Episodes in history of the Hemiptera

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Diversity of insects

- Coleoptera – ca. 400.000 species, 204 families; 38%
- Lepidoptera – ca. 180.000 species, 126 families; 17%
- Hymenoptera – ca. 155.000 species, 132 families; 15%
- Diptera – ca. 125.000 species, 241 families; 12%
- Hemiptera – ca. 82.000 species, 300 families; 8%
- other insects – ca. 100.000 species; 10%

INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

IUGS

www.stratigraphy.org

International Commission on Stratigraphy

v 2016/04

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	numerical age (Ma)
					present
Phanerozoic	Cenozoic	Quaternary	Holocene		0.0117
			Pleistocene	Upper	0.126
				Middle	0.781
				Calabrian	1.80
				Gelasian	2.58
		Neogene	Pliocene	Piacenzian	3.600
				Zanclean	5.333
			Miocene	Messinian	7.246
				Tortonian	11.63
				Serravallian	13.82
				Langhian	15.97
				Burdigalian	20.44
				Aquitanian	23.03
		Paleogene	Oligocene	Chattian	28.1
				Rupelian	33.9
			Eocene	Priabonian	37.8
				Bartonian	41.2
				Lutetian	47.8
				Ypresian	56.0
			Paleocene	Thanetian	59.2
				Selandian	61.6
				Danian	66.0
	Mesozoic	Cretaceous	Upper	Maastrichtian	72.1 ±0.2
				Campanian	83.6 ±0.2
				Santonian	86.3 ±0.5
				Coniacian	89.8 ±0.3
				Turonian	93.9
				Cenomanian	100.5
			Lower	Albian	~ 113.0
				Aptian	~ 125.0
				Barremian	~ 129.4
				Hauterivian	~ 132.9
				Valanginian	~ 139.8
				Berriasian	~ 145.0

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	numerical age (Ma)
					~ 145.0
Phanerozoic	Mesozoic	Jurassic	Upper	Tithonian	152.1 ±0.9
				Kimmeridgian	157.3 ±1.0
				Oxfordian	163.5 ±1.0
			Middle	Callovian	166.1 ±1.2
				Bathonian	168.3 ±1.3
				Bajocian	170.3 ±1.4
				Aalenian	174.1 ±1.0
			Lower	Toarcian	182.7 ±0.7
				Pliensbachian	190.8 ±1.0
				Sinemurian	199.3 ±0.3
				Hettangian	201.3 ±0.2
		Triassic	Upper	Rhaetian	~ 208.5
				Norian	~ 227
				Carnian	~ 237
			Middle	Ladinian	~ 242
				Anisian	247.2
			Lower	Olenekian	251.2
				Induan	252.17 ±0.06
	Paleozoic	Permian	Lopingian	Changhsingian	254.14 ±0.07
				Wuchiapingian	259.8 ±0.4
			Guadalupian	Capitanian	265.1 ±0.4
				Wordian	268.8 ±0.5
				Roadian	272.3 ±0.5
			Cisuralian	Kungurian	283.5 ±0.6
				Artinskian	290.1 ±0.26
				Sakmarian	295.0 ±0.18
				Asselian	298.9 ±0.15
		Carboniferous – Pennsylvanian	Upper	Gzhelian	303.7 ±0.1
				Kasimovian	307.0 ±0.1
			Middle	Moscovian	315.2 ±0.2
			Lower	Bashkirian	323.2 ±0.4
		Carboniferous – Mississippian	Upper	Serpukhovian	330.9 ±0.2
			Middle	Visean	346.7 ±0.4
			Lower	Tournaisian	358.9 ±0.4

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	numerical age (Ma)
					358.9 ± 0.4
Phanerozoic	Paleozoic	Devonian	Upper	Famennian	372.2 ±1.6
				Frasnian	382.7 ±1.6
			Middle	Givetian	387.7 ±0.8
				Eifelian	393.3 ±1.2
			Lower	Emsian	407.6 ±2.6
				Pragian	410.8 ±2.8
				Lochkovian	419.2 ±3.2
		Silurian	Pridoli		423.0 ±2.3
			Ludlow	Ludfordian	425.6 ±0.9
				Gorstian	427.4 ±0.5
			Wenlock	Homerian	430.5 ±0.7
				Sheinwoodian	433.4 ±0.8
			Llandovery	Telychian	438.5 ±1.1
				Aeronian	440.8 ±1.2
				Rhuddanian	443.8 ±1.5
		Ordovician	Upper	Hirnantian	445.2 ±1.4
				Katian	453.0 ±0.7
				Sandbian	458.4 ±0.9
			Middle	Darriwilian	467.3 ±1.1
				Dapingian	470.0 ±1.4
			Lower	Floian	477.7 ±1.4
				Tremadocian	485.4 ±1.9
		Cambrian	Furongian	*Stage 10*	~ 489.5
				Jiangshanian	~ 494
				Paibian	~ 497
			Series 3	Guzhangian	~ 500.5
				Drumian	~ 504.5
				Stage 5	~ 509
			Series 2	*Stage 4*	~ 514
				Stage 3	~ 521
			Terreneuvian	*Stage 2*	~ 529
				Fortunian	541.0 ±1.0

Eonothem / Eon		Erathem / Era	System / Period	numerical age (Ma)
				541.0 ±1.0
Precambrian	Proterozoic	Neo-proterozoic	Ediacaran	~ 635
			Cryogenian	~ 720
			Tonian	1000
		Meso-proterozoic	Stenian	1200
			Ectasian	1400
			Calymmian	1600
		Paleo-proterozoic	Statherian	1800
			Orosirian	2050
			Rhyacian	2300
			Siderian	2500
	Archean	Neo-archean		2800
		Meso-archean		3200
		Paleo-archean		3600
		Eo-archean		4000
	Hadean			~ 4600

Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

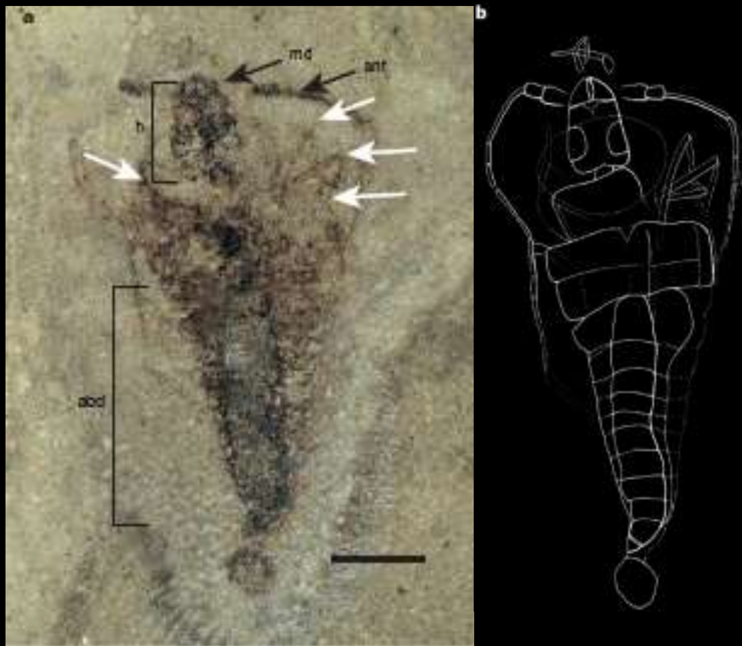
Numerical ages are subject to revision and do not define uni ts in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.

Numerical ages for all systems except Lower Pleistocene, Permian, Triassic, Cretaceous and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012); those for the Lower Pleistocene, Permian, Triassic and Cretaceous were provided by the relevant ICS subcommissions.

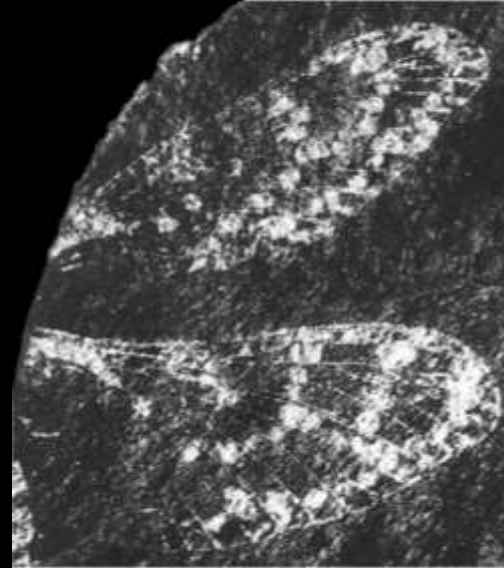
Coloring follows the Commission for the Geological Map of the World (http://www.ccgm.org)

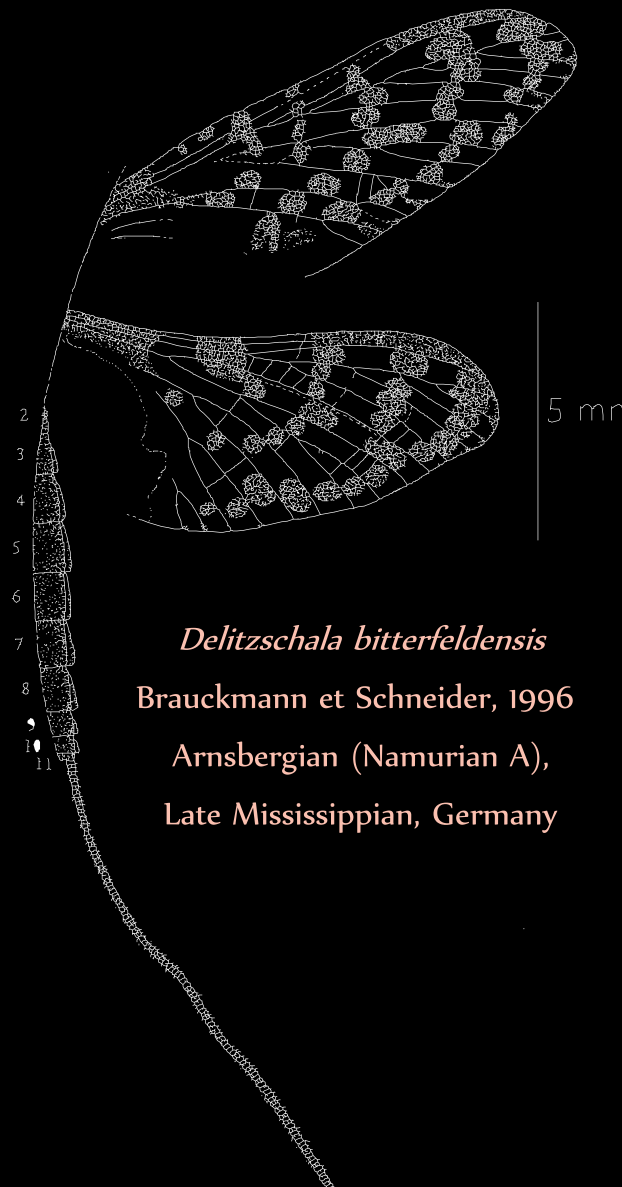
To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.

URL: http://www.stratigraphy.org/ICSchart/ChronostratChart2016-04.pdf

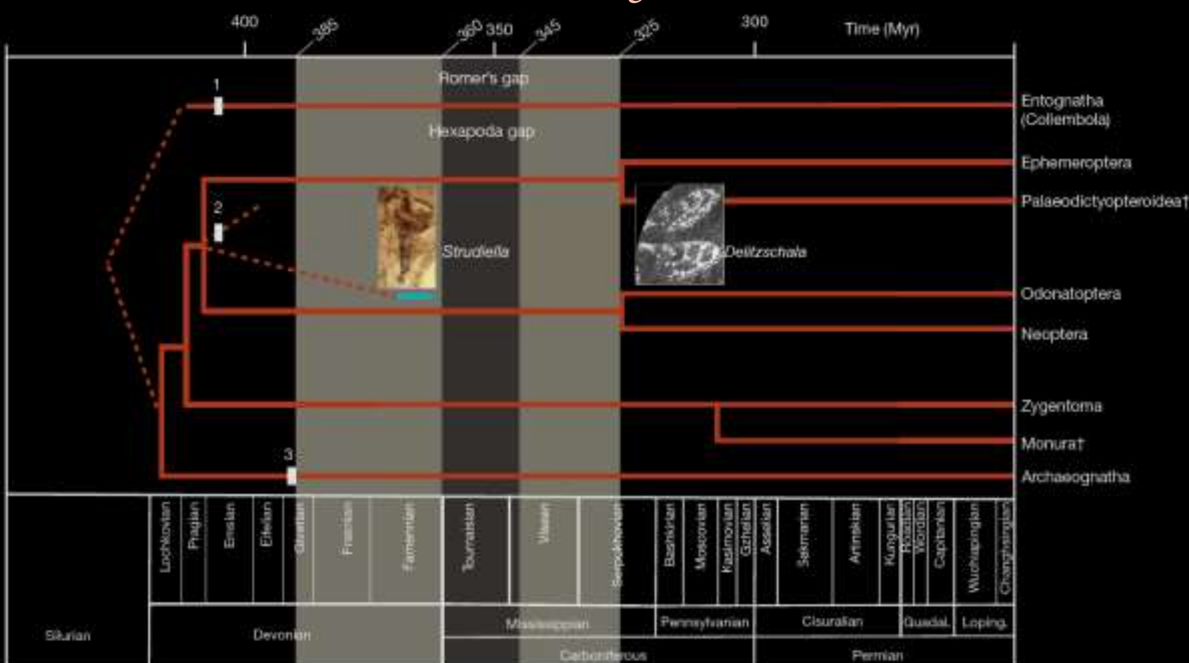


Strudiella devonica Garrouste *et al.*, 2012
Fammenian, Devonian; Strud, Namur, Belgium





Delitzschala bitterfeldensis
Brauckmann et Schneider, 1996
Arnsbergian (Namurian A),
Late Mississippian, Germany



System and classification:

Ordo: Hemiptera Linnaeus, 1758

Subordines:
- †Paleorrhyncha Carpenter, 1931
- Sternorrhyncha Duméril, 1806
- Fulgoromorpha Evans, 1946
- Cicadomorpha Evans, 1946
- Coleorrhyncha Myers et China, 1929
- Heteroptera Latreille, 1810

300 families known (recently 178 present),

the highest number among the insects!



