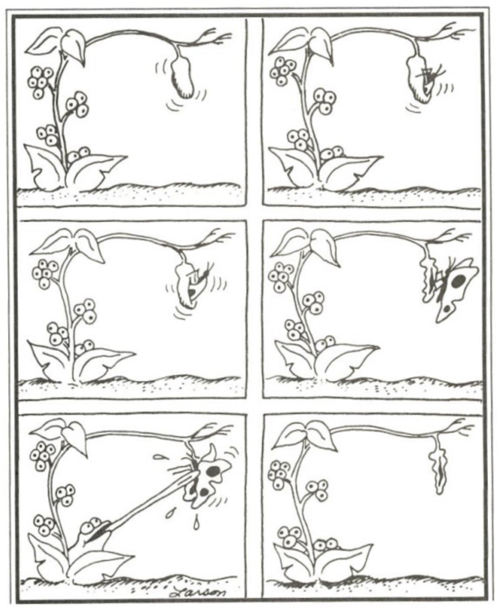
ENTOMOLOGY 101

Insect Development and Life Histories

Insect Development and Life History

- Topics
  - Growth
  - Phases
  - Process of Molting
  - Voltinism
  - Diapause
  - Dealing with Environmental Extremes
  - Migration
  - Effects on Development
  - Climate and Distribution



Metamorphosis

Growth

- Insects grow by:
  - Molting: the formation of new cuticle
  - Ecdysis: shedding of the old cuticle
- Sclerotized portions grow in increments
- Instar: stage of insect between molts
- Stadium: time period between molts

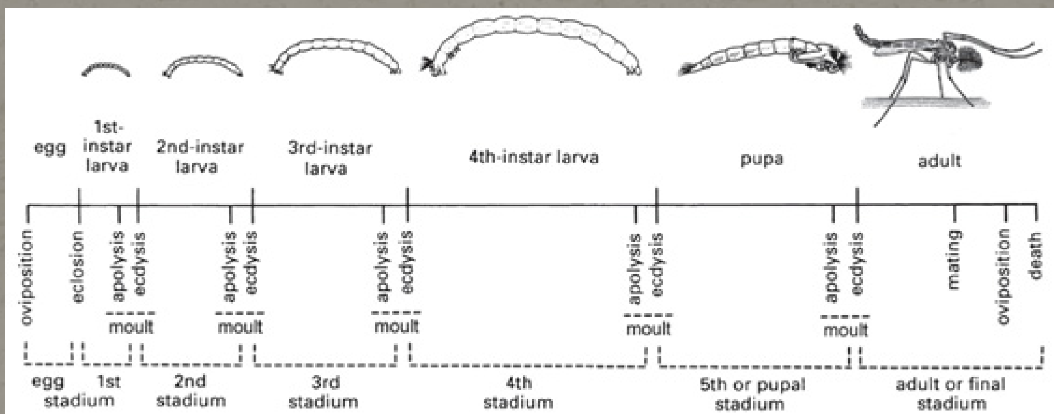


Fig. 6.1 Schematic drawing of the life cycle of a non-biting midge (Diptera: Chironomidae, *Chironomus*), showing the various events and stages of insect development.

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Growth

- Magnitude of growth affected by:
  - Food supply
  - Temperature
  - Larval density
  - Physical damage

- Determinate vs. Indeterminate growth
- Mature insect called adult or 'imago'
- Most mature insects are fully winged (notable exceptions include: lice, fleas, and scale insects)
- Subimago: winged penultimate instar of mayflies

Growth

- Varying vs. set number of instars

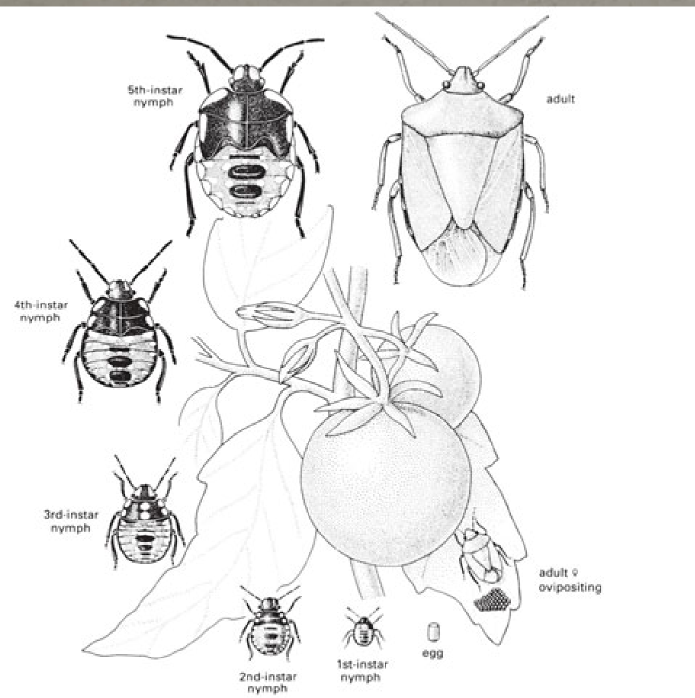


Fig. 6.2 The life cycle of a hemimetabolous insect, the southern green stink bug or green vegetable bug, *Nezara viridula* (Hemiptera: Pentatomidae), showing the eggs, nymphs of the five instars, and the adult bug on a tomato plant. This cosmopolitan and polyphagous bug is an important world pest of food and fibre crops. (After Hely *et al.* 1982.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

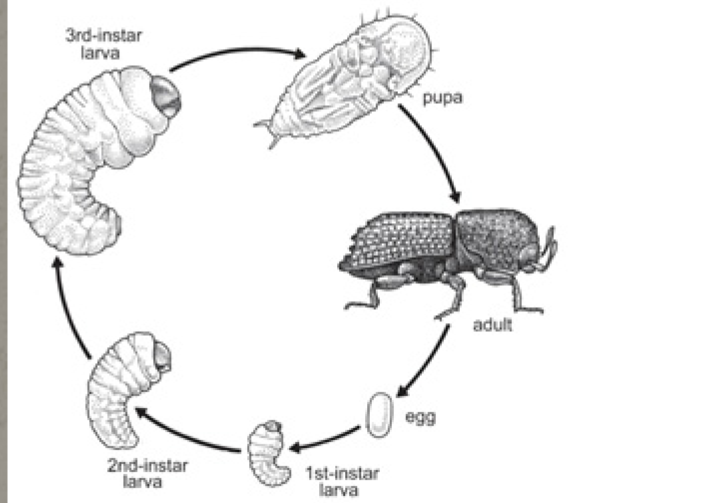
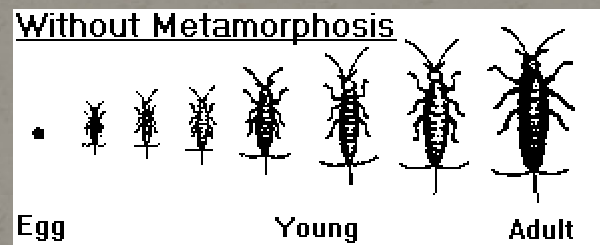


Fig. 6.3 The life cycle of a holometabolous insect, a bark beetle, *Ips grandicollis* (Coleoptera: Curculionidae: Scolytinae), showing the egg, the three larval instars, the pupa, and the adult beetle. (After Johnson & Lyon 1991.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

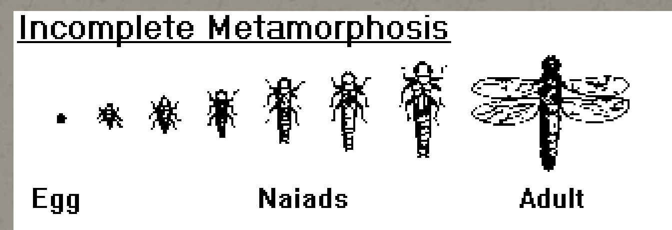
Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Phases

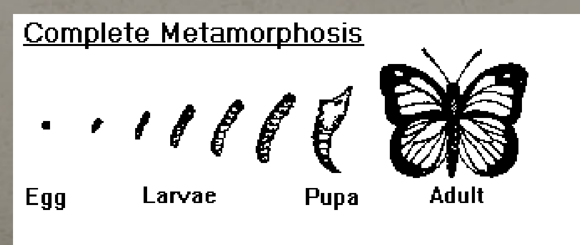
- Refresher:
- Ametabolous



- Hemimetabolous



- Holometabolous



Phases

- Larval / Nymphal Phase
  - Utilization of resources by young and adult (larvae vs. naiad)
  - Different forms

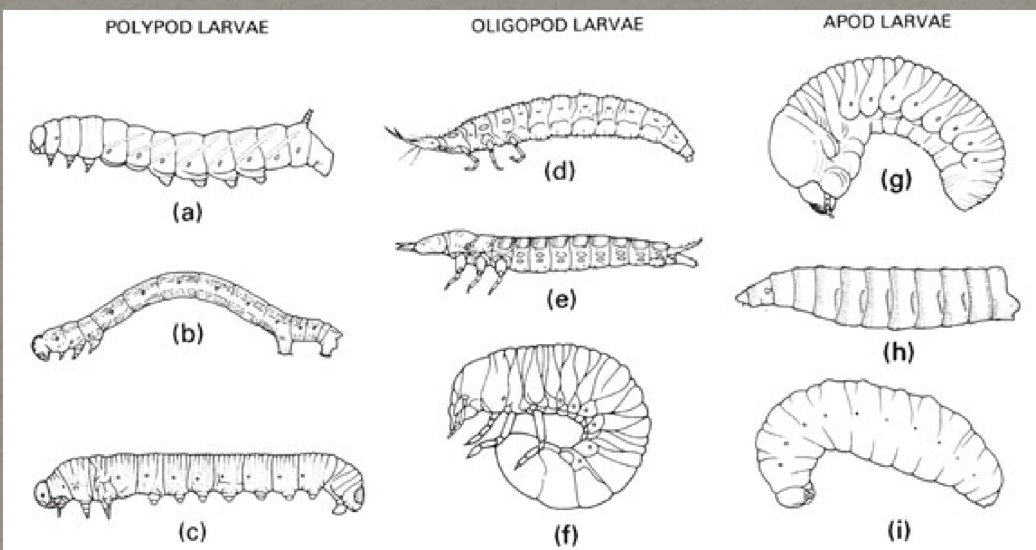


Fig. 6.6 Examples of larval types. Polypod larvae: (a) Lepidoptera: Sphingidae; (b) Lepidoptera: Geometridae; (c) Hymenoptera: Diprionidae. Oligopod larvae: (d) Neuroptera: Osmylidae; (e) Coleoptera: Carabidae; (f) Coleoptera: Scarabaeidae. Apod larvae: (g) Coleoptera: Scolytinae; (h) Diptera: Calliphoridae; (i) Hymenoptera: Vespidae. ((a,e–g) After Chu 1949; (b,c) after Borror *et al.* 1989; (h) after Ferrar 1987; (i) after CSIRO 1970.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

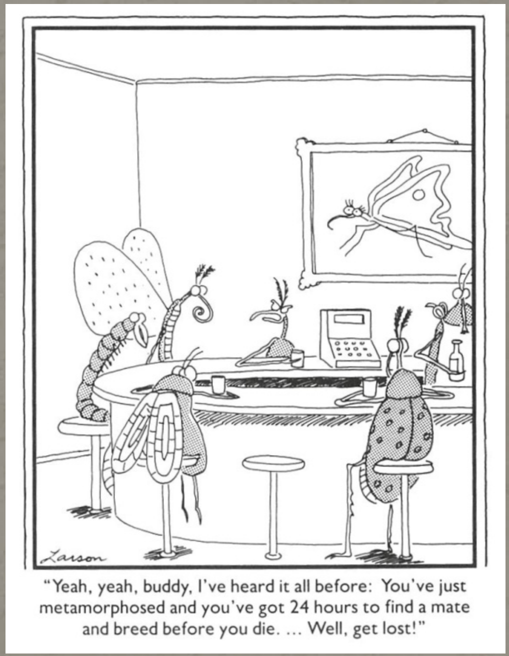
WILEY Blackwell

Phases

- Metamorphosis
  - Adult organs develop at a faster rate than rest of body (wings, genitalia, etc.)
  - Pupation: process of becoming a pupa
    - Survive unfavorable developmental conditions in this stage
    - Pupal types

Phases

- Adult
  - Primary role is reproduction
  - Reproductive cycles range from one to many
  - Lifespans
    - Several years (termite/ant/bee queens)
    - Few hours (mayflies, midges)



  - Changes in light or temperature may synchronize emergence

Phases

- Adult
  - 5 important hormones are involved in eclosion:
    - Ecdysis-triggering hormone
    - Eclosion hormone
    - Crustacean cardioactive peptide
    - Bursicon
    - Cardiopeptides

Process of Molting

- Simple steps of the molting process:
  1. Epidermal cells separate from the inner face of the old cuticle
  2. Apolysial space fills with inactive molting fluid
  3. Endocuticle is resorbed
  4. Hemolymph pressure increases, splitting the old cuticle along the dorsal midline
  5. New cuticle is expanded by swallowing air and increasing hemolymph pressure

Process of Molting

- Hormones and nervous system control the process of molting, especially neuropeptides, ecdysteroids, and JH
- How do insects know when to molt to the adult phase?
  - JH inhibition and high hemolymph level (absent at the pupal-adult molt)
- Ecdysis-triggering hormone and eclosion hormone crucial

Voltinism

- Number of generations per year
  - Univoltine: 1 gen / year
  - Bivoltine: 2 gen / year
  - Multivoltine: >2 gen / year
  - Semivoltine: <1 gen / year

- Extreme examples:
  - Periodic cicadas (17 years)
  - Aphids (5 days)

- Lifespans of different voltine insects

Diapause

- Insect development is often interrupted by a period of dormancy
- Diapause: delayed development not caused by environmental conditions
- Can last days, months, or sometimes even years
- Major environmental cues that can induce or terminate diapause:
  - Photoperiod – significant cue
  - Temperature
  - Moisture – flooding mosquito eggs
  - Chemicals

Dealing with Environmental Extremes

- Cold
  - Cryobiology
  - Antarctic insects
  - Glaciers, snowfields
  - Examples
  - Cryoprotection: mechanisms that allow organisms to survive periods of extreme cold

- Tactics for dealing with cold
  - Freeze tolerance
  - Freeze avoidance
  - Chill tolerance
  - Chill susceptibility
  - Opportunistic survival

Dealing with Environmental Extremes

- Cold
  - Freeze tolerance
    - Most occur in extreme areas such as the Arctic and Antarctic
    - Protection provided by production of icenucleating agents induced by falling temps
    - Freezing is encouraged outside of the cells
    - Supercooling: lowering the temperature of a liquid below its freezing point without it becoming a solid
    - Does not guarantee survival- depends on other factors and conditions

Dealing with Environmental Extremes

- Heat
  - Insects can be found in thermal vents, like those in Yellowstone NP
  - Temperatures up to 122 degrees Fahrenheit
  - Mostly Diptera, but others include Odonata and Coleoptera
  - Heat kills by denaturing proteins, altering structures, and by dehydration
  - Little is known about how they do this, but “acclimation” certainly helps
  - Options for escaping / dealing with heat include burrowing and others, such as…

Dealing with Environmental Extremes

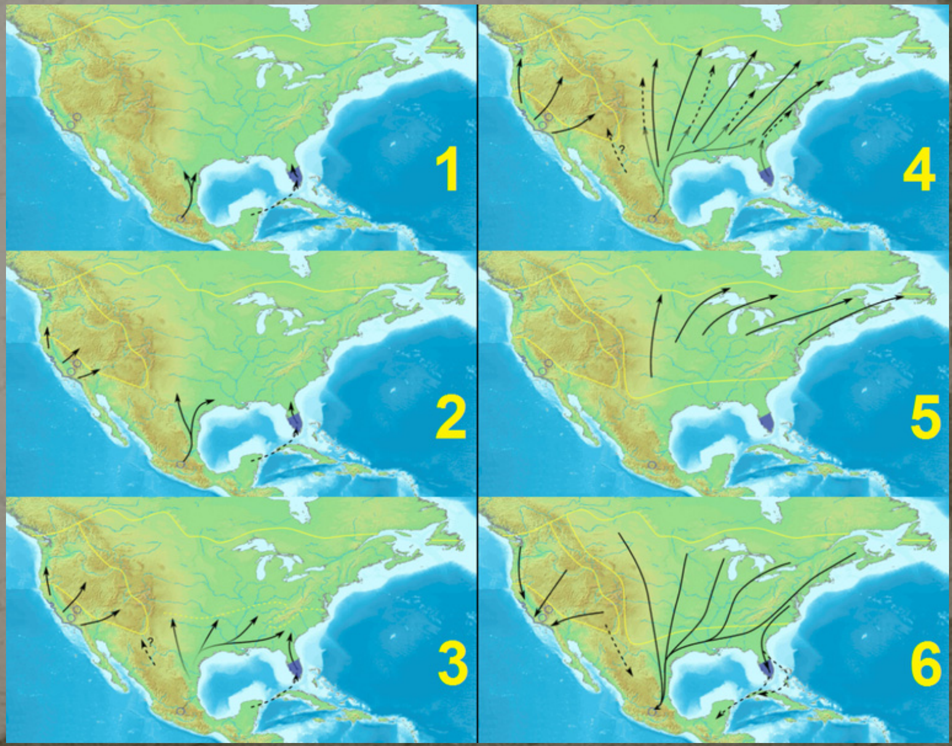
- Heat
  - *Cataglyphis* ant aka “Saharan silver ant”

Dealing with Environmental Extremes

- Aridity
  - “Fog basking” of Namibian beetles
  - Water loss prevention strategies
    - Cuticular
    - Spiracular
    - Metabolic
    - Excretory
  - Tenebrionids vs. carabids

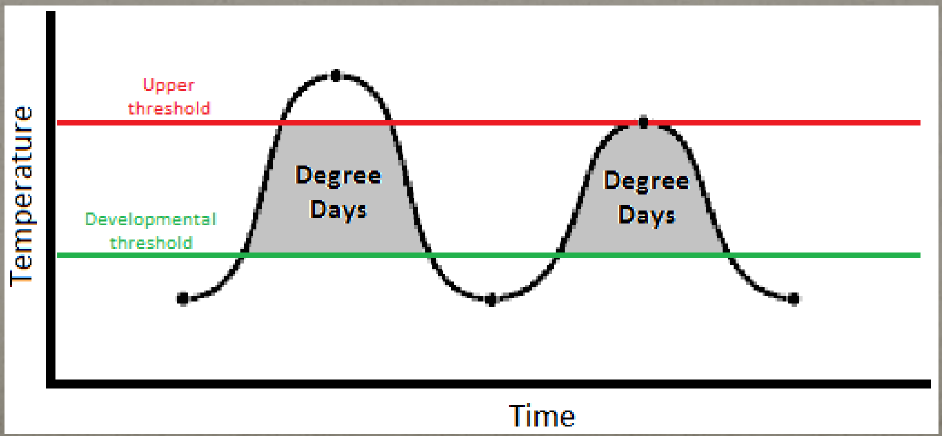
Migration

- Migration: directional movement to more appropriate conditions
- Typified by certain criteria
- Pre-migration behaviors
- Hormonal control and environmental cues
- Monarch butterflies



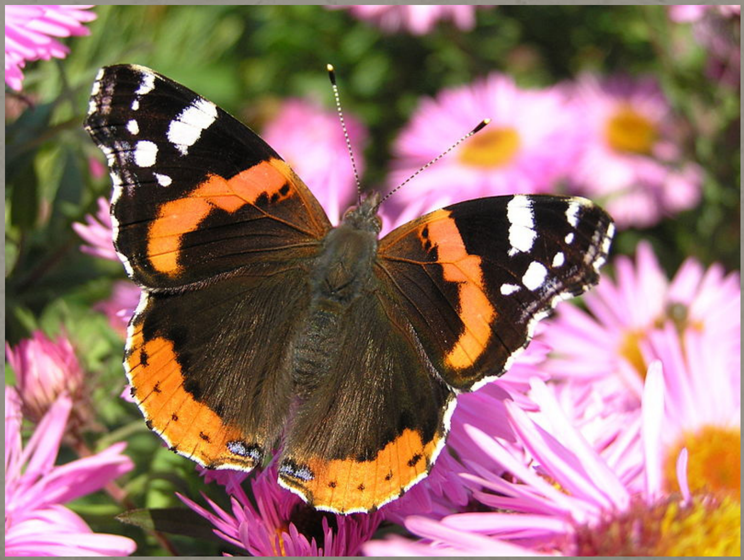
Effects on Development

- Temperature
  - Poikilothermic: having a body temperature that varies with its surroundings
  - Heat drives rate of growth and development (quite predictably!)
  - Heat speeds up metabolism and development
  - "Degree-days": a measure of physiological time as the product of time and temperature above the "developmental threshold"
    - Also: "Degree-hours"
    - Cumulative hours x temperature (in degrees) above threshold
    - Known by extensive laboratory testing
    - Issues and problems establishing degree-days



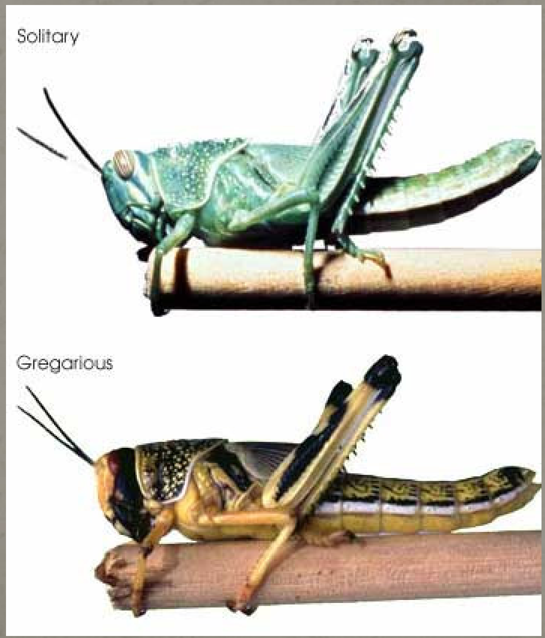
Effects on Development

- Photoperiod
  - Photoperiod: Duration of the light part of the the 24-hr daily cycle
  - Most predictable environmental indicator of changing seasons
  - Many insects measure duration of light phase in the 24-hr period
- Humidity
- Mutagens and toxins



Effects on Development

- Biotic effects
  - Food
    - Quantity
    - Quality
  - Crowding
    - Solitary and gregarious locusts



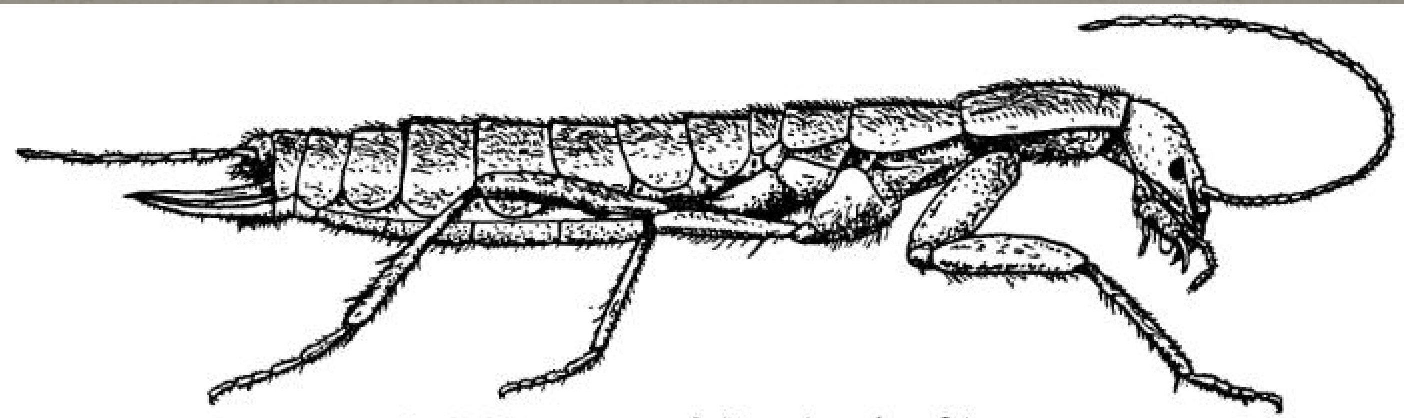
Climate and Distribution

- Knowledge of climatic influences on insect development is vital for:
  - Prediction of pest outbreaks (malaria)
  - Successful pest management
- CLIMEX
- "Ecoclimatic index" and the 4 stress indices – Figure 6.15
  - Example: bishopi vs. geometricus
- Real world examples include: screwworm flies, fire ants, ticks
- Great potential for: epidemiology, quarantine, pest management

vs.

Climate and Distribution

- Climate change and distribution
  - Short or long term climate change can result in:
    - Expansion of vectors and arboviruses
    - Northward extension of ranges
    - Habitat loss and/or extinction
    - Early emergence



Grylloblatta campodeiformis. (× 6.)
(Adapted from Walker.)

Pictures by Slide

no modifications were made to any pictures on any of the slides

1. (no picture)
2. The Far Side Gallery 1 by Gary Larson, 1984, page 91
3. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 6.1
4. Picture taken by me
5. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 6.2 & Figure 6.3
6. https://www.uky.edu/Ag/Entomology/ythfacts/4h/unit2/metavari.htm (permission granted)
7. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 6.6
8. https://commons.wikimedia.org/wiki/File:Cetoine_global.jpg
9. Phases
    1. https://commons.wikimedia.org/wiki/File:CSIRO_ScienceImage_2289_A_mature_queen_termite.jpg
    2. The Far Side Gallery 4 by Gary Larson, 1993, page 129
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12. (no picture)
13. https://commons.wikimedia.org/wiki/File:Aphids_May_2010-2.jpg
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21. My picture. Idea from: http://www.ipm.ucdavis.edu/WEATHER/ddconcepts.html (see permission)
22. https://commons.wikimedia.org/wiki/File:Vanessa_atalanta_brok_beentree.jpg
23. https://commons.wikimedia.org/wiki/File:DesertLocust.jpeg
24. Widows
    1. Red: http://bugguide.net/node/view/1048452/bgpage
    2. Brown: https://commons.wikimedia.org/wiki/File:Latrodectus_RUSVM_sideview.jpg
25. https://commons.wikimedia.org/wiki/File:GrylloblattaCampodeiformis.jpg

Questions?

Permission

On Friday, January 15, 2016 3:40 PM, B K <widowman10@yahoo.com> wrote:

Thank you sir, I appreciate it greatly!!

On Friday, January 15, 2016 3:38 PM, "Newton, Blake L" <blaken@uky.edu> wrote:

No problem!
Sent from Outlook Mobile

On Fri, Jan 15, 2016 at 2:23 PM -0800, "B K" <widowman10@yahoo.com> wrote:

Hello, I hope I've reached the right folks for this email. I'm teaching an Intro to Entomology course at a local university here in Colorado Springs. I was wondering if I could use a snapshot of the metamorphosis types from this page (https://www.uky.edu/Ag/Entomology/ythfacts/4h/unit2/metavari.htm), assuming of course I credit the University of Kentucky and cite the URL?

Cheryl Reynolds <creynolds@ucanr.edu> Feb 11 at 6:28 PM
To widowman10@yahoo.com

Hi:

Your email went to a different Cheryl but was forwarded to me. I am the photo librarian for the UC IPM Program.

Are you just using this image in a PowerPoint or part of a lecture and not on the web or in print? If so, you would be welcome to use it. You can just cite The UC Statewide IPM Program and this web page: http://www.ipm.ucdavis.edu/WEATHER/ddconcepts.html

Thank you,
Cheryl

--
Cheryl Reynolds
Senior Editor / Interactive Learning Developer

UC ANR Statewide IPM Program
2801 Second Street
Davis, CA 95618-7774
(530) 750-1237

Visit our website!
www.ipm.ucanr.edu

Permission

Called Wenzel Construction at 1-800-657-8085 on 2/18/2016 @ 11:59am MST and received permission to use the "rubbertank" image from their website, assuming of course credit was given and cited.

B K <widowman10@yahoo.com>
To tmurray74@yahoo.com

Today at 12:36 PM

Hello Tom, Widowman10 (from BugGuide.net) here. I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image, assuming of course I credit you and cite the URL? It would be for a lesson on freeze tolerance in insects.

Snow Scorpionfly - Boreus brumalis - BugGuide.Net

Snow Scorpionfly - Boreus brumalis - BugGuide.Net

An online resource devoted to North American insects, spiders and their kin, offering identification, images, and information.

View on bugguide.net | Preview by Yahoo

Reply, Reply All or Forward | More

Tom Murray <tmurray74@yahoo.com>
To B K

Today at 12:42 PM

Hi Widowman,

You're welcome to use the picture in your course. Thanks for asking.

Tom

12:47 PM
2/18/2016

Permission

BugGuide - L. bishopi (3)

B K <widowman10@yahoo.com> Feb 18 at 3:44 PM
To daidunno@hotmail.com

Hello David, Widowman10 (from BugGuide.net) here. I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image, assuming of course I credit you and cite the URL? It would be for a lesson on climate conditions on ranges of insects and their relatives.

red widow in palmetto in scrub habitat - Latrodectus bishopi - BugGuide.Net

red widow in palmetto in scrub habitat - Latrodectus

An online resource devoted to North American insects, spiders and their kin, offering identification, images, and information.

View on **bugguide.net** Preview by Yahoo

Reply, **Reply All** **or** **Forward** **|** **More**

daidunno@hotmail.com Feb 18 at 4:06 PM
To widowman10@yahoo.com

You might be interested in this
http://fnai.blogspot.com/2015/07/species-in-focus-floridas-red-widow.html?m=0
You are welcome to use the bugguide/blog image or images for non-profit educational purposes as long as you credit me.

