Insect Evolution:

Evolutionary change may be viewed as occurring in three successively longer time frames.

1. **Microevolution**: evolution with in a single population on a small scale is termed as microevolution. These changes occur in populations in response to changes in selection pressures (changes can occur in a short period).

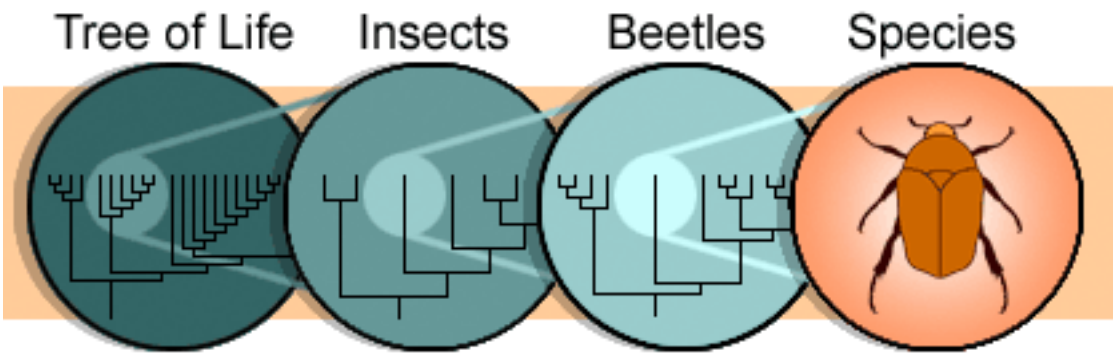


Fig: Microevolution *Image credit: http://evolution.berkeley.edu*

Examples: insecticide resistance (Meinke et al. 1998); industrial melanism (Kettlewell 1961, Bishop and Cook 1975, Grant 1999). Thus, a group of organisms that interbreed with each other is called a population. In the picture, above, the species of beetles could be called as a population and potential mates.

2. **Speciation**: changes that occur over much longer time frames than microevolution and which result in distinct lineages that are reproductively isolated form related species.
3. **Macroevolution**: the major phylogenetic patterns that develop over long spams of geological time (includes extinct forms: no longer exist except as fossils; and extant forms: groups that are present today)

Traditionally, most closely related arthropods were annelids and onychophorans. Annelids are segmented worms (e.g., oligochaetes, leeches,

earthworms, etc.), onychophorans are a small group of terrestrial animals that live in tropical forests of the world (wormlike bodies, several bilateral pairs of lobe-like legs). However, results of recent molecular studies have completely changed this perspective and separate the arthropods from the annelids and onychophorans. In many current classification schemes, arthropods are grouped with other invertebrates that have similar ribosomal RNA sequences and characterized by a cuticle that is periodically molted. Arthropods have paired segmented appendages and are a very diverse group of animals (structure and function).

Origin of Arthropoda

There are still debates as to whether arthropods constitute a single phylum (monophyletic) sharing a common arthropodian ancestor or are two or three groups (polyphyletic) of distantly related animals in which major arthropodian traits converged (e.g., jointed appendages).