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ACAD. UPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.

SYSTEMA NATURÆ

PER

REGNA TRIA NATURÆ,

SECUNDUM

CLASSES, ORDINES,
GENERA, SPECIES,

CUM

CHARACTERIBUS, DIFFERENTIIS,
SYNONYMIS, LOCIS.

TOMUS I.

EDITIO DECIMA, REFORMATA.

Cum Privilegio S:æ R:æ M:tis Sveciæ.

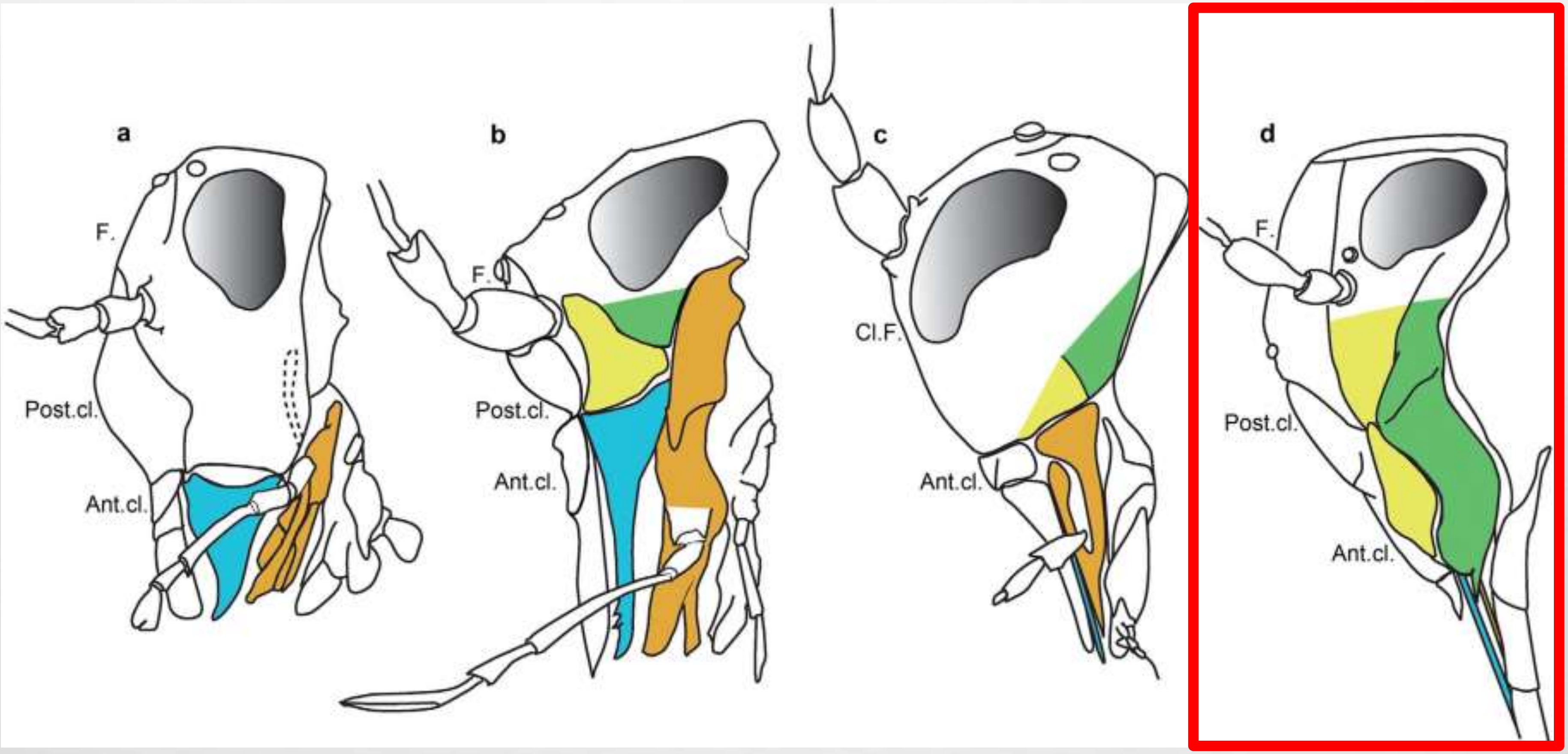
HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII,
1758.

II. HEMIPTERA.

195. CICADA *Roſtrum* inflexum. *Pedes* poſtici ſaltatorii.
196. NOTONECTA *Roſtrum* inflexum. *Pedes* poſtici natatorii (ciliati.)
197. NEPA *Roſtrum* inflexum. *Pedes* antici capitis cheliferi.
198. CIMEX *Roſtrum* inflexum. *Pedes* curſorii.
199. APHIS *Roſtrum* inflexum. *Abdomen* bicorne.
200. CHERMES *Roſtrum* pectorale. *Pedes* poſtici ſaltatorii.
201. COCCUS *Roſtrum* pectorale. *Abdomen* poſtice ſetoſum maribus.
202. THRIPS *Roſtrum* obſoletum. *Alæ* incumbentes abdomini reflexil[illegible]

Hemiptera (Thripida included) – paraphyletic unit

Hypothesis of head and mouthpart morphologies in Acercaria (Paraneoptera) (Huang *et al.* 2016)



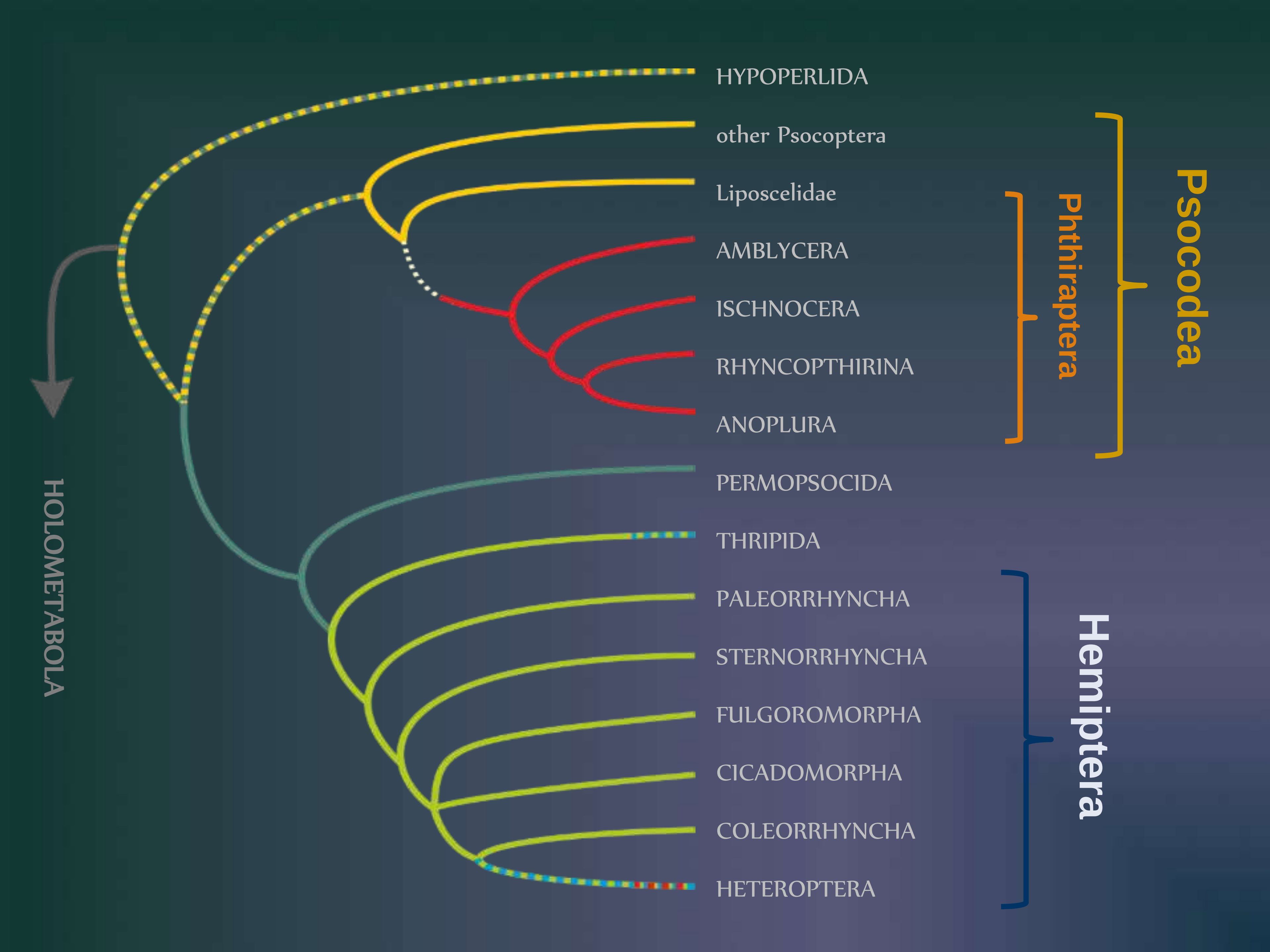
(a) Psocodean groundpattern (also present in Hypoperlidae). (b) Permopsocidan groundpattern. (c) Thripidan groundpattern, reconstructed after the head of an adult Tubulifera, and Moundthrips. (d) Hemipteran groundpattern. Mandible: blue; maxilla: brown; anterior part of gena (mandibular lobe): yellow; posterior part of gena (maxillary lobe?): green. Ant.cl. anteclypeus; Cl.F. clypeo-frons; F. frons; Post.cl. postclypeus.

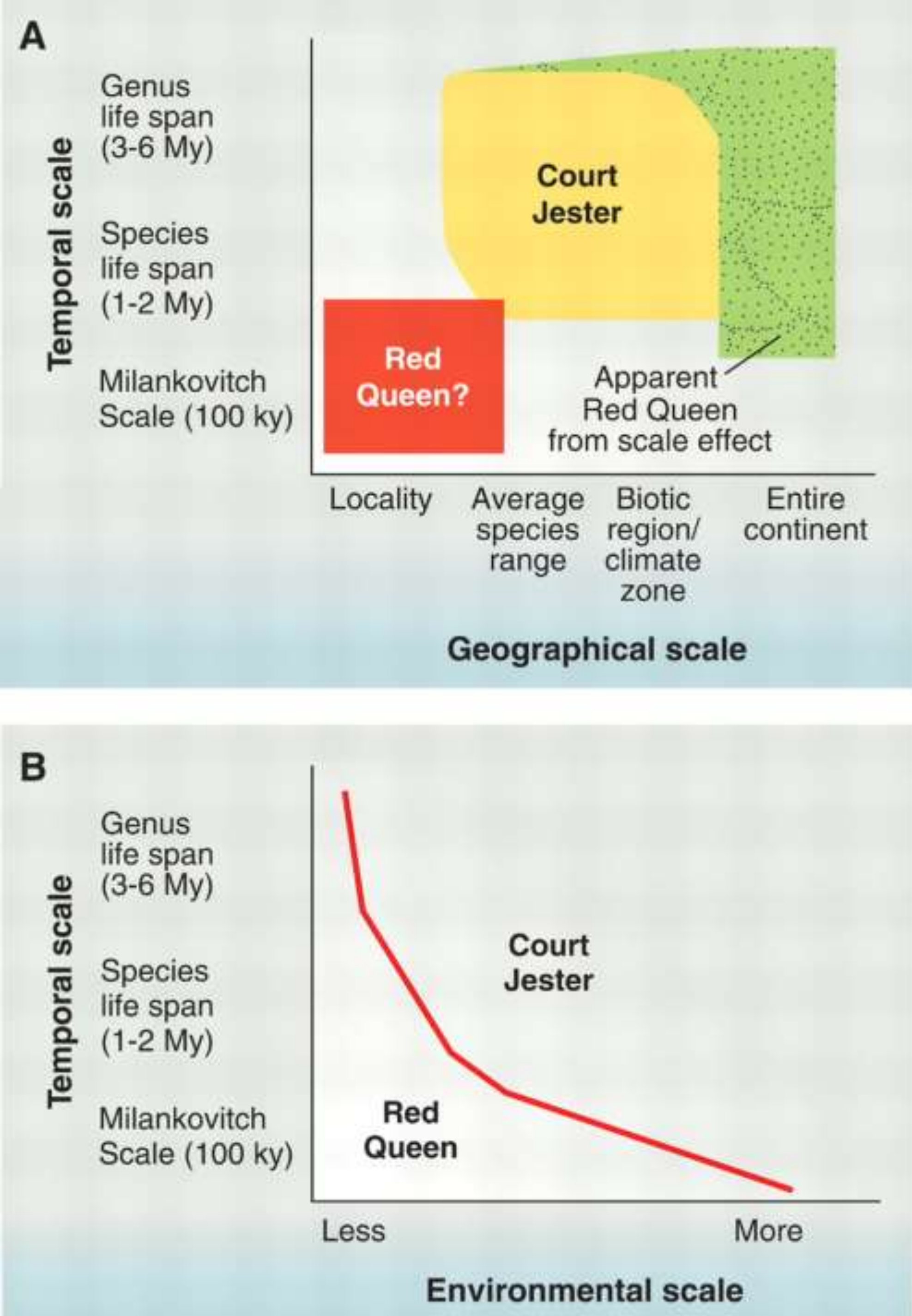
Synapomorphies of the Hemiptera:

- mouthparts developed into suctorial beak, with two pairs of mandibular and maxillary stylets lying in a long, grooved labium;
- maxillary and labial palps lost;
- ocelli close to compound eyes, median ocellus near postclypeus;
- veins ScP+R+M+CuA fused at base as common stem; transverse veinlet *cua-cup* developed in various degree
- vein ScP fused with RA, vein MA completely fused with vein RP;
- tarsi 3-segmented;
- cerci reduced;
- primarily, nymphs oval, flattened dorsoventrally, with short legs;
- chitin-protein peritrophic membrane lost replaced by lipoprotein perimicrovillar membrane

Possible synapomorphies (modern forms):

- hind legs jumping, hind tibia with apical rows formed by teeth provided with setae; first two tarsomeres enlarged;


HYPOPERLIDA
other Psocoptera
Liposcelidae
AMBLYCERA
ISCHNOCERA
RHYNCOPTHIRINA
ANOPLURA
PERMOPSOCIDA
THRIPIDA
PALEORRHYNCHA
STERNORRHYNCHA
FULGOROMORPHA
CICADOMORPHA
COLEORRHYNCHA
HETEROPTERA
Psocodea
Phthiraptera
Hemiptera
HOLOMETABOLA



Generally speaking, evolutionary processes may be dominated by biotic factors, as in the Red Queen model, or abiotic factors, as in the Court Jester model, or a mixture of both. These two models appear to operate predominantly over different geographic and temporal scales: competition, predation, parasitism and other biotic factors shape ecosystems locally and over short time spans, but extrinsic factors such as climate and tectonic events shape larger-scale patterns regionally and globally, and through thousands and millions of years. The current studies suggest that Hemiptera evolution is driven largely by abiotic factors such as climate, landscape, but biotic factors as food supply or new niches occupation are important factors for lineages formation. Comparative phylogenetic approach offer new insights into Hemiptera clade dynamics.

Benton 2009

"It takes all the running you can do, to keep in the same place."

The Red Queen, *Through the Looking-Glass, Lewis Carroll.*

"I believe whatever doesn't kill you, simply makes you…. **stranger**."

Joker, *The Dark Knight, Christopher Nolan.*

The Red Queen hypothesis was originally used to describe competition between species being the driving factor behind the large number of species we see today.

Another hypothesis, known as the Court Jester hypothesis suggests that changes in species may result not due to competition between species, but due to random geological or climate events that act as the driving force behind evolution, and the formation of new species.

… another player in the game of the Hemiptera evolution is involved – **The Red King**.

Co-evolution of two partners is regarded usually as the factor increasing the speed of evolutionary process, to avoid the run of Red Queen.

Contrary, when two partners are tightly bond in mutualistic relationship, the **Red King** effect may appear, i.e. the slowly evolving species is likely to gain a disproportionate share of the benefits.

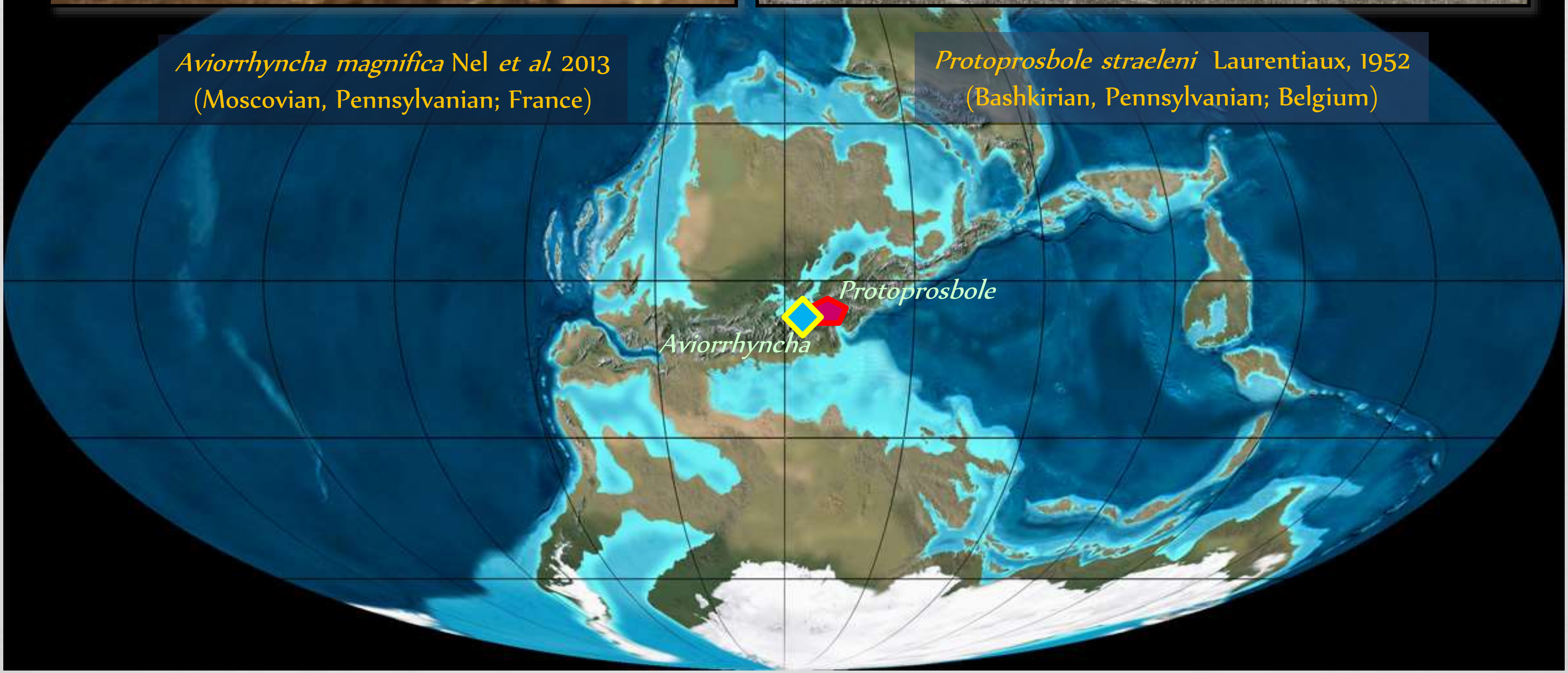
Moreover, population structure serves to magnify the advantage to the slower species.

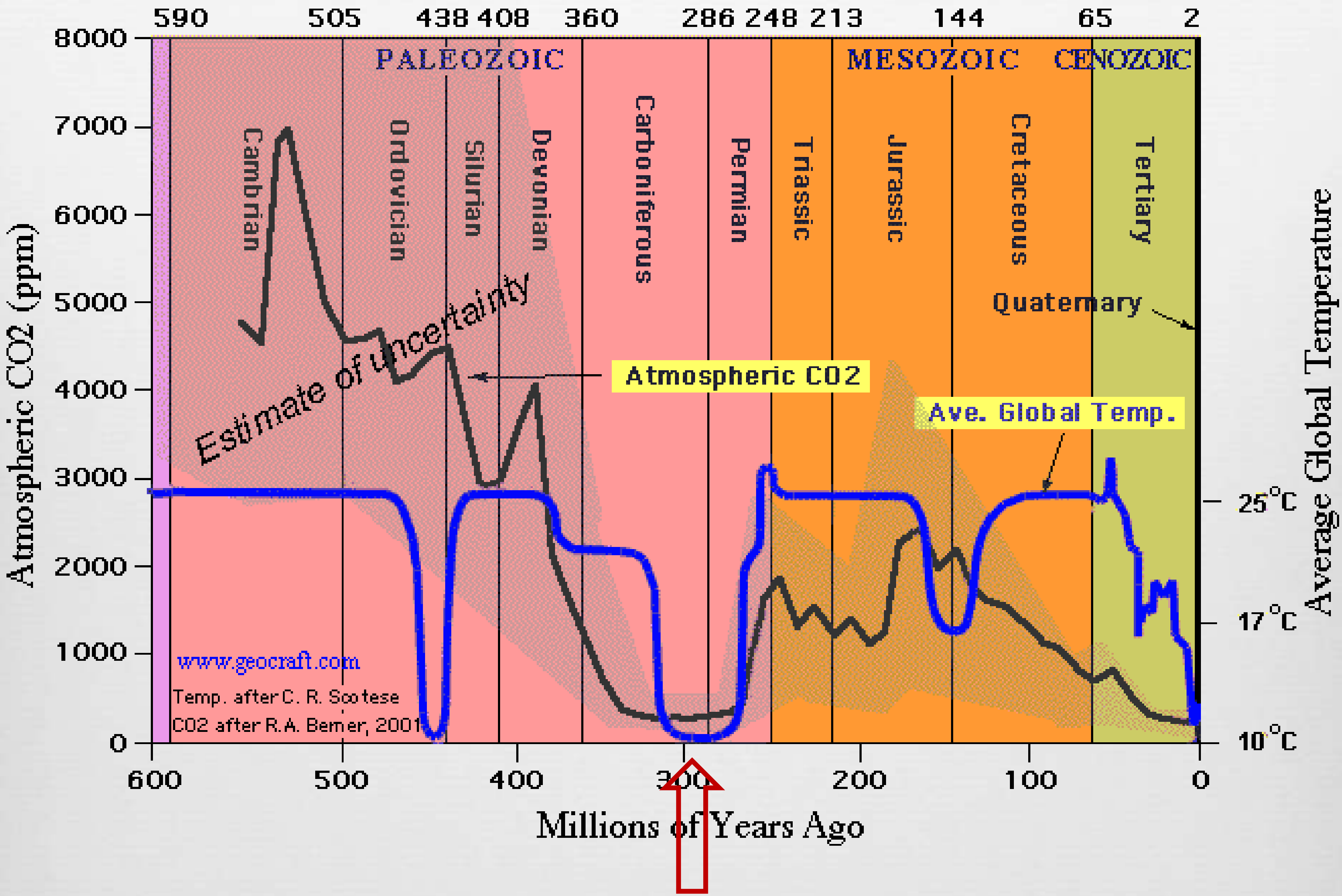
Episode 1

ORIGINS

Aviorrhyncha magnifica Nel *et al.* 2013
(Moscovian, Pennsylvanian; France)

Protoprosbole straeleni Laurentiaux, 1952
(Bashkirian, Pennsylvanian; Belgium)





Do global cooling and atmosphere composition changes triggered diversification of the Hemiptera?