ENTOMOLOGY 101

Biogeography and Evolution

Biogeography & Evolution

- Topics
  - Biogeography
  - Antiquity of Insects
  - Aquatic or Terrestrial
  - Evolution of Wings
  - Insect Diversification
  - Pacific Insect Evolution

Biogeography

- Biogeography: the study of biotic distribution in space and time
- Different locations have different flora and fauna
- Examples
- “Oceans” and “islands”

Biogeography

- Biogeographic patterns – difficulties
- Biogeographic patterns – explanations
  - Anthropophilic
  - Human-associated
  - External / internal parasites
  - Agriculture / horticulture
  - Anthropogenic introduction

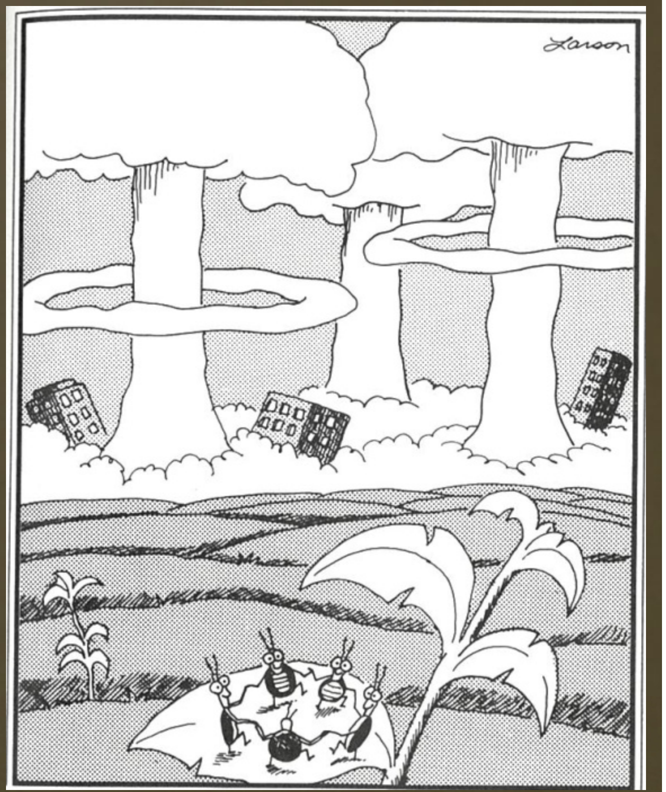
- Regulation of shipments and international travel

Antiquity of Insects

- Oldest hexapod fossils are from Devonian (over 400 mya)
  - *Rhyniognatha hirsti* (a springtail)
- Carboniferous (359-299mya) explosion
  - The earliest winged insects are from this time period
- Permian (299-245mya) insects
  - Protodonata (largest wingspan ever)
    - The top predators for over 100 my?
  - Origination of beetles

Antiquity of Insects

- Extinctions (and cockroaches!)
  - Carboniferous (359-299mya)
    - Cockroach origination: early Carboniferous
    - Many cockroach remains found in coal deposits
  - Permian – Triassic extinction event
    - the largest extinction event in the history of the Earth
    - 30% of all insect species became extinct
  - Triassic – Jurassic extinction event
  - Cretaceous – Paleogene extinction event



Antiquity of Insects

- Triassic period
  - 245-201mya
  - Much radiation occurred
  - Major orders are well represented in this period
  - Appearance of Hymenoptera and immature aquatic insects

Antiquity of Insects

- Jurassic period
  - 201-145mya
  - Origin and development of birds marked the first aerial competition for insects
  - Many species started to spread globally
  - Dramatic increase in Coleoptera families
  - Proliferation of phytophagous insects

Antiquity of Insects

- Cretaceous – Tertiary
  - 145-65mya / 65-1.7mya
  - Excellent preservation of specimens in amber
  - Preservation in amber vs. compression
  - Smaller, forest-dwelling insects over-represented
  - Coleoptera and Lepidoptera underwent massive radiation
  - By 65mya, insect fauna looks rather modern
  - Like dinosaurs, Cretaceous-Tertiary boundary marked a major extinction event

Antiquity of Insects

- Cretaceous – Tertiary
  - Attempts to extract, amplify, sequence DNA from amber insects
    - Positives
    - Negatives

  - Attributable types of feeding damage (despite absence of actual insect)

Antiquity of Insects

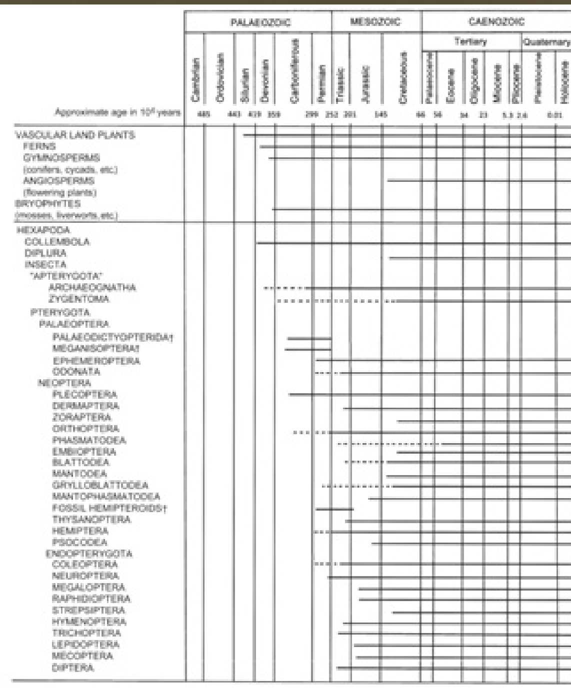


Fig. 8.2 The geological history of insects in relation to plant evolution. Taxa that contain only fossils are indicated by the symbol †. The record for extant orders is based on definite members of the crown group and does not include stem-group fossils; dashed lines indicate uncertainty in placement in the crown group. Thus, this chart does not include records of most early insect radiations; for example "roachoid" fossils occur in the Palaeozoic but are not part of the more narrowly defined Dictyoptera and Blattodea. Protura and Siphonaptera are not shown due to inadequacy of their fossil record; Isoptera is part of Blattodea. The placement of *Rhyniognatha* is unknown. (Insect fossil records have been interpreted from primary sources and after Grimaldi & Engel 2005; the date for the start of each geological period is from the International Commission on Stratigraphy; the Tertiary often is divided into the Palaeogene (66–23 Ma) and the Neogene (23–2.6 Ma.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

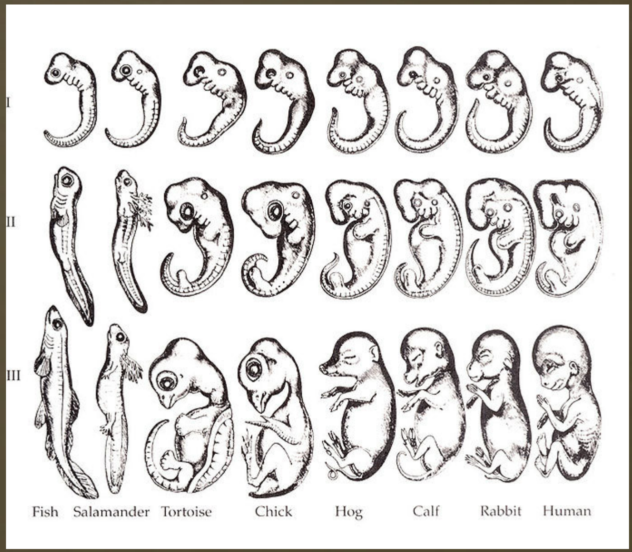
Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Aquatic or Terrestrial

- First arthropods were from the sea
- First insects, however, were terrestrial
- Independent colonization of land seen from:
  - Arachnids
  - Crustaceans
  - Myriapods
- Other terrestrial hexapods include:
  - Diplura
  - Collembola
  - Protura
- Ancestral condition for winged insects might have involved aquatic immatures
- Problems with the rise of a tracheal system in water
- Why have immature aquatic insects retained an aerial adult stage?

Evolution of Wings

- Evo-devo: a field of biology that compares the developmental processes of different organisms to determine the ancestral relationship between them, and to discover how developmental processes evolved.
  - Examples
  - Impact



- Hypotheses of the origin of wings
  1. Paranotal lobes (Paranotal Hypothesis)
  2. Limb modification (Endite-Exite Hypothesis)
  3. Tracheated gills (Epicoxal Hypothesis)

Evolution of Wings

- 4 routes to flight
  1. Floating
  2. Paragliding
  3. Running-jumping
  4. Surface sailing

- Support / criticism of route theories
- Flight had evolved by the middle of the Carboniferous (315mya)

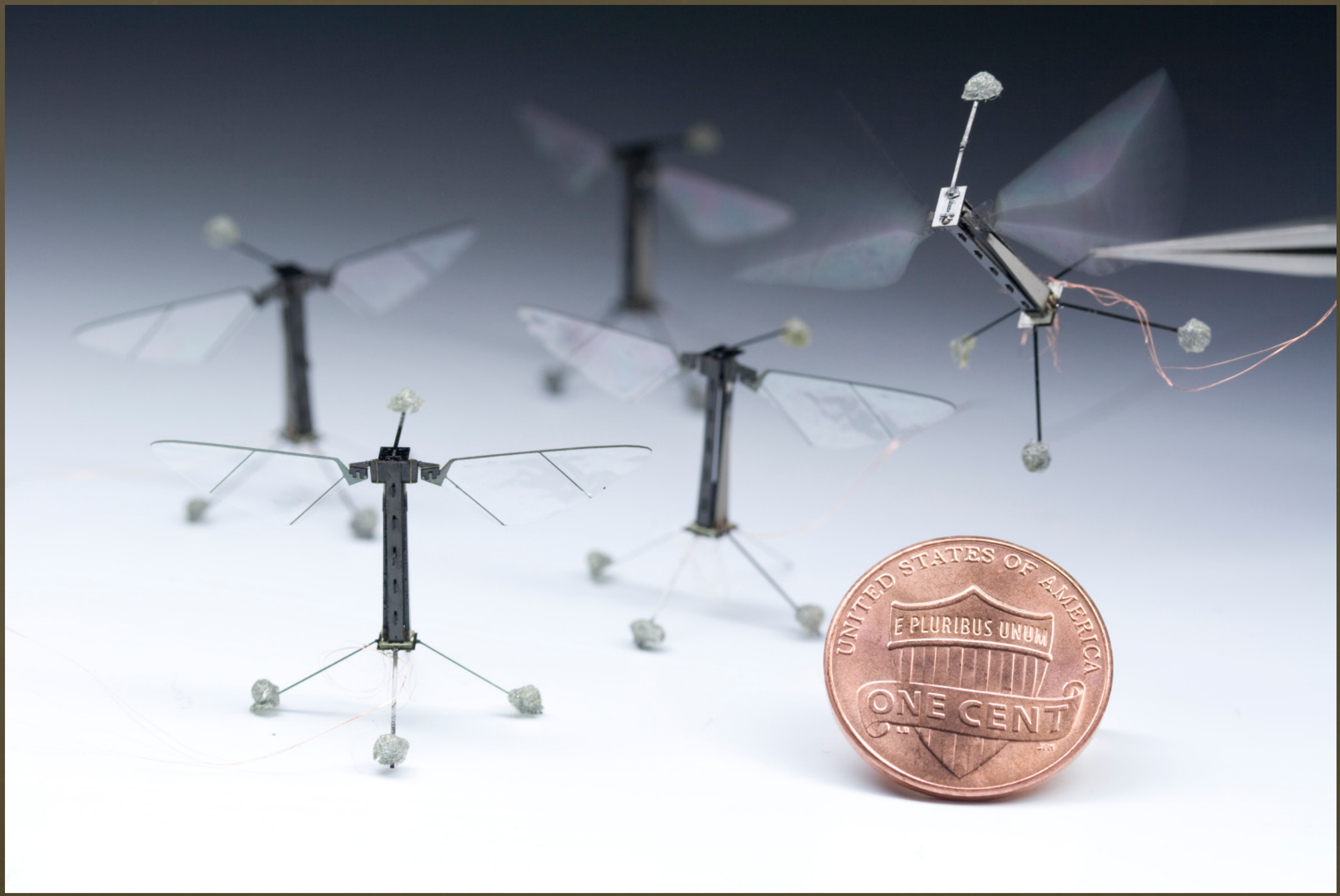
Evolution of Wings

- Division of pterygotes (winged insects) into:
  - Paleoptera – moveable, non-folding wings
    - Mayflies, dragonflies
  - Neuroptera – complex wing articulation
    - Bees, butterflies, beetles, etc

- Some suggest that wings have originated twice due to differences
- Venational patterns, however, point to single origin (monophyly)

Evolution of Wings

- Applications for military purposes

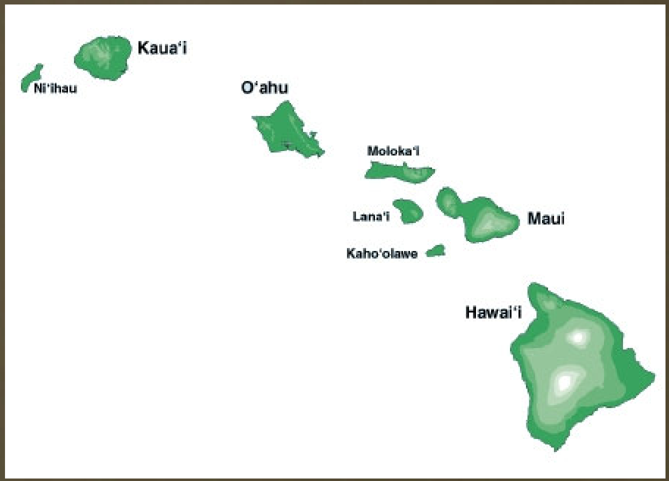


Insect Diversification

- Phytophagous insects diversified rapidly
- In direct correlation, parasites and parasitoids also diversified rapidly
- Effects of flight on diversification
  - Isolated populations
  - Fragmentation
- North American apple maggot fly
- No single factor explains the diversification of insects

Pacific Insect Evolution

- Importance of studying isolated fauna populations
  - Galapagos and Hawaii
- Comparable to "Darwin's finches"



- Geology of the Hawaiian islands
- Origination of colonization
  - Rare event – due to extreme isolation
  - Unbalanced biota, with major groups missing
  - Strange behaviors
  - Sources
- Loss of features
- Human influences

Pictures by Slide

1. (no picture)
2. (no picture)
3. https://commons.wikimedia.org/wiki/File:Ball%27s_Pyramid_North.jpg
4. Biogeography:
    1. http://www.cbp.gov/sites/default/files/u192/0334-0414%20Travelers%20Avoid%20Fines%20and%20Delays%20%28Vertical%208.5x11%29%20ENG.jpg
    2. https://help.cbp.gov/app/answers/detail/a_id/1253/kw/image/sno/1
5. https://commons.wikimedia.org/wiki/File:Meganeura_fossil_1.JPG
6. The Far Side Gallery 2 by Gary Larson, 1986, page 147
7. https://commons.wikimedia.org/wiki/File:Tenomerga_mucida01.jpg
8. https://commons.wikimedia.org/wiki/File:Archaeopteryx_lithographica_%28Berlin_specimen%29.jpg
9. https://commons.wikimedia.org/wiki/File:Amber2.jpg
10. https://commons.wikimedia.org/wiki/File:Jurassic_Park_Museo_nazionale_del_cinema.jpeg
11. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 8.1
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13. https://commons.wikimedia.org/wiki/File:Haeckel_drawings.jpg
14. http://3.bp.blogspot.com/-HVcFzAP5Mf8/UT5UwPnIDfI/AAAAAAAAIKA/-ePpQFV_PjQ/s1600/Large+winter+stonefly+surface-skimming+%25281024x681%2529.jpg
15. Evolution of wings
    1. https://commons.wikimedia.org/wiki/File:CrocothemisErythraeaMale.jpg
    2. https://commons.wikimedia.org/wiki/File:Dolycoris_baccarum_wings.jpg
16. http://wyss.harvard.edu/staticfiles/newsroom/pressreleases/RoboticInsectPhoto02.jpg
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18. https://commons.wikimedia.org/wiki/File:Hawaii_islands.jpg

Questions?

Permission

B K <widowman10@yahoo.com> Feb 24 at 3:54 PM
To dana@naturewalks.us

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use one of your images, assuming of course I credit you and cite the URL?

http://www.abundantnature.com/2013/03/winter-stoneflies.html

Reply, Reply All or Forward | More

Dana <dana@naturewalks.us> Feb 24 at 4:16 PM
To B K

Yes, that's fine.

Dana

Permission

Image for classroom use? (4)

People

B K <widowman10@yahoo.com>
To info@wyss.harvard.edu

May 20 at 3:13 PM

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could have permission to use your image for educational use, assuming of course I credit you and cite the URL? - Brian Kelly

http://wyss.harvard.edu/staticfiles/newsroom/pressreleases/RoboticInsectPhoto02.jpg

Reply, Reply All or Forward | More

Kroll, Seth Brian, Thanks for reaching out. Which university do you teach at, and do you have a university email address? And, in what context will the RoboBee image be used? Once I hear back from you I will cont

May 23 at 3:21 PM

B K Hey Seth, I am taking my curriculum to Pikes Peak Community College here in Colorado Springs and hope to teach an Intro to Entomology there. I do not have a university email address yet. The image wou

Today at 8:14 AM

Kroll, Seth <Seth.Kroll@wyss.harvard.edu>
To B K

Today at 11:17 AM

Brian,

Sounds good. The Wyss Institute grants permission to use the RoboBee image. Is the version you found acceptable or do you need me to send another version of it.

Regardless, please credit the image as "Wyss Institute at Harvard University."

Thanks and be well,
Seth

Seth Kroll
Associate Director of Digital & Multimedia
Wyss Institute for Biologically Inspired Engineering
Harvard University - Center for Life Sciences Building
3 Blackfan Circle, 5th Floor, Boston, MA 02115
wyss.harvard.edu

Watch on Vimeo | Listen on SoundCloud

1:01 PM
5/24/2016

ENTOMOLOGY 101

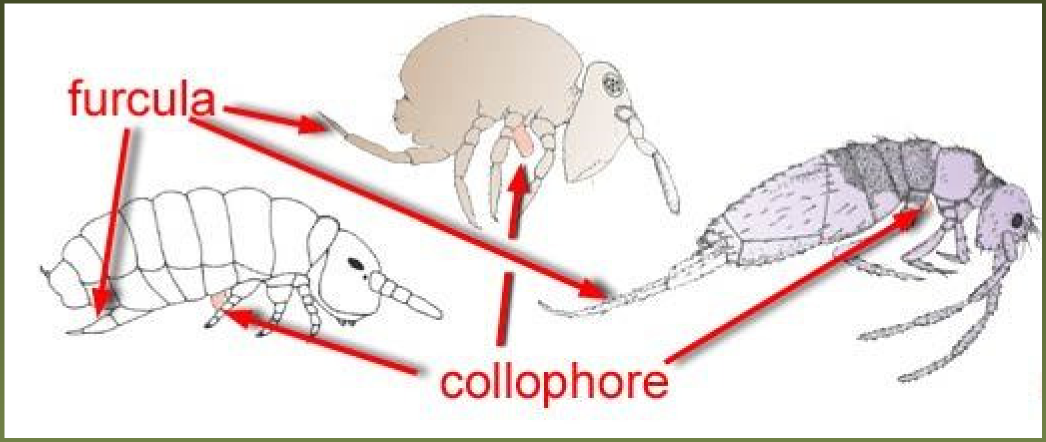
Ground-Dwelling Insects

Ground-Dwelling Insects

- Topics
  - Litter and Soil
  - Dead / Decaying Wood
  - Dung
  - Carrion
  - Fungal Interactions
  - Cave Insects

Litter and Soil

- Soil composition and profile
- Morphology often reflects soil layer
  - Pigmentation
  - Wings
  - Appendages
- Adaptations
- Seasonal distribution in soil level



Litter and Soil

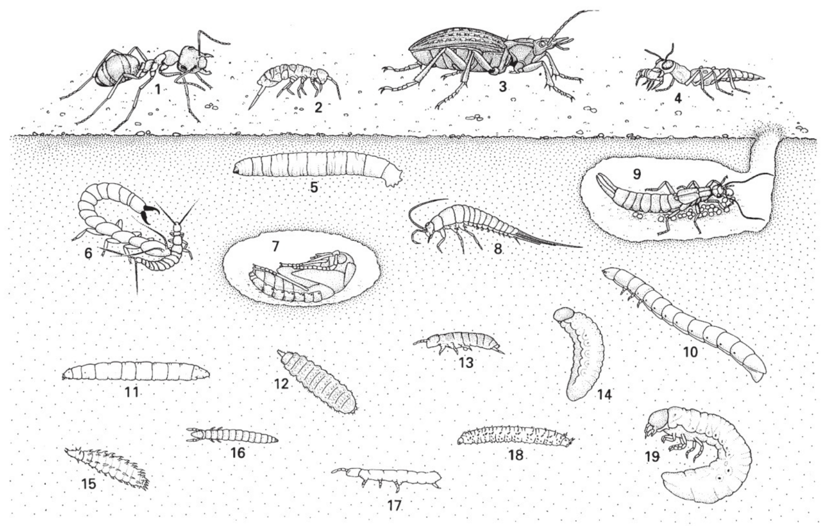


Fig. 9.1 Diagrammatic view of a soil profile showing some typical litter and soil insects and other hexapods. Note that organisms living on the soil surface and in litter have longer legs than those found deeper in the ground. Organisms occurring deep in the soil usually are legless or have reduced legs; they are unpigmented and often blind. The organisms depicted are: (1) worker of a wood ant (Hymenoptera: Formicidae); (2) springtail (Collembola: Isotomidae); (3) ground beetle (Coleoptera: Carabidae); (4) rove beetle (Coleoptera: Staphylinidae) eating a springtail; (5) larva of a crane fly (Diptera: Tipulidae); (6) japygid dipluran (Diplura: Japygidae) attacking a smaller campodeid dipluran; (7) pupa of a ground beetle (Coleoptera: Carabidae); (8) bristletail (Archaeognatha: Machilidae); (9) female earwig (Dermaptera: Labiduridae) tending her eggs; (10) wireworm, larva of a tenebrionid beetle (Coleoptera: Tenebrionidae); (11) larva of a robber fly (Diptera: Asilidae); (12) larva of a soldier fly (Diptera: Stratiomyidae); (13) springtail (Collembola: Isotomidae); (14) larva of a weevil (Coleoptera: Curculionidae); (15) larva of a muscid fly (Diptera: Muscidae); (16) proturan (Protura: Sinentomidae); (17) springtail (Collembola: Isotomidae); (18) larva of a March fly (Diptera: Bibionidae); (19) larva of a scarab beetle (Coleoptera: Scarabaeidae). (Individual organisms after various sources, especially Eisenbeis & Wichard 1987.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

WILEY Blackwell

Litter and Soil

- Strategies to combat infection by microorganisms
- European beewolf, *Philanthus triangulum*

- Detritivore: an organism that consumes detritus (plant and animal parts)

Litter and Soil

- Difficulties in studying root-feeding insects
- Plant responses
- Pests and crop damage
- Estimating damage / losses
- Biological control agent strategies

Dead / Decaying Wood

- Transmission of pathogens to trees
- "The evolution of agriculture" in beetles
  - Symbiosis
  - Origination
  - Role of the fungi
- Locating burned trees
- Rotten timber a valuable resource
- Xylophagous: an organism that eats wood

Dead / Decaying Wood

- Tunnels in wood caused by beetles

Dung

- Dung as a rich source of nutrients
- Coprophage: an organism that feeds on dung
- Insects that utilize dung:
    - Flies
    - Beetles
    - Bees / wasps
    - Termites
    - Sloth moth

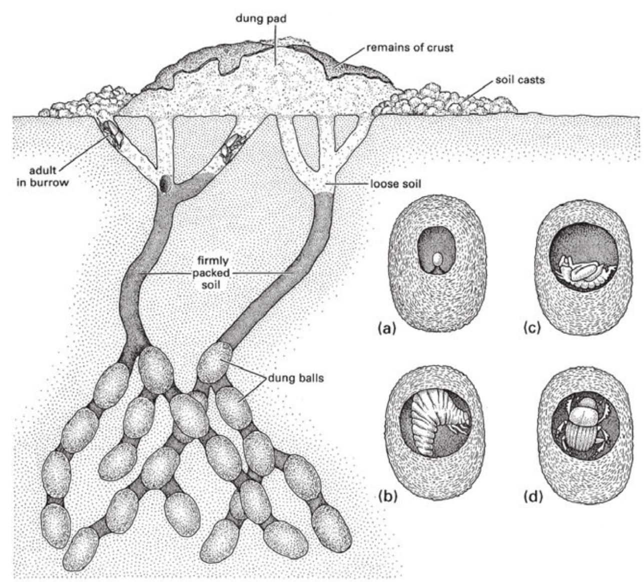
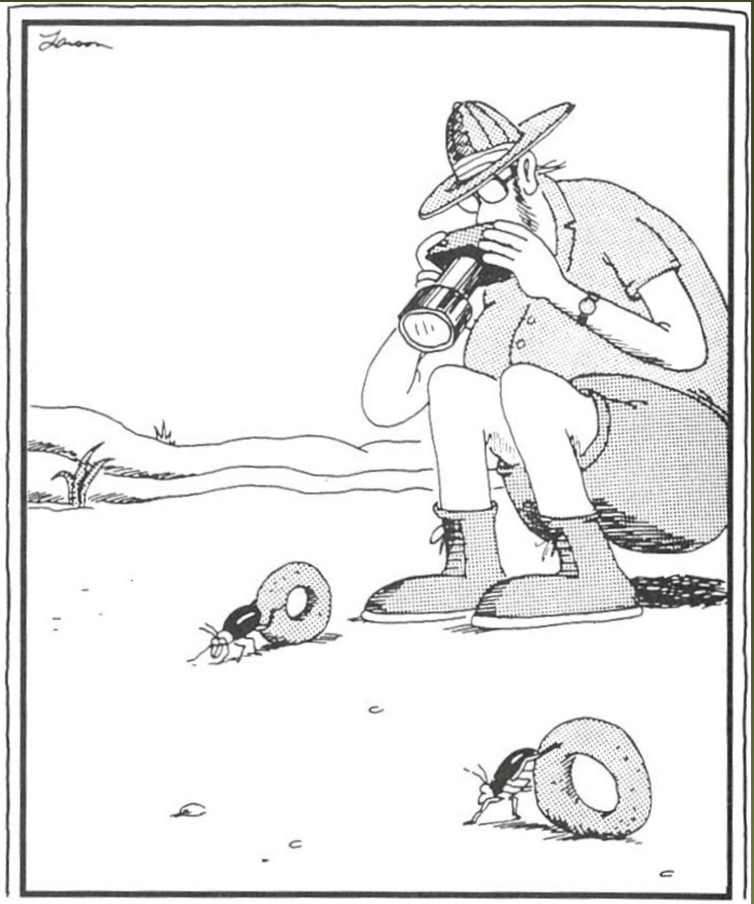


Fig. 9.6 A pair of dung beetles of *Onthophagus gazella* (Coleoptera: Scarabaeidae) filling in the tunnels that they have excavated below a dung pad. The inset shows an individual dung ball within which beetle development takes place: (a) egg; (b) larva, which feeds on the dung; (c) pupa; and (d) adult just prior to emergence. (After Waterhouse 1974.)

Dung

- Beetles
  - Roles and benefits
    - Billions of dollars in America alone
    - Seed dispersal
    - Parasite suppression
    - Soil fertilization
    - Soil aeration
  - Types
    - Rollers (Milky Way), Tunnellers, Dwellers



Studying the African bagel beetle

Dung

- Australia introductions
  - Introduction of cattle
  - Putrification of landscape / environment
  - No natural excrement decomposers
  - Australian Dung Beetle Project
  - “Decomposition control agents”

Carrion

- 5 stages of decay:
  1. Initial decay
     - aka “fresh”
  2. Putrefaction
     - aka “bloat”
  3. Black putrefaction
     - aka “active decay”
  4. Butyric fermentation
     - aka “advanced decay”
  5. Dry decay

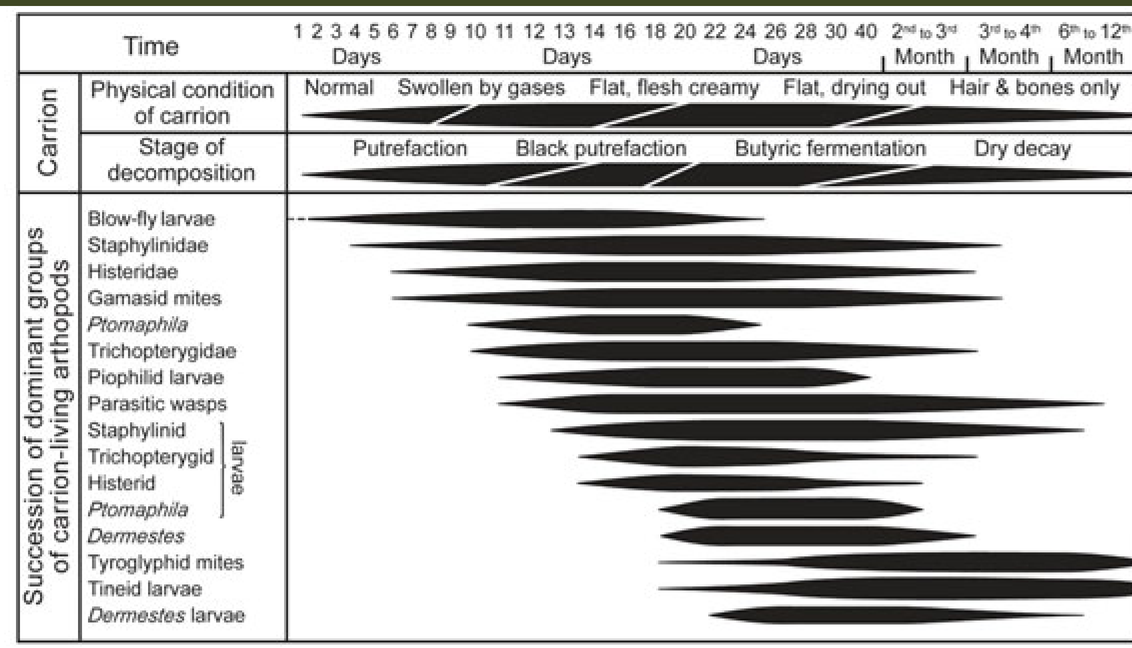


Fig. 15.2 The stages of carcass (carrion) decomposition associated with a succession of arthropod groups in guinea-pig carcasses during spring in a woodland habitat in Perth, Australia. Variation in the thickness of each band indicates the approximate relative abundance within the groups at different times. (After Bornemissza 1957.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

WILEY Blackwell

Carrion

- Necrophage: an organism that eats dead/decaying animals
- Succession: a continuous, sequential pattern of insect species exploiting a carcass as decay progresses
- Waves of colonization
- Interactions
- Experiences

Fungal Interactions

- Fungivore:
- Fungus farming
  - Attini ants
  - Cultivate fungi on dead matter
  - Leaf cutting and transport
  - Processing and cultivation
  - Domination of ecosystems
  - Defense / deterrence
- Fungus cultivation

Cave Insects

- Habitat
- Food sources
- 3 categories of cave dwellers:
  - Trogloxene
  - Troglophile
  - Troglobiont: occur exclusively in caves, never in the open
- Reduction in body pigmentation
- Last refuge for many ancient types of insects
- Studies in Hawaii

Pictures by Slide

no modifications were made to any pictures on any of the slides

1. (no picture)
2. (no picture)
3. http://itp.lucidcentral.org/id/mites/invasive_mite/Invasive_Mite_Identification/key/Is_it_a_mite/Media/Html/Collembola1.html
4. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 9.1
5. https://commons.wikimedia.org/wiki/File:European_beewolf_%28Philanthus_triangulum%29_coming_out_of_its_nest,_Sandy,_Bedfordshire_%287726825004%29.jpg
6. https://passel.unl.edu/Image/KohmetscherAmy1129928556/Image%203%20Corn%20Plant%20Roots.jpg
7. https://commons.wikimedia.org/wiki/File:Fallen_timber_in_East_Dundurn_Wood,_Perthshire_-_geograph.org.uk_-_1592044.jpg
8. Dead/Decaying Wood
    1. https://commons.wikimedia.org/wiki/File:Bark_Beetle_%28Scolytinae%29_larval_galleries_in_dead_wood_%2817083092007%29.jpg
    2. https://commons.wikimedia.org/wiki/File:Patterns_on_wood_caused_by_tunnelling_beetles_-_geograph.org.uk_-_1075995.jpg
9. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 9.5
10. Dung
    1. https://commons.wikimedia.org/wiki/File:Flightless_Dung_Beetle_Circellium_Bachuss,_Addo_Elephant_National_Park,_South_Africa.JPG
    2. The Far Side Gallery 4 by Gary Larson, 1993, page 118
11. https://commons.wikimedia.org/wiki/File:Namibia-dung-beetle-feast.jpg
12. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 15.2
13. https://commons.wikimedia.org/wiki/File:Nicrophorus_vespilloides_in_dead_rodent_flash_reduced.jpg
14. Fungal interactions
    1. https://commons.wikimedia.org/wiki/File:Leafcutter_ants.jpg
    2. https://commons.wikimedia.org/wiki/File:Leafcutter_ants_transporting_leaves.jpg
15. https://en.wikipedia.org/wiki/File:Ceuthophiluscricket.jpg

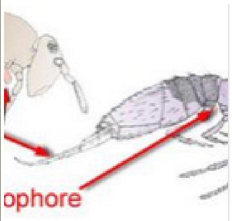
Questions?