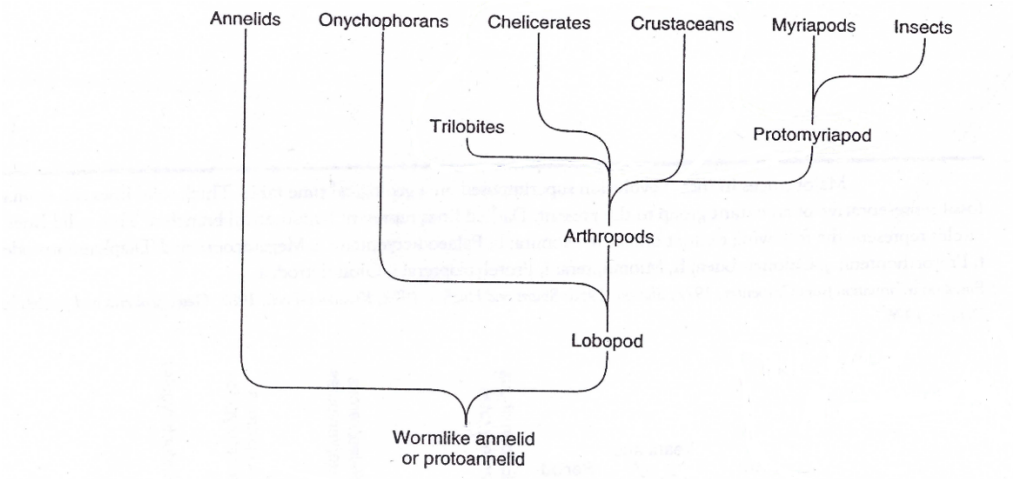


Fig: Sharov (1966) monophyletic school; Hypothetical phylogeny of arthropods, annelids and onychophorans. Redrawn from data of Snodgrass, 1952, and Sharov, 1966.

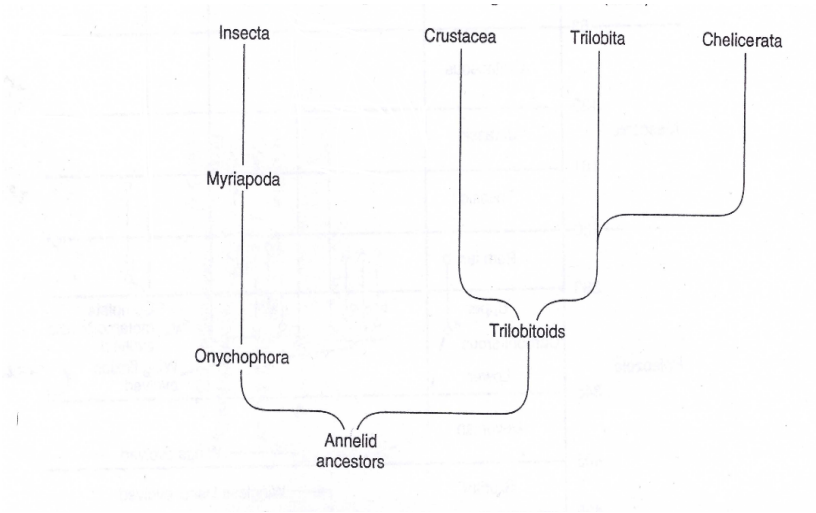


Fig: Hypothetical phylogeny of arthropods based on Tiegs and Manton (1958): Polyphyletic school

More recent evidence (molecular study: Ballard et al. 1992; fossil-based studies: Kukalova-Peck 1992, Willis et al. 1995) appears to support the monophyletic origin of arthropods.

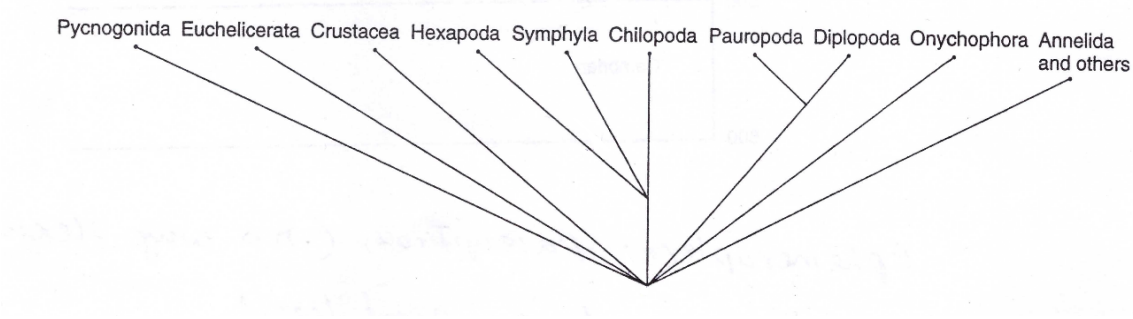


Fig. Depicting consensus tree of arthropod evolution of both morphological and molecular data supporting the monophyletic interpretation (Stys and Zrzavy 1994).

