Insect Orders I: Apterygota, Paleoptera

I. Introduction.

A. In the last lecture we learned that the superclass Hexapoda is composed of two major subdivisions, the Entognatha and the Class Insecta. We concluded that the Entognatha is the sister group to the Class Insecta, however this conclusion ignores recent fossil evidence casting doubt on the monophyly of the Entognatha.

B. In today's lecture we begin our examination of the orders that make up the Class Insecta. These orders are arranged several higher-level groupings.

C. Major groups within Class Insecta.

1. The Class Insecta is divided into two major subgroups the **Apterygotes** (=primitively wingless insects) and the **Pterygota** (=winged insects). The Pterygota appears to be a monophyletic group consisting of all winged insects and those that lost their wings secondarily. As a group apterygotes do not appear to be monophyletic, and therefore cannot be thought of as the sister group to the Pterygota.

2. The Pterygota is divided into the **Paleoptera** (=old wing) and the **Neoptera** (=new wing). These two groups differ in their ability to flex their wings. The Paleoptera cannot flex their wings over the abdomen, while the Neoptera can. Only two orders of Paleoptera are still extant, the Ephemeroptera and the Odonata. It's unclear whether the Paleoptera is a natural group. The Neoptera, consisting of 24 orders, does appear to be monophyletic.

3. The Neoptera is divided into one formal group, the Holometabola, and two informal groups, the "Orthopteroids" and the "Hemipteroids" orders. The Holometabola is a monophyletic group that includes the 9 orders with complete metamorphosis. There are 8 orders informally gathered into the Orthopteroids. The phylogenetic relationships of these orders is very unclear. Five orders are included among the Hemipteroids, and may together comprise a monophyletic group. Two orders, the Plecoptera and the Zoraptera, are not associated with any group.

4. Orders in the Holometabola are divided into three major groups, the Neuopteroid orders, the Panorpoid orders, and the Hymenoptera.

D. We begin our examination of insect orders with the Apterygotes and the Paleoptera.

II. Apterygotes.

A. Two orders are grouped in the informal Apterygotes, the Archaeognatha and the Thysanura. The Apterygota is no longer recognized as a formal group because it is clearly paraphyletic. The order Archaeognatha is the sister group to the Thysanura + Pterygota, and the Thysanura is the sister group of the Pterygota.

B. Archaeognatha (=old jaw). Name used in BTJ is the Microcoryphia (=small head). Common name is the jumping bristle tails.

1. Classification.

a. Two extant families, one extinct family.

b. 250 species worldwide.

2. Structure.

a. Large compound eyes with contiguous medial border (autapomorphy).

b. Mandibles are monocondylic (single point of articulation with the head capsule). Apical incisors widely separated from the molar process, which operates with a rolling motion as in crustacea. Tentorium with very simple structure.

c. Appendages have a ventral articulation with body instead of a more lateral one as seen in more derived insects. Coxae have small exites (styli), reminiscent of the biramous condition in crustaceans. Abdominal styli also presence which may be homologous to the appendages found in myriapods.

d. Specialized jumping structures and musculature in the abdomen.

e. Body covered with scales.

3. Natural history.

a. Active at night, hiding by day under bark or in rock crevices.

b. Feed on algae, lichen and vegetable debris. Primitive mandibles used a augers.

c. Moderately good runners and jumpers. Jump by flexing abdomen.

d. Sperm transfer is indirect via a spermatophore. Some species may be parthenogenetic.

e. Ametabolous development with immatures closely resembling adults. Molting continues throughout life.

C. Thysanura (=bristle tail). Common name is silverfish.

1. Classification.

a. Five living families.

b. 330 species worldwide.

2. Structure.

a. Mandibles are dicondylic (two points of articulation with the head capsule). Apical incisors and molar region are not widely separate. Biting is transverse as in more derived insects.
b. Coxae do not have styli. Abdominal styli variably present.

c. Body covered in scales.

3. Natural history.

a. Free-living cryptozoics living under bark and rocks, and in leaf-litter. Very common in ant nests.

b. Most species are omnivorous. Some species in one family (Nicoletiidae) are subterranean or cavernicolous herbivores. Some species produce cellulase to aid in the digestion of cellulose.

c. Sperm transfer is indirect via a spermatophore.

d. Ametabolous development with immatures closely resembling adults. Molting continues throughout life. Lifespan of some species may reach 4 years.