Permission

To Terrence.W.Walters@aphis.usda.gov

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image, assuming of course I credit you and cite the URL?

Collembola



Collembola

Collembola Common names: springtails, collembolans, lucerne flea Probability of encounter: high Quarantine importance: some species are pests of plants.

View on itp.lucidcentral.org Preview by Yahoo

Reply, Reply All or Forward | More

Walters, Terrence W - APHIS <Terrence.W.Walters@aphis.usda.gov> Today at 2:26 PM

To 'B K'

Thank you for asking. You bet you can use it. You might look at the url below (first one) that is a node of our pest images.

Terrence

Permission

B K <widowman10@yahoo.com> Feb 25 at 3:40 PM
To lsandall5@unl.edu

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs (consequently, I'm also a current student at UNL!). I was wondering if I could use your image, assuming of course I credit you and cite the URL?

The image is the one of damage on the "Corn Rootworm Management Strategies" page.

Reply, Reply All or Forward | More

Leah Sandall Greetings, Would you be willing to share your name and where are you teaching? Your email did not include this. Yes, generally speaking you may use images from the eLibrary with proper citation of the Feb 26 at 10:36 AM

B K Leah, it would be from this page: https://passel.unl.edu/pages/printinformationmodule.php?idinformationmodule=1130447168&idcollectionmodule=1130274172 specifically this image: https://passel.unl.edu/I Feb 26 at 11:00 AM

Leah Sandall <lsandall5@unl.edu> Today at 12:34 PM
To B K

Brian,

Thank you for sending this information. Yes, you may use this image with proper credit given to Dr. Jim Kalisch, University of Nebraska-Lincoln, from The Plant and Soil Sciences eLibrary (https://passel.unl.edu).

I appreciate your inquiry and request for image use.

Leah

Leah Sandall
Distance Education Coordinator
Assistant Professor of Practice
Dept. of Agronomy and Horticulture
University of Nebraska-Lincoln
402.472.9295
http://agrohortonline.unl.edu

ENTOMOLOGY 101

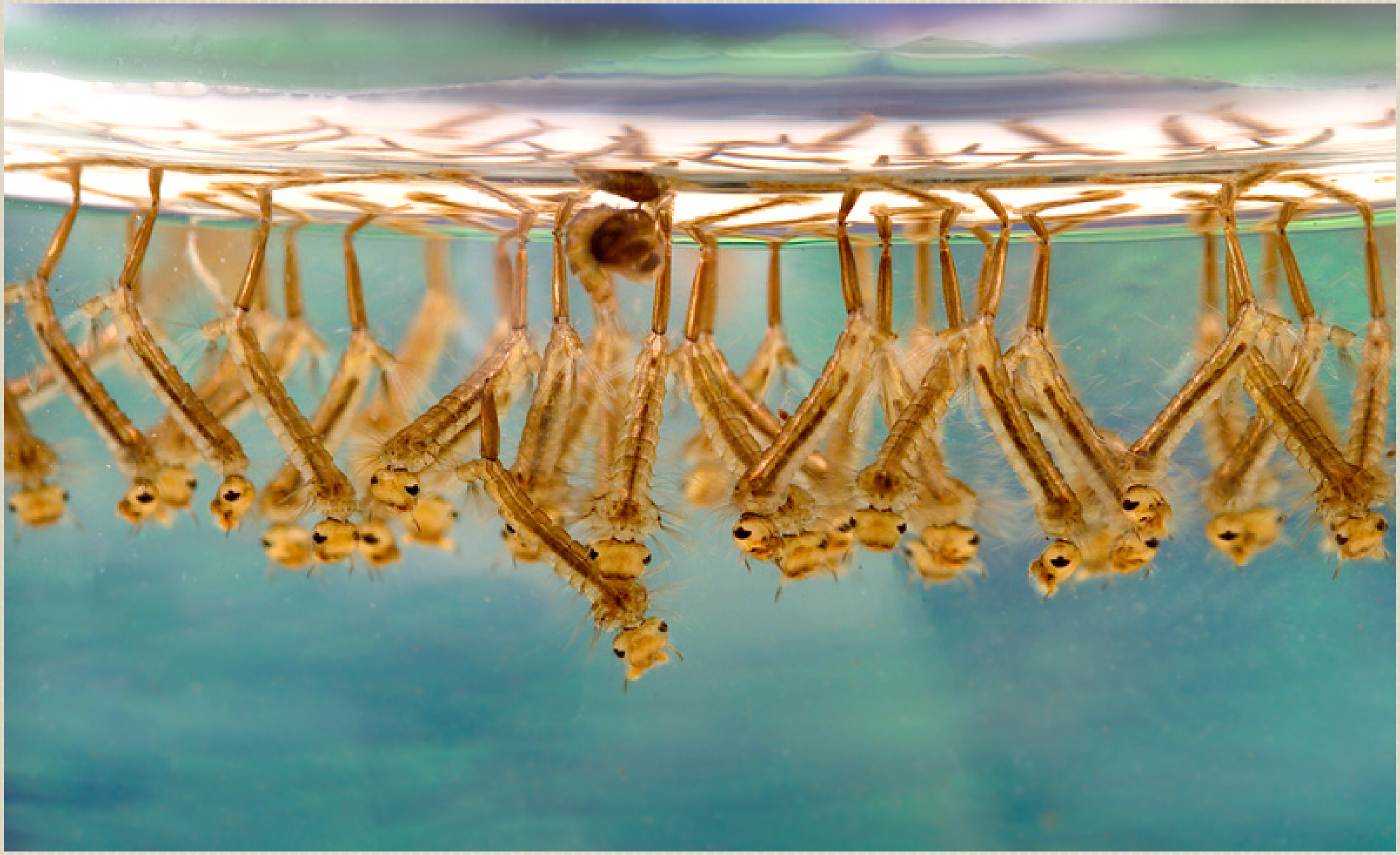
Aquatic Insects

AQUATIC INSECTS

- Topics
  - Common Aquatic Insects
  - Distribution & Terminology
  - Oxygen Supply
  - Aquatic Environment
  - Environmental Monitoring
  - Functional Feeding Groups
  - Temporary Waterbodies
  - Marine Insects

AQUATIC INSECTS

- Insects dominate freshwater aquatic systems
- Nearly all orders of insects are associated with water in at least 1 stage
- Diving beetles in aquifers



COMMON AQUATIC INSECTS

- Diptera (true flies)
  - Over 10,000 aquatic species
  - Includes:
    - Non-biting midges
    - Biting midges
    - Mosquitos
    - Black flies
  - Larvae commonly worm-like
  - Breathe through gills, plastron, or siphon
  - Emergence occurs at water surface

COMMON AQUATIC INSECTS

- Hemiptera (true bugs)
  - Most diversity in aquatic habitats
  - Over 4,000 species
  - Commonly includes:
    - Water striders / pond skaters
    - Water boatmen
    - Back-swimmers
    - Toe-biters
  - Often a loss of wings
  - Many are predators or scavengers

COMMON AQUATIC INSECTS

- Coleoptera (beetles)
  - Over 5,000 aquatic species
  - Predominately aquatic as larvae and terrestrial as adults
  - Rarely terrestrial as larvae and aquatic as adults
  - Includes:
    - Whirligig beetles
    - Predaceous diving beetles
  - Commonly use bubbles for respiration
  - Pupation is terrestrial (unlike the flies)
  - Most are predators or scavengers

DISTRIBUTION & TERMINOLOGY

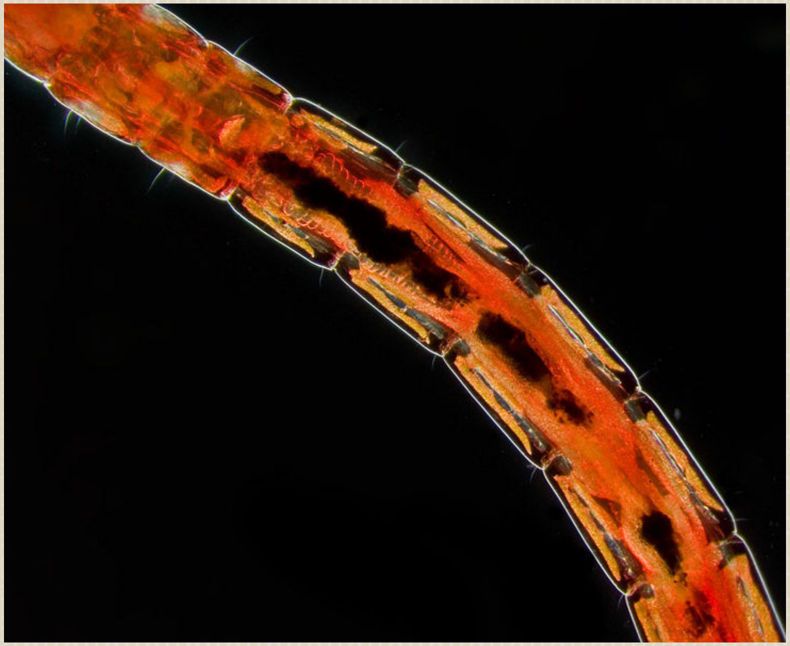
- Exclusively (or nearly) aquatic immature insect orders:
  - Megaloptera
  - Neuroptera
  - Ephemeroptera
  - Odonata
  - Plecoptera
  - Trichoptera
- Many representatives in major orders
  - Diptera
  - Hemiptera
  - Coleoptera
- Nymph / naiad
- Aquatic larva, aerial adult
  - Exploitation of different habitats
  - Exceptions

OXYGEN SUPPLY

- Lentic: standing water
- Lotic: flowing water
- Gas exchange across different mediums
- Oxygen supply for aquatic eggs

OXYGEN SUPPLY

- Cutaneous gaseous exchange is not enough
- Gills: tracheated cuticular extensions from the body
- Found in many important insect orders
- Great diversity in mayflies
- Hemoglobin in insects (bloodworms)



OXYGEN SUPPLY

- Examples of gills:

OXYGEN SUPPLY

- Open spiracular system
  - Surface suspension
  - Siphon
  - Regardless of dissolved oxygen content
  - Oil-tar ponds
  - Cuticular extensions
  - Plant piercing

OXYGEN SUPPLY

- Open spiracular system
  - Compressible gills
    - Subelytron retention
    - Atmospheric equilibrium and exchange of O, N, CO_2
    - Replenishment
    - Longevity
  - Plastron
    - Held by hydrofuge hairs or cuticular mesh
    - Diffusion

OXYGEN SUPPLY

- Manual ventilation
  - Slow diffusion rate of oxygen through water
  - Ventilation behaviors
    - Undulation
    - Selective positioning
    - Leg movements
    - Pumping

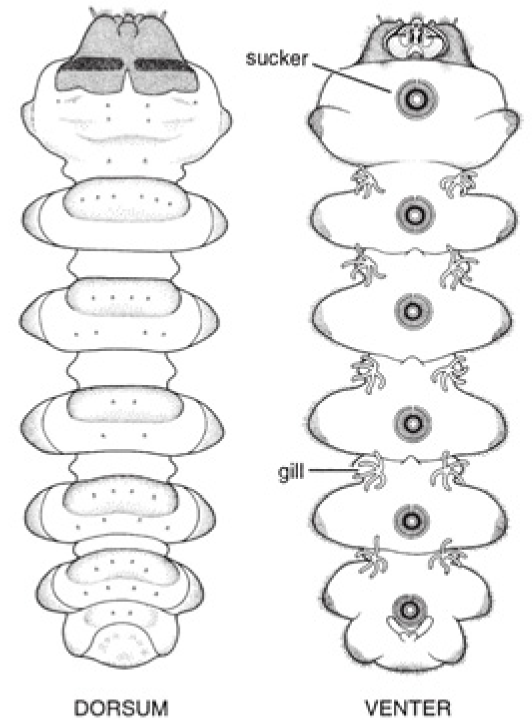


Fig. 10.4 Dorsal (left) and ventral (right) views of the larva of *Edwardsina polymorpha* (Diptera: Blephariceridae): the venter has suckers, which the larva uses to adhere to rock surfaces in fast-flowing water.
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

AQUATIC ENVIRONMENT

- Lotic adaptations
  - Rheophilic: strong currents
    - Dorsoventrally flattened
    - Caddisfly
      - Cases
      - Suckers
      - Silk
  - Benthos: bed of the stream
    - Drift
    - Burrowing
  - Hyporheic: substrate of the stream

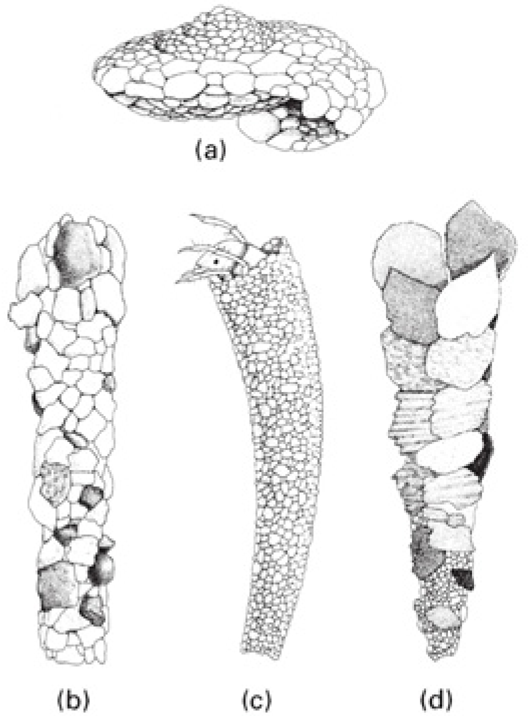


Fig. 10.5 Portable larval cases of representative families of caddisflies (Trichoptera): (a) Helicopsychidae; (b) Philorheithridae; (c) and (d) Leptoceridae.
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

AQUATIC ENVIRONMENT

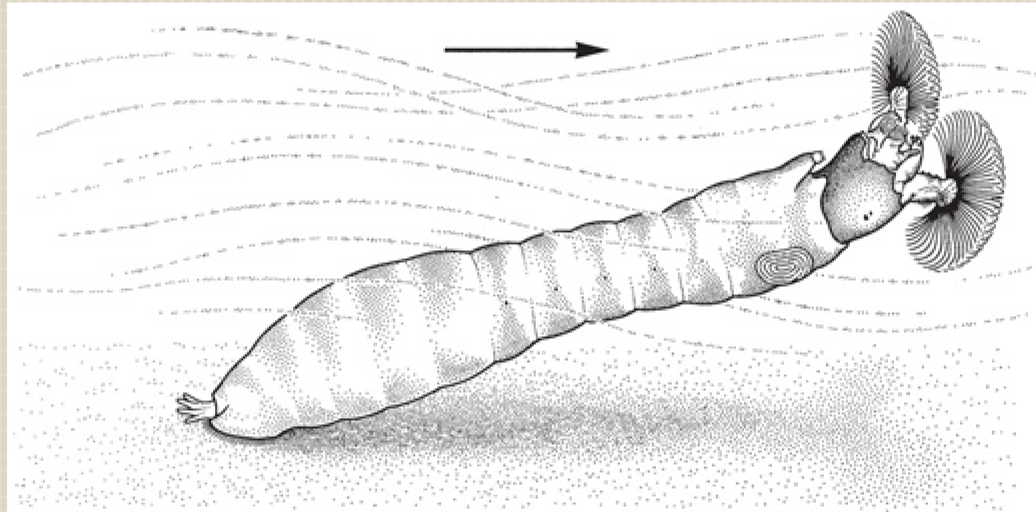
- Lentic adaptations
  - Neuston: surface of the water
    - Water striders
    - Whirligig beetles
  - Limnetic and profundel zones: between the surface and the bed
    - Deep lakes
  - Littoral zone: between surface and bed, where light penetrates completely
    - Typical example: most shallow ponds encountered
    - Diversity is at maximum

ENVIRONMENTAL MONITORING

- Importance and advantages to using insects in monitoring
- Pollutants
- Surrogates for humans – “early warning system”
- Responses to aquatic disturbance
  - Abundance of certain mayflies
  - Increase of bloodworms
  - Loss of stoneflies
  - Reduction in diversity

FUNCTIONAL FEEDING GROUPS

- Reasons for categorizing
- Types of feeders:
  - Shredders
  - Collectors
  - Scrapers
  - Piercers
  - Predators
  - Parasites
- Groups span across taxa
- Locations in river of the different feeding groups



A black-fly larva in the typical filter-feeding posture. (After Currie 1986.)

FUNCTIONAL FEEDING GROUPS

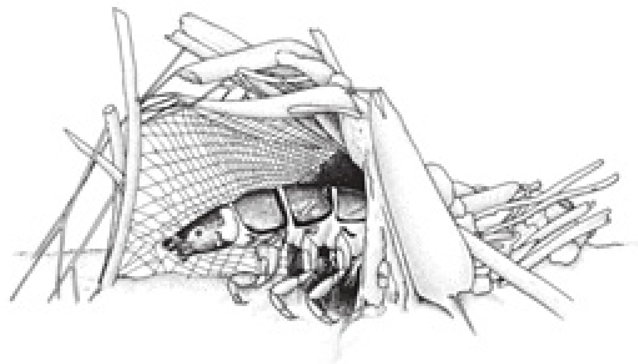


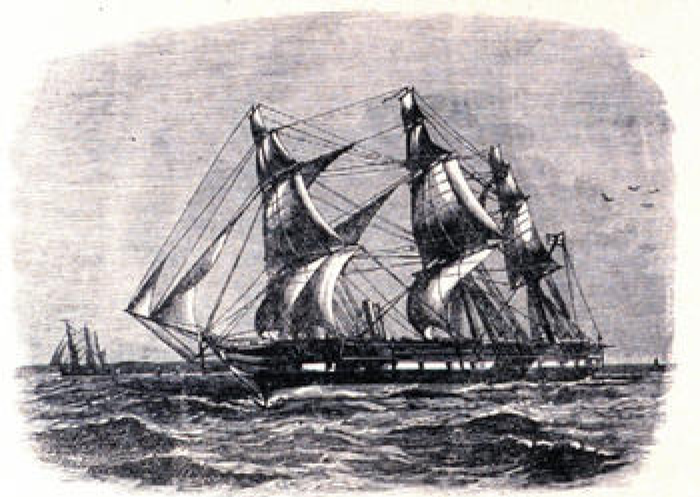
Fig. 10.6 A caddisfly larva (Trichoptera: Hydropsychidae) in its retreat; the silk net is used to catch food. (After Wiggins 1978.)

TEMPORARY WATERBODIES

- Ephemerality
- Rainfall, floods, pools
- Utilization of fleeting water sites
- Developmental adaptations
- Colonization

MARINE INSECTS

- Saltmarsh zone supports several insects
- Intertidal zone
- *Telmatogeton*
- *Pontomyia*
- *Halobates*
- Why are there not more insects in / on the ocean?



H.M.S. CHALLENGER UNDER SAIL, 1874.

Halobates sericeus, female, feeding on a *Drosophila* fly in the laboratory (from Cheng, 1974)

PICTURES BY SLIDE

NO MODIFICATIONS WERE MADE TO ANY PICTURES ON ANY OF THE SLIDES

1. (no picture)
2. https://commons.wikimedia.org/wiki/File:Hellgrammite_in_TN_stream.JPG
3. https://commons.wikimedia.org/wiki/File:Culex_sp_larvae.png
4. https://commons.wikimedia.org/wiki/File:Chironomus_plumosus01.jpg
5. https://commons.wikimedia.org/wiki/File:Water_strider_Vellathilaasaan.jpg
6. https://commons.wikimedia.org/wiki/File:Dryops_ernesti_side.jpg
7. https://commons.wikimedia.org/wiki/File:Brown_hawker_dragonfly_%28Aeshna_grandis%29_dragonfly_nymph_late_instar.JPG
8. https://commons.wikimedia.org/wiki/File:Nepa_cinerea_%28Nepidae_sp.%29,_Arnhem,_the_Netherlands.jpg
9. https://commons.wikimedia.org/wiki/File:Bloodworm.jpg
10. Oxygen Supply:
    1. https://commons.wikimedia.org/wiki/File:Dragonfly_Nymph_eating_tadpole.jpg
    2. https://commons.wikimedia.org/wiki/File:Mayfly_nymph_dorsal_view_wing_buds_paired_gills.JPG
11. https://en.wikipedia.org/wiki/File:Helaeomyia.petrolei.imago.-.sbmnh.jpg
12. https://www.cals.ncsu.edu/course/ent425/library/tutorials/internal_anatomy/aquatic_insects.html
13. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 10.4
14. Aquatic Environment
    1. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 10.5
    2. https://commons.wikimedia.org/wiki/File:L6_Dragovi%C5%A1tica_3_Sericostoma.jpeg
15. http://1.bp.blogspot.com/-e-AOkudVNI0/TZZB-sleorI/AAAAAAAAAMs/umGk4l7m0yE/s1600/gyrinidae.jpg
16. https://commons.wikimedia.org/wiki/File:Animas_River_spill_2015-08-06.JPG
17. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Chapter 10 vignette
18. Functional Feeding Groups
    1. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 10.6
    2. http://bugguide.net/node/view/502166/bgimage
19. https://en.wikipedia.org/wiki/File:MawsonPlateau-04.jpg
20. Marine Insects
    1. https://commons.wikimedia.org/wiki/File:Challenger.jpg
    2. http://www.zmuc.dk/entoweb/halobates/images/HALOBA10.JPG

QUESTIONS?

PERMISSION

Insect physical gill image use? (3)

People

B K <widowman10@yahoo.com>

Today at 6:33 PM

To john_meyer@ncsu.edu, dorr@ncsu.edu, aeko@ncsu.edu

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image, assuming of course I credit you and cite the URL?

https://www.cals.ncsu.edu/course/ent425/tutorial/bubble02.jpg

View on www.cals.ncsu.edu

Preview by Yahoo

Reply, **Reply All** or **Forward** | **More**

John Meyer <jrmeyer@ncsu.edu>

Today at 7:59 PM

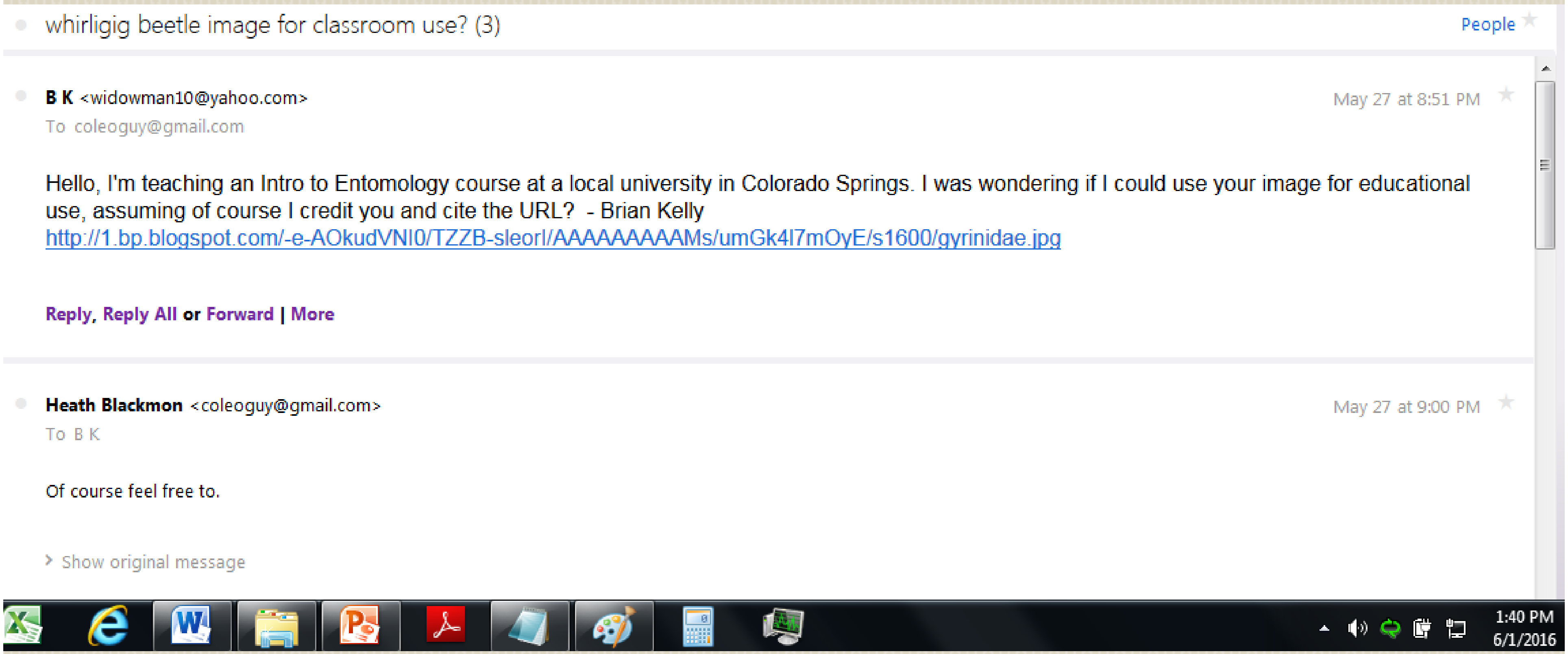
To B K

Permission granted.

John Meyer

8:44 PM
3/10/2016

PERMISSION



whirligig beetle image for classroom use? (3)

People

B K <widowman10@yahoo.com>

To coleoguy@gmail.com

May 27 at 8:51 PM

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image for educational use, assuming of course I credit you and cite the URL? - Brian Kelly

http://1.bp.blogspot.com/-e-AOkudVNI0/TZZB-sleorI/AAAAAAAAAMs/umGk4I7mOyE/s1600/gyrinidae.jpg

Reply, Reply All or Forward | More

Heath Blackmon <coleoguy@gmail.com>

To B K

May 27 at 9:00 PM

Of course feel free to.

› Show original message

PERMISSION

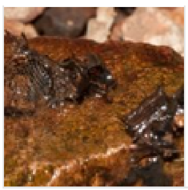
netspinner caddisfly image? (2)

B K <widowman10@yahoo.com>
To bugs@moonlittrails.com

Mar 10 at 7:44 PM

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image, assuming of course I credit you and cite the URL?

Netspinner Caddisfly Hydropsychid? - BugGuide.Net



Netspinner Caddisfly Hydropsychid? -

An online resource devoted to North American insects, spiders and their kin, offering identification, images, and information.

View on bugguide.net   Preview by Yahoo

Reply, Reply All or Forward | More

Debbi B. <groups@moonlittrails.com>
To B K

Today at 1:08 PM

Yes Brian,

It's fine to use that in your course with credit/URL.

Debbi

On 3/10/2016 6:44 PM, B K wrote:

PERMISSION

Halobates? (3)

B K <widowman10@yahoo.com>
To lcheng@ucsd.edu

Mar 10 at 8:23 PM

Hello Lanna, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image, assuming of course I credit you and cite the URL?

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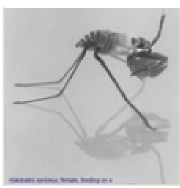

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Lanna Cheng <lcheng@ucsd.edu>
To B K

Today at 12:56 PM

You are must welcome to use the image. BTW, what is your name and affiliation? Just curious.

Lanna

ENTOMOLOGY 101

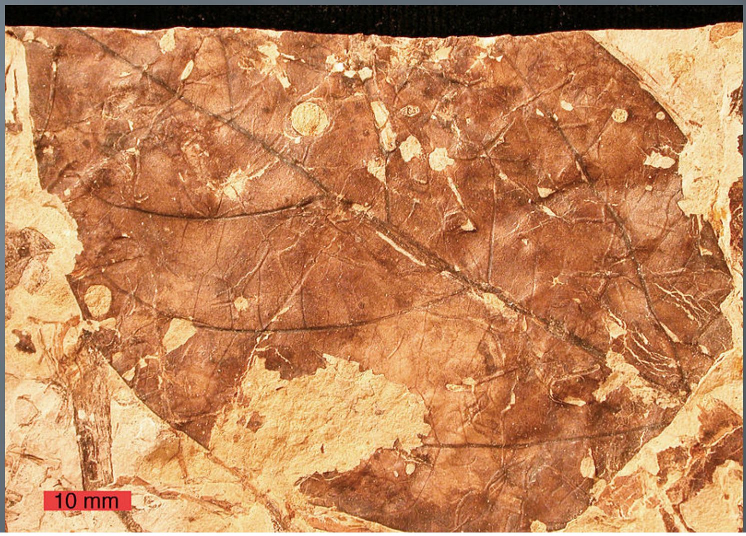
Insects and Plants

Insects and Plants

- Topics
  - Coevolutionary Interactions
  - Phytophagy
  - Insects & Plant Reproduction
  - Mutualistic Occupancy in Plants
  - Carnivorous Plants

Insects and Plants

- Insects and plants share ancient associations
  - Date back to the Carboniferous (300mya)
  - Evidence of insect damage preserved in fossilized plant parts
- Closely related histories
  - Radiating and diversifying together
  - Responsible for each others' speciation
- Pollinators may have promoted speciation in angiosperms
- Race between insect feeding and plant defense



Coevolutionary Interactions

- Coevolution: evolutionary interactions between two organisms
- Specific / pair-wise evolution
  - Evolution of a trait of one species in response to a trait of another species, which in turn evolved originally in response to the trait of the first species
  - Example: figs and fig wasps

- Guild evolution: reciprocal evolutionary change among groups
- Difficulties of observing such interactions

Phytophagy

- Insects can be categorized based on the range of plant taxa they use
  - Monophagous
  - Oligophagous
  - Polyphagous
- Continuous spectrum of insects that feed on 1 vs many plants
- No clear boundaries exist between these categories
- May occur in different groups depending on location / flora
- Some oligophagous species eat more plant species than polyphagous species- a reminder that these are based not on the number of plants but rather on the diversity of plants

Phytophagy

- Monophagous insects
  - Feed on only 1 species of plant (or plants within a single genus)
  - Occurs in all major groups of herbivorous insects
  - Potential for use in biological control
    - *Chrysolina quadrigemina* in Klamath weed
  - Examples:
    - *Bootettix argentatus* on creosote bushes in southwestern deserts of the US
    - *Heliconius melpomene* on passion flower vines

Phytophagy

- Oligophagous insects
  - Feed on a number of plants, usually in different genera within 1 plant family (but may extend to a limited number of different families)
  - Can be restricted or widened based on a characteristic found in similar plants
    - Could be a chemical compound
    - May span several taxa
  - Good examples: Colorado potato beetle- feeds on 14 different plants, all within the potato family (genus *Solanum*); monarch butterflies on various milkweeds

Phytophagy

- Polyphagous insects
  - Feed on a large number of plants from different families
  - Desert locust, *Schistocerca gregaria,* eats over 400 plant species
  - *Spodoptera littoralis* eats plant species from over 50 different families

Phytophagy

- Secondary plant compounds: plant chemicals assumed to be produced for defensive purposes
- Apparency: obviousness of a plant to an insect herbivore
  - Large clump of long-lived trees vs. scattered herb plants
  - Effects of human agriculture
- Insect feeding on stressed vs. vigorous trees
- 2 assumptions of herbivory theory
  1. Damage by herbivores is a dominant selective force on plant evolution
  2. Food quality has a dominant influence on the abundance of insects and the damage they cause
- Do insects impair or help plants by feeding on them?