Classification of Barnes (1987) recognizes four groups within Arthropoda as subphyla. Insects are shown to be most closely related to millipedes, centipedes, pauropods and symphylans.

Origin of Insects

Evidence based on fossils, gill structure, life histories, and tracheal structure weighs in favor of a terrestrial as opposed to an aquatic origin of insects (Pritchard et al. 1993). Older literature supports the idea that insects evolved from a myriapod or protomyriapod of some sort prior to Devonian period. More recent molecular (e.g., Ballard et al. 1992), morphological, and developmental data do not support the close relationship between insects and myriapods but provide convincing evidence for a sister-group relationship between the Hexapoda and the Crustacea. This debate is far from resolved.

Four major stages in the evolution of insects are generally recognized.

See Fig. depicting stages on a geological time scale

1) Appearance of primitively wingless insects (apterygotes), Collembola found in Devonian age Fossils

2) Development of wings (pterygotes); unknown when evolution started taking place but insects with fully formed functional wings first appear in the Carboniferous period; insects were the first animals to fly (paleopterous: simple wing articulations, no flexing, wings held out from the body at rest, represented by only two extant orders today ----- Odonata, Ephemeroptera)

3) Development of a wing-flex mechanism (neopterous: "new winged" insects could flex wings posteriorly over the body at rest); dominant insect group today

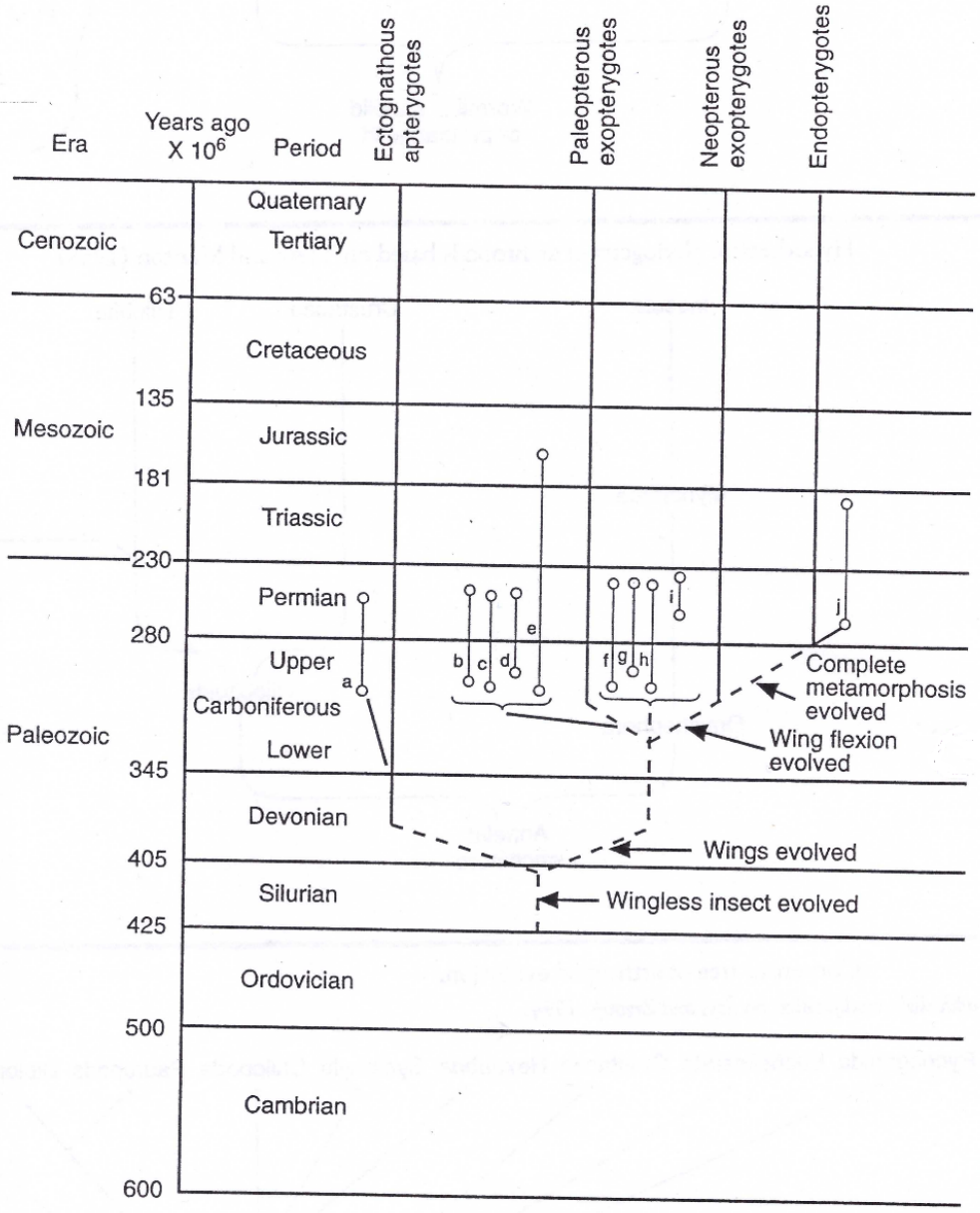
4) Development of complete metamorphosis (See metamorphosis table)