III. Ephemeroptera (=short-lived). Common name is mayflies.

A. Classification.

1. 10-20 families divided into two suborders based on structure of immatures.

2. Several hundred species worldwide.

B. Structure.

1. Mouthparts of adult reduced and non-functional.

2. Wings of adults have simple venation and strong fluting. Hind wings are absent in some groups.

3. Alimentary canal of adult is reduced and functions as a reservior for air which is pumped in and out through the mouth. Air aids in flying and it is the strong fluting of the wings and active pumping of air that gives mayflies their distinctive flight pattern.

4. Nymphs respire by means of abdominal gills. Development of gills is related to habitat. Species living in standing water have large plumose gills. Species living in rapidly running water have smaller gills, some of which act as holdfasts to help maintain position on rocks. Strength and structure of legs also varies with habitat.

C. Natural history.

1. Adults.

a. Adults live only a few hours or a few days at most. Mouthparts are reduced and non-functional and adults consequently do not feed. The alimentary canal in many species is filled with air.
b. Synchronous emergence in many species, producing great swarms near water (called "swamp bugs" in Texas). Synchronous emergence may satiate predators. Flight capabilities are poor, which limits dispersal and ability to escape predators. Up-and-down flight pattern very distinctive.

c. Sperm transfer is direct with mating taking place in flight. Eggs are deposited in the water. Females of some species characteristically drop into the water during oviposition and drown.

2. Immatures.

a. Immatures of all species are aquatic.

b. Nymphal period is relatively long, lasting 2 years or longer in some species. The number of larval molts varies with environmental conditions (poor conditions increase the number of molts).

c. Nymphs of most species are herbivores or scavengers. Some species may be predaceous.

d. Mayfly nymphs are an important source of food for freshwater fish.

3. **Hemimetabolous** (incomplete) metamorphosis. Unlike all other insects with hemimetabolous development, all mayfly species emerge from the water as a winged **subimago**, not as an adult. The subimago flies to vegetation and molts again to the adult or **imago** stage. Mayflies are the only order of pterygotes that molt again after acquiring functional wings. The subimaginal stages lasts from 5 mins to 4 days depending on the species. Some species reproduce and die in the subimaginal stage.

IV. Odonata (=toothed mandibles). Common names are dragonflies and damselflies.

A. Classification.

1. Two major suborders.

a. Suborder **Zygoptera** (Damselflies). Contains 16 families.

b. Suborder **Anisoptera** (Dragonflies). Contains 7 families.

2. 3500 species worldwide.

B. Structure.

1. Adults.

a. Mandibles, eyes and head capsule are very well-developed.

b. Legs are weak and not used for walking but for perching on vegetation and for seizing and holding prey. Legs form a basket when in flight.

c. Copulatory organs of the male are located on the second and third abdominal segments. Males transfer their sperm from the 9th abdominal segment to these unique secondary genitalia.

2. Immatures.

a. Labium is highly modified as an extensible grasping organ with palps adapted for seizing prey.

b. Legs are well-developed and used for walking, clinging to substate and burrowing.

c. Zygopteran nymphs respire through modified wing pads and through large caudal tracheal gills. Anisoptera respire through gills on the inside of the rectal area.

C. Natural history.

1. Adults.

a. Adults are strong fliers with large well-developed wings. Adults are relatively long-lived and therefore feed. Most species are active predators, capturing prey in flight and returning to defended perches to consume it. Different species exhibit different hunting techniques (sit-and-wait at territorial perch, or active hunting).

b. Males use defended perches to locate and persue females for mating. Sperm transfer is direct. Males grab females behind the neck in flight and sperm transfer takes place either in flight or after the mated pair alights on vegetation. Males frequently remain attached to females after sperm transfer is complete and the female proceeds to oviposit in water.

c. Odonates are a well-researched group. There is much interest in their mating and hunting behavior.

2. Nymphs.

a. Nymphs are almost always aquatic, inhabiting a variety of habitats (waterfalls, torrents, permanent and intermittent streams, lakes, ponds, temporary rain pools, tree holes, swamps, bogs, etc.).

b. Nymphs are efficient sit-and-wait or stalking predators.

c. The number o nymphal stages varies within and among species depending on the environmental conditions. Nymphal stage may last as long as 2-3 years.

d. Nymphal stage diapauses in some species.