Phytophagy

- Leaf chewing
  - Damage is readily visible and measurable
  - Leaf pests easier to identify than root pests
  - Most diverse leaf chewers: moths/butterflies and beetles
  - Damage mostly confined to leaves, but can include other parts
  - Douglas-fir Tussock moth
  - Damage: measuring and differences

Phytophagy

- Plant mining
  - Leaf mining
  - Agromyzids
  - Commercial damage
  - Stem mining

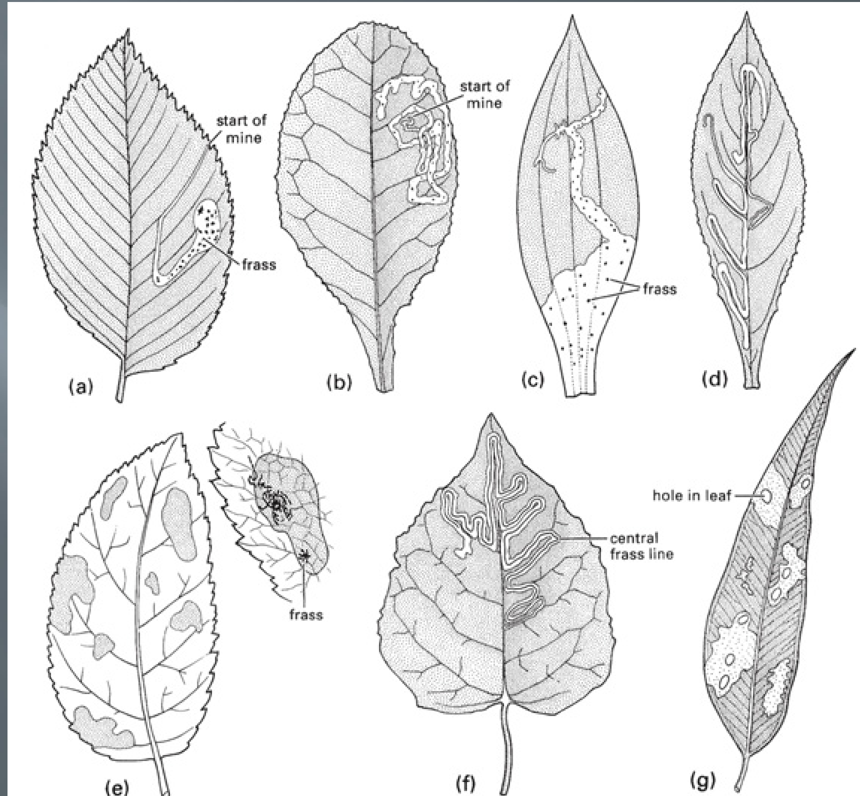


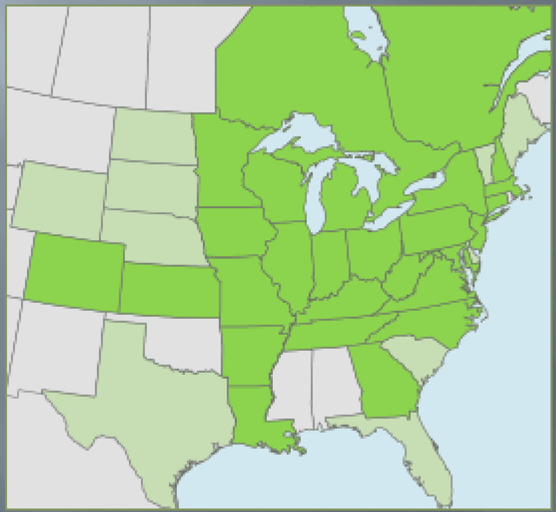
Fig. 11.2 Leaf mines: (a) linear-blotch mine of *Agromyza aristata* (Diptera: Agromyzidae) in leaf of an elm, *Ulmus americana* (Ulmaceae); (b) linear mine of *Chromatomyia primulae* (Agromyzidae) in leaf of a primula, *Primula vulgaris* (Primulaceae); (c) linear-blotch mine of Chromatomyia gentianella (Agromyzidae) in leaf of a gentian, *Gentiana acaulis* (Gentianaceae); (d) linear mine of *Phytomyza senecionis* (Agromyzidae) in leaf of a ragwort, *Senecio nemorensis* (Asteraceae); (e) blotch mines of the apple leaf miner, *Lyonetia prunifoliella* (Lepidoptera: Lyonetiidae), in leaf of apple, *Malus sp.* (Rosaceae); (f) linear mine of *Phyllocnistis populiella* (Lepidoptera: Gracillariidae) in leaf of poplar, *Populus* (Salicaceae); (g) blotch mines of jarrah leaf miner, *Perthida glyphopa* (Lepidoptera: Incurvariidae), in leaf of jarrah, *Eucalyptus marginata* (Myrtaceae). ((a,e–f) After Frost 1959; (b–d) after Spencer 1990.)

Phytophagy

- Plant boring
  - Stem boring
  - Common types of borers:
    - Stalk borers
    - Wood borers
    - Root borers
    - Fruit borers
  - Use as biological control agents

Phytophagy

- Emerald ash borer
  - Introduced from Asia in 2002
  - Feed primarily on ash trees and is a major pest
  - Countless trees (in the 10's of millions) have been destroyed
  - Spread to many states in short amount of time
  - Great example of accidental importation of damaging invasive species



Phytophagy

- Sap sucking
  - Most sap-sucking insects belong to the order Hemiptera (true bugs)
  - Difficult to observe and quantify damage
  - Serious agricultural and horticultural pests
  - Damage: slow root growth, fewer leaves, less overall biomass
  - Details of feeding

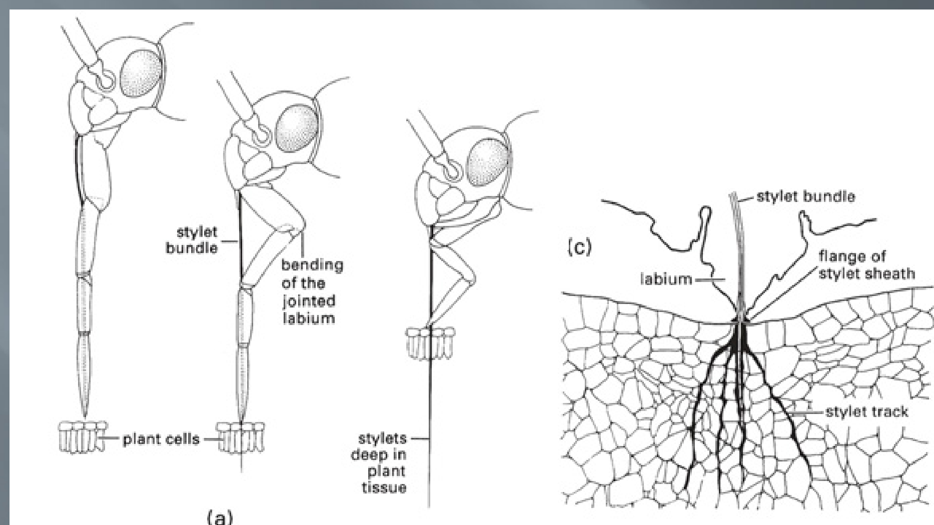


Fig. 11.4 Feeding in phytophagous Hemiptera: (a) penetration of plant tissue by a mirid bug, showing bending of the labium as the stylets enter the plant; (b) transverse section through a eucalypt leaf gall containing a feeding nymph of a scale insect, *Apiomorpha* (Eriococcidae); (c) enlargement of the feeding site of (b), showing multiple stylet tracks (formed of solidifying saliva), resulting from probing of the parenchyma. ((a) After Poisson 1951.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

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Phytophagy

- Galls
  - Gall: an aberrant plant growth produced in response to the activities of an insect
  - Plant part morphology is altered
  - Usually stimulated on young plant parts
  - Can be caused by: viruses, bacteria, fungi, nematodes, mites, insects
  - Primarily: true bugs, flies, bees/wasps
  - Cynipidae wasps on oaks and roses
  - Enormous diversity of galls
  - Common types of galls (Figure 11.5)
  - Benefits of galling: protection, quality of food

Phytophagy

- Seed predation
  - Target for consumption due to high level of nutrients
  - Serious pests of stored products
  - Timing and development of seeds and use by insects
  - Plant defenses against seed predation
  - Harvester ants

Insects & Plant Reproduction

- Pollination
  - Pollination: the transfer of pollen from male to female flower parts
  - Relationship is mutualistic- both parties benefit
  - Insects pollinate most flowering plants
  - Insects are more efficient pollinators than wind
  - Pseudocopulatory pollination

Insects & Plant Reproduction

- Pollination
  - Major pollinators
  - Different types of –phily
  - Bees are the most important pollinators
  - All species of bees (>20,000) are pollinators
  - Main bee pollinator worldwide: Apis mellifera
  - Nectar guides

Insects & Plant Reproduction

- Pollination
  - Malagasy star orchid and the giant hawkmoth

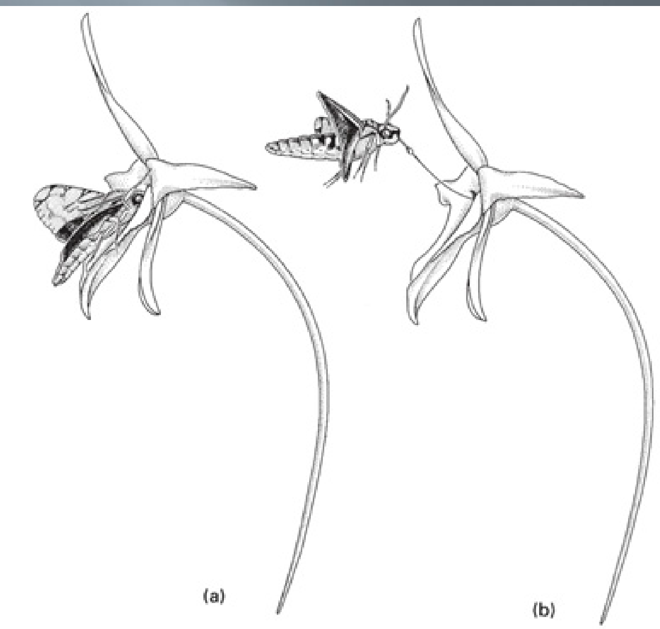

Fig. 11.7 A male hawk moth of *Xanthopan morganii praedicta* (Lepidoptera: Sphingidae) feeding from the long floral spur of a Malagasy star orchid, *Angraecum sesquipedale*: (a) full insertion of the moth's proboscis; (b) upward flight during withdrawal of the proboscis with the orchid pollinium attached. (After Wasserthal 1997.)

Insects & Plant Reproduction

- Myrmecochory
  - Myrmecochory: the collection and dispersal of seeds by ants
  - Elaiosomes: a food body attached to a plant seed
  - Elaiosome is consumed, seed is discarded
  - Plants have become adapted for interactions with ants
  - Benefits both parties: food for ants, dispersion for plants

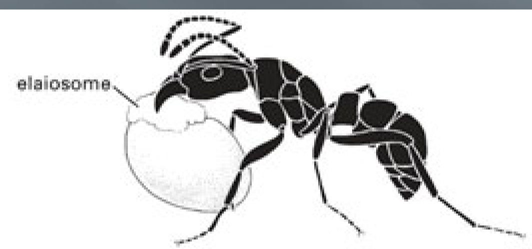

Fig. 11.8 An ant of *Rhytidoponera tasmaniensis* (Hymenoptera: Formicidae) carrying a seed of *Dillwynia juniperina* (Fabaceae) by its elaiosome (seed appendage).
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
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Mutualistic Occupancy in Plants

- Domatia
  - Domatia: plant chambers produced specifically to house ants
  - Different than galls
  - Used for feeding, nesting, or both
  - Food bodies, EFNs, and "farming" for food
  - Association benefits both ants and plants
  - Ants provide: protection, removal of pests, pruning

Mutualistic Occupancy in Plants

- Plant-held water containers
  - Pitcher plants
  - Odor, color, and nectar attract insects
  - Guard hairs and slippery walls prevent exit
  - Insects drown in the liquid, which contains digestive enzymes
  - Mosquitos and midges can live in them without harm
  - Insects living within the plant are mutualistic with the plant
  - *Camponotus* ants in Borneo

Carnivorous Plants

- Pitcher and pitfall plants
- Sticky plants (sundew)

Carnivorous Plants

- Venus fly trap

In the Fly House of Horrors

Pictures by Slide

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    2. The Far Side Gallery 3 by Gary Larson, 1988, page 96

Questions?

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To MTSpiderLady@gmail.com

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Douglas-fir Tussock Moth - Orgyia pseudotsugata - BugGuide.Net

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Lynette <mtspiderlady@gmail.com>
To B K
Today at 1:50 PM

Yes you can use my image. Please credit it as Lynette Elliott.

Thanks for asking.

1:59 PM
3/21/2016

Permission

BugGuide image use for classroom? (3)

B K <widowman10@yahoo.com>
To pogolumina@davidlouisquinn.com

Today at 11:35 AM

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Pogonomyrmex occidentalis worker. - Pogonomyrmex occidentalis - BugGuide.Net

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paleoland@msn.com
To B K

Today at 11:40 AM

Yes, of course, use any of my images on BugGuide for teaching purposes.

Also see pogolumina.net - the photos there are much higher quality.

Thanks!

11:49 AM
3/22/2016

Permission

Image use for classroom? (3)

B K <widowman10@yahoo.com> Today at 1:55 PM
To nickrent@plant.siu.edu

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Vachellia cornigera Fabaceae image

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Daniel L Nickrent <nickrent@siu.edu> Today at 2:27 PM
To B K

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By the way, it is generally considered courteous to include your name, address, etc. in an email with such a request.

Best,
Dan Nickrent

2:44 PM
3/22/2016

****

Dr. Daniel L. Nickrent, Professor Emeritus
Department of Plant Biology
1125 Lincoln Drive, LSII 420
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Carbondale, IL 62901-6509

(618) 453-3223 - office

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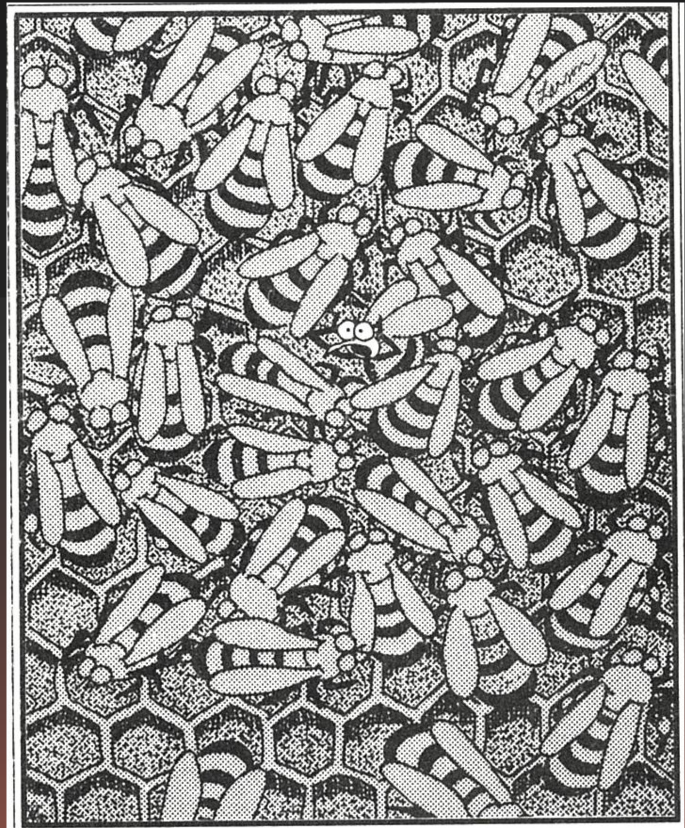
ENTOMOLOGY 101

Insect Societies

Insect Societies

- Topics
  - Subsociality in Insects
  - Eusociality in Insects
  - Inquilines and Parasites
  - Evolution, Origin, & Maintenance
  - Success of Eusocial Insects



“No more! No more! I can’t take it! ... That incessant buzzing sound!”

Insect Societies

- Social insects are a source of fascination and study
- They are highly successful
- They perform many important ecological functions
- Colonies can be extremely large
  - Siafu, or driver ants
- Varying degrees of sociality:
  - Eusocial insects (true social)
  - Subsocial insects (below social)
  - Solitary (not social)

Insect Societies

- Eusociality is defined by 3 important traits:
  1. Division of labor, with a caste system involving sterile or non-reproductive individuals assisting those that reproduce
  2. Co-operation among colony members in tending the young
  3. Overlap of generations capable of contributing to colony functioning
- Restricted to: ants, termites, and some bees / wasps
- Subsociality is a more widespread phenomenon
- Aphids and Thrips
- Quasisociality
- Semisociality
- Subsociality may or may not be an evolutionary precursor of eusociality

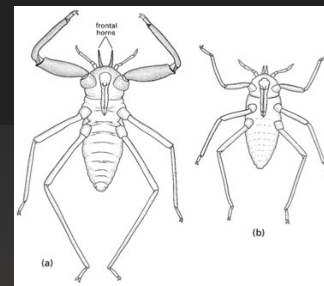


Fig. 12.1 First-instar nymphs of the subsocial aphid *Pseudoregma alexanderi* (Hemiptera: Hormaphidinae): (a) pseudoscorpion-like soldier; (b) normal nymph. (After Miyazaki 1987b.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
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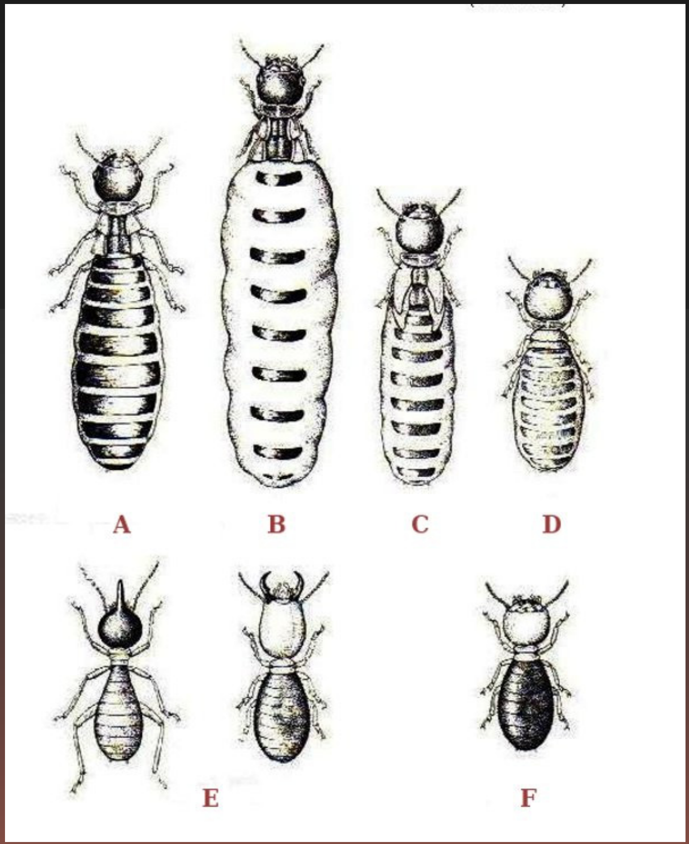
Subsociality in Insects

- Parental care
  - Varying degrees of parental care
  - Parental care without nesting
    - Mortality and guarding
    - Delegation to other species
  - Parental care with solitary nesting
    - Beetles
    - Wasps
  - Parental care with communal nesting
    - Sharing of nests
    - Selfish behavior
    - Attract specialized parasites
    - Females guard and maintain
    - Provisioning

Eusociality in Insects

- There is division in labor, involving a caste system
- Members of the caste:
  - Queen, or gyne
  - Secondary queen
  - King
  - Soldiers
  - Drones
  - Workers
  - Brood
- Primary differentiation is gender
- Polyphenism
- Polyethism



Eusociality in Insects

- Hymenopterans showing primitive eusociality
  - Such as the paper wasps
  - Monogynous – dominated by 1 queen
    - The queen's rise to dominance
  - Polygynous – several functional queens
  - Serially polygynous – a succession of functional queens
  - Bumble bees
  - Late season changes

Eusociality in Insects

- Specialized eusociality: bees and wasps
  - Colony and castes
    - Female castes are dimorphic, differing in appearance
    - Worker duties involve:
      - Distribution of food
      - Cleaning services
      - Ventilation and air-conditioning
      - Defense of the nest
      - Foraging for water and food
      - Construction and repair
    - Age polyethism and roles

Eusociality in Insects

- Specialized eusociality: bees and wasps
  - Colony and castes
    - Differences in stingers
    - Caste determination in the cell
      - Royal jelly
      - Full differentiation after only 4 days
    - Drones
      - Their 'contribution'
      - Winter time
    - Queen controls worker reproduction through pheromones

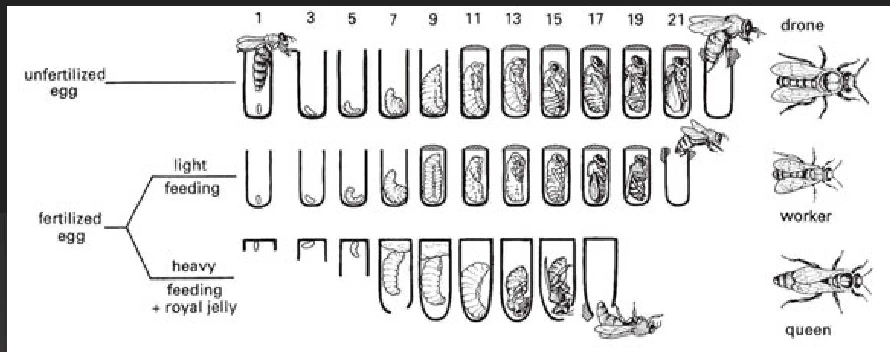


Fig. 12.5 Development of the honey bee, *Apis mellifera* (Hymenoptera: Apidae), showing the factors that determine differentiation of the queen-laid eggs into drones, workers, and queens (on the left), and the approximate developmental times (in days) and stages for drones, workers and queens (on the right). (After Winston 1987.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
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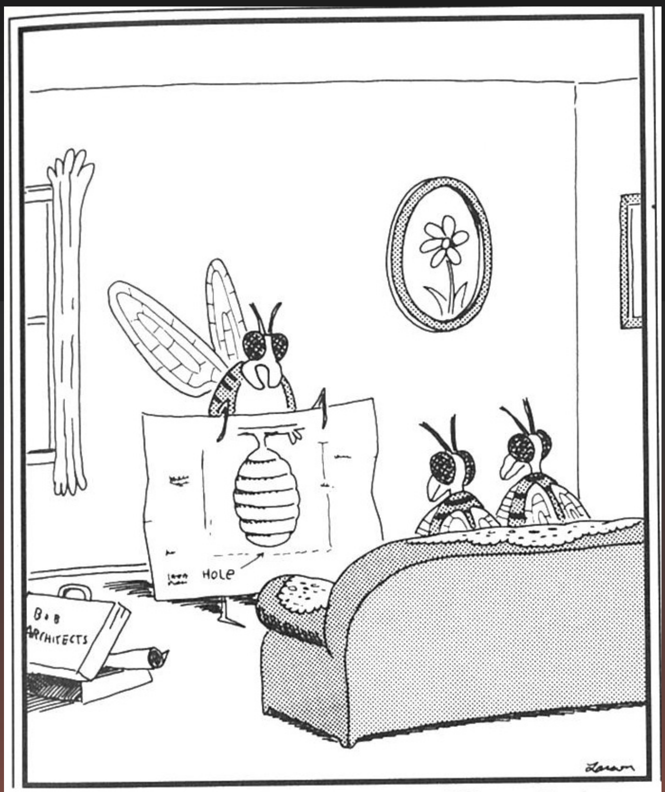
Eusociality in Insects

- Specialized eusociality: bees and wasps
  - Nest construction
    - Founding takes place in spring
    - Nest materials include:
      - Wood fibers
      - Water
      - Saliva
    - Construction
      - Pillar
      - Cells
      - Envelope
    - Growth
    - Combs
    - Heating and cooling



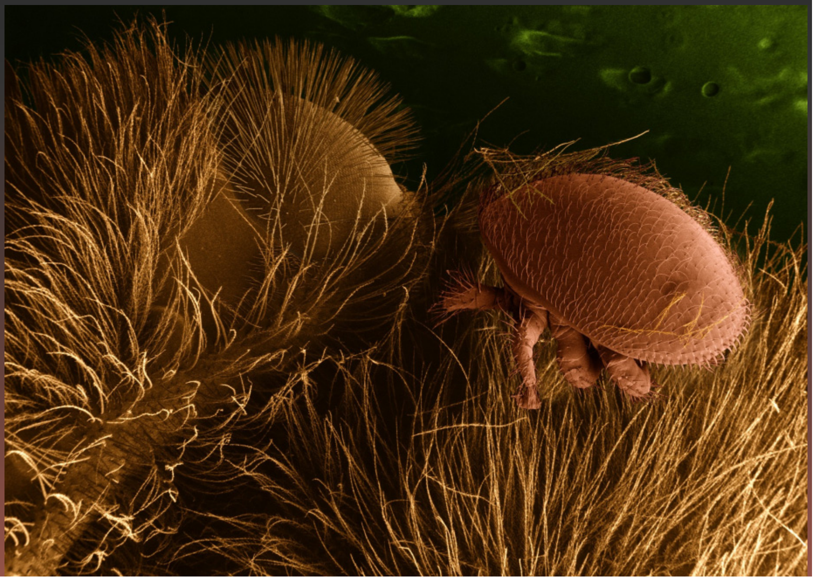
"Voila! … Your new dream home! If you like it, I can get a crew mixing wood fibers and saliva as early as tomorrow."

Eusociality in Insects

- Specialized eusociality: bees and wasps
  - Nesting in honey bees
    - Wax
    - Building with wax
    - Cells and dimensions
    - Wax and honey production
    - Activity continues through winter
    - Food reserves and 'huddling'
    - Hive boxes and apiculture
    - Commercial pollination and benefits

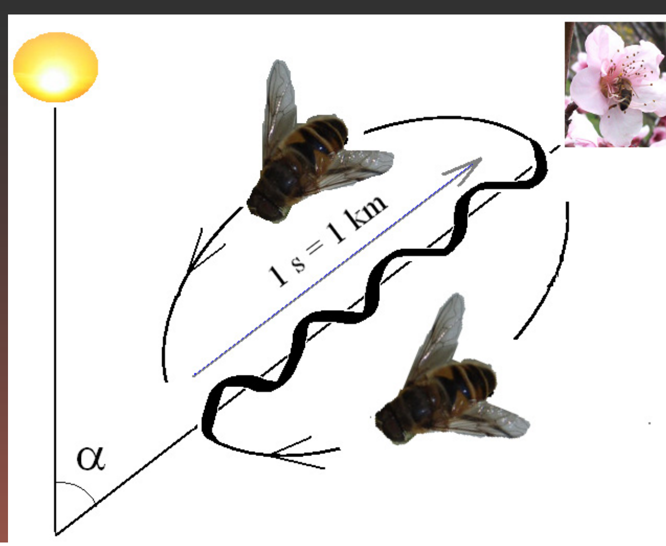
Eusociality in Insects

- "Colony collapse disorder" or CCD
  - Decline in bees across the USA since 1970s
  - Losses:
    - Over 1/3 of all the bee hives and 1/2 of the beekeepers
  - Symptoms:
    - Abandoned hive by all live bees
    - Honey and pollen stores intact
    - Pests and usurpers slow to capitalize
  - Caused by a number of factors, including:
    - Varroa mite
    - IAPV virus
    - Tracheal mite
    - Pesticides
    - Pollution
    - Stress: transport and other



Eusociality in Insects

- The dance language of bees
  - Ability to communicate the location of a food source
  - The discovery of the behavior
  - Initial worker performs a dance upon returning to the hive
  - 3 different types of dances depending on purpose:
    1. Round dance - Alerts other workers to a nearby food source
    2. Waggle dance - Alerts workers to more distant food sources
    3. Vibration dance - Acts as a recruitment dance



Dance of the Beekeepers

Eusociality in Insects

- Killer bees aka Africanized honey bees
  - Hybridization
  - Introduction and subsequent escape
  - Increased tendency to swarm, defend wider areas, and be more aggressive
- Asian giant hornet
  - Effect on 2 different species of honey bees, local and introduced

Eusociality in Insects

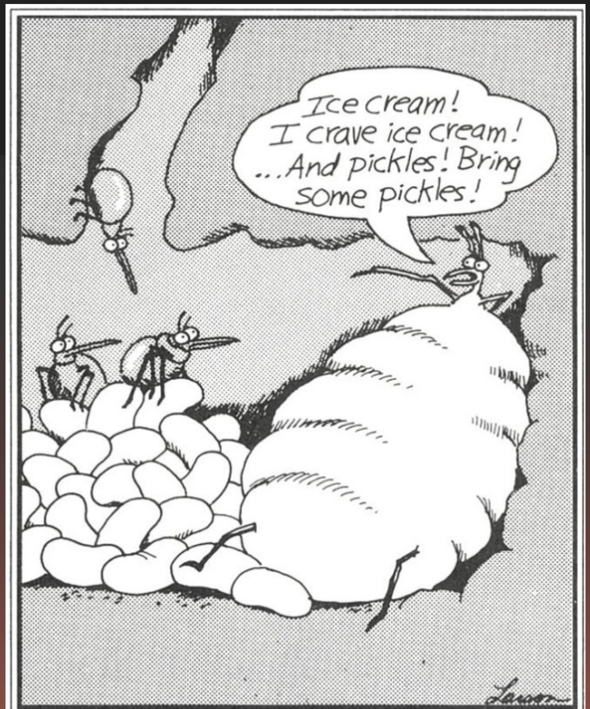
- Specialized hymenopterans: ants
  - Colony and castes
    - 2 major female castes:
      - Queen
      - Workers
    - Some have distinct subcastes based on size:
      - Minor
      - Media
      - Major
    - Polymorphism and polyethism
    - Worker reproduction

Eusociality in Insects

- Specialized hymenopterans: ants
  - Nesting
    - Locations of nests
    - Honeypot ants
    - Weaver ants

Eusociality in Insects

- Termites
  - Colony and castes



The termite queen in her egg chamber

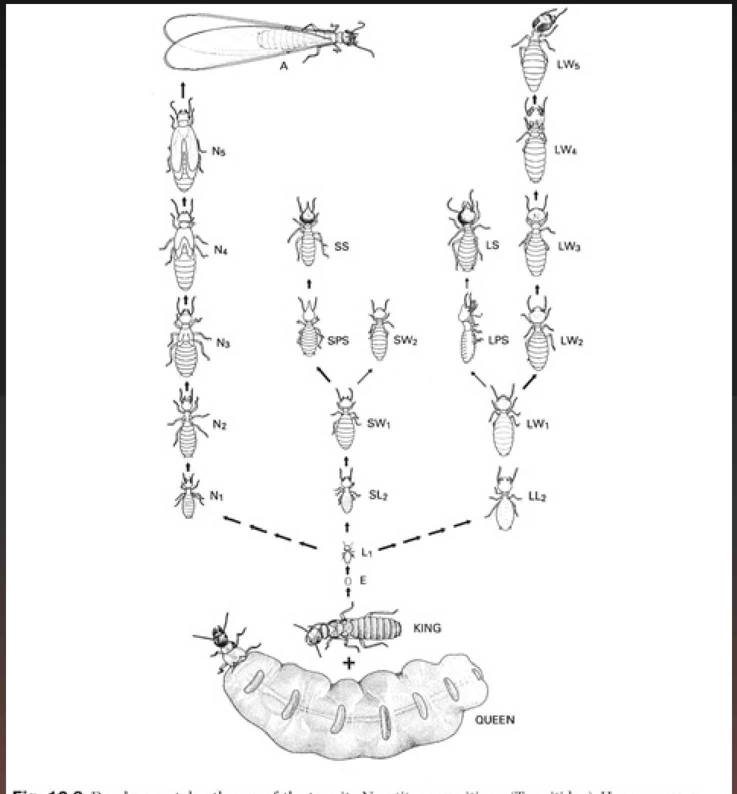


Fig. 12.8 Developmental pathways of the termite *Nasutitermes exitiosus* (Termitidae). Heavy arrows indicate the main lines of development, light arrows indicate the minor lines. A, alate; E, egg; L, larva; LL, large larva; LPS, large presoldier; LS, large soldier; LW, large worker; N, nymph; SL, small larva; SPS, small presoldier; SS, small soldier; SW, small worker. The numbers indicate the stages. (Pathways based on Watson & Abbey 1985.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