Text (read chapter 6) follows phylogeny of hexapod orders developed by wheeler et al. (2001) which was based on analysis of morphological and molecular data.

Also, see Fig. depicting a cladogram of postulated relationship of extant hexapod orders based on morphological data and molecular sequence data (from Gullan and Cranston 2000).

Major stages in insect evolution superimposed on a geological time table. Thick solid lines run from earliest kno fossil representative of an extant group to the present. Dashed lines represent hypothetical branches. Thin solid lines bounded b circles represent the following extinct orders: a, Monura; b, Palaeodictyoptera; c, Megasecoptera; d, Diaphanopterodea; e, Protod f, Protorthoptera; g, Caloneurodea; h, Miomoptera; i, Protelytroptera; j, Glosselytrodea.

Based on information from Carpenter, 1977; Sharov, 1966; Smart and Hughes, 1972; Kukalová-Peck, 1987. Geological eras and periods based on Villee Dethier, 1976.



Insect Orders and their Type of Metamorphosis

Simple			Complete
Ametabolus	Hemimetabolous	Paurometabolous	Holometabolous
(No external metamorphosis)	(Gradual or incomplete metamorphosis Aquatic immature [naiads]	(Gradual or incomplete metamorphosis Immatures called nymphs	(Complete metamorphosis) Larvae
Protura Collembolla Microcoryphia Thysanura Phtyiraptera	Ephemeroptera Odonata Plecoptera	Grylloblattodea Mantophasmatodea Phasmatodea Orthoptera Dermaptera Embiidina Zoraptera Isoptera Mantodea Blattodea Psocoptera Hemiptera (Orders with prepupal and pupal stage) Some Hemiptera (e.g., whiteflies, male scale insects) Thysanoptera	Neuroptera Coleoptera Strepsiptera Mecoptera Siphonaptera Diptera Trichoptera Lepidoptera Hymenoptera

From Gullan, P.J. and P. S. Cranston. 2000. The insects. An outline of entomology. 2nd Ed. Blackwell Science, Oxford, UK.