3. Development is by hemimetabolous metamorphism.

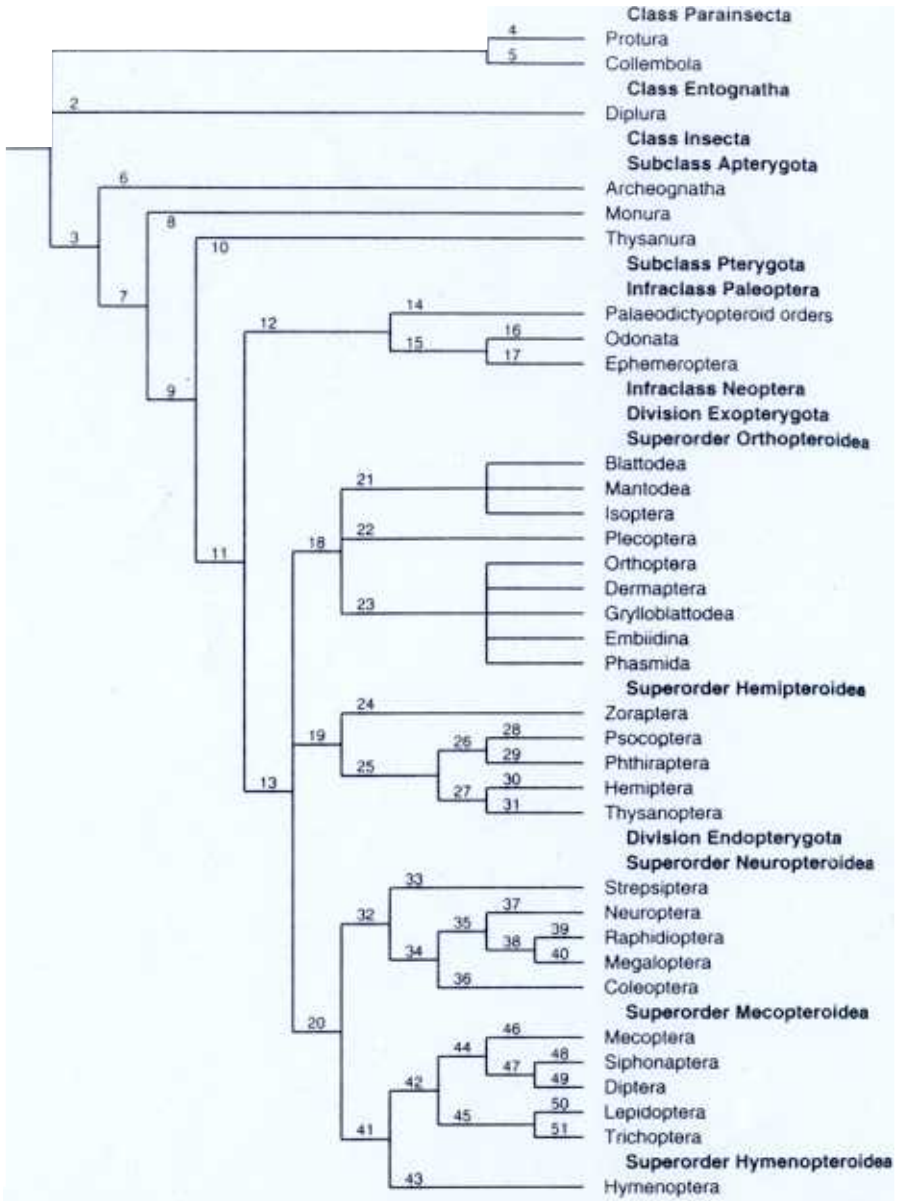

Figure 15.2 Diagram of relationships of the insect orders, indicating important characteristics of insects and closely related sexapodous arthropods.

Important characteristics of insects and closely related hexapodous arthropods.