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Eusociality in Insects

- Termites
  - Nesting
    - Timber
    - Mounds
    - Subterranean
    - Colony size varies greatly
    - Colony maturity
    - Diverse mound architecture
    - Microclimatic control

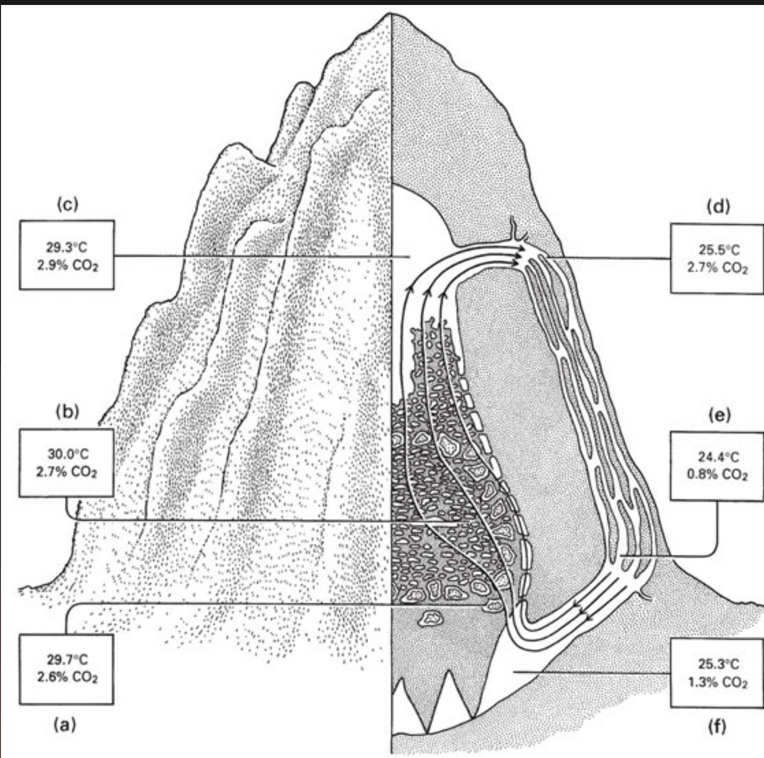

Fig. 12.11 Section through the mound nest of the African fungus-farming termite *Macrotermes natalensis* (Termitidae) showing how air circulating in a series of passageways maintains favourable culture conditions for the fungus at the bottom of the nest (a) and for the termite brood (b). Measurements of temperature and carbon dioxide are shown in the boxes for the following locations: (a) the fungus combs; (b) the brood chambers; (c) the attic; (d) the upper part of a ridge channel; (e) the lower part of a ridge channel; and (f) the cellar. (After Lüscher 1961.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

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Inquilines and Parasites

- Inquiline: an organism that lives in the home of another, sharing food
  - Integrated
  - Non-integrated
- Wasmannian mimicry: a form of mimicry that allows an insect of another species to be accepted into a social insect colony
- Use of chemicals to blend in
  - Caterpillars in ant nests
  - Staphylinid beetles
- Flies in termite nests
- Hover flies in bee nests
- Varroa mites in honeybee hives

Inquilines and Parasites

- Dulosis: a slave-like relationship between parasitic ant species and the captured brood from another species
- Aka “slave-making ants”
- Manipulation and colony response in the laboratory
- Roles
- Slave raiding
    - Can capture several thousand
    - Fight or flight by host
    - Zero to many deaths may occur
    - Rebellions by the slaves

Evolution, Origin, & Maintenance

- Origins of eusociality in Hymenoptera
  - Eusociality has arisen independently in wasps, bees, and ants
  - Possible scenarios of solitariness to sociality:
    1. Single queen remains associated with her offspring through maternal longevity
    2. Several unrelated females associate and establish a nest with division of labor; 1 generation
    3. Communal group with related females, multiple queens, and increasing division of labor
  - Altruism: behavior costly to the individual but beneficial to others
  - Genetic theories about the origin of eusociality:
    1. Kin selection
       1. Genes and relatedness
    2. Maternal manipulation
    3. Mutualism

	sister	half-sister	own son	son of full sister	queen's son (brother)	son of half-sister
worker	0.75	0.375	0.5	0.375	0.25	0.125

Fig. 12.12 Relatedness of a given worker to other possible occupants of a hive. (After Whitfield 2002.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

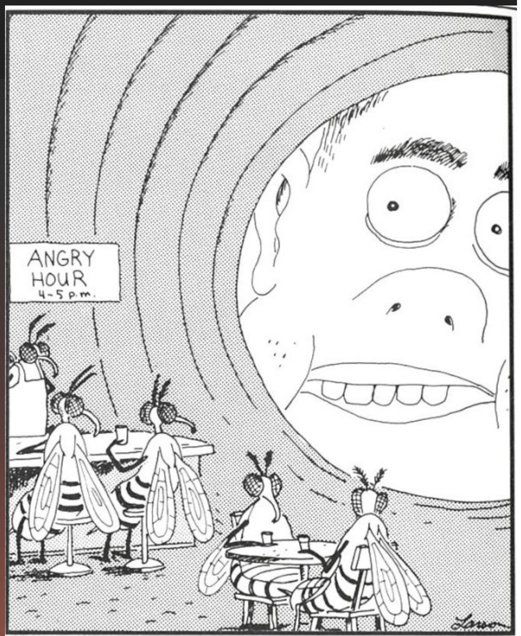
Evolution, Origin, & Maintenance

- Maintenance of eusociality
  - Control of eggs laid by workers
  - Relatedness of colony if workers reproduce
    - Values
    - When the queen dies
  - Hierarchies in other species
  - Anarchy
  - Cape honey bees and African honey bees

Success of Eusocial Insects

- 3 qualities contribute to their success
    1. Foraging, feeding, caring, maintenance can be performed simultaneously by different groups rather than sequentially by an individual- activities don't jeopardize each other
    2. Ability to overcome greater obstacles as a group
    3. Specialization of function allows homeostatic regulation for the colony

- Able to allocate individuals according to demand
- Use of pheromones allows for a high level of control
- Labor structure can rival human socities
- Implications for studying ageing (using termites)



It was foolish for Russell to approach the hornets' nest in the first place, but his timing was particularly bad.

Pictures by Slide

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23. The Far Side Gallery 4 by Gary Larson, 1993, page 116

Questions?

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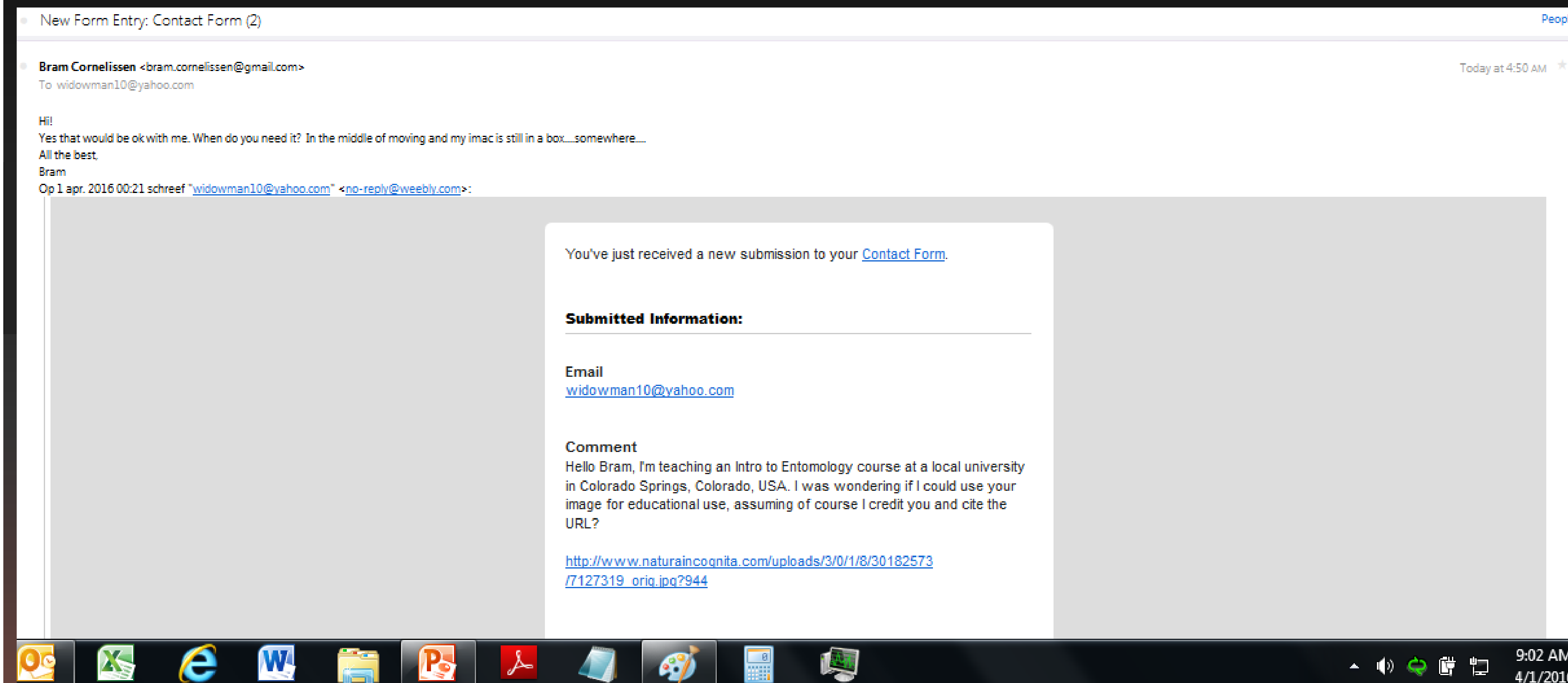

New Form Entry: Contact Form (2)

People

Bram Cornelissen <bram.cornelissen@gmail.com>
To widowman10@yahoo.com

Today at 4:50 AM

Hi!
Yes that would be ok with me. When do you need it? In the middle of moving and my imac is still in a box.....somewhere.....
All the best,
Bram
Op 1 apr. 2016 00:21 schreef "widowman10@yahoo.com" <no-reply@weebly.com>:

You've just received a new submission to your Contact Form.

Submitted Information:

Email
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Image use for classroom? (3)

B K <widowman10@yahoo.com> Apr 1 at 11:51 AM
To ants@tightloop.com

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ants@tightloop.com Today at 10:04 AM
To B K

Yes, that would be fine.
Thank you for asking

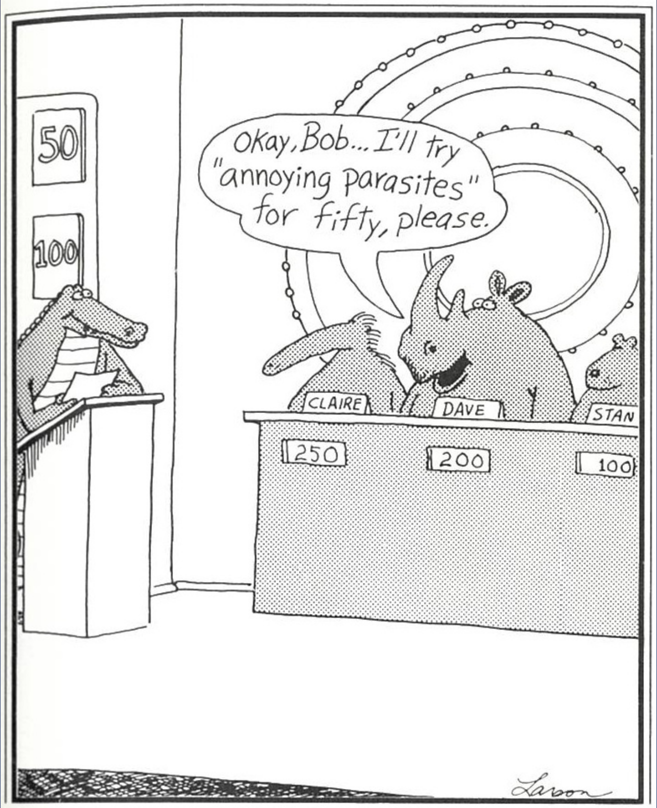
- Dale

ENTOMOLOGY 101

Predation and Parasitism

Predation and Parasitism

- Topics
  - Prey/Host Location
  - Acceptance & Manipulation
  - Selection & Specificity
  - Population Biology
  - Evolutionary Success



Animal game shows

Predation and Parasitism

- Predation: preying on other organisms and their interactions
  - Predator
  - Prey
- Parasitism: the relationship between the parasite and its host
  - Host
  - Parasite: lives at the expense of host, but does not kill it
    - Ectoparasites
    - Endoparasites
  - Parasitoid: a parasite that kills its host
    - Ectoparasitoids
    - Endoparasitoids

- About 25% of all species are predatory or parasitic at some stage
- Representatives from nearly every insect order

Prey/Host Location

- Optimal foraging strategy maximizes cost/benefit ratio
  - Where and how to search
  - How much time to devote to fruitless searching before moving on
  - How much energy to expend in capturing food once located
- Responses to patches and prey:
  - Active search
  - Trapping
  - Sit and wait
- Waiting strategy is economically effective, but time-consuming
- Active strategy is energy-intensive but time-efficient

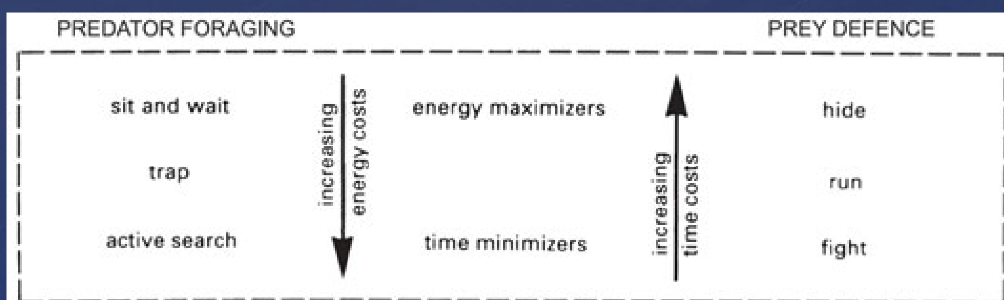


Fig. 13.1 The basic spectrum of predator foraging and prey defence strategies, varying according to costs and benefits in both time and energy. (After Malcolm 1990.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

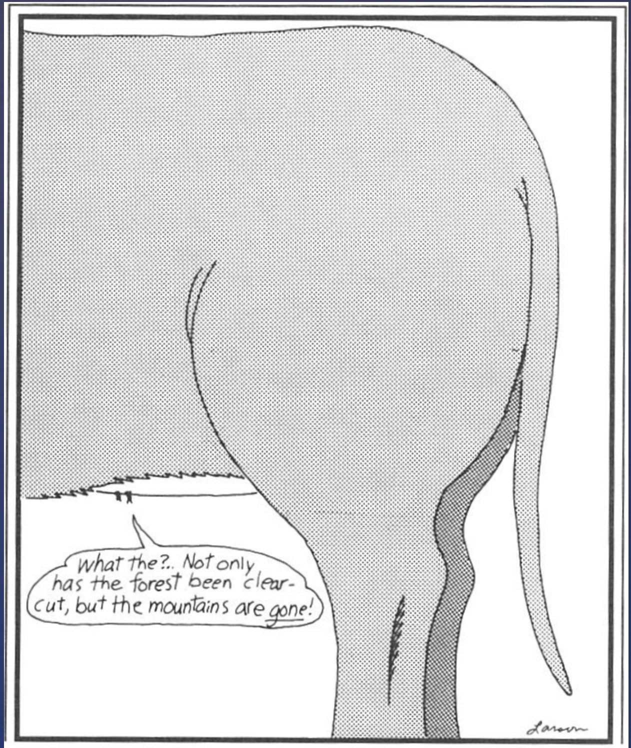
Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Prey/Host Location

- Sitting and waiting
  - Predators find a suitable spot to ambush prey
  - Some may have camouflage, but many just remain motionless
  - Aggressive foraging mimicry
    - Flower-mimicking mantid
    - Silver argiope spider
  - Not just ‘sit-and-wait’ (dragons and robbers)

Prey/Host Location

- Sitting and waiting
  - Use of stimuli
    - Cat flea uses:
      - Vibrations
      - Rise in temperature
      - Carbon dioxide
      - Etc.
  - Use of traps
    - Most notably by the spiders
    - Also by the antlions



Environmental disasters in a flea's world

Prey/Host Location

- Sitting and waiting
  - Antlions
    - Larvae dig pits into soft sand
    - Effectiveness depends on steepness of sides, diameter, and depth of pit
    - Larvae waits at the bottom of the pit for passing prey to fall in
    - Escape by prey is prevented by the slippery slope
    - Larvae may also flick sand at prey
    - Location and construction are vital for prey capture
    - Potential as ‘pets’

Prey/Host Location

- Active foraging
  - Random foraging
    - Ladybug larvae and casting for aphids
  - Non-random foraging
    - Host finding can depend on cues: chemical, sound, light, tactile
    - European crabronid wasp and use of different cues
    - Chemical
      - Sex pheromones, plant chemicals, frass odors, carbon dioxide
    - Sound
      - Mating sounds, vibrations
    - Light
      - Bioluminescence, flashing signals

Prey/Host Location

- Phoresy: a phenomenon in which an individual is transported by a larger individual of another species
  - Benefits the carried without directly affecting the carrier
  - Egg parasitoid wasp and European mantid
  - Human bot fly and mosquito
  - Burying beetle (*Nicrophorus*) and phoretic mites

Acceptance & Manipulation

- Prey capture and restraint
  - Morphological modifications
    - Legs
    - Mouthparts

- Host acceptance by parasitoids
  - Phorid flies and leaf-cutter ants

- Overcoming host immune responses
  - Encapsulation: surrounding the invading egg/larva by an aggregation of hemocytes
  - Parasitoids cope with host immune system by:
    1. Avoidance
    2. Evasion
    3. Destruction
    4. Suppression
    5. Subversion

Selection & Specificity

- Insects vary in the number and type of food sources they use

- Some are monophagous (using only a single species of prey)
  - Typically involves only parasitoids
  - Very few exceptions, one being the termite-eater spider

- Some are oligophagous (using a few prey species)
  - Ambush predators may have a restricted diet

- Most are polyphagous (using a variety of species)
  - Predators are mostly polyphagous

- Terminology: -xenous refers to parasites

Selection & Specificity

- Host use by parasitoids
  - Require only a single host to complete development
  - Always kill their immature host
  - Entomophagous: insect-eating parasitoids
  - May develop internally or externally
  - Ectoparasitoids are less host specific than endoparasitoids
  - May be solitary or gregarious

Selection & Specificity

- Host use by parasitoids
  - Most parasitoids "host discriminate"
    - Generally involves a marking pheromone
  - Superparasitism
    - Competition
    - Advantages
    - Disadvantages – viruses
  - Multiparasitism
    - Occurs more often than superparasitism

Selection & Specificity

- Host use by parasitoids
  - Hyperparasitism
    - Develops on other parasitoid
    - Obligate or faculitative
    - “Inception” parasitism
    - Caterpillar may host up to 4 tiers of parasites
    - Jonathan Swift refers to hyperparasitism
    - "On Poetry: A Rhapsody":
      - So nat'ralists observe, a flea
        Hath smaller fleas that on him prey;
        And these have smaller fleas to bite 'em.
        And so proceeds ad infinitum.

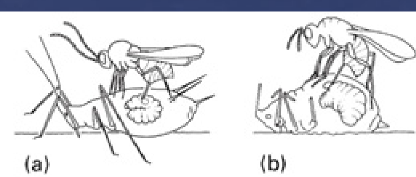


Fig. 13.6 Two examples of the ovipositional behaviour of hymenopteran hyperparasitoids of aphids: (a) endophagous *Alloxysta victrix* (Hymenoptera: Figitidae) ovipositing into a primary parasitoid inside a live aphid; (b) ectophagous *Asaphes suspensus* (Hymenoptera: Pteromalidae) ovipositing onto a primary parasitoid in a mummified aphid. (After Sullivan 1988.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

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Selection & Specificity

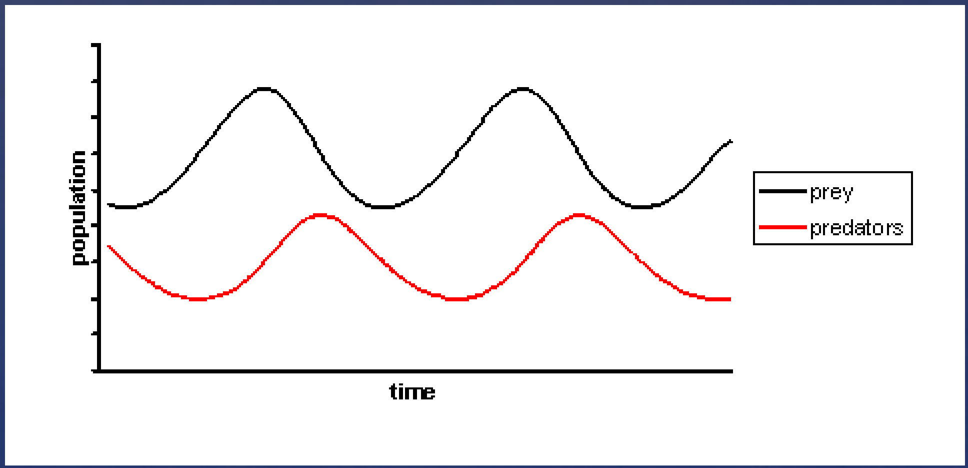
- Host manipulation and development of parasitoids
  - Host regulation by use of pheromones
  - Host quality/size can induce variation
  - Larval competition may occur inside of host
  - Strepsiptera
    - Parasitize other insects exclusively
    - Endoparasitoids
    - Laid on pollen where hosts frequent
    - "Stylopized" (malformations)
    - Displacement of internal organs
    - Host is castrated
    - Adult Strepsipteran emerges from host

Selection & Specificity

- Patterns of use and specificity
  - Patterns of host-specificity and preference of parasites raise questions
    - Most orders of mammals bear lice
    - Even seals have lice (but whales do not)
    - Bats do not have lice
  - Host/parasite correlation
  - Comparison of phylogenies
  - Cospeciation: identical patterns of speciation in regards to tree typology
    - Although, host switching has been observed
    - *Columbicola extinctus* and the passenger pigeon
    - *Strigiphilus garylarsoni* found only on owls

Population Biology

- Accurate estimation of population density and its regulation is important for: population ecology, biodiversity studies, conservation biology, and management of pests
- Sampling techniques
- Carrying capacity
- Parasitoids and predators are major influences on population dynamics
- Time-lagged cycle of predator / prey abundance (aka Lotka-Volterra)



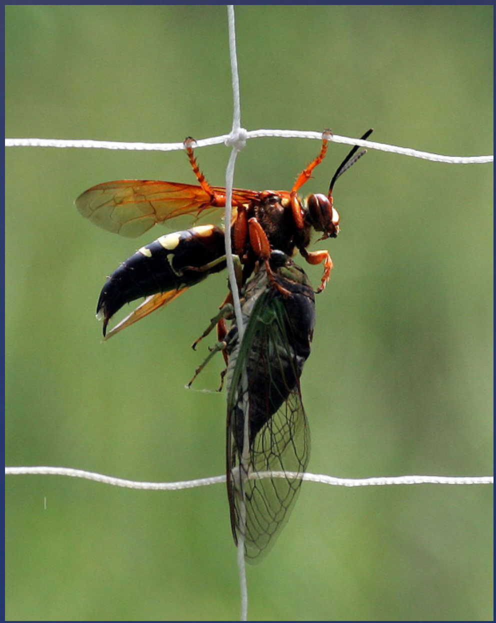
Population Biology

- Interference
- Refuges
- Effects of predators trickle down
- Trophic cascades: the ecosystem-wide effects of the removal or introduction of predators on primary production via herbivores
- Results of predator removal
- Should be an important aspect of pest control

- "How Wolves Change Rivers" video

Evolutionary Success

- Adoption of parasitic lifestyles is often due to a major evolutionary radiation
- Assuming each insect was host to a single monophagous parasitoid:
  - Degree of host specificity
    - Hard to measure due to size and associations
  - Number of parasitoids harbored by each insect host
    - Many hosts support multiple parasitoids
    - Role of amateur entomologists
- Evolutionary interactions
  - Between parasites and their hosts
  - Niche differentiation
  - Host diapause
    - 13 & 17 year cicadas



Evolutionary Success

- Parasite / host strategies
- Have been envisaged as evolutionary arms races
- Red Queen hypothesis (Alice in "Through the Looking-Glass")
  - Contrasted with the recent "Court Jester" theory

Pictures by Slide

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7. Prey/Host Location
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18. (no picture) – https://www.youtube.com/watch?v=ysa5OBhXz-Q
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Questions?

Permission

ENTOMOLOGY 101

Insect Defense

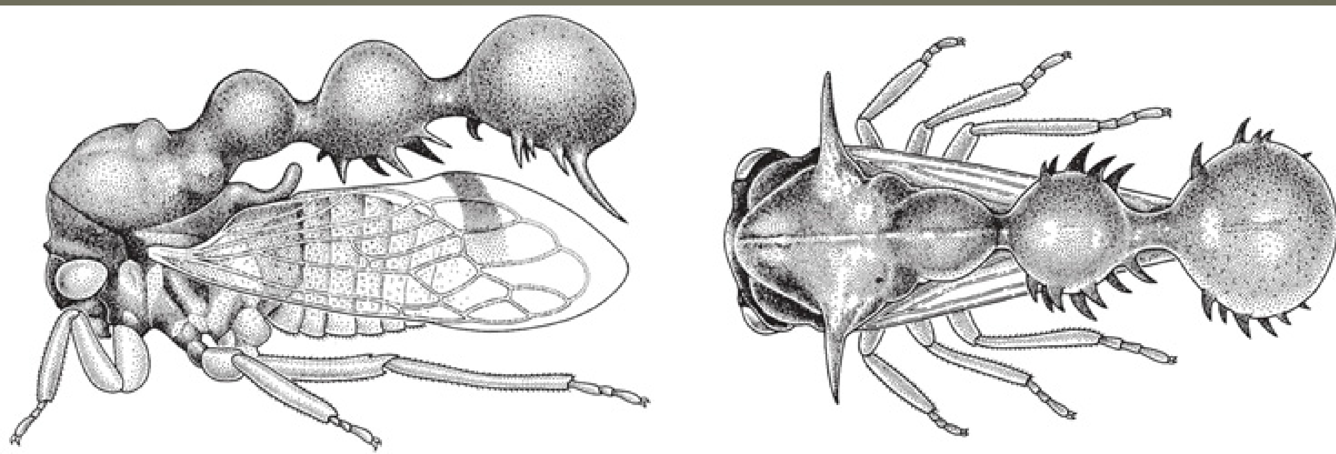
Insect Defense

Topics

- Defense by Hiding
- Secondary Lines of Defense
- Mechanical Defenses
- Chemical Defenses
- Defense by Mimicry
- Collective Defenses

Insect Defense

- Insects are a substantial food source for many organisms
- They are nutritious, abundant, and diverse
- Insectivores rely almost exclusively on insects
- Insects passively or actively avoid getting eaten
- Many defensive strategies exist
- Insects can change to another strategy if the first one fails



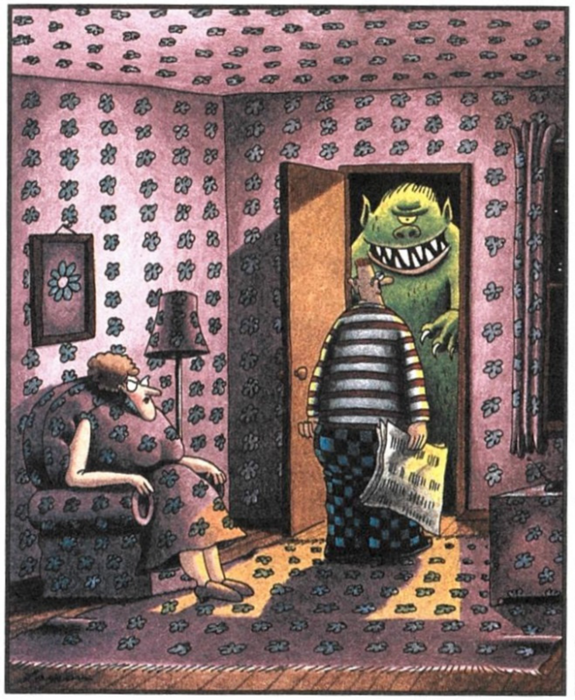
An African ant-mimicking membracid bug, shown in side and dorsal view. (After Boulard 1968.)

Defense by Hiding

- Visual deception reduces probability of being found
- Crypsis: camouflage by resemblance to environmental features
- Camouflage- a form of crypsis
  - Resemble uniform or patterned backgrounds
  - Countershading (light below and dark above)
  - Having bizarre shapes (to disrupt silhouette)

Defense by Hiding

- Peppered moths
  - Dark moths more abundant as industrial pollution increased
  - Classic example of evolution through natural selection
  - Selective predation
  - Proportions of light and dark moths
  - Industrial melanism



When the monster came, Lola, like the peppered moth and the arctic hare, remained motionless and undetected. Harold, of course, was immediately devoured.

Defense by Hiding

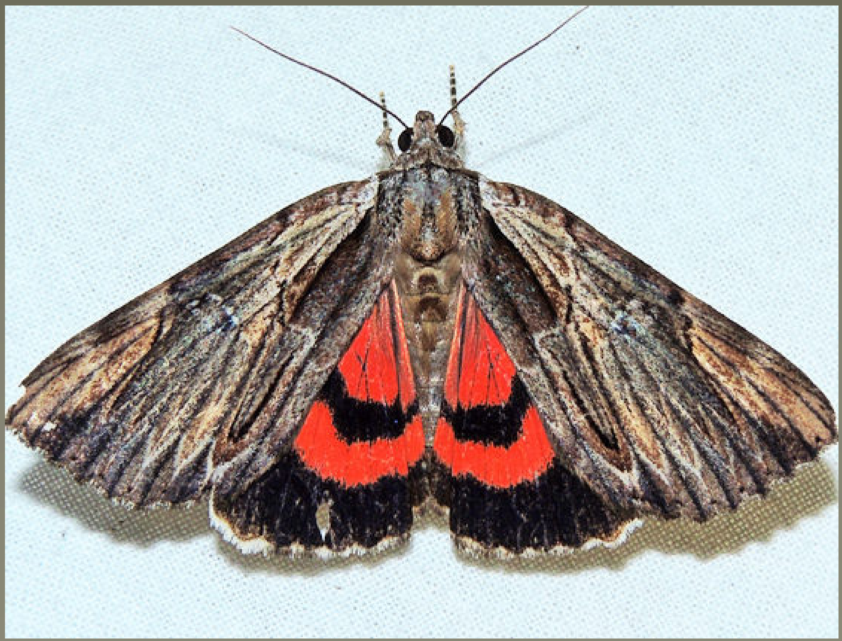
- Birds and lubbers
  - No insect can escape predation completely
  - Birds can overcome even the best of defenses
  - Lubber grasshopper defenses
  - Loggerhead shrike impales lubber
  - Prey becomes edible after a couple of days

Defense by Hiding

- Masquerade- another form of crypsis
  - Resembles a feature of the environment
  - Bird dropping caterpillars
  - Looper caterpillars
  - Thorn bugs
  - Stick insects
  - Resemblance to leaves
- Orientation to appropriately colored backgrounds

Secondary Lines of Defense

- Cryptic insects are not immune to predation
  - Birds
  - Monkeys
- Insect prey may have further defenses
- Taking flight and flashing of under color wings



Secondary Lines of Defense

- Thanatosis: behavior of feigning death
  - Widows, beetles
- Startle display
  - Opening of forewings to show eye spots
  - May serve to startle or target away from vitals

Cornered and sensing danger, Sidney flares his "eye spots."