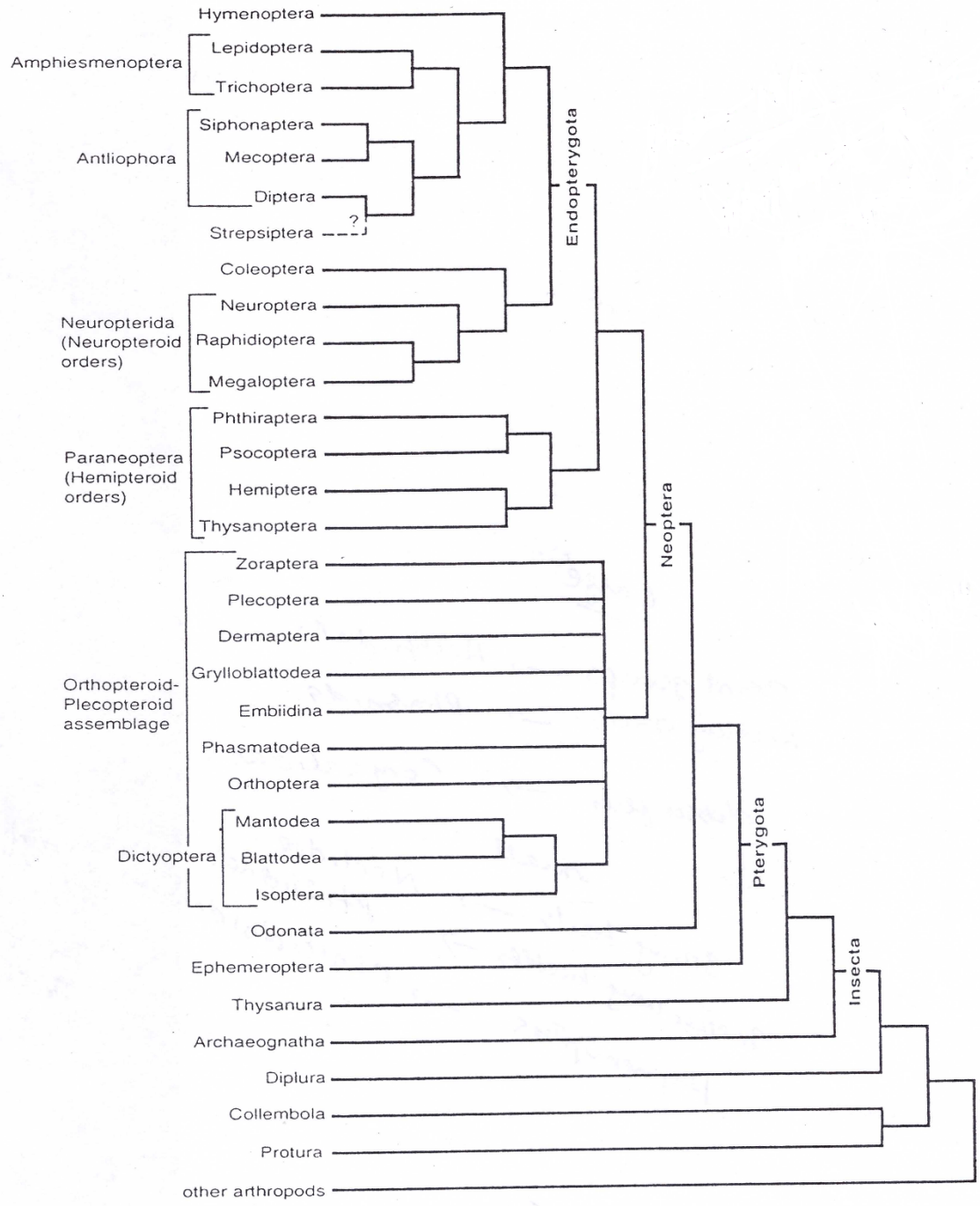


Fig. 7.6 Cladogram of postulated relationships of extant hexapod orders, based on a combination of morphological data and molecular sequence data. (Compiled from various sources, including Kristensen, 1991; Wheeler *et al.*, 1993; Whiting *et al.*, 1997; Flook & Rowell, 1998; Whiting, 1998.)