The Permian diversification

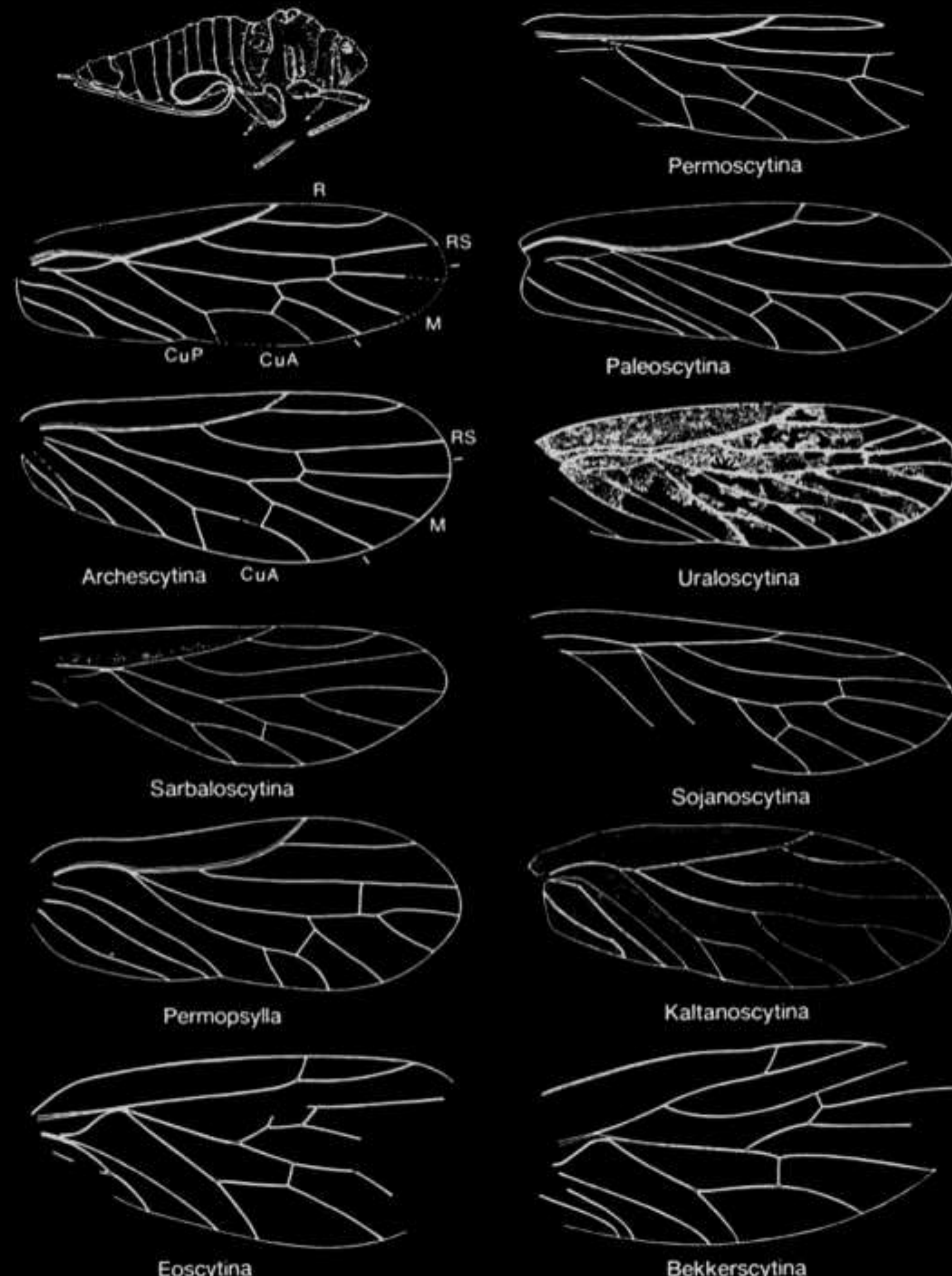
- Palaeorrhyncha – paraphyletic assemblage of 'Archescytinidae'
- earliest Sternorrhyncha – Pincombeomorpha, earliest Aphidomorpha
- rapid and immense diversification of Cicadomorpha
- earliest (but specialized) Fulgoromorpha – a few only
- earliest Coleorrhyncha - Progonocimicidae
- <u>no record </u>of the Heteroptera

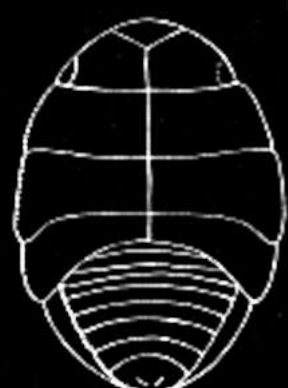
- first endosymbiotic relationships very probable, but not necessarily the bacteria and yeasts we know in recent lineages
- all these groups supposedly were phloem-feeders
- open questions of biochemistry and physiology of Permian seed-ferns, early gymnosperms
- abiotic and environmental conditions and challenges not comparable to the recent ones

Paleorrhyncha

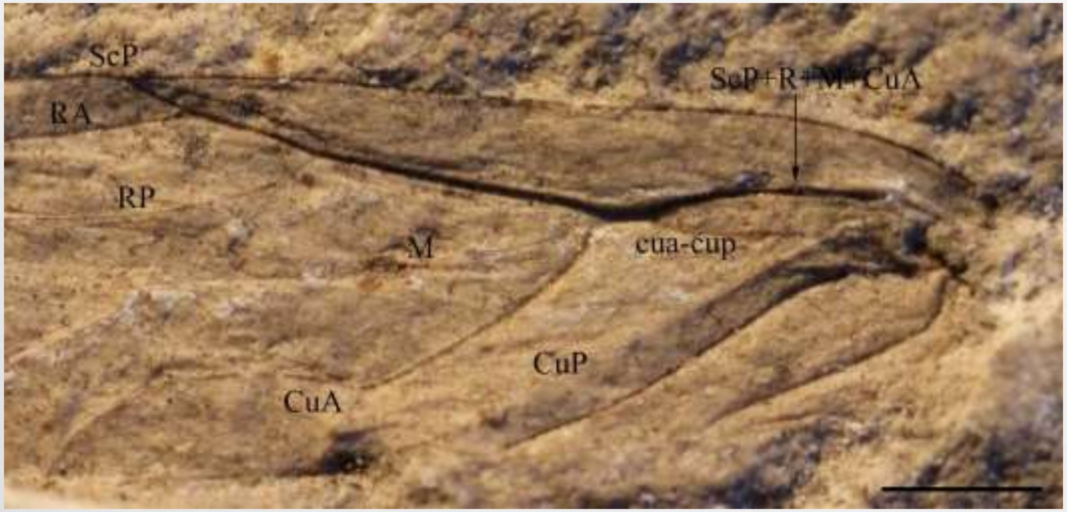
Permian 'Archescytinidae'

- miniaturisation
- homonomic venation of forewings and hind wings
- differentiated placement of rostrum base
- antennae 10-segmented with rhinaria
- elongated ovipositors
- nymphs cryptic, flattened
- gall-making
- trophic relationships with seed ferns and early gymnosperms