Secondary Lines of Defense

- Resemblance of body part to a feature of a vertebrate
  - Alligator bug
  - Monkey head lycaenid, aka apefly
  - Snake caterpillars

Mechanical Defenses

- Cuticular horns and spines
- Shape and schlerotization provide defense (as in fleas and lice)
- Construction of retreats and coverings
- Assassin bug nymphs and their 'backpack'
  - Bugs with debris survived far better
  - Confused visual, tactile, and chemical-orientating predators

Mechanical Defenses

- Waxes and powders secreted by hemipterans
- Wing scales can help prey escape
- Autonomy: shedding of limbs to escape predation
  - Stick insects
  - Crane flies
- Secretions
  - Cockroaches and slimy abdomens
  - Termites and resin
  - Termites and nasal spray

Chemical Defenses

- Aposematic: the coloration of distasteful animals characterized by bright or conspicuous markings
- Classification and nature of chemicals
  - Class 1 chemicals
    - Noxious chemicals that hurt, poison, or drug predators
    - More specific and effective against vertebrates
    - Nearly always accompanied by aposematism
  - Class 2 chemicals
    - Innocuous chemicals that taste or smell bad
    - Appear unable alone to deter many birds
  - Many insects use mixtures of both classes
  - Learning by predators
  - 'Anting'

Chemical Defenses

- Sources of chemical defenses
  - Many defensive chemicals come from the plants insects eat
  - Insects are able to detoxify or sequester the plant toxins
  - Certain insects can produce their own toxins (Meloidae)
  - Rarely insects will obtain their chemicals otherwise (*Photurus*)
  - Reflex bleeding: the deliberate action of ejecting blood from the body (typically joints) as a defense mechanism
- Organs of chemical defense
  - Lepidopterans are unique in using osmeterium and urticating hairs

Chemical Defenses

- Bombardier beetles
  - Chemical spray is released under pressure from anus
  - Is able to be directed toward threat
  - 2 chambers containing different compounds
  - When threatened, contents from chambers are combined
  - Chemical superheats and is expelled due to pressure
  - Same principles as pulse jet propulsion

Bombardier beetles at home

Defense by Mimicry

- Batesian mimicry
  - A form of mimicry where a harmless species has evolved to imitate the warning signals of a harmful species directed at a predator of them both
  - Most commonly known and widely studied of mimicry complexes
  - Name comes from Henry Bates and his study of butterflies
  - Each member has a positive or negative effect on the others
    - Model / mimic / observer
  - This mimicry works well until the populations fluctuate
  - Acoustic mimicry

Defense by Mimicry

- Mullerian mimicry
  - Model and mimic are both distasteful and warningly colored
  - Both benefit from this mimicry as observers learn from any individual
  - Name comes from Fritz Muller and his study of butterflies
  - This mimicry works well even if the population fluctuates
  - History of the monarch and viceroy butterflies

Defense by Mimicry

- Wasmannian mimicry
  - Mimic resembles a model along with which it lives (inquilines)
- Myrmecomorphy
  - Ant mimicry
  - Grasshoppers
  - Spiders
  - True bugs
  - Stick insects
  - Thrips
  - Mantids
  - Flies
  - Beetles

Collective Defenses

- Chemically defended aposematic insects are typically clustered
  - Aggregations of butterflies, wasps, beetles
  - Cycloalexy: defended circles
    - Aggregation pheromones
    - Kin selection in subsocial insects
- Eusocial insects
  - Defensive tasks undertaken by morphologically modified individuals
  - Focus is on defending the nest

Collective Defenses

- Termites
  - Complex warfare with ants often takes place
    - Phragmosis: blocking of access to nest with modified head
    - Nasute and spraying
    - Salivary glands
    - Many use mandibles
    - Elastic energy and snapping mandibles
    - Suicidal phenomenom

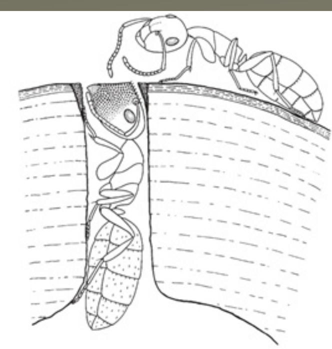


Fig. 14.9 Nest guarding by the European ant *Camponotus* (*Colobopsis*) *truncatus* (Hymenoptera: Formicidae): a minor worker approaching a soldier that is blocking a nest entrance with her plug-shaped head. (After Hölldobler &Wilson 1990; from Szabó-Patay 1928.)

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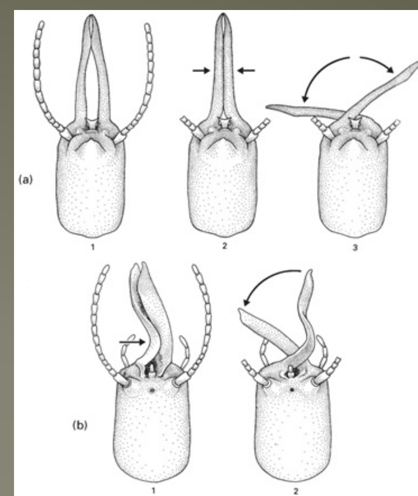

Fig. 14.10 Defence by mandible snapping in termite soldiers (Blattodea: Termitoidae). (a) Head of a symmetric snapping soldier of *Termes* in which the long thin mandibles are pressed hard together (1) and thus bent inwards (2) before they slide violently across one another (3). (b) Head of an asymmetric snapping soldier of *Homallotermes* in which force is generated in the flexible left mandible by being pushed against the right one (1) until the right mandible slips under the left one to strike a violent blow (2). (After Deligne *et al*. 1981.)

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Collective Defenses

- Social hymenopterans
  - Restriction of the defensive caste to females
  - Venom is a vital defense
  - Effective against even large predators
  - Where the stinger is absent, other strategies have arisen
  - Pheromones incite others to attack

Pictures by Slide

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ENTOMOLOGY 101

Medical & Veterinary Entomology

Medical & Veterinary Entomology

- Topics
  - Insect Nuisance and Phobia
  - Venoms and Allergens
  - Causes and Vectors of Disease
  - Generalized Disease Cycles
  - Pathogens
  - Forensic Entomology

Medical & Veterinary Entomology

- Major scientific disciplines due to:
  - Widespread impact
  - Seriousness of consequences
  - Frequency of nuisance
- Vector: organism that transmits a pathogen to another species
- Very broad in scope:
  - Motivation and study usually focused on the disease
  - Must have wide understanding of host, vector, and parasite
  - Have to consider other arthropods as well

"My goodness, Harold . . . Now there goes one big mosquito."

Insect Nuisance and Phobia

- Arachnophobia – fear of spiders and other arachnids
  - Many different physical reactions
  - Even a picture / drawing can trigger it
  - Little Miss Muffet
  - Can the fear of spiders develop before birth? (crickets)
  - Affects ~5% of the population
- Entomophobia – fear of insects

Insect Nuisance and Phobia

- Delusory parasitosis
  - Aka "Ekbom's syndrome", a form of psychosis
  - Strong delusional belief that they are infested with parasites
  - Sensation of formication often manifests
  - "Meth mites" and "cocaine bugs"

- Appropriate investigations often ought to be psychological

Insect Nuisance and Phobia

- Bed bugs
  - Used to be a big problem
    - Nearly eradicated from the developing world in 1940
  - Resurgence in numbers lately, since 1995
  - Can get them nearly anywhere
  - Signs / symptoms:
    - Mysterious bites, specks of blood on sheets, sweet / sickly odor
  - Hiding spots in the daytime
    - Where to look and how to check
    - “Harborages”
  - Earliest recorded use of the word “bug” referred to bed bugs!

Insect Nuisance and Phobia

- Swarms of insects
  - Buzzers
  - Biters
  - Mayflies on roads

"Wait a minute! ... McCallister, you fool! *This* isn't what I said to bring!"

Venoms and Allergens

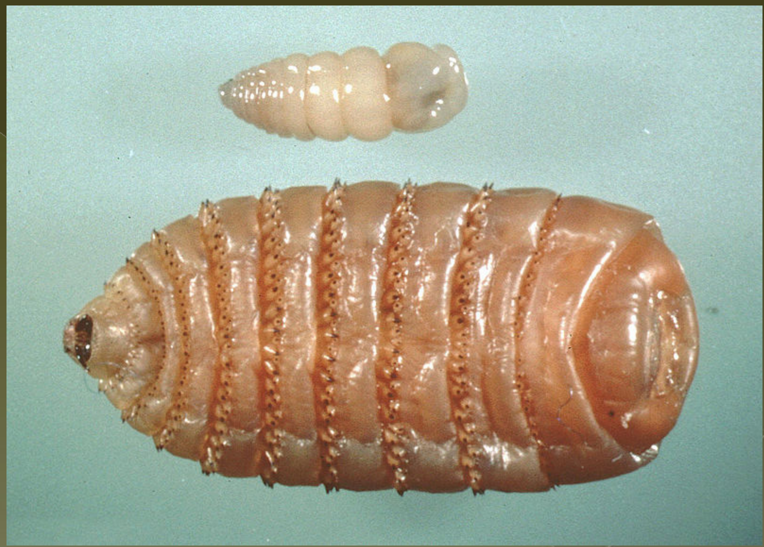
- Insect venoms
- Blister- and itch-inducing insects
  - Blister beetles
    - Cantharadins
    - “Spanish fly”
  - Caterpillars
    - Urtication
    - Hollow spines – venom released when broken
    - Deaths
  - Tarantulas

Venoms and Allergens

- Insect allergenicity
  - Insect allergens
  - Common in those who handle insects for their job
  - Stored products (infested with mites)
  - Fecal material of house-dust mites
  - Cockroaches and frass
  - Sensitization and anaphylactic shock
    - Bee stings
    - Epipens

Causes and Vectors of Disease

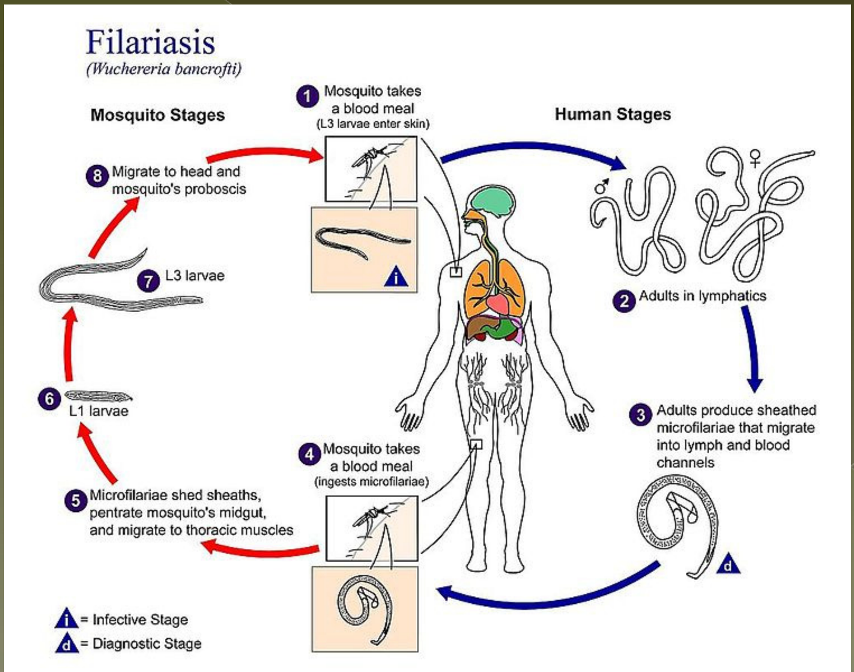
- Insects can transmit: protists, viruses, bacteria, nematodes
- Such diseases include: malaria, dengue, yellow fever, onchocerciasis, leishmaniasis, filariasis, and trypanosomiasis
- Diseases may be caused by:
  - The insect itself
    - Lice – pediculosis
    - Mite – scabies
    - Flies – myiasis, strike, screw-worms
  - Pathogen from an insect vector
    - Mechanical transfer
    - Biological transfer



- Disease control requires detailed knowledge of the biology of all 3 components: vector, pathogen, host

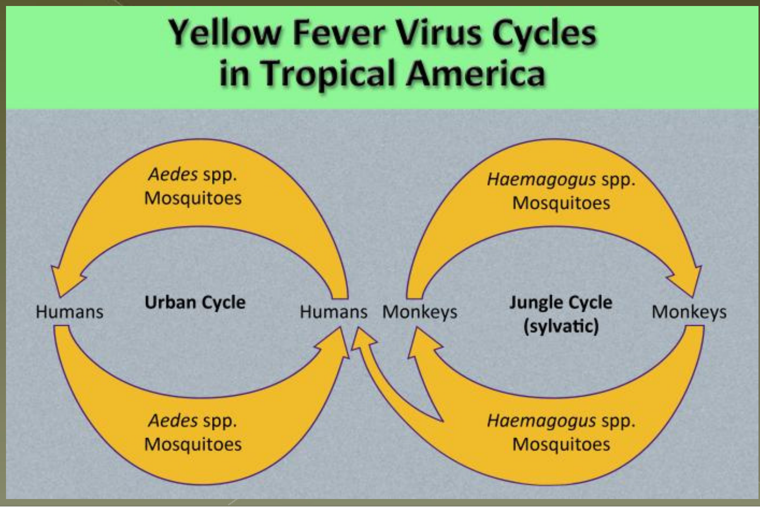
Generalized Disease Cycles

- Host: organism that harbors the pathogen
- Reservoir: natural host and geographical range; can harbor the pathogen indefinitely with no ill effects
- Single cycle
  - Pathogen completes its lifecycle in vector and human host only
  - It is rare
  - Ex: malaria
  - Ex: filariasis



Generalized Disease Cycles

- Secondary cycle
  - A different animal serves as a primary host
  - Human inclusion not required for completion of disease cycle
  - More common
  - Ex: monkeys & yellow fever
  - Ex: rats & bubonic plague
  - Ex: desert rodents & leishmaniasis
- Outbreaks and spread
  - "Sylvan" cycle - monkeys and humans
- Disease control is complicated
  - Presence of reservoirs
  - Encroachment of people

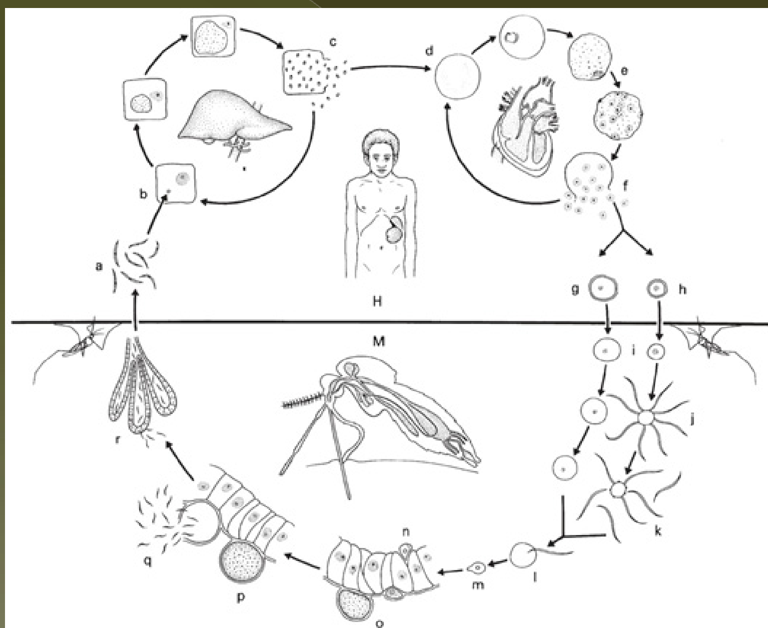


Pathogens

- Arbovirus: an **AR**thropod-**BO**rne virus
- Malaria
  - Affects more people than any other insect-borne disease
  - 214 million cases in 2015
  - Estimated ½ million + deaths every year
  - Exposure rate lowered in the past, but has risen steadily lately
  - "Roman fever" / "marsh fever"
  - Used to be common in the U.S. and N.A.
  - Always vectored by *Anopheles* mosquitos

Pathogens

- Malaria
  - Sporozoan: *Plasmodium*
  - Life cycle
    - Incubation period and time frames
    - 5 different parasites and their effects



Box 15.1 Life cycle of *Plasmodium*

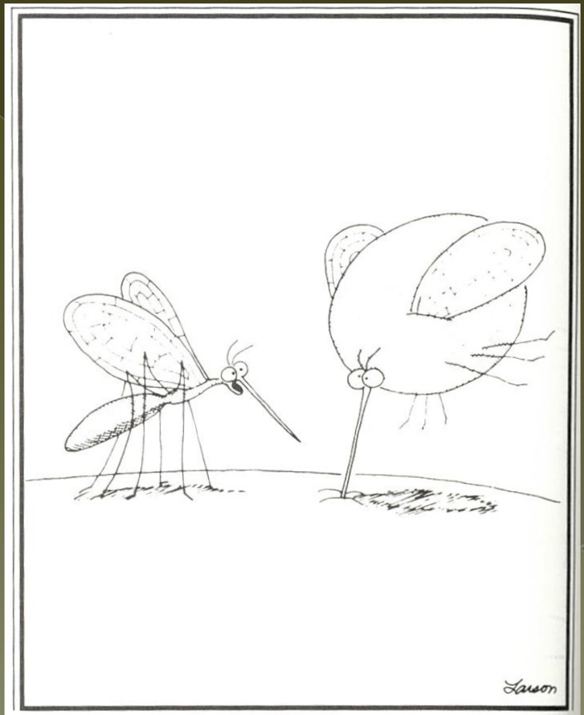
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects

WILEY Blackwell

Pathogens

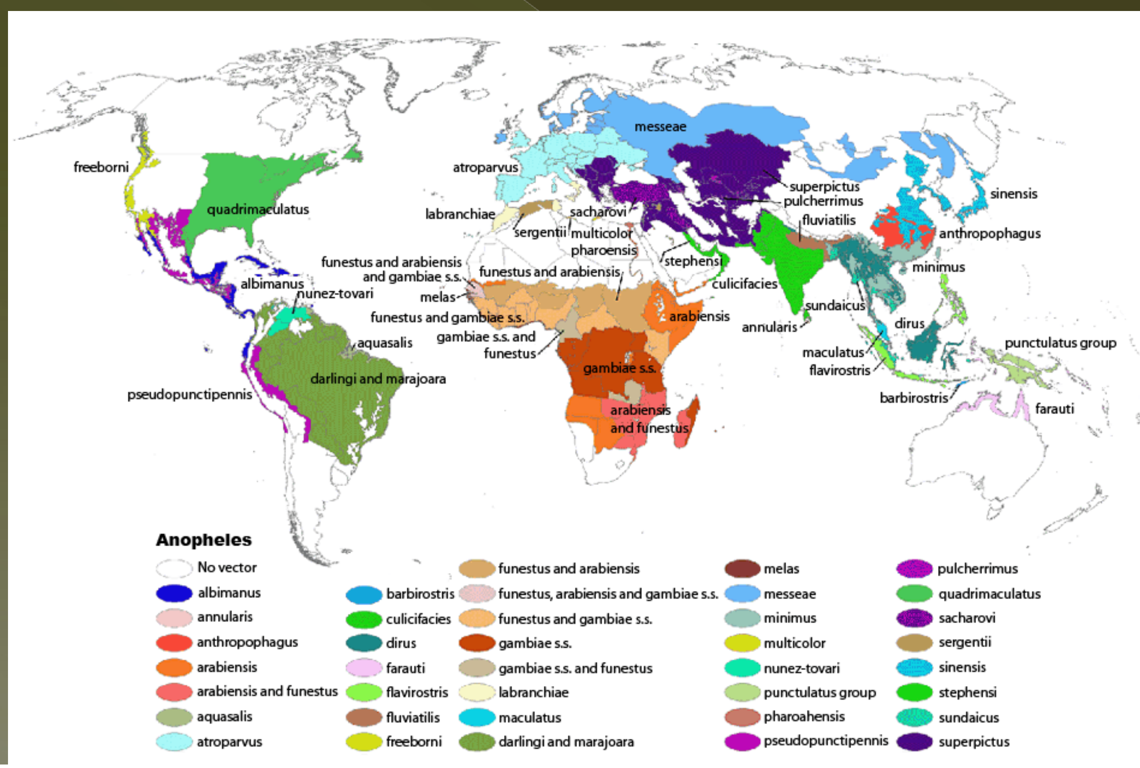
- Malaria
  - Epidemiology
    - Endemic: geographical area a disease is typically restricted to
    - Epidemic: the spread or breakout of a disease
    - Disease transmission is understood in the potential of the vector:
      - Vector distribution
      - Vector abundance
      - Life expectancy of the vector
      - Anthropophily
      - Feeding rate of the vector
      - Vector competence
      - Vectorial capacity



"Pull out, Betty! Pull out! . . . You've hit an artery!"

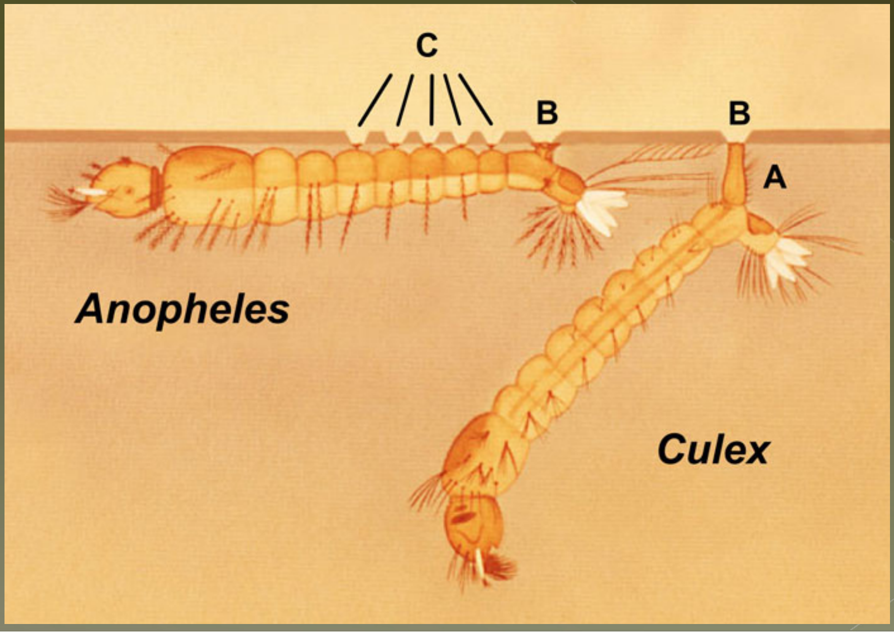
Pathogens

- Malaria
  - Epidemiology
    - Vector distribution
      - *Anopheles* mosquitos occur almost worldwide
      - Mostly found in warm climates
      - A select few species vector the majority of the pathogens



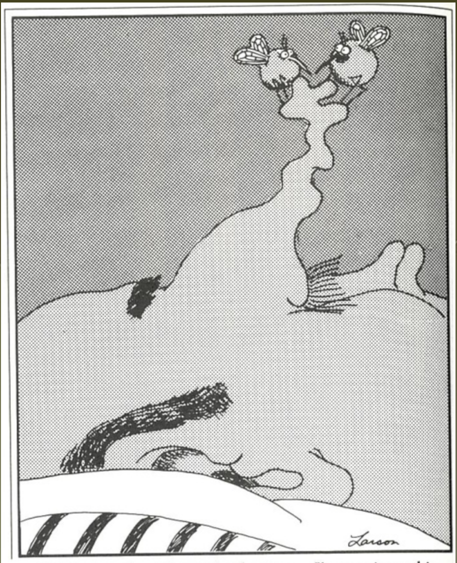
Pathogens

- Malaria
  - Epidemiology
    - Vector abundance
      - Development is temperature-dependent
      - Generation time can be as short as 10 days in the tropics
      - Potential for 100-fold increase in adults in 14 days
      - Increased rainfall typically increases numbers
      - Adult survivorship related to elevated humidity



Pathogens

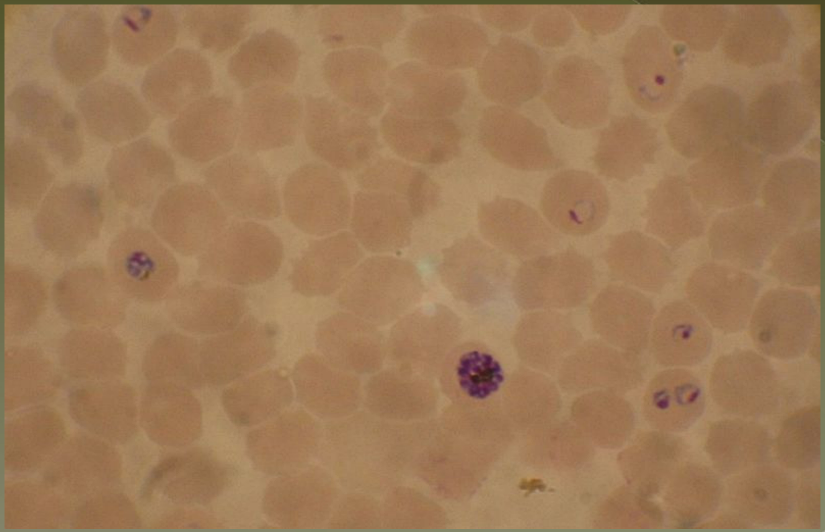
- Malaria
  - Epidemiology
    - Life expectancy of the vector
      - Lifespan is of great significance
      - No disease is transmitted if the vector dies too soon
    - Anthropophily of the vector
      - Must feed twice to be a vector
      - Propensity of vector to feed on host
      - Preference for humans (anthropophily) over others (zoophily)
      - Stable malaria and anthropophilic vectors
      - Transmission can take place even under low populations



"Well, that about does it for the nose — I'm starting to hit cartilage."

Pathogens

- Malaria
  - Epidemiology
    - Feeding rate of the vector
      - Frequency of feeding is important in disease transmission
      - Number of blood meals needed for eggs
      - Already-infected vectors may have difficulty feeding
      - Disturbance may lead to multiple transmissions
    - Vectorial capacity
      - Mathematical expression of the probability of disease transmission by the vector
      - Factors involved



Pathogens

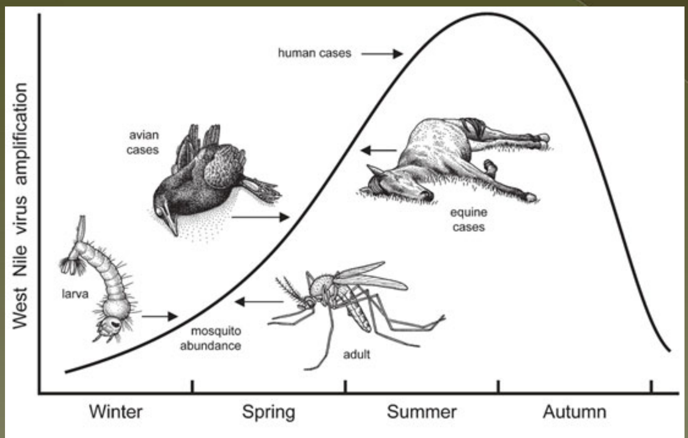
- Malaria
  - Control
    - 2 pronged approach: mosquitos or disease
      - Mosquitos – spraying on a large and small scale
      - Mosquitos – bed nets
      - Disease – an infected person will not transmit the disease if treated within the first 10 days
      - Disease – where treated, incidence rate fell by over 99%
      - Disease – prompt detection and treatment are key

Pathogens

- Arboviruses
  - Modes of transmission
    - Vertical
    - Horizontal
  - Yellow fever
  - Encephalitis, Japanese encephalitis
  - Bluetongue virus
  - Dengue
    - Symptoms
    - Vector
    - Spread

Pathogens

- Arboviruses
  - West Nile virus
    - Part of the Japanese encephalitis complex
    - Originally from the West Nile district of Uganda
    - Symptoms
    - Principle vectors are bird-feeding *Culex* mosquitos
    - birds are natural reservoirs and principle hosts
    - First appeared in 1999 in New York
    - Extraordinary spread across almost all of North America



Box 15.5 West Nile virus – an arbovirus disease emergent in North America

Pathogens

- Rickettsias and plague
  - Bacteria
  - Typhus
    - Caused millions of deaths over hundreds of years
    - Vector is lice (body louse)
  - Other types of typhus and their vectors
  - Plague, aka "Black Death"
    - Found in rodents, vectored by fleas
    - In only 5 years (1347-1352), 25 million people died

Pathogens

- Protists
  - Malaria
  - Trypanosoma
    - Transmitted by blood-feeding flies and "kissing bugs"
    - Chagas' disease
    - Affects millions and causes tens of thousands of deaths annually
    - Presence in Colorado
  - Sleeping sickness
    - Humans and cattle in Africa
    - Tsetse fly
  - Leishmaniasis
    - Sand flies
    - Disfigurement

Pathogens

- Filariases
  - Canine heartworm
  - Elephantiasis aka lymphatic filariasis
    - Vectored by *Culex* mosquitos
    - Cycle and transmission
    - Severe swelling, mainly in legs and genitals
    - Worms live only in the lymphatic system
    - No vaccine, but treatment exists
  - Onchocerciasis aka river blindness
    - Debilitating, but does not cause death
    - Vectored by *Simulium* black flies
    - Worms invade eye tissues and die there
    - 37 million people are infected
    - 99% of cases occur in Africa
    - "OCP" – launched in 1974

Forensic Entomology

- Divided into 3 sub-fields
  1. Urban forensic entomology
     - Pest infestations in buildings
     - Between private parties and landlords or exterminators
  2. Stored-product forensic entomology
     - Infestation of commercially distributed foods
  3. Medico-legal forensic entomology
     - Used in cases of: murder, rape, suicide, physical abuse, contraband
     - Some prominent murder cases
- Sung Tzu

Forensic Entomology

- 5 stages of decay:
  1. Initial decay
     - aka “fresh”
  2. Putrefaction
     - aka “bloat”
  3. Black putrefaction
     - aka “active decay”
  4. Butyric fermentation
     - aka “advanced decay”
  5. Dry decay

- Typical succession

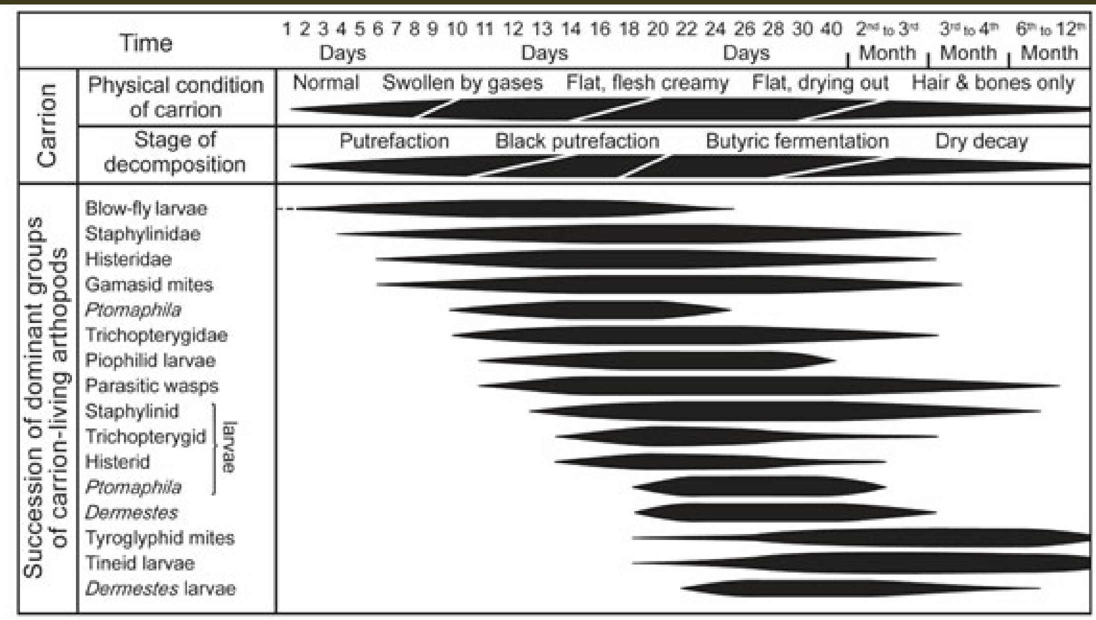


Fig. 15.2 The stages of carcass (carrion) decomposition associated with a succession of arthropod groups in guinea-pig carcasses during spring in a woodland habitat in Perth, Australia. Variation in the thickness of each band indicates the approximate relative abundance within the groups at different times. (After Bornemissza 1957.)