1. development anamorphic (paedogenetic in Collembola); antennae musculate or absent; mouthparts entognathous
2. development epimorphic; antennae musculate; mouthparts entognathous
3. development epimorphic; antennae flagellate; mouthparts ectognathous
4. antennae and tentorium absent; development anamorphic
5. abdomen with 6 segments (apparently paedogenetic) and 3 sets of specialized appendages
6. mandibles monocondylic (single articulation)
7. mandibles dicondylic (2 articulations)
8. abdominal appendages with claws
9. abdominal appendages usually absent; lacking claws if present
10. primitively wingless
11. primitively winged (wings may be secondarily lost)
12. paleopterous
13. neopterous
14. mouthparts suctorial; nymphs terrestrial
15. mouthparts mandibulate; nymphs aquatic
16. indirect flight muscles very small; males with unique secondary copulatory structures
17. indirect flight muscles large; subimago and imago functionally winged
18. mouthparts mandibulate; Malpighian tubules numerous; central nervous system diffuse (numerous separate ganglia); development exopterygote
19. mouthparts modified, suctorial in most; 4–6 Malpighian tubules; central nervous system concentrated (posterior ganglia fused); development exopterygote
20. mouthparts, Malpighian tubules and central nervous system variable; development endopterygote
21. dorsal longitudinal muscles very small; corporotentorium perforated; immatures terrestrial; eggs in specialized ootheca (lost in Isoptera)
22. dorsal longitudinal muscles large; corporotentorium imperforate; immatures aquatic; ootheca absent
23. dorsal longitudinal muscles large; corporotentorium imperforate; immatures terrestrial; ootheca absent
24. cerci present; nymphs with ocelli; mouthparts simply mandibulate
25. cerci absent; nymphs without ocelli; mouthparts specialized
26. mandible retained and laciniae modified as rods, or all mouthparts highly modified (Anoplura)
27. mandibles and laciniae modified as stylets
28. free-living
29. ectoparasitic
30. mouthparts symmetrical; both mandibles modified as stylets; labium modified as sheath
31. mouthparts asymmetrical; right mandible absent; labium unmodified
32. head with gula or pregular bridge; larvae campodeiform or highly modified
33. legs without trochantins; immatures endoparasitic in insects
34. legs with trochantins; immatures never endoparasitic in insects (but some are endoparasitoids)
35. forewings membranous
36. forewings modified as elytra
37. larvae with incomplete intestine and suctorial mouthparts
38. larvae with complete intestine and chewing mouthparts
39. larvae terrestrial
40. larvae aquatic
41. head without gula (pregular bridge may be present); larvae usually eruciform or apodous; larvae frequently with abdominal legs
42. adult with rostrate (modified as rostrum or proboscis) mouthparts; 4–6 Malpighian tubules
43. adult with mandibulate mouthparts; Malpighian tubules numerous
44. larvae usually apodous (exception, Mecoptera); labial glands seldom producing silk; wing membrane bare or with few, unmodified setae
45. larvae eruciform, frequently with abdominal legs; silk production by labial glands; adults with wing membrane covered with hairs or scales
46. adults with 4 wings; larvae with thoracic legs and usually with abdominal prolegs
47. adults with 2 wings or wings absent; larvae apodous
48. adults apterous; ectoparasites living on mammals and birds
49. adults almost always with 1 pair wings; usually free living; when ectoparasitic seldom living on host
50. adults with mouthparts developed as coiled proboscis (occasionally atrophied); wings covered with scales; larvae almost always terrestrial
51. adults with mouthparts atrophied; wings covered with hairs; larvae aquatic

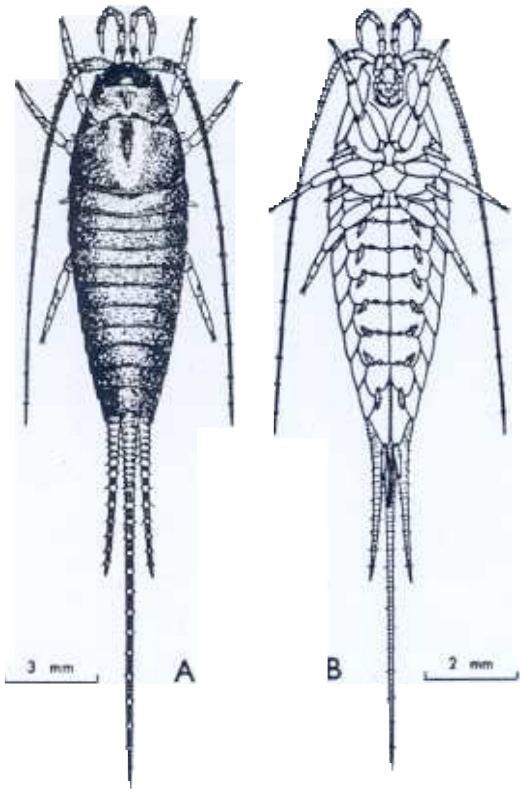

Fig. 11.2. Archaeognatha: A, *Allomachilis froggatti*, ♂, dorsal; B, *Nesomachilis australicus*, ♀, ventral with vesicles exserted (scales omitted). [M. Quick]