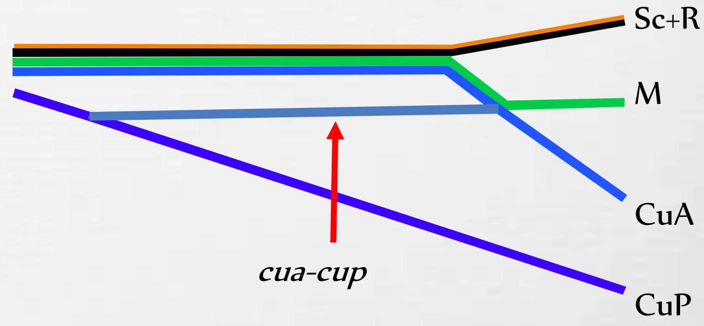


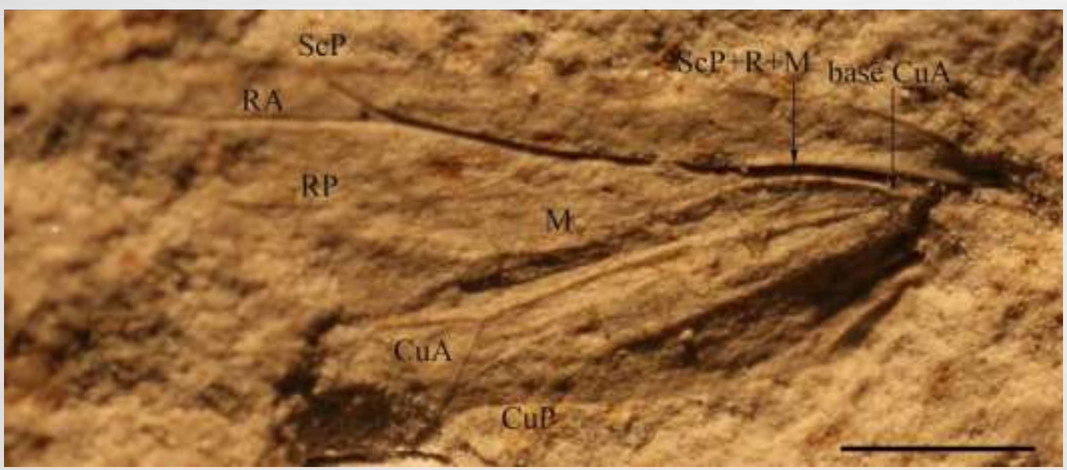


Hemiptera: Paleorrhyncha

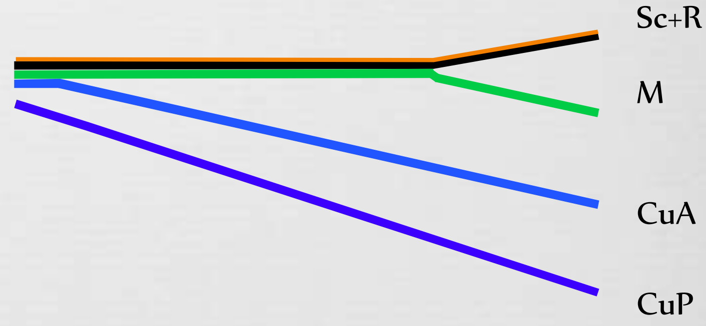


Archescytina permiana





Lithoscytina cubitalis



Paleorrhyncha

Fam: Archescytinidae

= Permopsylliidae

= Lithoscytinidae

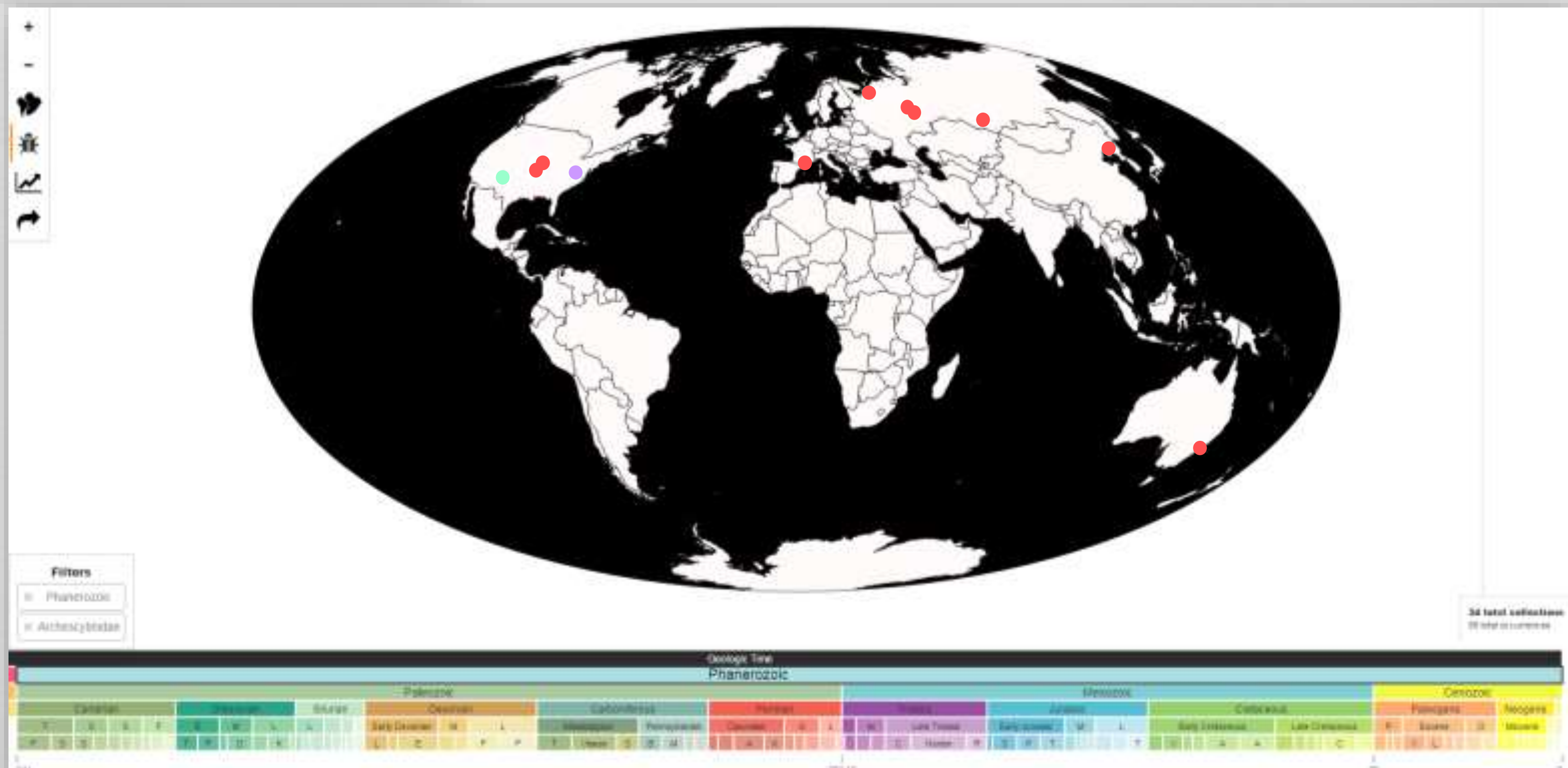
= Maueriidae

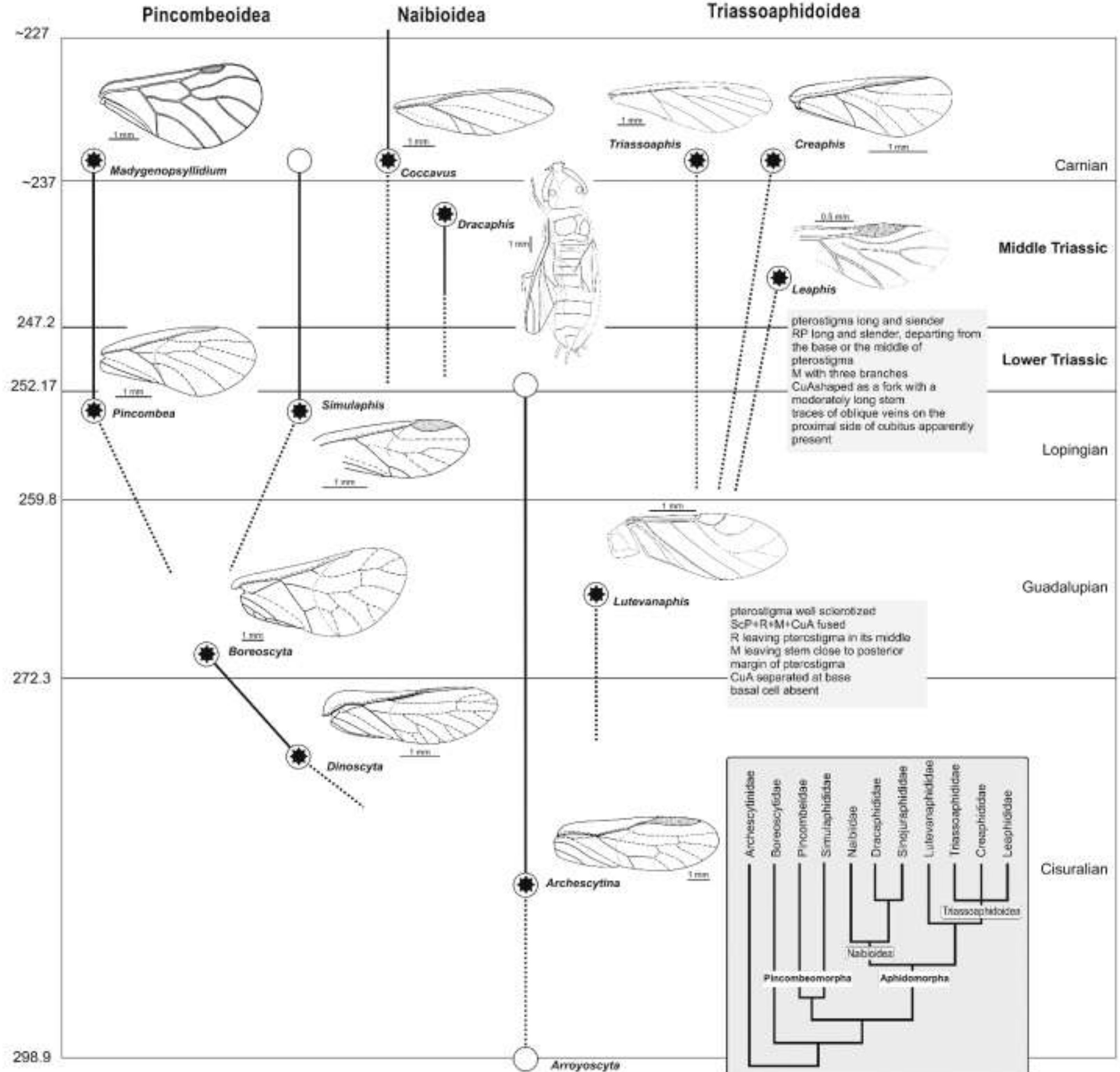
= Permoscytinopsidae

= Uraloscytinidae

= Maripsocidae

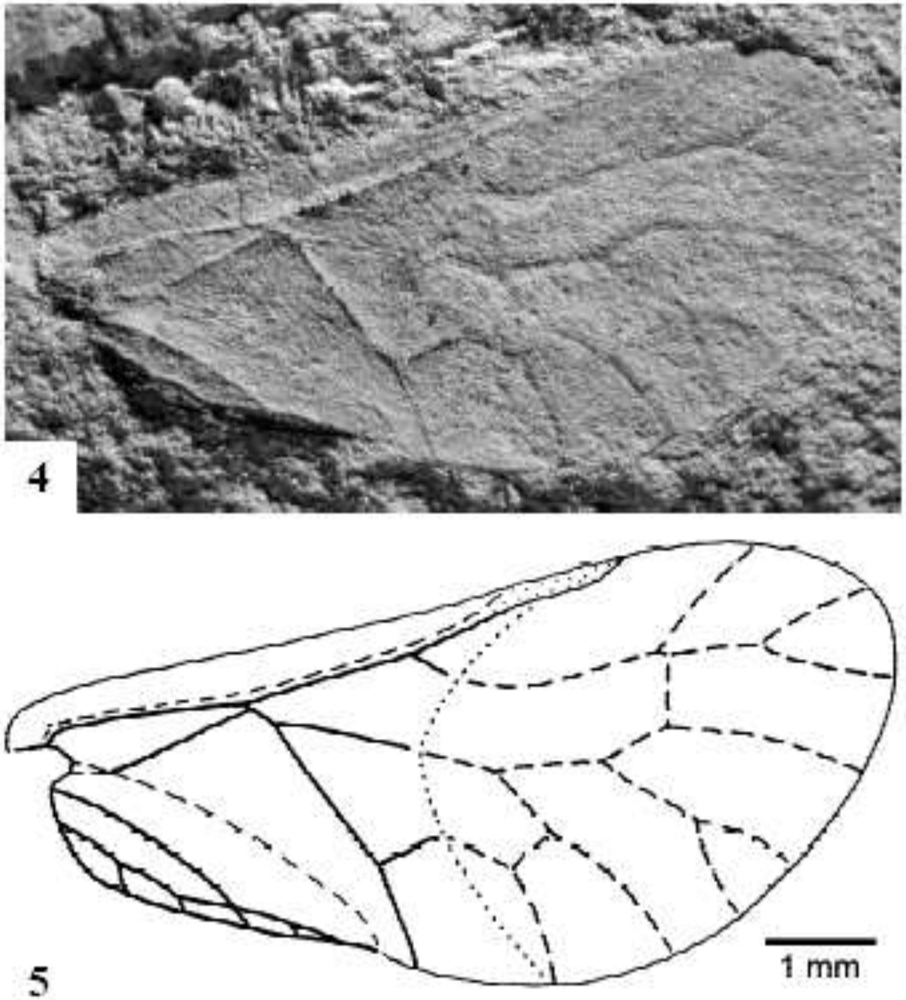
= Kaltanaphididae





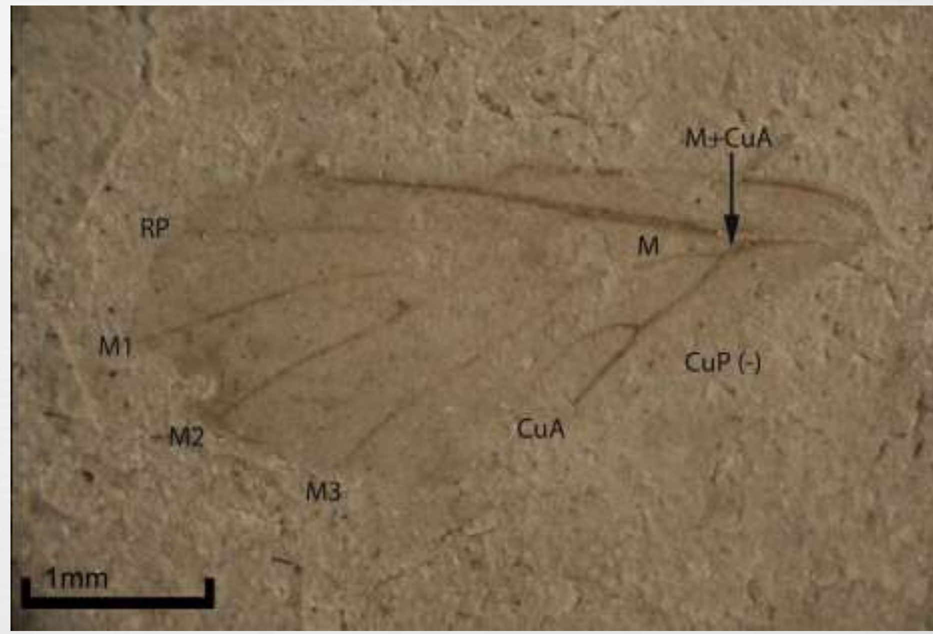
Pincombeoidea
Naibioidea
Triassoaphidoidea
~227
~237
247.2
252.17
259.8
272.3
298.9
Carnian
Middle Triassic
Lower Triassic
Lopingian
Guadalupian
Cisuralian
Madygenopsyllidium
Coccavus
Triassoaphis
Creaphis
Dracaphis
Leaphis
Pincombea
Simulaphis
Lutevanaphis
Boreoscyta
Dinoscyta
Archescytina
Arroyoscyta
pterostigma long and slender
RP long and slender, departing from the base or the middle of pterostigma
M with three branches
CuAshaped as a fork with a moderately long stem
traces of oblique veins on the proximal side of cubitus apparently present
pterostigma well sclerotized
ScP+R+M+CuA fused
R leaving pterostigma in its middle
M leaving stem close to posterior margin of pterostigma
CuA separated at base
basal cell absent
Archescytinidae
Boreoscytidae
Pincombeidae
Simulaphididae
Naibiidae
Dracaphididae
Sinojuraphididae
Lutevanaphididae
Triassoaphididae
Creaphididae
Leaphididae
Triassoaphidoidea
Naibioidea
Pincombeomorpha
Aphidomorpha

Hemiptera: Sternorrhyncha



Figs 4—5. *Boreoscyta nefasta* Becker-Migdisova, 1949. PIN 3353/716, Middle Permian of North European Russia; 4 — forewing; 5 — venation of forewing.