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

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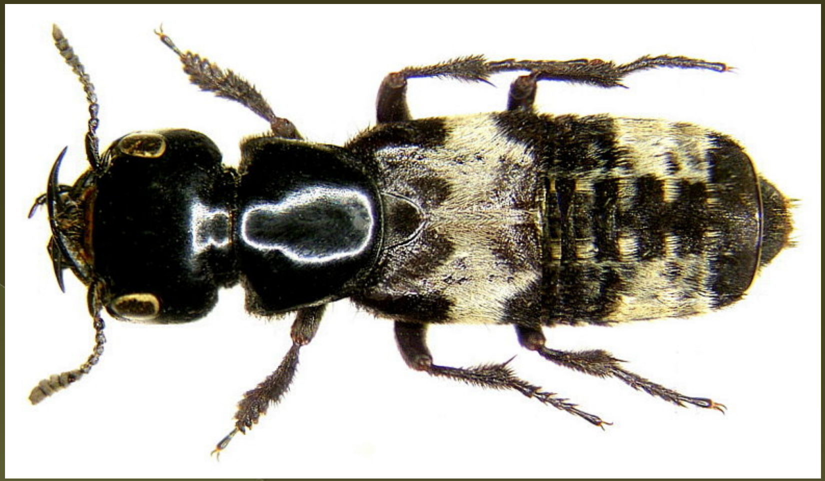
Forensic Entomology

- Insects of most importance in forensics
  - Flies
  - Beetles



- Post mortem interval (PMI)
- Accumulated degree days
- Estimating time of death
- Importance of environmental factors
  - Moisture level
  - Exposure: sun / air / water
  - Geography
  - Various weather conditions

Forensic Entomology

- Career as a forensic entomologist
  - ABFE – American Board of Forensic Entomology
  - Only 17 in all of North America

Pictures by Slide

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Yes, you may, and thanks for asking.
Sounds like a great course.
James

ENTOMOLOGY 101

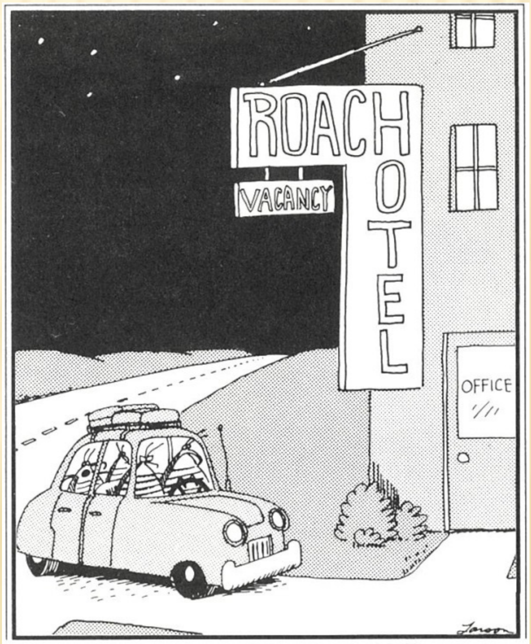
Pest Management

PEST MANAGEMENT

- Topics
  - Insects as Pests
  - Effects of Insecticides
  - Integrated Pest Management
  - Chemical Control
  - Biological Control
  - Host-Plant Resistance to Insects
  - Physical Control
  - Cultural Control
  - Pheromones and Attractants
  - Genetic Manipulation of Pests

PEST MANAGEMENT

- Become ‘pests’ when they interfere with welfare, aesthetics, or profits
- Defined from a purely anthropocentric point of view
- Pest can be a normal insect in the wrong place or numbers
- Main pests are of crops and health



“Dad! Find out if they have cable!”

INSECTS AS PESTS

- Assessment of pest status
  - Injury vs. damage
  - Most plants tolerate injury without loss of vigor
  - Level of injury for fruits is much lower (due to blemishes)
  - Control becomes economic when:
    - Financial loss outweighs cost of control
    - Economic injury level (EIL):

$$EIL = C / VDK$$

    - C = cost of control measure
    - V = value in market per unit
    - D = yield loss per number of insects
    - K = reduction of pest numbers by control measure

INSECTS AS PESTS

- Assessment of pest status
  - EIL will not be the same in all (or even similar) conditions - Miridae
  - Varies based on many conditions
  - Economic threshold (ET):
  - Different level than EIL and is predictive

INSECTS AS PESTS

- Assessment of pest status
  - Pests can be: non-economic, occasional, perennial, or severe / key

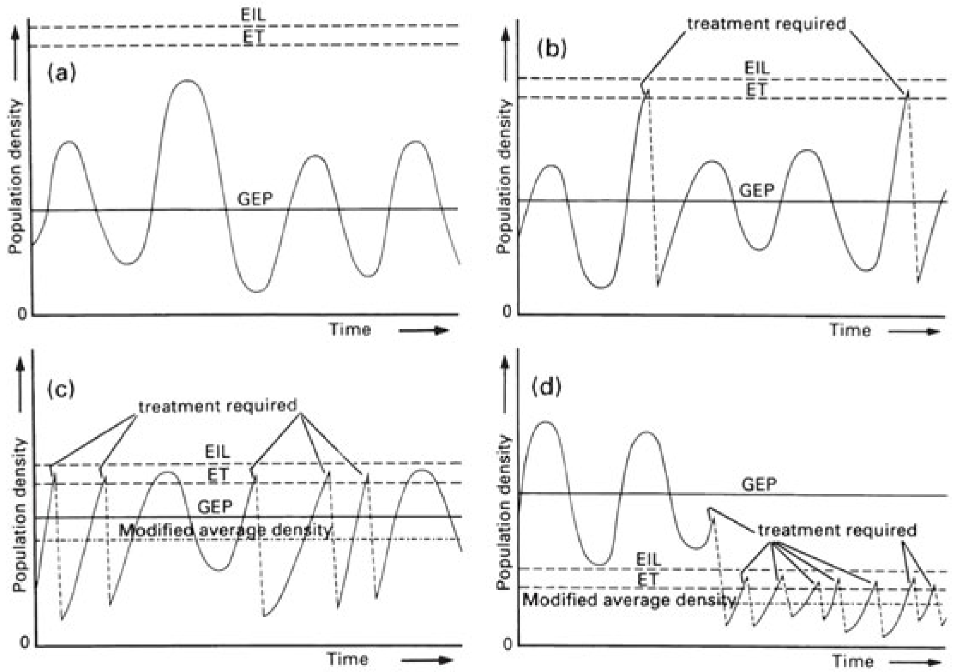


Fig. 16.1 Schematic graphs of the fluctuations of theoretical insect populations in relation to their general equilibrium position (GEP), economic threshold (ET) and economic injury level (EIL). From comparison of the GEP with the ET and EIL, insect populations can be classified as: (a) non-economic pests if population densities never exceed the ET or EIL; (b) occasional pests if population densities exceed the ET and EIL only under special circumstances; (c) perennial pests if the GEP is close to the ET so that the ET and EIL are exceeded frequently; or (d) severe or key pests if population densities always are higher than the ET and EIL. In practice, as indicated here, control measures are instigated before the EIL is reached. (After Stern *et al.* 1959.)

The Insects: An Outline of Entomology. Fifth Edition. P.J. Gullan and P.S. Cranston.

INSECTS AS PESTS

- Assessment of pest status
  - EIL does not consider external factors such as:
    - Natural enemies
    - Insecticide resistance
    - Adjacent control areas
  - Developed mostly as a means for more sensible pesticide use
  - EILs largely relevant only to agriculture
  - Limited when multiple pests are present

INSECTS AS PESTS

- Why insects become pests
  - Insects become pests for many reasons:
    - Harmless insects are introduced to areas outside their native range
    - Previously harmless insects become vectors of pathogens
    - Move from feeding on native plants to introduced ones
    - Monocultural ecosystems create dense aggregations of predictable resources
    - Cultivation methods lead to increase in pest status and numbers
      - Continuous cultivation without a fallow period – broccoli, potatos, herbs, etc
      - Prolonged use of insecticides

EFFECTS OF INSECTICIDES

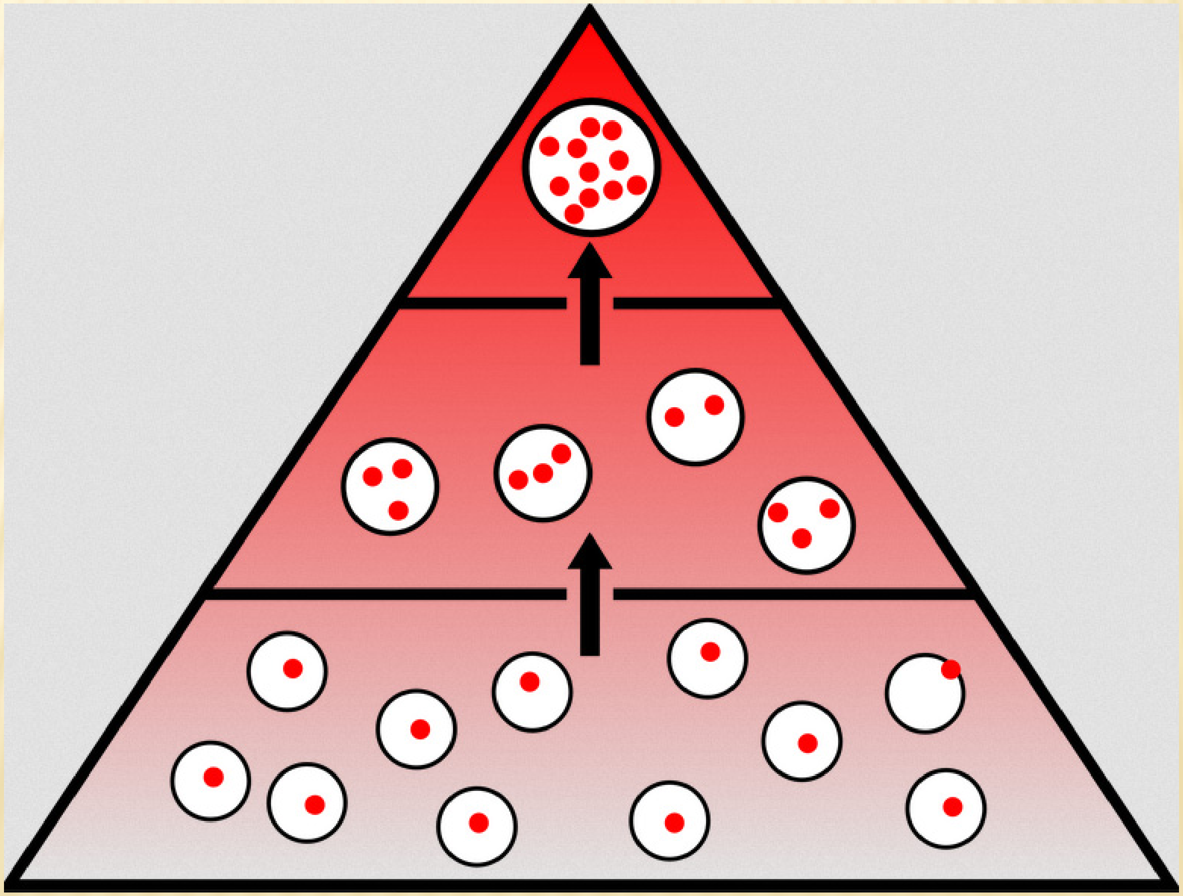
- Many insecticides developed during the 1950's and 1960's
- They are still the main tactic used today
- Undesirable effects of insecticides include:
  - Selection for genetically resistant insects
  - Collateral damage of non-pests
  - Pest resurgence
    - As a result of resistance and elimination of predators
    - Natural enemies often recover more slowly
  - Secondary pest outbreak
  - Economic contamination and biomagnification
  - Danger to human health

"You idiot! I said get the room freshener! That's the insecticide!"

- Pest damage continues to increase despite heavy pesticide use

EFFECTS OF INSECTICIDES

- Biomagnification



EFFECTS OF INSECTICIDES

- Insecticide resistance
  - Insecticide resistance: insects that are predisposed genetically to survive insecticide; develops over time, essentially a selection of a specific biotype
  - Tolerance: the ability to survive insecticide at some level; a natural tendency and not a result of selection pressure
  - CO potato beetle is resistant to nearly every chemical control
  - Multiple resistance: resistance to many different insecticides

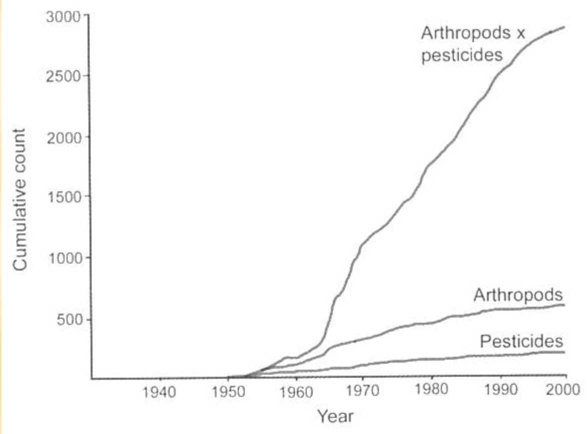
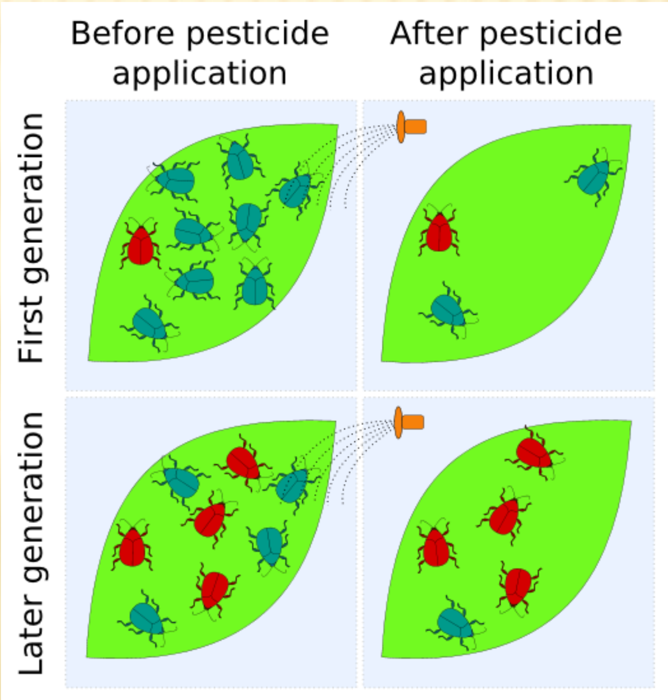


Fig. 16.2 Cumulative increase in the number of arthropod species (mostly insects and mites) known to be resistant to one or more insecticides up to year 2000; the number has increased since then. (After Bills et al. 2000.)

EFFECTS OF INSECTICIDES

- Insecticide resistance
  - 4 mechanisms of insecticide resistance
    - Tobacco hornworm
    - Polyphagous insects are pre-adapted to evolve resistance
  - Problem of "kill-all" applications
  - This and other factors have led to other control methods



INTEGRATED PEST MANAGEMENT

- IPM: a broad-based approach that integrates practices for economic control of pests
- Aims to suppress pest populations below the economic injury level (EIL)
- Successful IPM requires knowledge of several key factors
- Key concept: compatibility of pest-management tactic
- Philosophy that may approach organic farming
- Allows for safer pest control
- Implementation of IPM has been slow
- Reasons why the adoption rate of IPM is low

INTEGRATED PEST MANAGEMENT

- IPM system is designed around 6 basic components:
  - Acceptable pest levels
    - Emphasis on control, not eradication
    - Annihilation can be costly and unsafe
  - Preventive cultural practices
    - Sanitation
  - Monitoring
    - Inspection and identification
  - Mechanical controls
    - Barriers, traps, picking, tillage, etc.
  - Biological controls
    - Natural processes and materials
  - Responsible use
    - As required and at specific times

INTEGRATED PEST MANAGEMENT

- Control measures of IPM include: insecticides, biological control, cultural control, plant resistance, genetic modification, pheromones, and growth regulation

CHEMICAL CONTROL

- Despite the hazards, some use is unavoidable
- Carefully timed doses reduce ecological damage
- Chemicals enter the insect in 1 of 3 primary ways:
  1. Cuticle
     - Contact poisons
  2. Trachea
     - Inhalation poisons
     - Fumigants
  3. Mouth
     - Stomach poisons
- Some may act as all 3 simultaneously
- Typically attack the nervous system

CHEMICAL CONTROL

- Chemical insecticides
    - Alkaloids
        - Used since 1600's
        - Natural, plant-derived; from nicotine in tobacco
    - Pyrethrins
        - Kills effectively on contact at low dosage
        - Low environmental persistence
        - Low mammalian toxicity
    - Nicotinoids / Neonicotinoids
        - Synthetic, modeled on natural nicotine
    - Carbamates
    - Organophosphates
        - Malathion, parathion
    - Organochlorines
        - DDT
    - Phenylpyrazoles
        - New class
        - Frontline, Maxforce

CHEMICAL CONTROL

- Chemical insecticides
  - Formulation: components and proportions of additional substances that accompany an insecticide when prepared for application
  - Modes of application:
    - Solutions or emulsions
    - Unwettable powders dispersed in water
    - Dusts or granules
    - Gaseous fumigants
  - Can be formulated in different ways

  - Concern about sublethal effects of pesticides on non-target organisms (honey bees)
  - Sublethal effects generally not considered

CHEMICAL CONTROL

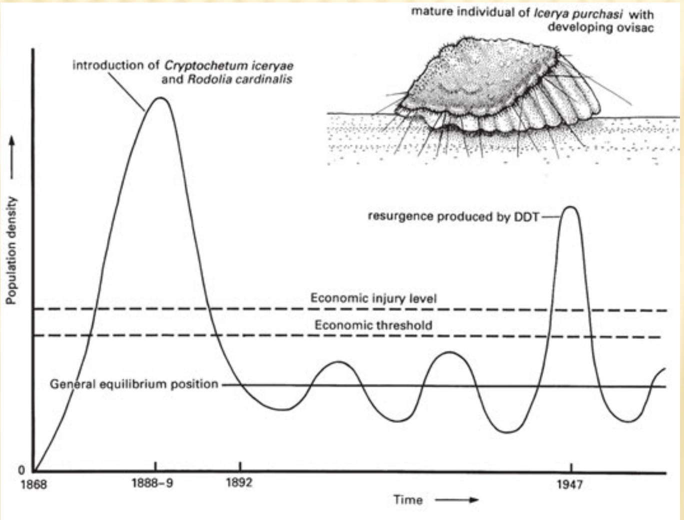
- Insect growth regulators
  - “IGR” – compound that inhibits an insect’s growth or development
  - Very efficient against specific stages of an insect pest
  - 2 types of IGRs, distinguished by their mode of action
    1. Chemicals that disrupt the hormonal control of metamorphosis
       - Insect fails to reach adulthood, or is sterile and malformed
       - Useful when the adult is the pest
    2. Chemicals that prevent the formation of chitin / cuticle
       - Insects die at or immediately after the molt
       - Useful for larval pests
  - Can result in severe pest outbreaks

BIOLOGICAL CONTROL

- Biological control: the establishment of natural enemies to control pests
- Deliberate human intervention
- Goal is reduction, not elimination
- 3 types of biological control:
    1. Classical biological control aka importation
        - Appropriate for when insect spread outside their natural range
        - Some great successes, many failures
        - Disastrous side effects (Hawai'I, Fiji)
        - Neoclassical biological control: importation of non-native species to control native ones
            - High risk

BIOLOGICAL CONTROL

- 3 types of biological control:
  1. Classical biological control aka importation
     - Vedalia beetle and cottony-cushion scale
       - Great success story of classical biological control
       - Scale was devastating the California citrus industry in the late 1800's
       - Vedalia ladybug and parasitoid fly were introduced
       - Controlled the scale population within just a few years
       - DeBach and Rosen suggested this "established the biological control method like a shot heard around the world". (1991, Biological control by natural enemies, 2nd edition. Cambridge University Press)



Box 16.3 The cottony-cushion scale

The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

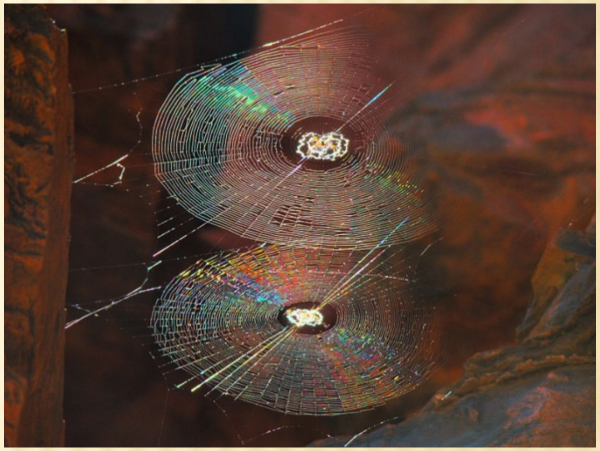
Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

BIOLOGICAL CONTROL

- 3 types of biological control (continued):
  2. Augmentation: supplementation of existing natural enemies
     - Periodic release
     - Inoculation
     - Inundation
     - Can be helpful in reducing pesticide use
  3. Conservation: protect or enhance activities of natural enemies, reducing pest effects
     - Preservation
     - Environmental manipulation – to improve conditions for predators and parasitoids
- Failure in systematic studies can be very costly

BIOLOGICAL CONTROL

- Arthropod natural enemies
  - Predators
    - Spiders
      - Diverse and efficient predators
      - Great impact on insect populations
      - Lack of feeding specificity
    - Many predators are polyphagous
      - Unsuitable for targeting particular pest species



  - Parasites and parasitoids
    - Most important biological control agents are wasps and flies
  - Complexities of food webs and complications

BIOLOGICAL CONTROL

- Microbial control
  - Includes: nematodes, fungi, bacteria, viruses, protists
  - Many are specific to a particular genus or family of insect
  - Entry mode
  - Strategies of control mimic those used with natural enemies
  - Nematodes
    - Desiccation restricts use to moist environments
    - Other environmental restrictions
  - Fungi
    - Most common disease organisms in insects
    - Ability to infect insect during any stage

BIOLOGICAL CONTROL

- Microbial control
  - Bacteria
    - *Bacillus thuringiensis*, or Bt
      - Mode of action
      - Control is dependent on several factors
      - Increasingly used for control
      - Some resistance
      - Optimism that high levels of resistance is unlikely
      - Colorado potato beetle

  - Viruses
    - Considered safe because of their restriction to insects
    - Mode of action and persistence in the environment

HOST-PLANT RESISTANCE TO INSECTS

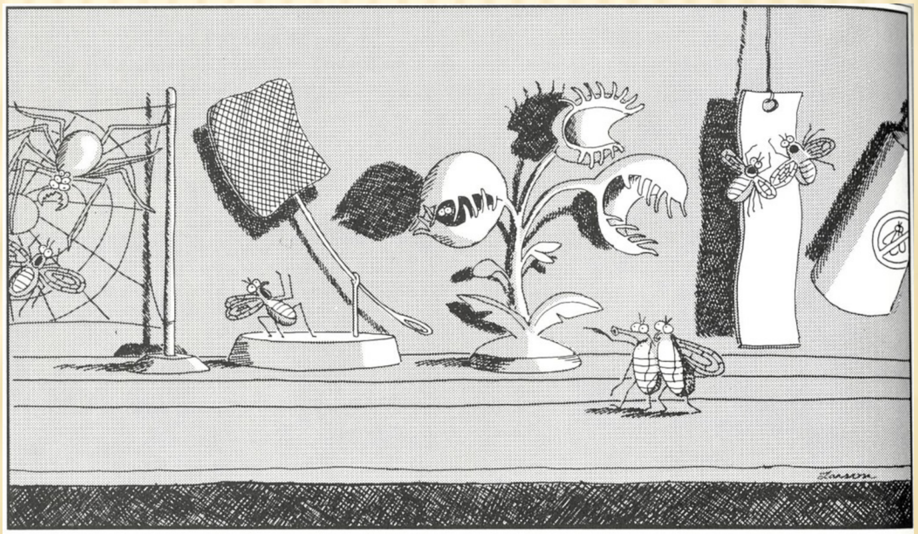
- Plant resistance: mechanisms by which plants resist insect attack
- 3 types of plant resistance:
  1. Antibiosis: plant negatively affects the biology of the insect
     - Factors include: toxins, growth inhibitors, low nutrients, trichomes, indigestibles
  2. Antixenosis: plant deters insect feeding due to being a poor host
     - Factors include: repellents, deterrents, trichomes, waxes, thickness, toughness
  3. Tolerance: plant is able to withstand or recover from insect damage
     - Involves only plant features and not interactions with insects

HOST-PLANT RESISTANCE TO INSECTS

- Insect-resistant varieties of: corn, cotton, tobacco, tomato, potato
- 2 methods of gene insertion into plants
- Advantages over insecticides
- Exacerbation of the situation by negatively affecting predators
- Environmental risks from the use of transgenic plants:
  - Genes may transfer to other plants
  - Plant my become weedy itself
  - Non-target organisms may be affected

PHYSICAL CONTROL

- Non-chemical and non-biological methods
- Indoors and outdoors
- Fences, traps, trenches, packaging, swatters
- Insect zappers
  - Should probably not be used
  - Statistical studies



In the Fly House of Horrors

CULTURAL CONTROL

- Crop pests
  - Crop rotation, tillage, burning of stubble, synchrony avoidance, plants for natural enemies, pest-free seeds
  - Intercropping
    - 4 hypotheses
- Medical pests
  - Draining marshes
  - Container removal
- Livestock pests
  - Removal of dung
  - Walk-throughs and dipping

PHEROMONES AND ATTRACTANTS

- Sex pheromones can be used with great success
- Other attractants such as food baits or oviposition sites can be used
- 3 main uses for pheromones:
  1. Monitoring
  2. Mass trapping
     - Attraction-annihilation
  3. Mating disruption
     - Pheromone dispensers create “noise”

GENETIC MANIPULATION OF PESTS

- Screw-worm fly
  - Devastating pest
  - Eradication in US
  - Female mates only once
  - Swamping with infertile males
  - Sterile insect technique (SIT, SIRM)
  - Gamma irradiation

- Tsetse fly
- Other successes around the world
- Lack of success can be due to many factors

PICTURES BY SLIDE

NO MODIFICATIONS WERE MADE TO ANY PICTURES ON ANY OF THE SLIDES

1. (no picture)
2. (no picture)
3. The Far Side Gallery 2 by Gary Larson, 1986, page 93
4. (no picture)
5. https://commons.wikimedia.org/wiki/File:Miridae_fg01_20060505_Nied_Selzerbrunnen.JPG
6. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 16.1
7. https://commons.wikimedia.org/wiki/File:SHOOT_TO_KILL_-_PROTECT_YOUR_VICTORY_GARDEN_-_NARA_-_515408.tif
8. https://commons.wikimedia.org/wiki/File:Potato_Crop,_Benacre_-_geograph.org.uk_-_470970.jpg
9. The Far Side Gallery 2 by Gary Larson, 1986, page 11
10. https://commons.wikimedia.org/wiki/File:Bioakkumulation_von_schadstoffen.png
11. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 16.2
12. https://commons.wikimedia.org/wiki/File:Pesticide_resistance.svg
13. https://commons.wikimedia.org/wiki/File:NRCSAZ02083_-_Arizona_%28449%29%28NRCS_Photo_Gallery%29.jpg
14. https://commons.wikimedia.org/wiki/File:IPMtrap4854.JPG
15. https://commons.wikimedia.org/wiki/File:Marienk%C3%A4fer_%2B_Blattlaus-3504.jpg
16. https://commons.wikimedia.org/wiki/File:Tent_fumigation.jpg
17. Chemical Control
    1. https://faa81132b7.site.internapcdn.net/products/Ortho/US-Ortho-Home-Defense-Max-Insect-Killer-For-Indoor-And-Perimeter-1-0196810-Main-Lrg.png (permission: I called number 866-324-9192 and spoke to Candice & her supervisor @ 3:01-3:14pm on 5/31/16)
    2. http://www.gardentech.com/media/Files/GardenTech/Product%20Images/Sevin%20Ready-To-Use%20Bug%20Killer.jpg
18. https://en.wikipedia.org/wiki/File:Besticidesandbees.jpg
19. (my picture)
20. https://commons.wikimedia.org/wiki/File:Corn_borer.jpg
21. Biological Control
    1. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Box 16.3
    2. https://commons.wikimedia.org/wiki/File:Vedalia_Beetle_%2815959056801%29.jpg
22. https://commons.wikimedia.org/wiki/File:Lady_bugs_are_a_beneficial_insect_commonly_sold_for_biological_control_of_aphids..jpg
23. https://commons.wikimedia.org/wiki/File:Spiral_Orb_Webs.jpg
24. https://commons.wikimedia.org/wiki/File:Cordyceps.jpg
25. https://commons.wikimedia.org/wiki/File:Krumplibog%C3%A1r2.JPG
26. https://commons.wikimedia.org/wiki/File:Cap1033-botao1.jpg
27. https://commons.wikimedia.org/wiki/File:Danaus_plexippus_on_Asclepias_incarnata_4999.jpg
28. The Far Side Gallery 3 by Gary Larson, 1988, page 96
29. https://commons.wikimedia.org/wiki/File:Cattle_tick_treatment.jpg
30. https://commons.wikimedia.org/wiki/File:Hagnau-9702.jpg
31. https://commons.wikimedia.org/wiki/File:Cochliomyia_hominivorax_%28Coquerel,_1858%29.jpg

QUESTIONS?

PERMISSION

Media inquiry (2)

GASupport <gasupport@groaccess.com> May 17 at 5:03 PM

To widowman10@yahoo.com

Message

Hello, I'm teaching an Intro to Entomology course at a local university in Colorado Springs. I was wondering if I could use your image of the Sevin insecticide for educational use, assuming of course I credit you and cite the URL? It would be for a lesson on effective insecticides used to control insect populations.

Response

Hello Brian,

Thank you for emailing us. Yes, you can use an image of our product for educational purposes as long as proper credit is given and the image is not modified.

