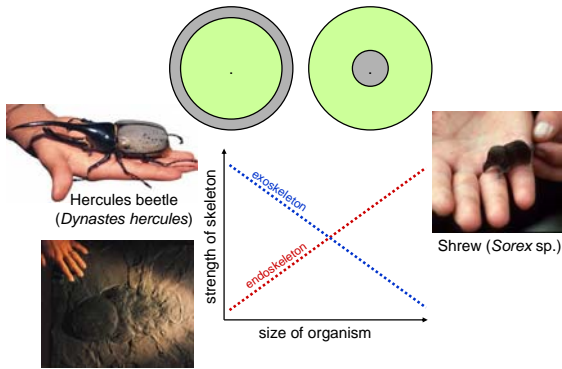
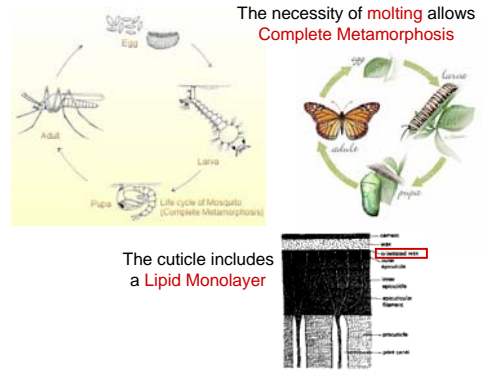


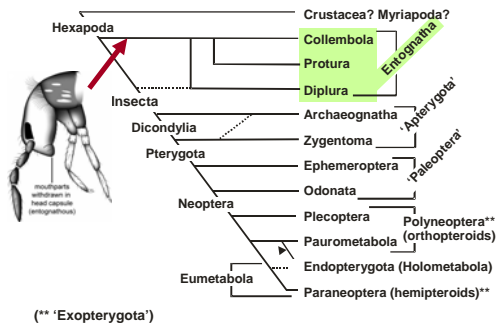
Exoskeleton vs. Endoskeleton: biomechanical trade-offs



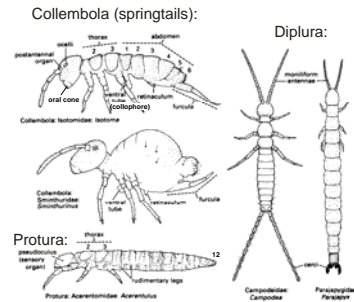
Other advantages of the exoskeleton



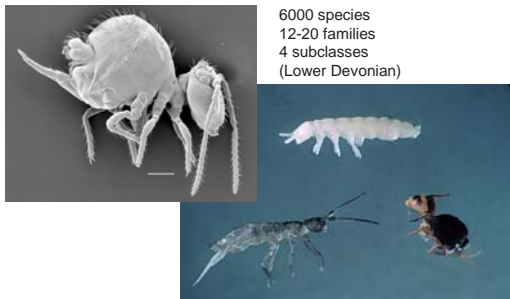
What about six legs??
"Hexapoda" may not be monophyletic



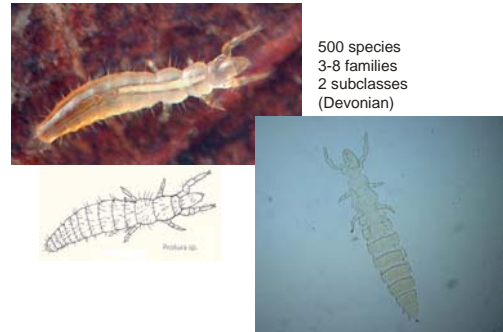
Entognathous hexapods:
Collembola, Protura, Diplura