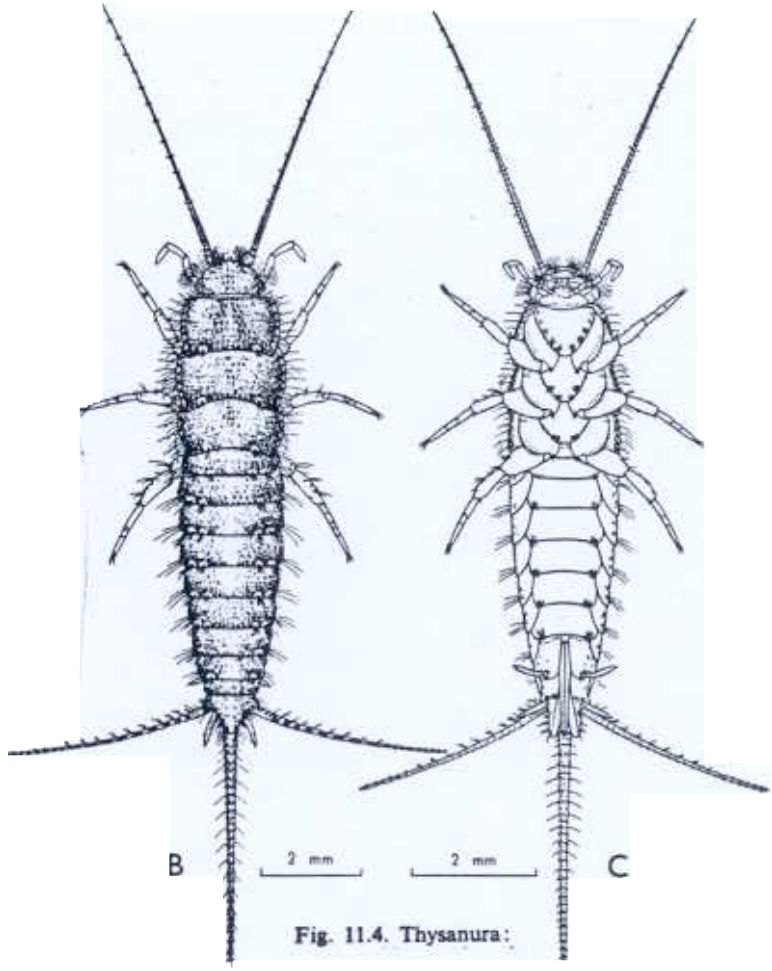

Fig. 11.4. Thysanura:

Figure 10–1. A mayfly, *Hexagènia bilineàta* (Say) (Ephemèridae). (Courtesy of Needham and the U.S. Bureau of Fisheries.)