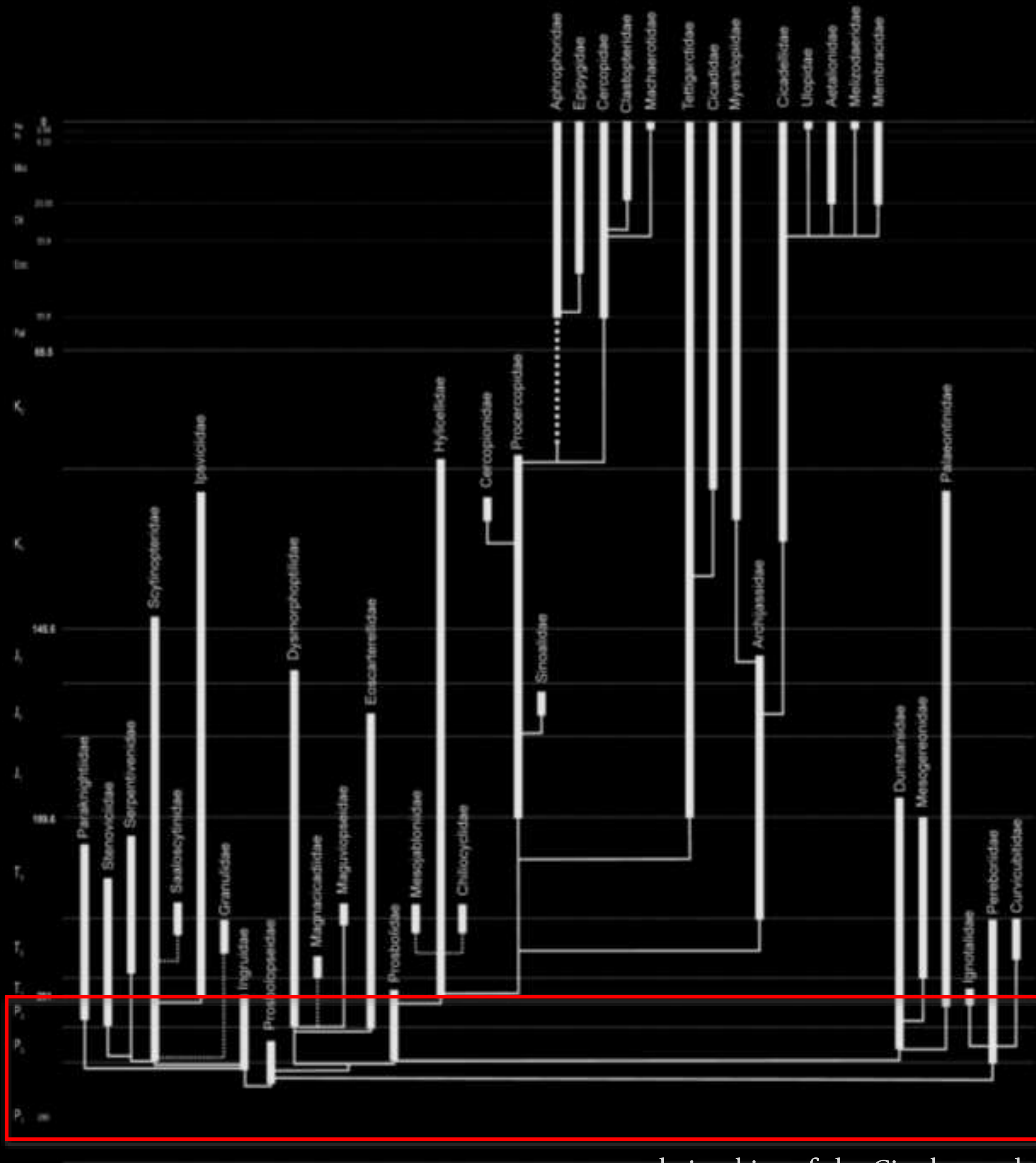
Boreoscytidae



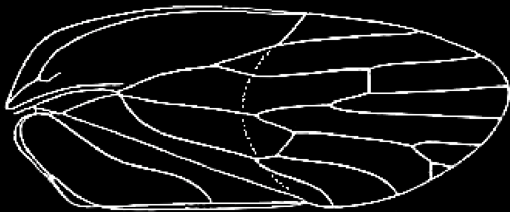
Pincombea parvifurcata
Pincombeidae

Cicadomorpha

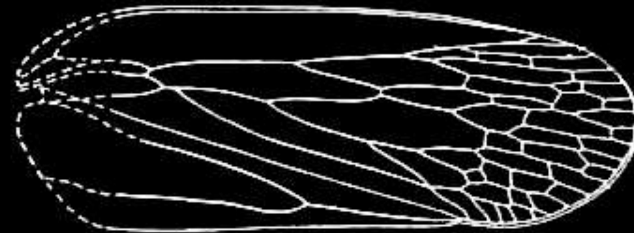
- long basicubital triangle preserved;
- basal cell elongated;
- costa enlarged with carina;
- ScP shifted from the stem R+M+CuA at base;
- tendency to fusion of M+CuA apicad of basal cell
- polimerisation of veins
- enlargement of size;
- shift to xylem-feeding;
- symbionts
- specialisation to sucking of cell content (miniaturisation);
- enlargement of frontoclypeus and salivary pump;
- spines and setae on legs;
- jumping legs;
- free-living nymphs;
- sound apparatuses



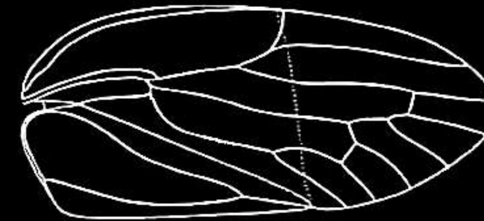
relationships of the Cicadomorpha



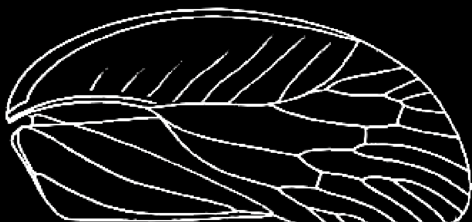
Permocicada integra
Prosbolidae



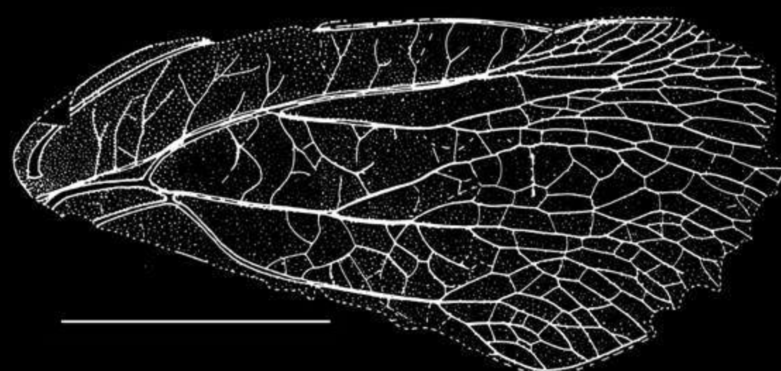
Scytophara extensa
Pereboriidae



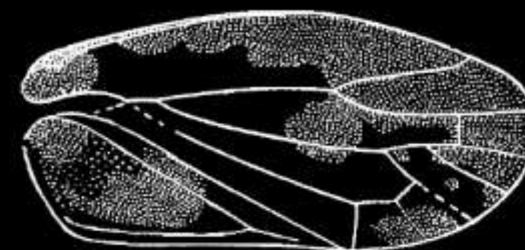
Scytoneurella major
Ingruidae



Prosbolopsis ovalis
Prosbolopseidae: Prosbolopseinae

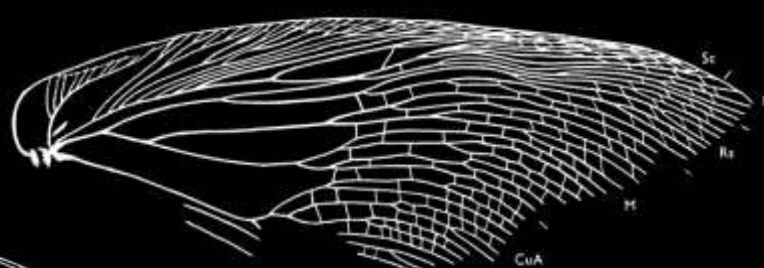


Gondwanaptera capsii
Pereboriidae



Scytinoptera kaltanica
Scytinopteridae

Prosboloneura kondomiensis
Prosbolopseidae: Ivaiinae

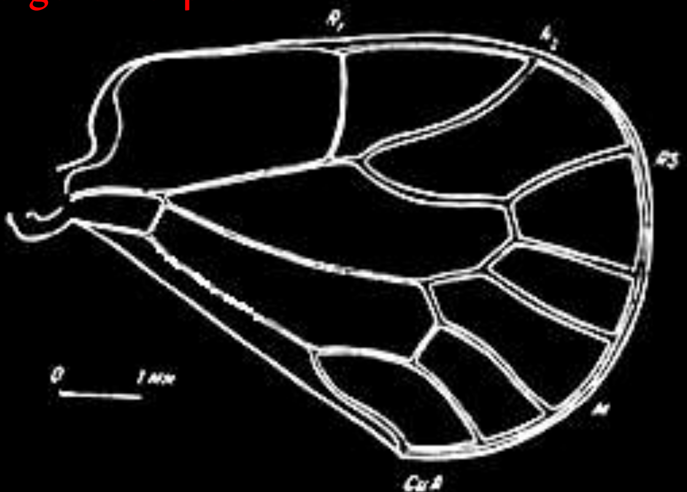


Ignotala mirifica
Ignotalidae

Stenoglyphis kimbiensis
Palaeontinidae

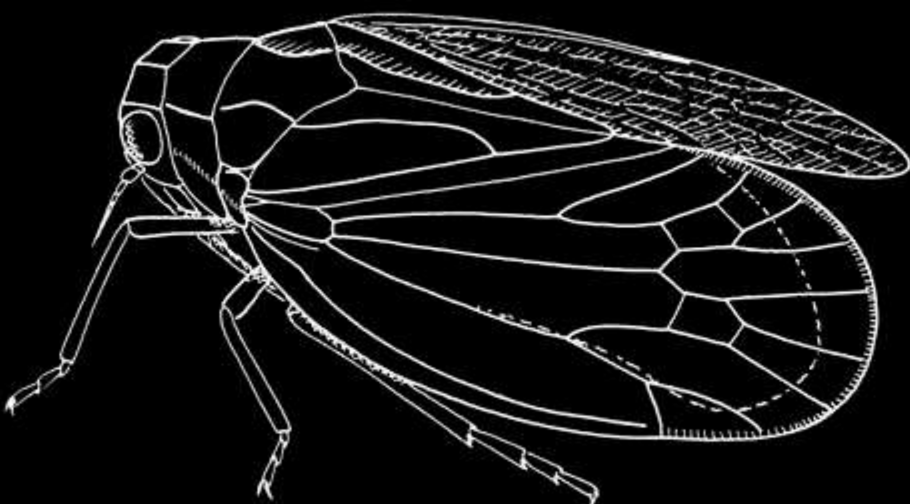
Paraknightia magnifica
Paraknightiidae

Fulgoromorpha



Coleoscytidae were highly specialised
with distinct microbrachypterism of tegmina

Coleoscyta sp.
Late Permian



Surijokocixius tomiensis
Surijokocixioidea: Surijokocixiidae
Late Permian

early Fulgoromorpha

short basicubital triangle of tegmen

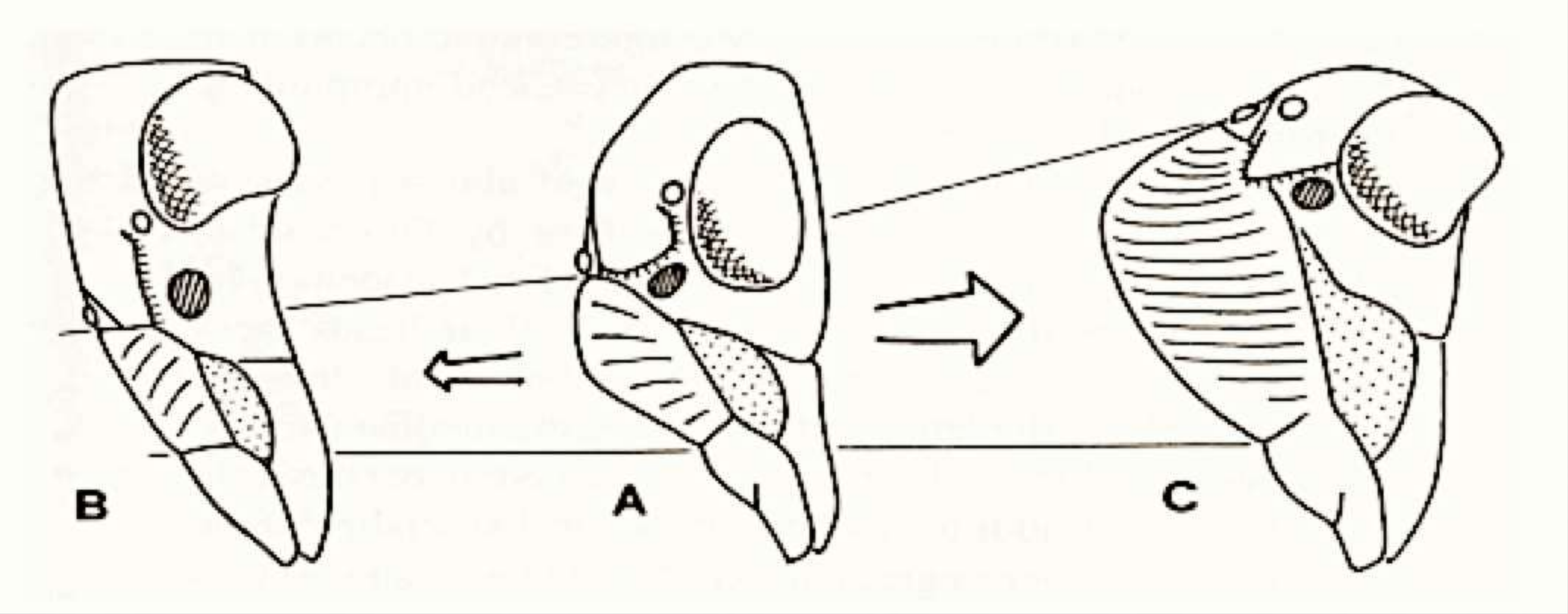
longitudinal carinae on pronotum and mesonotum