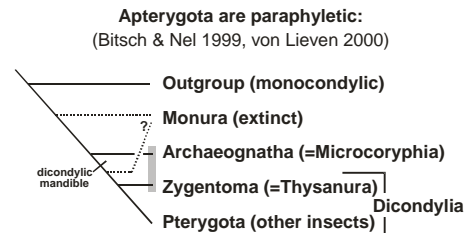
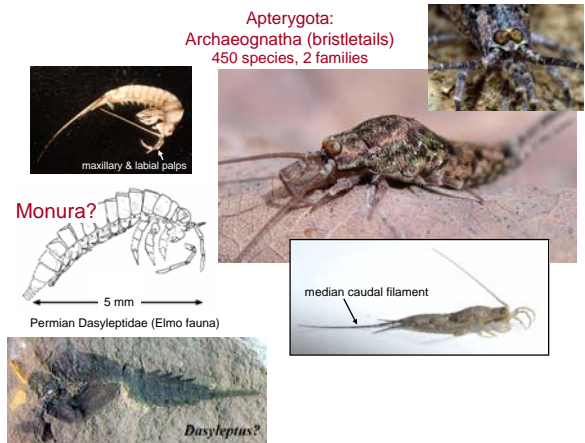
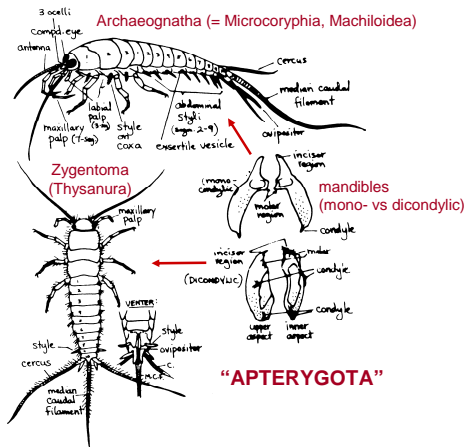
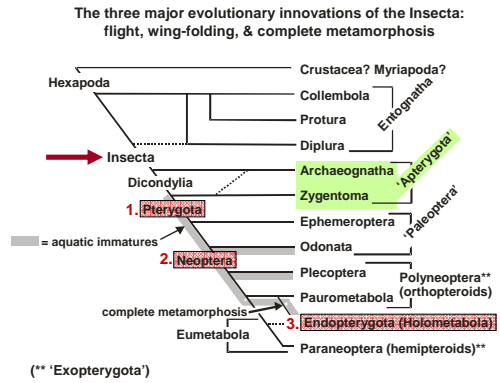
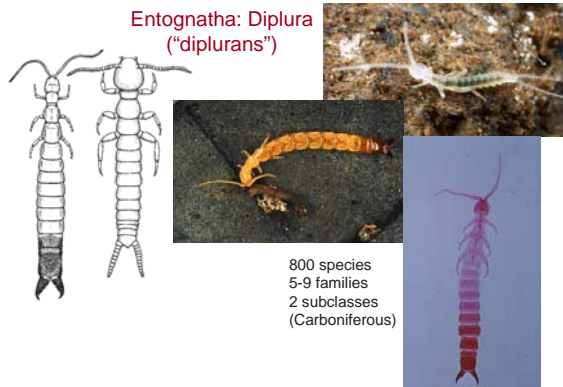


Entognatha: Collembola (springtails, snow fleas)



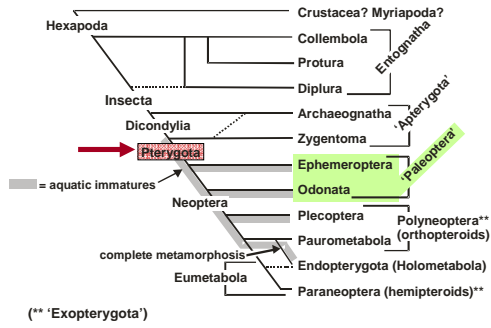
Entognatha: Protura ("proturans")



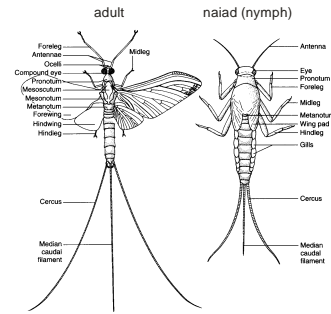


Apterygota are monophyletic: Thysanura s. lat.
(Koch 2001 [morphology], Regier 2004 [molecules])

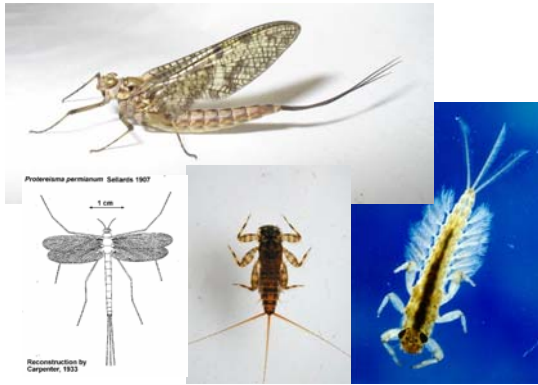
The Origin of Wings: Paleoptera



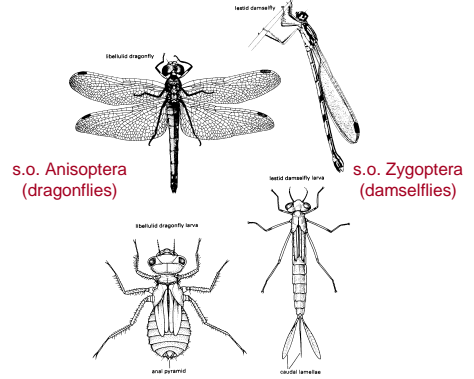
Pterygota, Paleoptera:
 Ephemeroptera (mayflies)
 2500 species, 6 superfamilies, 21-23 families