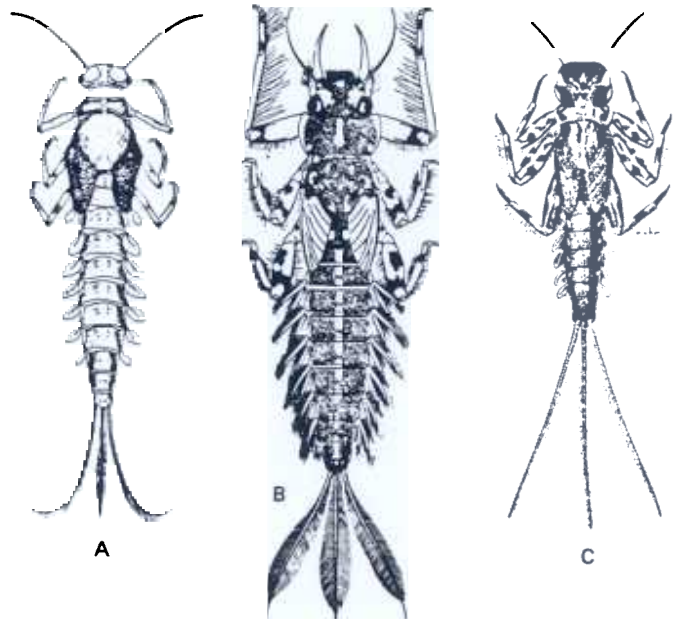

Figure 10–2. Mayfly nymphs. A, *Baètis hiemàlis* Leonard (Baètidae); B, *Potamánthus* sp. (Potamánthidae); C, *Heptagènia diabàsia* Burks (Heptageniidae). (A, courtesy of Leonard and the Entomological Society of America; B, courtesy of Needham and the U.S. Bureau of Fisheries; C, courtesy of Burks and the Entomological Society of America.)

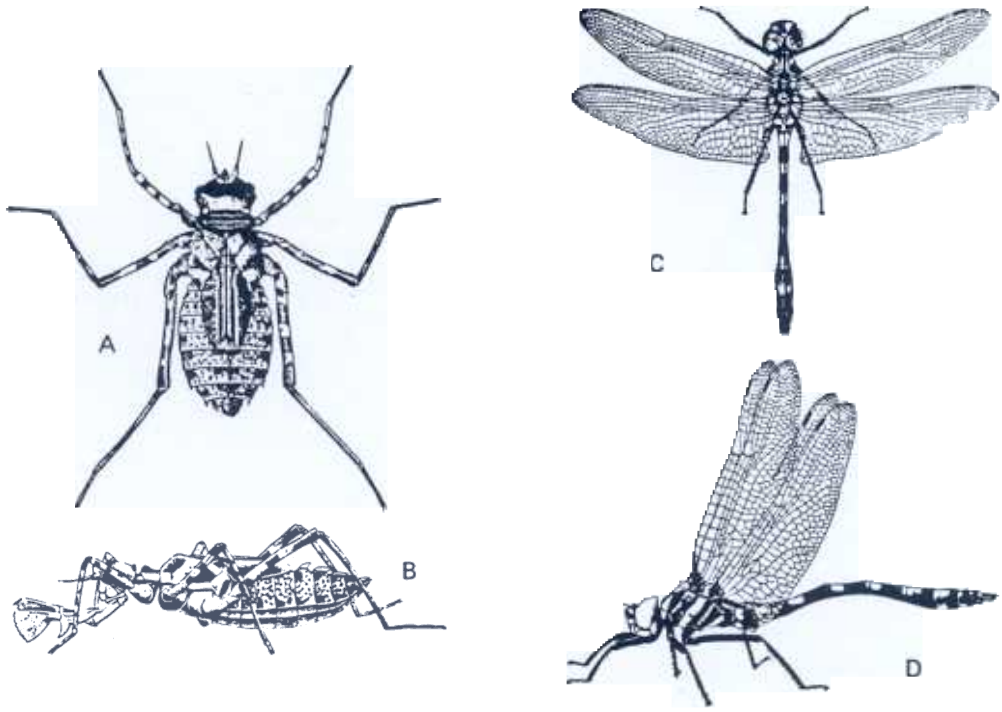

Figure 11–11. *Macròmia magnífica* MacLachlan (Macromìidae). **A,** nymph, dorsal view; **B,** nymph, lateral view, with labium extended; **C,** adult male, dorsal view; **D,** same, lateral view. (Courtesy of Kennedy and the U.S. National Museum.)

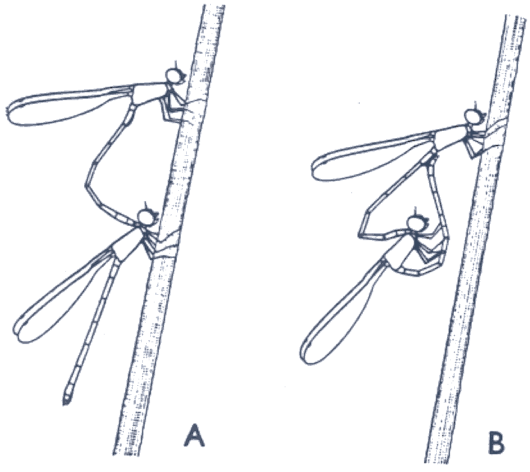

Fig. 13.13. Diagrams showing copulation in Zygoptera: A, tandem position; B, copulation.
[F. Nanninga]