head capsule strengthened with carinae

bases of antennae below the compound eyes

? modifications of head capsule structure

? median ocellus present, shifted down to frontoclypeal suture



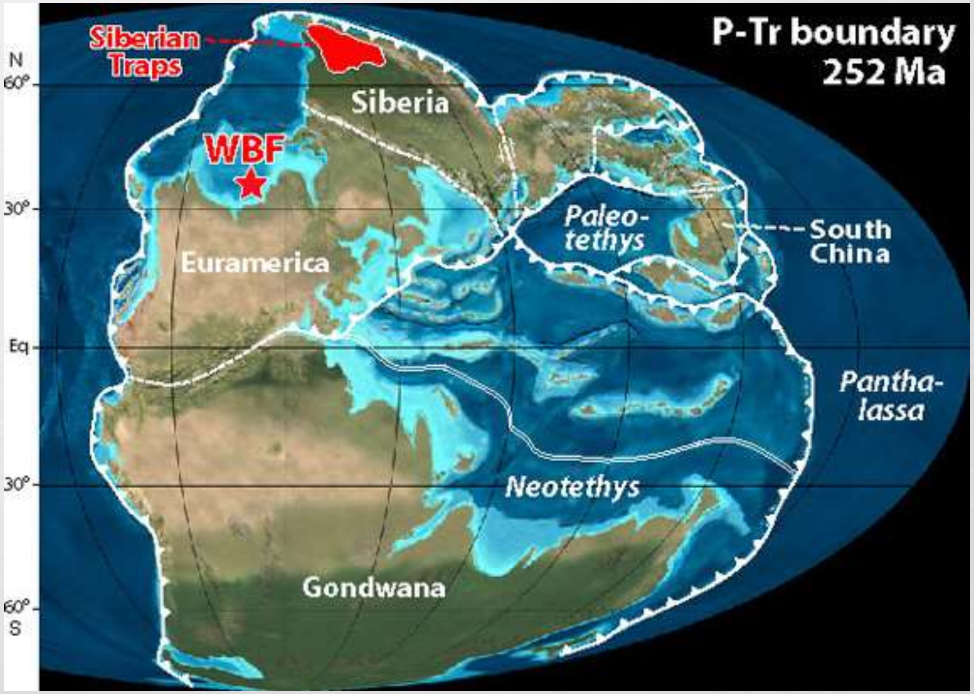
Episode 2

GREAT PERMIAN-TRIASSIC EXTINCTION AND REBUILDING THE DIVERSITY

Permian-Triassic mass extinction

- 252.28 Ma ago;
- the Earth's most severe extinction event (up to 96% of all marine species and 70% of terrestrial vertebrate species);
- the only known mass extinction of insects.

"Daddy's going to make some extinctions, darling"

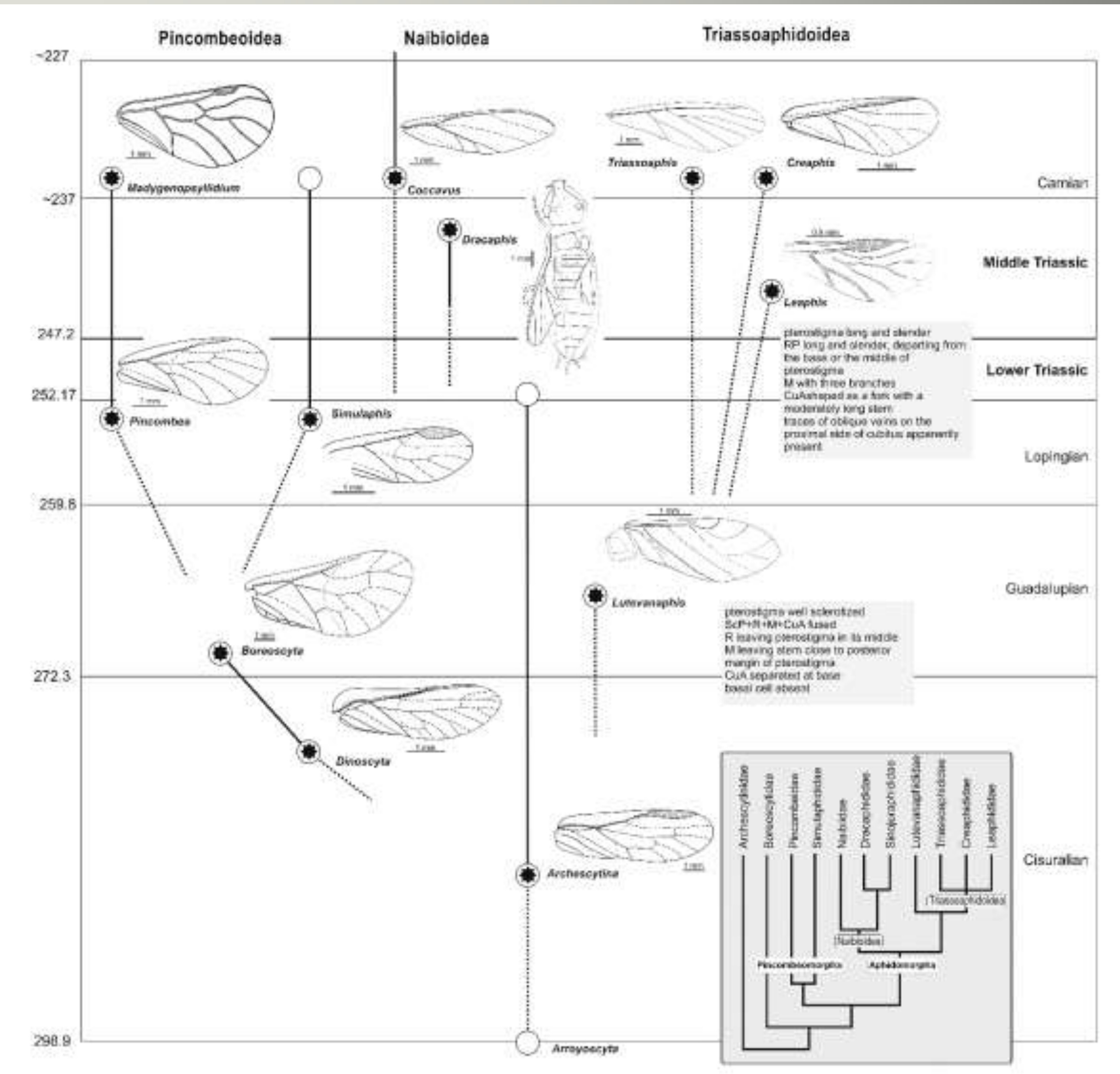


Fossils from earliest Triassic, just after extinction, are virtually unknown

- Archesctynidae seems to gone extinct
- First records of the Hemiptera from the Middle Triassic times:
- Various Sternorrhyncha – Aphidomorpha, Pincombeomorpha, Naibioidea and probably earliest Coccomorpha; Protopsyllidiidae
- Fulgoromorpha not diverse – latest Coleoscytidae and Surijokocixiidae
- Cicadomorpha highly diversified – shift from phloem-feeding to xylem feeding in the Clypeata lineage
- Scytinopteroidea highly diversified and specialized
- diversification of Coleorrhyncha: Progonocimicidae
- earliest true bugs – Heteroptera: Nepomorpha and Dipsocoromorpha

which was the reason of shift to xylem feeding in the Clypeata?
earliest endosymbiotic relationships retained in the modern Cicadomorpha: Clypeata?
shift to cryptic, endogeic life-style in earliest Coccomorpha?
scavenging and predatory behaviours in the earliest Heteroptera
sound production with wings – Cicadomorpha: Dysmorphoptilidae

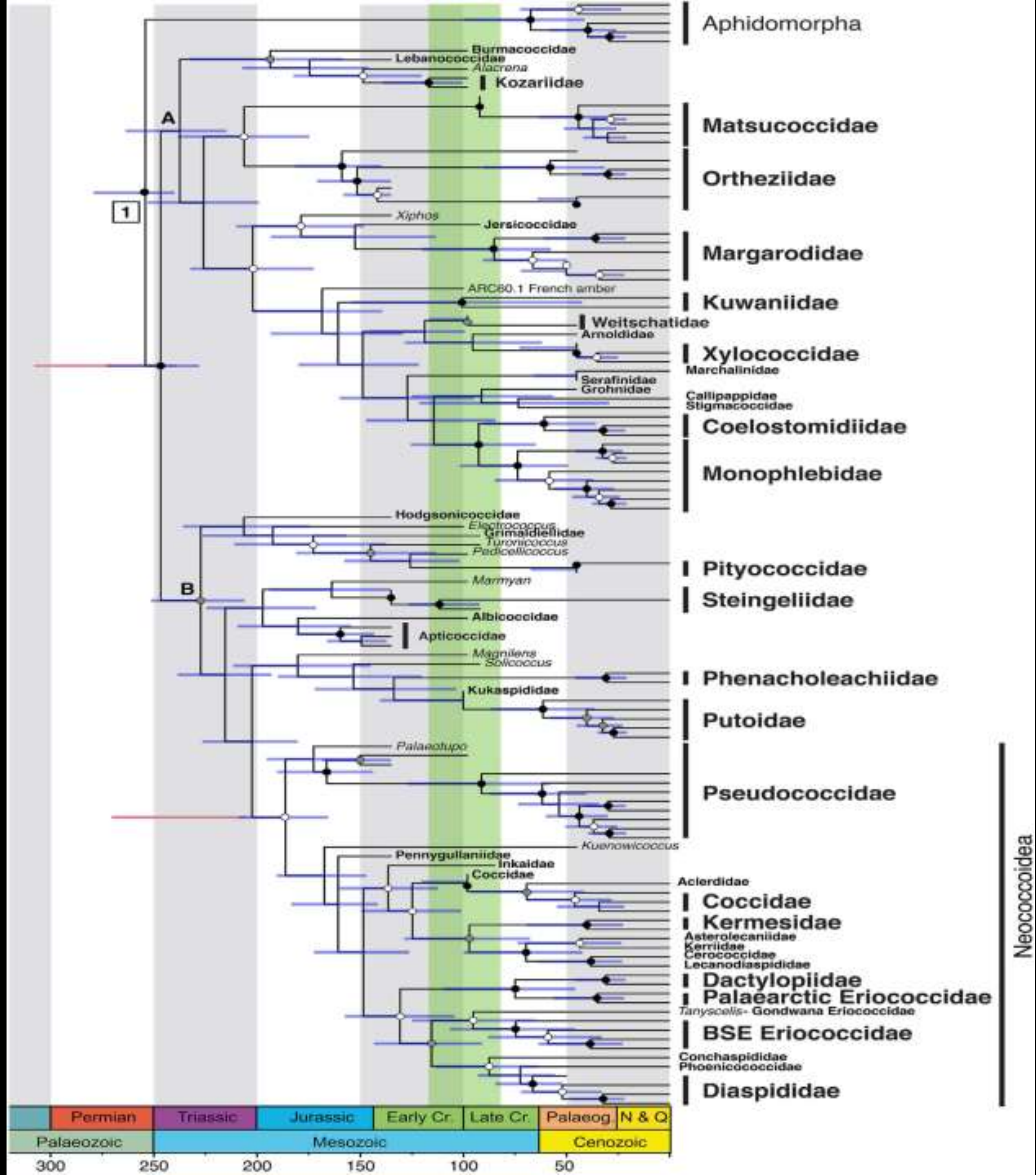
Sternorrhyncha: Aphidomorpha



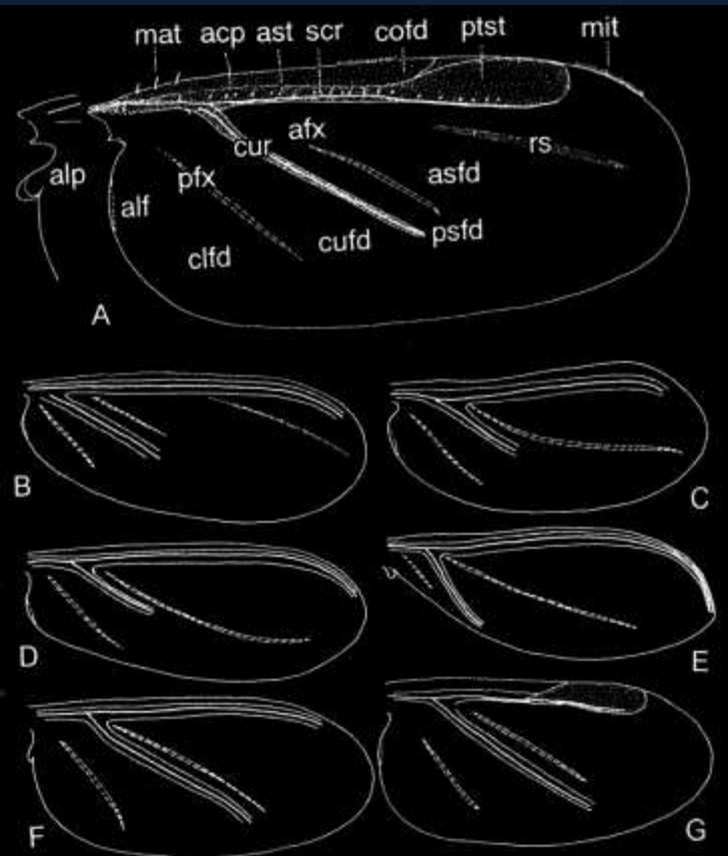
- first diversification during the Triassic
- modifications of the wing shapes from oval to triangular
- reduction of basal cell
- elongated common stem ScP+R+(M)+CuA
- reduction of venation
- loss of vein M connection with stem
- costalization
- reduction of anal lobe (clavus)
- dipterization (?) and miniaturization
- oligomerization of antennal segments (?); primary and secondary rhinaria
- diploidal parthenogenesis (?)