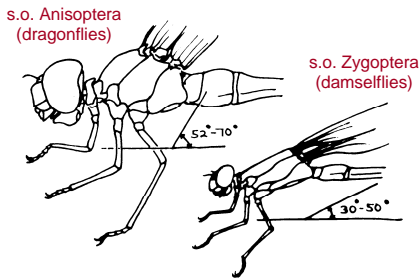
Mayflies



Pterygota, Paleoptera:
 Odonata (dragonflies & damselflies)
 6500 species, 2 suborders, 27 families

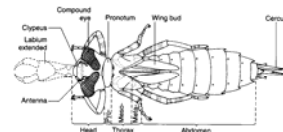


Thoracic tilt

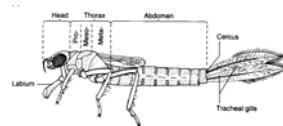


Tracheal gills

Anisoptera naiad (rectal gills)



Zygoptera (caudal gills)



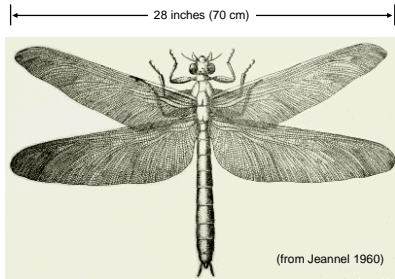
Damselflies



Dragonflies

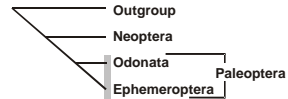


**Meganeura (Protodonata)
(Carboniferous, approx 320 mya)**



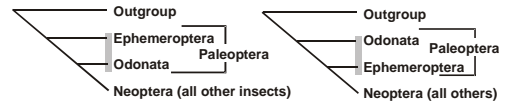
Phylogenetic hypotheses for Paleoptera

I. Paleoptera are monophyletic (Hennig)

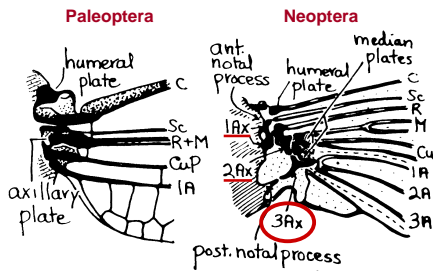


II. Paleoptera are paraphyletic

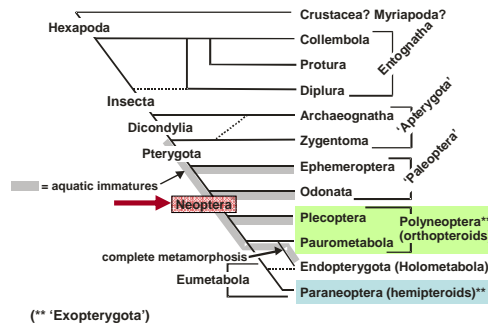
(Kristensen) (Boudreaux)



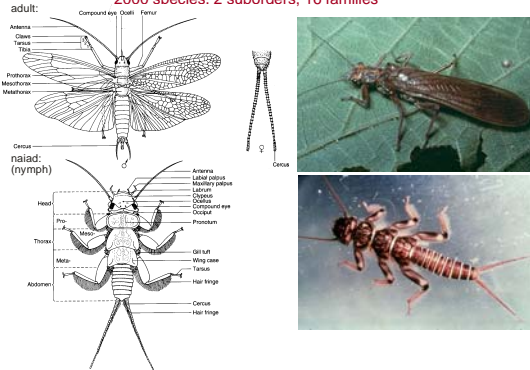
The morphological basis of wing-folding (neoptery)