Regards,
GardenTech
Customer Support
800-265-0761

8:09 AM
5/18/2016

ENTOMOLOGY 101

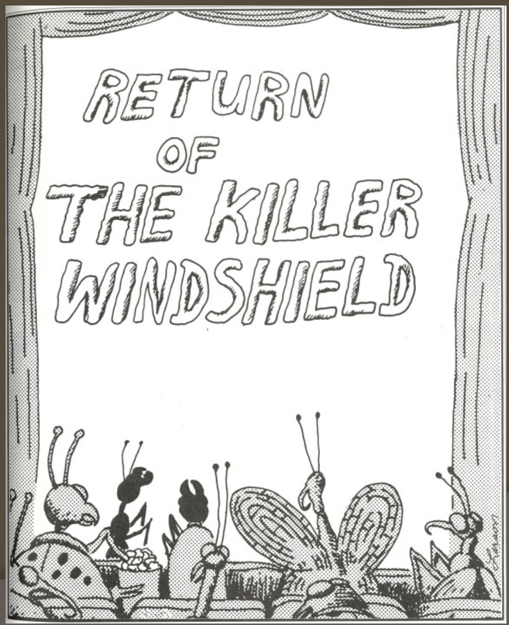
Insect Collecting

Insect Collecting

- Topics
  - Collection
  - Preservation and Curation
  - Identification

Insect Collecting

- Method of collection depends on many factors
- Identification of specimen is necessary
- Proper identification requires appropriate preservation
- Collections remain important after many years
- Ethical collecting

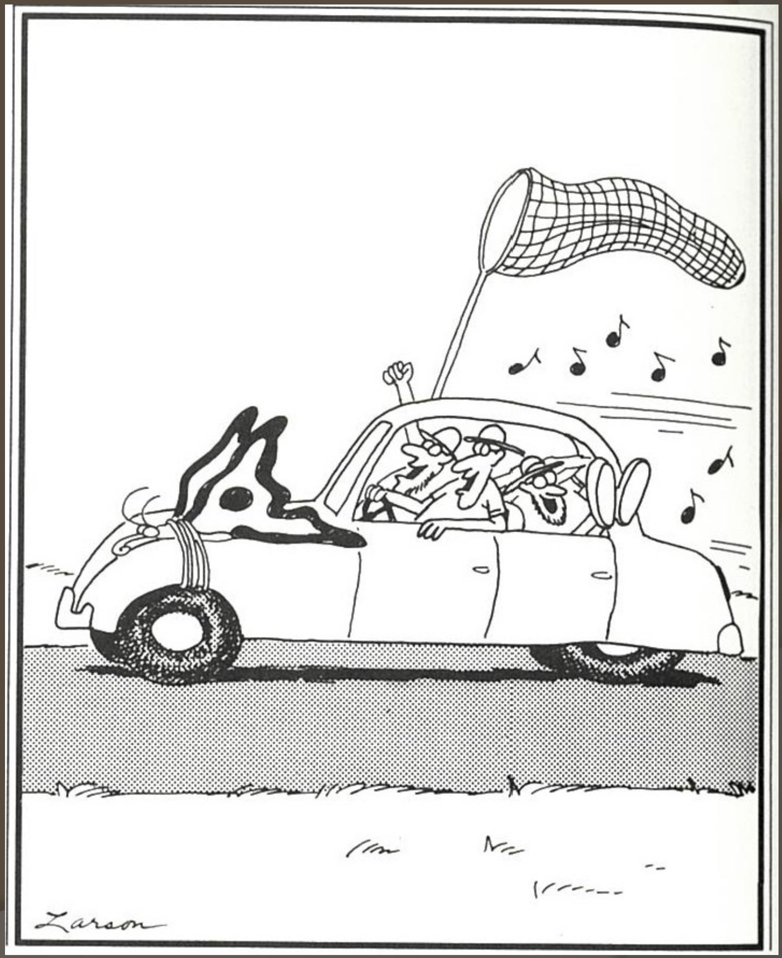


Collection

- Active collecting
  - A lot of insects are collected this way
  - Useful for slow or sedentary insects
  - Methods include:
    - Forceps
    - Brushes and cups
    - Aspirators
    - Lighted sheets at night

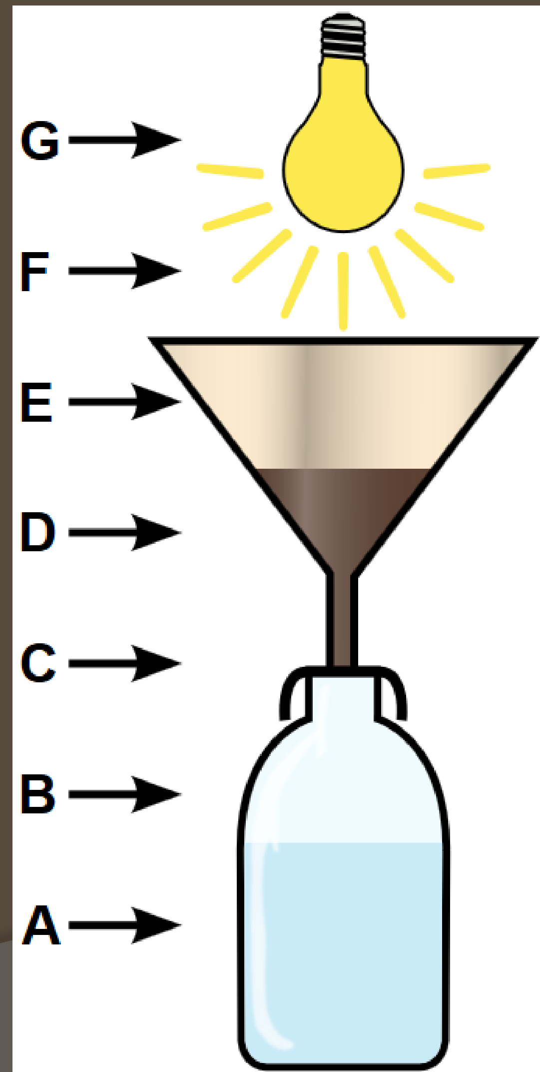
Collection

- Active collecting
  - Methods include (cont.):
    - Netting
      - Very popular technique
      - For all ages and purposes
      - Net sizes
      - Deep net bag necessary
      - On the fly or by sweeping
      - Beating bushes
    - Aquatic nets



Collection

- Passive collecting
  - Leaf litter, debris, and soil
  - Insect movement to / from stimulus
  - Berlese funnel



Collection

- Passive collecting
  - Winkler bag
  - Separating bag
  - Barrier trap
    - Flight patterns
    - Intercept flying insects
  - Malaise trap
    - Modified tent
    - Gutter below
  - Window trap

Collection

- Passive collecting
  - Ground and crawling insects
  - Pitfall traps
    - Sink containers to rim-level
    - Used often to estimate species richness and relative abundance
    - Trappability
  - Baiting for different insects
  - Sugaring
  - Pan traps
    - Outdoor pools
  - Light trapping

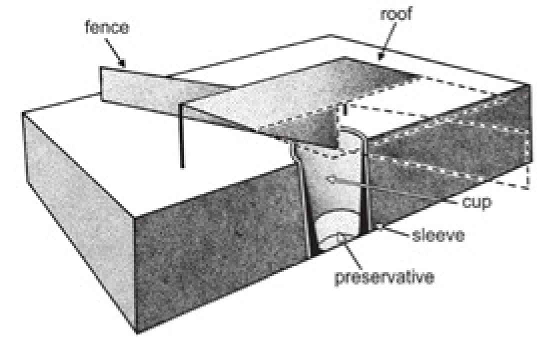
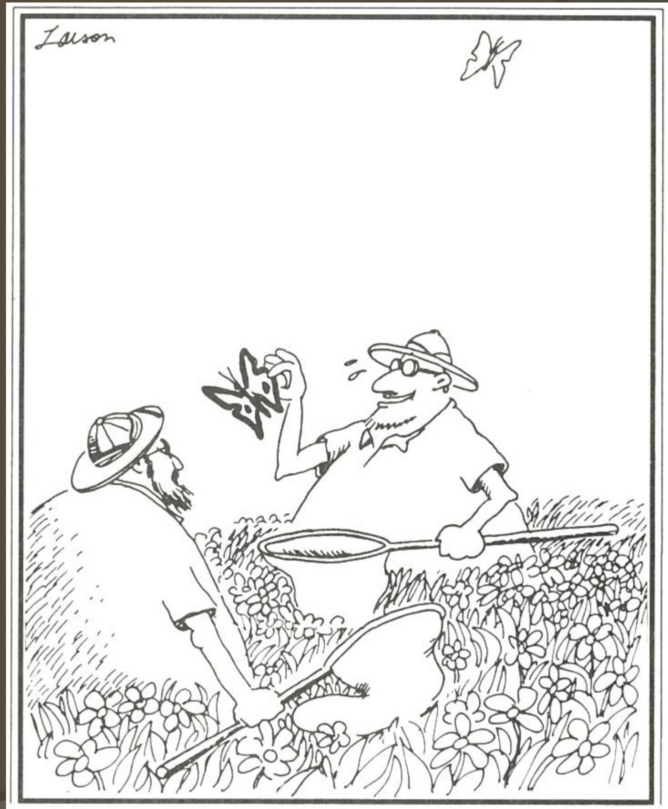


Fig. 18.1 A diagrammatic pitfall trap cut away to show the in-ground cup filled with preserving fluid. (After an unpublished drawing by A. Hastings.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Preservation and Curation

- Dry preservation
  - Most adult insects are preserved dry
  - Killing and handling prior to dry mounting
    - Best kill methods: killing bottle or freezing
    - Care must be taken when freezing
    - Best killing agent is ethyl acetate
    - Creating and charging the killing bottle
    - Only stay relaxed for a period of hours
    - Gutting large insects
    - Relaxing chamber



"An excellent specimen . . . symbol of beauty, innocence, and fragile life . . . hand me the jar of ether."

Preservation and Curation

- Dry preservation
  - Appropriate method depends on size and kind of insect
  - Entomology pins only
  - Pinning
    - Thickness relative to size
    - Placement dependent on taxa
    - Avoid identifying features

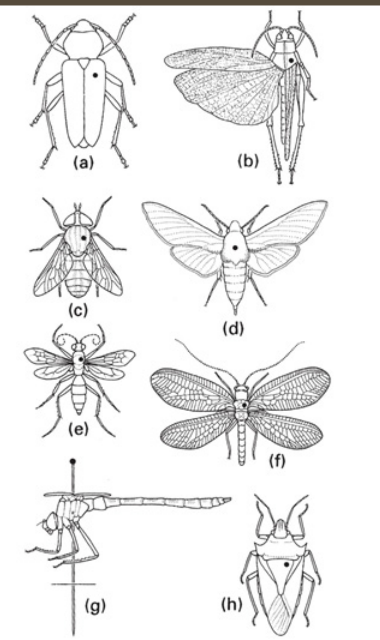


Fig. 18.2 Pin positions for representative insects: (a) larger beetles (Coleoptera); (b) grasshoppers, katydids and crickets (Orthoptera); (c) larger flies (Diptera); (d) moths and butterflies (Lepidoptera); (e) wasps and sawflies (Hymenoptera); (f) lacewings (Neuroptera); (g) dragonflies and damselflies (Odonata), lateral view; (h) bugs, cicadas, leafhoppers and planthoppers (Hemiptera: Heteroptera, Cicadomorpha and Fulgoromorpha).
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Preservation and Curation

- Dry preservation
  - Pinning (cont.)
    - Positioned ¾ way up on pin
    - Room to grab pin
    - Correct pinning placement

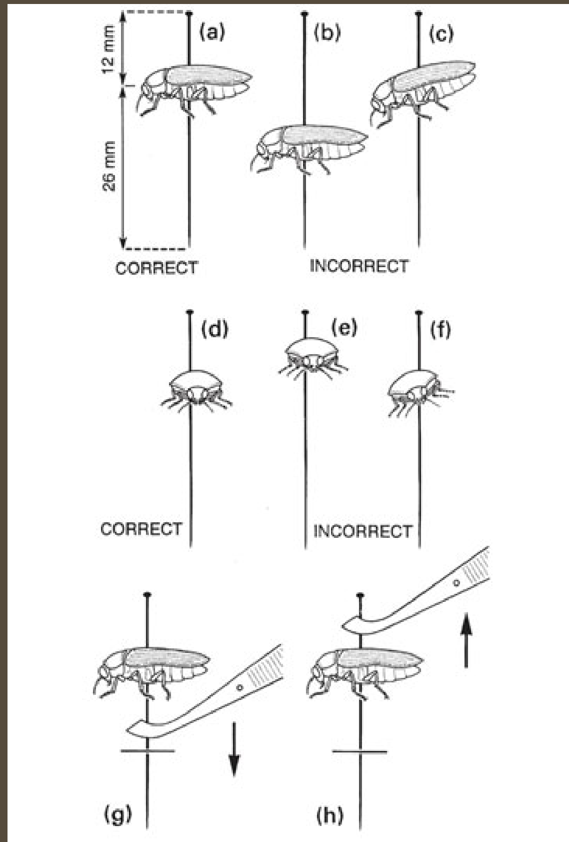


Fig. 18.3 Correct and incorrect pinning: (a) insect in lateral view, correctly positioned; (b) too low on pin; (c) tilted on long axis, instead of horizontal; (d) insect in front view, correctly positioned; (e) too high on pin; (f) body tilted laterally and pin position incorrect. Handling insect specimens with entomological forceps: (g) placing specimen mount into foam or cork; (h) removing mount from foam or cork. ((g,h) After Upton 1991.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Preservation and Curation

- Dry preservation
  - Carding
    - For select purposes
  - Pointing
    - Used for small insects
    - Small, triangular, white pieces of cardboard
    - Glue insect to end of point

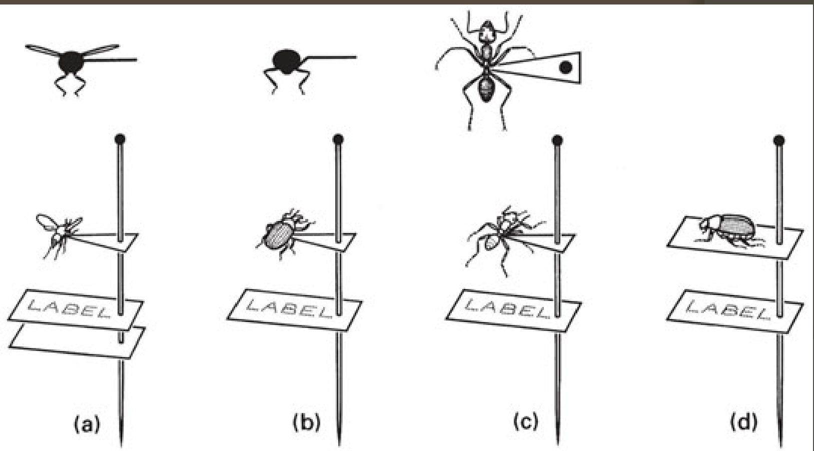


Fig. 18.5 Point mounts: (a) a small wasp; (b) a weevil; (c) an ant. Carding: (d) a beetle glued to a card mount. (After Upton 1991.)
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Preservation and Curation

- Dry preservation
  - Spreading
    - Important because of identifying features
    - Appendages spread with help of board
    - Much more attractive in a collection

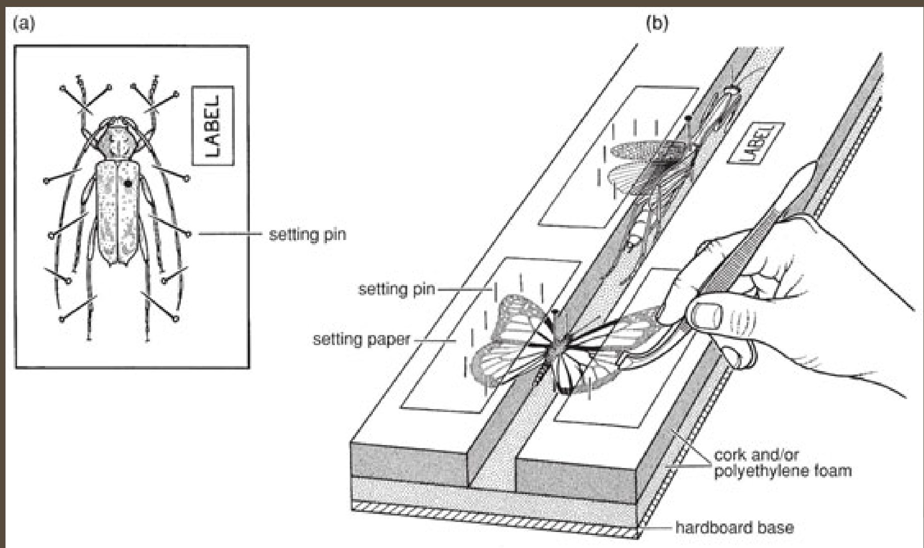
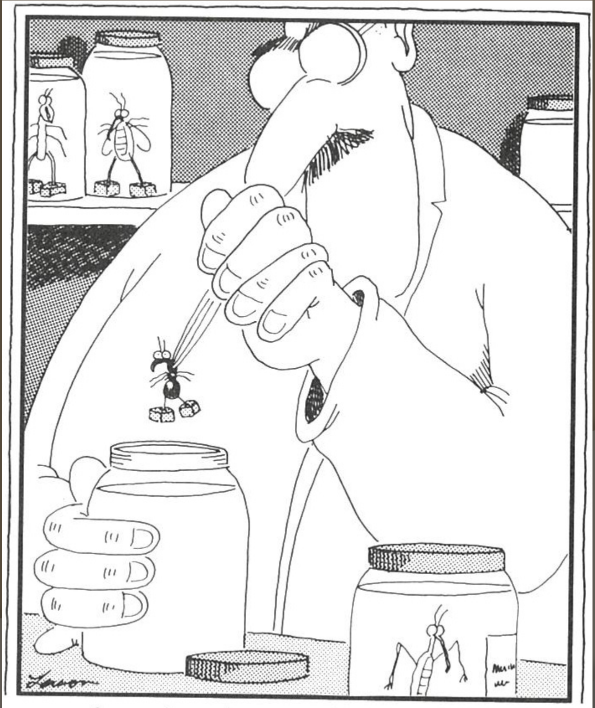


Fig. 18.6 Spreading of appendages prior to drying of specimens: (a) a beetle pinned to a foam sheet showing the spread antennae and legs held with pins; (b) setting board with mantid and butterfly showing spread wings held in place by pinned setting paper.
The Insects: An Outline of Entomology, Fifth Edition. P.J. Gullan and P.S. Cranston.

Companion Website: www.wiley.com/go/gullan/insects
WILEY Blackwell

Preservation and Curation

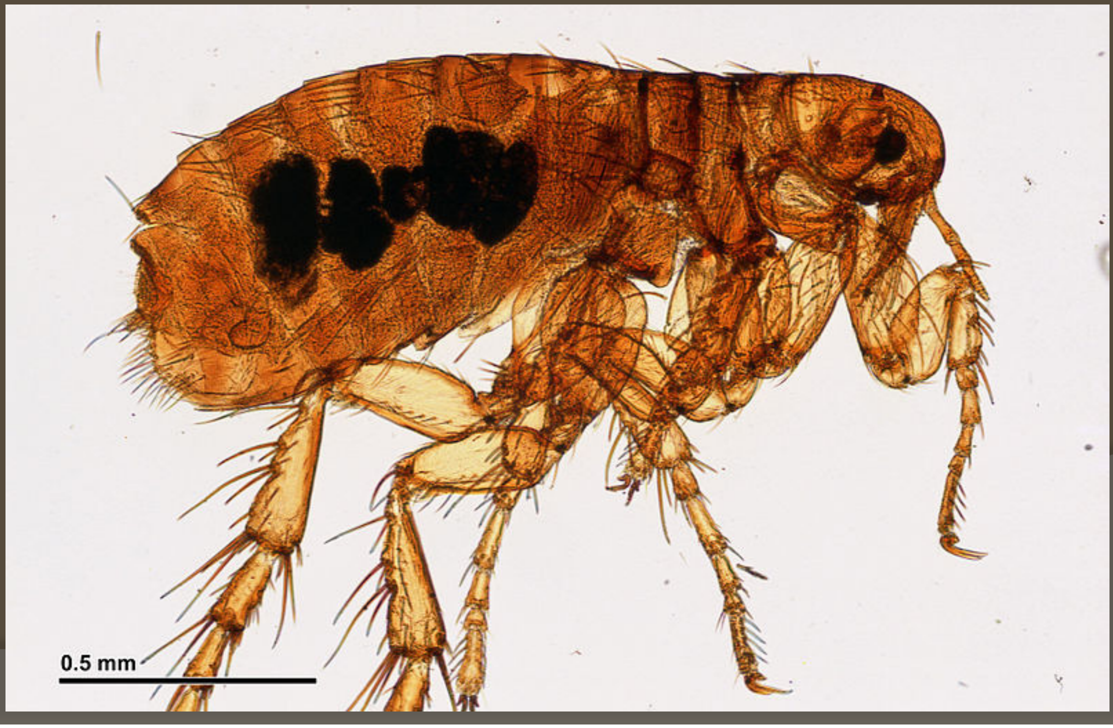
- Wet preservation and fixing
  - Drying causes certain insects to shrivel and rot
  - Eggs, nymphs, larvae, pupae, puparia, and soft-bodied insects should be preserved in liquid
  - Ethyl alcohol diluted with water
  - Discoloration and fixing
  - Different solutions



Scenes from the entomology underworld

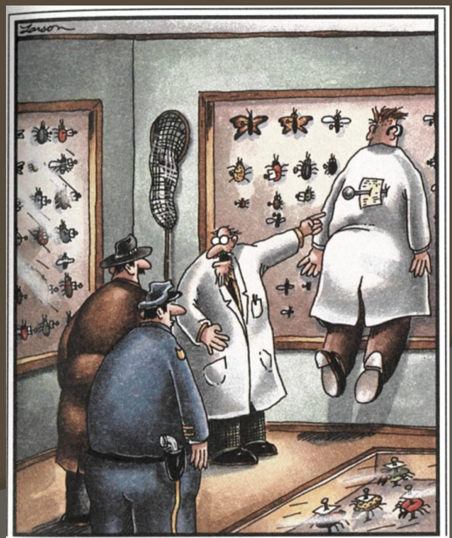
Preservation and Curation

- Microscope slide mounting
  - Magnification is necessary for many of the smaller insects
  - Must be mounted on a slide
  - Staining of the cuticle may be needed
  - Soaking to clear the specimens



Preservation and Curation

- Curation
  - Labelling
    - Collection has little-to-no value without information
    - 2 labels
    - The data on the labels should include:
      - Location: Country, state, city
      - GPS: lat / long coordinates are extremely valuable, especially today
      - Date: date, month (spelled out or abbreviated - to avoid cross-culture confusion), year
      - Name of collector
      - Order and genus / species



"Professor LaVonne had many enemies in the entomological world, detective, but if you examine that data label, you'll find exactly when and where he was—shall we say—'collected.'"

Preservation and Curation

- Care of collections
  - Can deteriorate rapidly due to pests, mold, etc.
  - Light can cause fading
  - Dermestid beetles can destroy collections
  - Insecticides or deep freezing can curtail pests
  - Good practices for future use

Identification

- Identification keys
  - Dichotomous key
  - Can lead to family, genus, or species
  - Importance to check other descriptions
  - Early mistakes in the key
  - Nomenclature in most keys
  - Sex or juvenile restrictions
  - Efficiency of computer keys
  - Vincent Brothers murder trial
  - Need for identification specialists

Pictures by Slide

no modifications were made to any pictures on any of the slides

1. (no picture)
2. (no picture)
3. The Far Side Gallery 1 by Gary Larson, 1984, page 71
4. https://commons.wikimedia.org/wiki/File:Mothing_on_BukitRetakBrunei2.jpg
5. The Far Side Gallery 2 by Gary Larson, 1986, page 128
6. https://commons.wikimedia.org/wiki/File:Berlese.svg
7. https://commons.wikimedia.org/wiki/File:Malaise_trap.jpg
8. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 17.1
9. The Far Side Gallery 1 by Gary Larson, 1984, page 54
10. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 17.2
11. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 17.3
12. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 17.5
13. Wiley Blackwell: The Insects: An Outline of Entomology, 4th edition – Figure 17.6
14. The Far Side Gallery 4 by Gary Larson, 1993, page 20
15. https://commons.wikimedia.org/wiki/File:Flea_%28251_01%29_Aphaniptera;_total_preparation.jpg
16. The Far Side Gallery 5 by Gary Larson, 1995, page 71
17. Preservation and Curation
    1. https://coloradospringsbugmuseum.files.wordpress.com/2014/03/maymuseum-27.jpg
    2. Called the John May Bug Museum (719-576-0450) on 6/10/16 at 14:19 and Eilena gave the ok
18. https://commons.wikimedia.org/wiki/File:Xanthippus_corallipes.jpg

Questions?

Permission

LECTURE 1

- What is a keystone species? Provide a non-termite example of one and describe what makes it a keystone species
- Visit BugGuide.net and find a feature on the website that would help in the study of entomology. Explain why this is beneficial to the scientific community.
- What is one of the benefits that insects provide, and what do you predict would happen if they ceased to provide that benefit?
- Why is there a higher diversity of insects in tropical regions?
- Pick an insect species (besides the mosquito) and write out the full taxa, from kingdom-species
- What are some types of insects that people eat, and what parts of the world are they eaten in?
- Explain why habitat loss and fragmentation are so detrimental to conservation

LECTURE 2

- Describe the difference between young and adults in the 4 types of metamorphosis
- Give 2 reasons why molting is beneficial for insects
- Pick a region of the insect body (head, thorax, or abdomen) and provide: the number of segments that make it up, and a characteristic of that region
- Contrast 2 different antennae types
- Pick an insect leg adaptation type (fossorial, raptorial, saltatorial, etc.) and explain the function of it

LECTURE 3

- Describe a type of ground locomotion and an insect that exhibits it
- Explain a benefit of aerial locomotion (flying) and why it would be beneficial to the insect
- Pick an endocrine center and tell the hormone it secretes and what the hormone controls
- What is hemolymph and why is it important?
- Explain the role of symbionts in the digestive system of termites
- What is a spermatophore and how is it used?

LECTURE 4

- Name an advantage and disadvantage of long range broadcasting when attracting a mate
- Describe what happens in “survival of the sneakiest”
- What is a nuptial gift and what factor does the size of the gift play?
- Describe an adaptation males use to increase their odds of paternity
- Name 2 functions of the eggshell and why they may be important

- Compare / contrast oviparity and viviparity

LECTURE 5

- Molting and ecdysis are often used interchangeably to describe an event in the life of an insect. What is the difference between the two?
- Name 3 different factors that affect magnitude of growth in insects
- How do insects know when to molt to the adult phase?
- Pick a form of voltinism (uni, bi, multi, or semi) and list: the number of generations per year and an insect that exhibits that type
- What is diapause and how long does it last
- Describe 2 different tactics that insects use to deal with cold temperatures
- Find an insect species or order (other than the monarch butterfly) that migrates long distances
- Describe the importance of photoperiod on the development of an insect

LECTURE 6

- What era are the following oldest fossils from: oldest hexapod, earliest winged insects, origination of beetles
- Name a major extinction event and something noteworthy about it
- During what period did the bees first appear?
- By what time (mya) did the insect fauna look much like it does today?
- Describe one of the hypotheses of the origin of wings in insects
- Pick a ‘route to flight’ theory and list both a support and criticism for it
- What is the difference between Paleoptera and Neuroptera and provide an example of each

LECTURE 7

- Explain how the morphology of insects often reflects the soil layer they occupy
- Name a couple of difficulties in studying root-feeding insects
- List a few types of insects that utilize dung
- List 2 benefits that dung beetles provide to us and tell why they are important
- What is insect “succession” (with regard to carrion) and what are some of the first insects to arrive?
- Name something unique about cave-dwelling insects

LECTURE 8

- Pick an insect order that is a common aquatic insect and list the number of aquatic species in the order and method of respiration

- List 3 insect orders that are exclusively (or nearly so) aquatic as immatures
- What is a plastron?
- Describe both a lotic and a lentic region/zone
- List 2 ways that aquatic insects can help indicate contamination when used in environmental monitoring
- Describe 2 different types of functional feeding groups and how they obtain their food
- Why are there not more insects living in or on the ocean?

LECTURE 9

- Contrast monophagous, oligophagous, and polyphagous and give an example of each
- Discuss the commercial damage caused by plant mining
- List a common type of borer and how it could be potentially be (or already is being) used as a biological control agent
- Describe why the emerald ash borer is such as destructive pest
- What is a gall? What are they used for, and what kinds of insects use them?
- Explain the importance of bees as pollinators
- Describe the unique relationship between ants and plants, specifically domatia

LECTURE 10

- What are the varying degrees of sociality?
- List the 3 traits that define eusociality?
- What is a caste system and who are some of the main members?
- How does age factor into the life of the worker bee? How do her responsibilities change over time?
- Discuss “colony collapse disorder.” Be sure to include the importance of it, symptoms, and potential causes.
- Describe how bees communicate with their fellow hive members
- Pick a eusocial insect and describe the colony members and the type of nest they make
- Define the term “inquiline” and describe how they are able to blend in?
- What factors contribute to the success of eusocial insects?

LECTURE 11

- Compare / contrast parasite and parasitoid
- Discuss the benefits and drawbacks of the waiting and active foraging strategies
- Describe a trap that a sit-and-wait insect predator uses
- List an active foraging insect and tell how it is able to find prey
- Define “phoresy” and give an example of it
- What is hyperparasitism and what makes it unique

- What is a "trophic cascade" and why is it important?

LECTURE 12

- Describe how a lubber grasshopper avoids predation and what the loggerhead shrike does to overcome those defenses
- Give an example of masquerade and what the insect is posing as
- Explain how backpack bugs are better able to avoid predation
- Compare / contrast Batesian and Mullerian mimicry
- What is myrmecomorphy, and what is an insect that exhibits it?
- Describe a type of complex warfare between termites and ants

LECTURE 13

- Discuss bed bugs. Include: signs/symptoms, and where/what to look for.
- Describe a type of blister / itch-inducing insect, and what could happen if you come in contact with one of them.
- List 3 different types of insects (and their products) that cause allergic reactions in people
- Why is malaria (as a disease) so important? What genus of mosquitos is responsible for vectoring malaria and what kind of pathogen is it?
- Scientists use a 2-pronged approach when combatting malaria. Which approach (mosquitos or disease) is more important in your opinion, and why?
- Discuss West Nile virus and be sure to include: origin, symptoms, natural reservoirs and hosts, and spread in recent years
- Pick a group of important insects in the field of forensic entomology and explain why they are significant

LECTURE 14

- Compare / contrast economic threshold (ET) and economic injury level (EIL)
- List 3 different reasons why insects may become pests
- List 2 undesirable effects of insecticides and explain why those effects are detrimental
- Explain the concept of biomagnification and why it is important
- Describe how insecticide resistance develops in an insect population and provide an example of an insect that has become resistant to an insecticide
- Define IPM and list the basic components of it
- List the 3 different types of biological control and explain 1 of those types
- Contrast the 3 types of host-plant resistance to insects
- Discuss a success story of the genetic manipulation of a pest

LECTURE 15

- Discuss the advantages of both active collecting and passive collecting
- Explain how a pitfall trap works
- Pick an insect and describe where the pin should be placed during preservation
- Explain the correct positioning of the insect on a pin (too high/low, tilted, etc.)
- What insect orders should be spread on a spreading board
- List the kinds of insects that should be preserved in liquid
- List the data that should be printed on labels attached to every preserved specimen