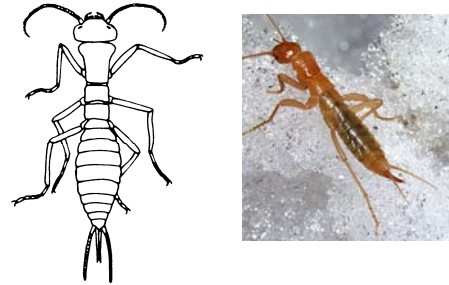
The Origin of Wing-Folding: Neoptera



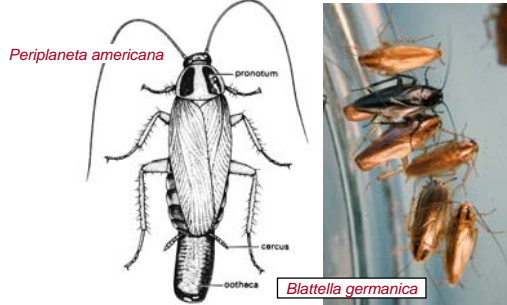
Pterygota, Neoptera, Polyneoptera:
Plecoptera (stoneflies)
 2000 species, 2 suborders, 16 families



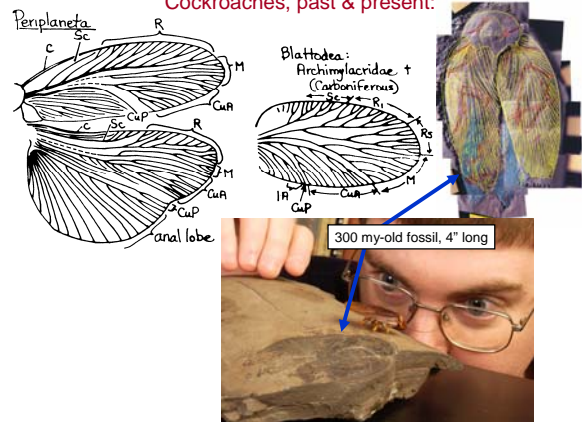
Pterygota, Neoptera, Polyneoptera:
Grylloblattodea (ice or rock crawlers)
 24 species, 1 family (Grylloblattidae)



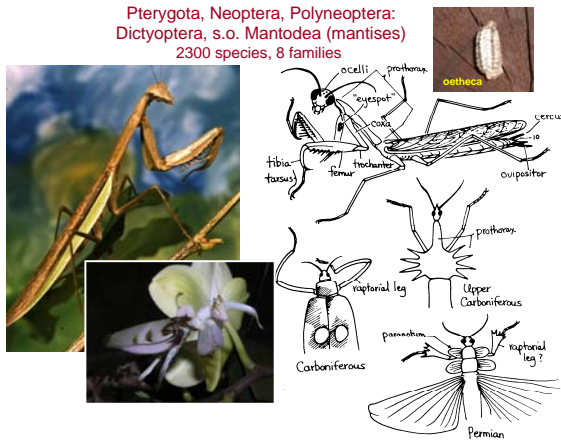
Pterygota, Neoptera, Polyneoptera:
Dictyoptera, s.o. Blattodea (cockroaches)
 3500 species, 6 families



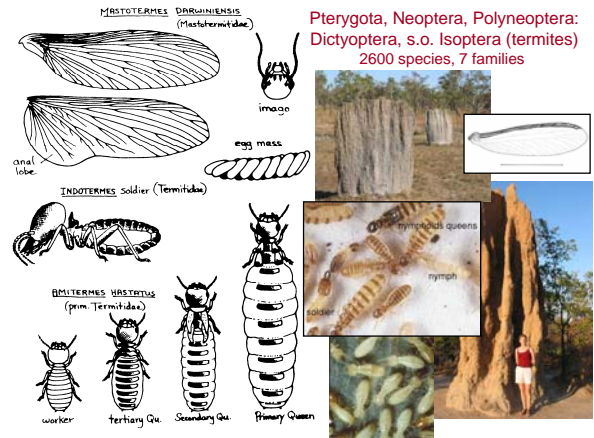
Cockroaches, past & present:



Pterygota, Neoptera, Polyneoptera:
Dictyoptera, s.o. Mantodea (mantises)
 2300 species, 8 families

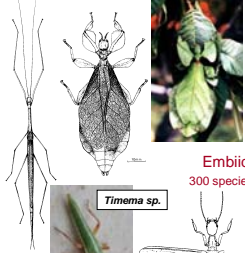


Pterygota, Neoptera, Polyneoptera:
Dictyoptera, s.o. Isoptera (termites)
 2600 species, 7 families

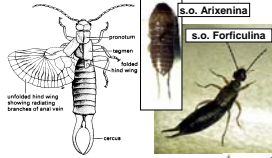


Pterygota, Neoptera, Polyneoptera:

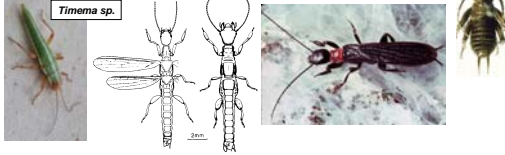
Phasmatodea (stick & leaf insects)
3000 species, 3 suborders, several (?) families



Dermaptera (earwigs)
1800 species, 3 suborders, 10 families

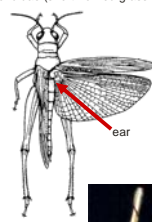


Embiidina (webspinners)
300 species, 2 suborders, 8 families

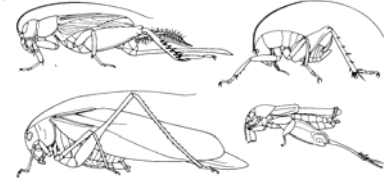


**Pterygota, Neoptera, Polyneoptera:
Orthoptera (grasshoppers, crickets, katydids)**

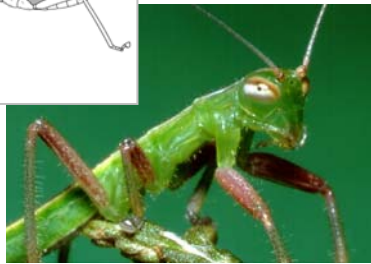
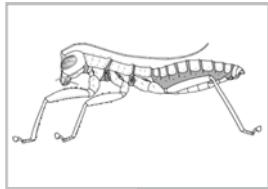
suborder **Caelifera** (11,000 spp):
Acrididae (short-horned grasshopper)



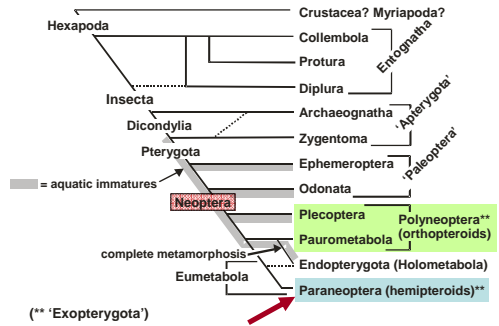
suborder **Ensifera** (11,000 spp):
crickets, katydids, long-horned grasshoppers



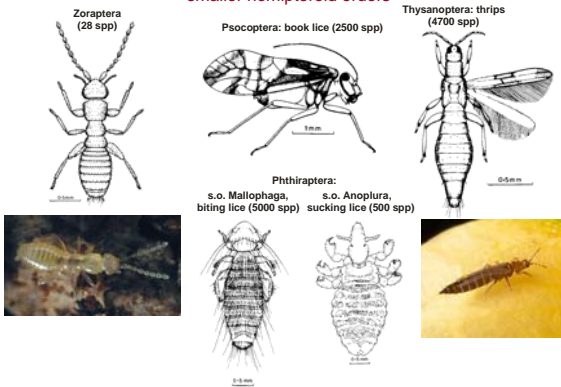
**Pterygota, Neoptera, Polyneoptera:
Mantophasmatodea (gladiators, heelwalkers)**
16 species, 3 families



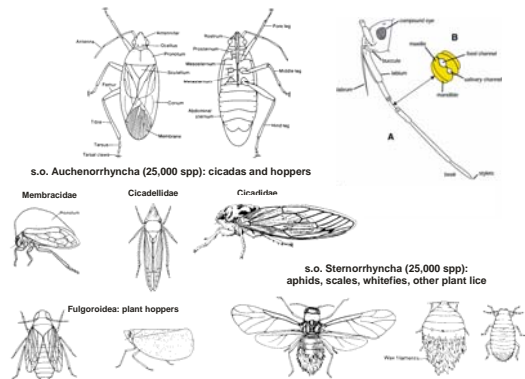
**Specialized Neoptera without complete metamorphosis:
the Paraneoptera**



**Pterygota, Neoptera, Eumetabola, Paraneoptera:
smaller hemipteroid orders**



Pterygota, Neoptera, Eumetabola, Paraneoptera: Hemiptera



Pterygota, Neoptera, Eumetabola, Paraneoptera: Hemiptera
s.o. Heteroptera – the true bugs (30,000 species)