Sternorrhyncha: Coccidomorpha

- first radiation in the Triassic (?)
- related to gymnosperms (mycorrhizal fungi?)
- transfer to live in litter, soil, on roots (?)
- lost of tarsal claw, legs transformed into digging organs (?)
- antennae with complete number of segments; without rhinaria, primitive sensorial organs, numerous sensilla trichoidea;
- motion and orientation (?)
- sexual dimorphism
- differentiation of chromosomal system
- fossil materials known since Jurassic/Cretaceous



Vea & Grimaldi 2015



Outline, ridges and flexing patches of scale insect wing. **A** – generalized (based on wing of *Weitschatus vysniauskasi* gen. et sp. n.), **B–F** – wings of species dealt with in the present paper. **B** – *Xylococcus grabenhorsti* sp. n., **C** – *Arnoldus capitatus* gen. et sp. n., **D** – *Arnoldus clavatus* gen. et sp. n., **E** – *Serafinus acutipterus* gen. et sp. n., **F** – *Grohnus eichmanni* gen. et sp. n., **G** – *Weitschatus stigmatus* gen. et sp. n. Wings enlarged to the same length independent of real size. Ridges shown as three parallel solid lines; flexing patches indicated by interrupted lines; pterostigma and sclerotized strips shown by dotting.
acp – alar cupolae, **afx** – anterior flexing patch, **alf** – alar fold, **alp** – alar lobe (pocket), **asfd** – anterior subcostal field, **ast** – alar setae, **clfd** – claval (anal) field, **cofd** – costal field or thickening, **cufd** – cubital field, **cur** – cubital ridge, **mat** – macrotrichia, **mit** – microtrichia, **pfx** – posterior flexing patch, **psfd** – posterior subcostal field, **ptst** – pterostigma, **rs** – „radial sector", **scr** – subcostal ridge.

Directions of Coccidomorpha evolution

males

- litter-living → dipterisation+polimophrizm
  → miniaturization → origin of pseudopupa
- fragility+feeding on above-ground parts of host-plants → composed chromosomal systems;
- feeding on plants → specialized digitulae;
- forewings placed aong the abdomen; venation reduced;
- reduction of hind wings to halterae;
- resting stadia (prepupa and pupa); sex determination

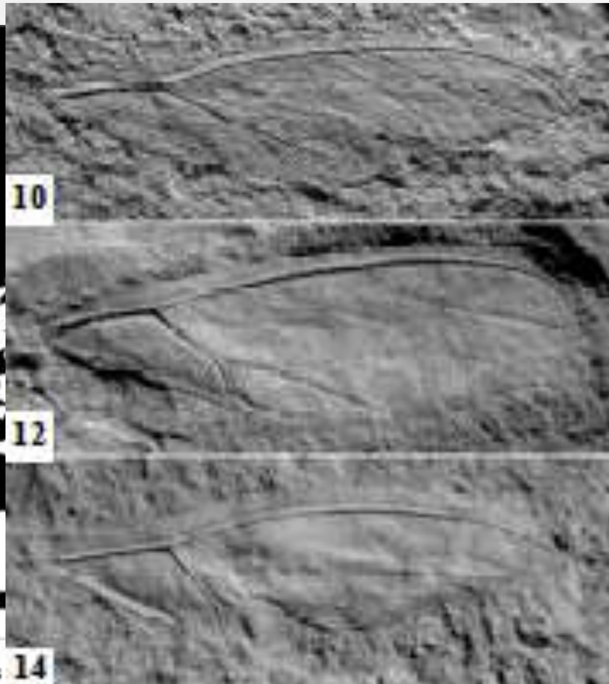
females

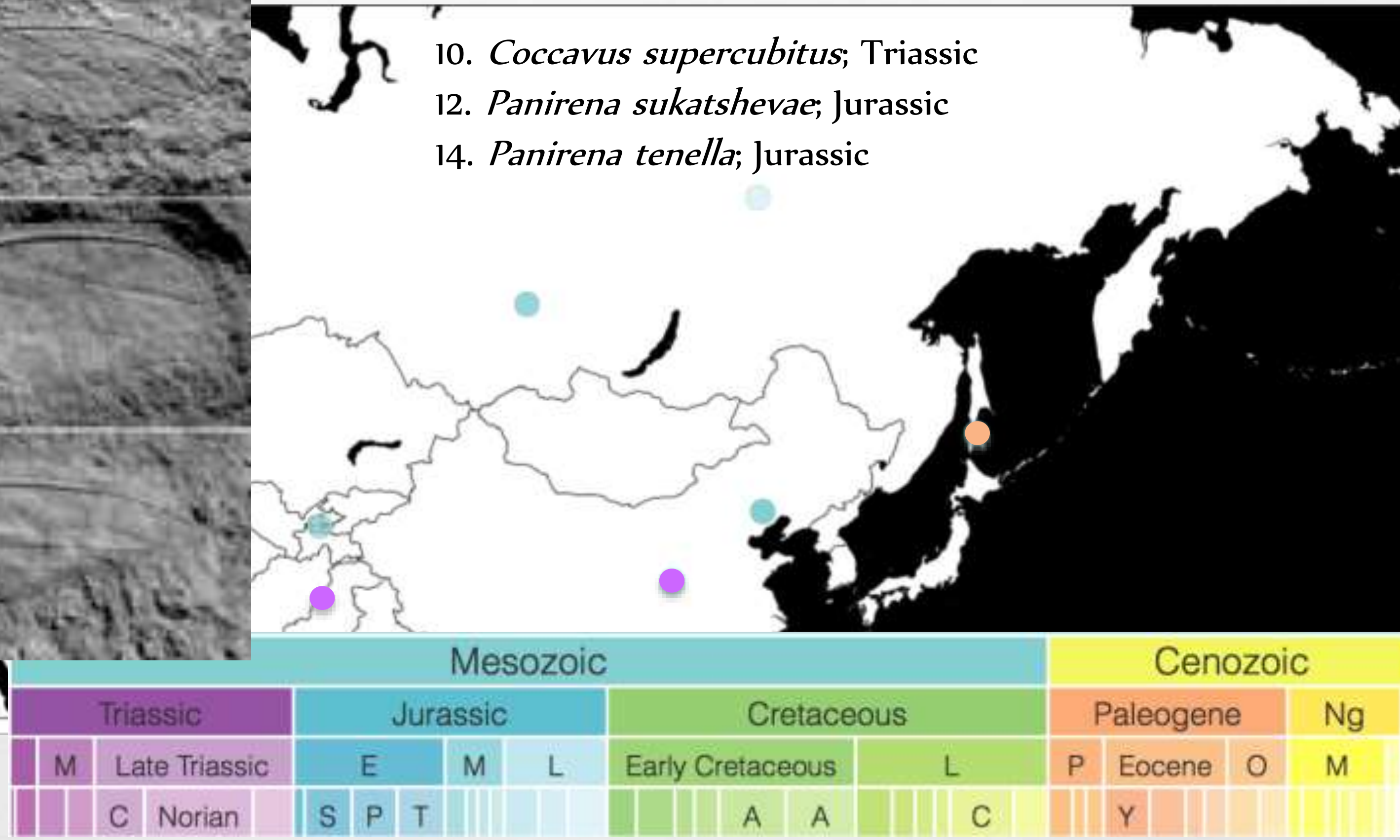
→ loss of wings

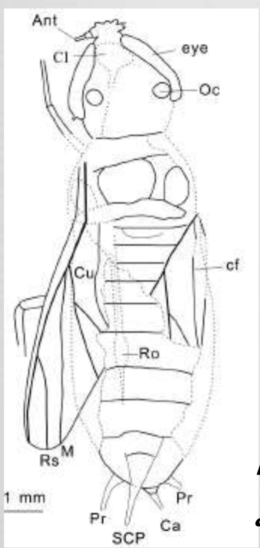
- litter-living

  → larvalisation (neoteny?), eggs in marsupium
- secondary, independent transfer in various lineages to feed on overground portions of plants → various systems of symbionts;
- morphological transformations due to sedentary habits; development of security systems

Naibioidea, Naibiidae, Sinojuraphidiae and Dracaphididae – missing ling or high specialization?

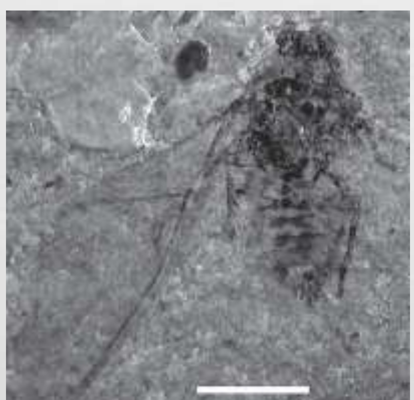






Dracaphis angustata

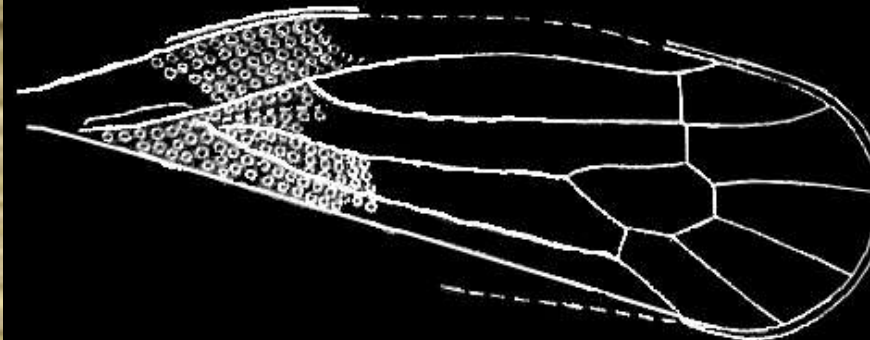
Sinojuraphis ningchengensis



Naibia zherikhini; Eocene

variety of Triassic Cicadomorpha

Dysmorphoptilidae



Hylicellidae

Dunstaniidae

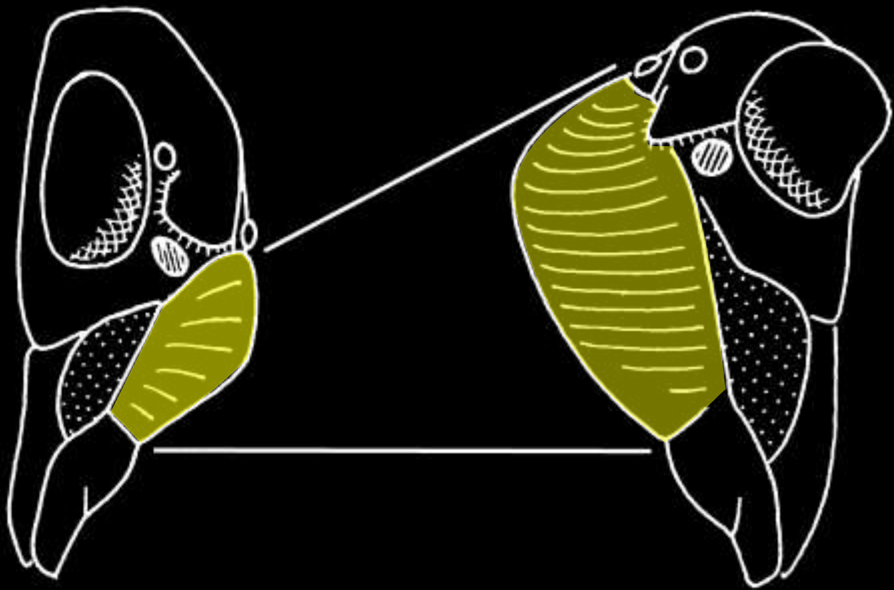
Palaeontinidae

During the Triassic various lineages of the Cicadomorpha were present

Episode 3

XYLEM-FEEDING

Clypeata



- enlarged, swollen frontoclypaeus, with distinct salivary muscle traces;
- frons with median ocellus shifted dorsally;
- xylem-feeding;
- nymphs (primarily) living underground;
- the first group with distinct adaptations for jumping;
- protection of body by the liquid produced by Malpighian tubules – brochosomes in Membracoidea
- development of spines and setae of legs in relation to covering the body with liquid and brochosomes;
- endosymbiotic *Sulcia* and other bacteria

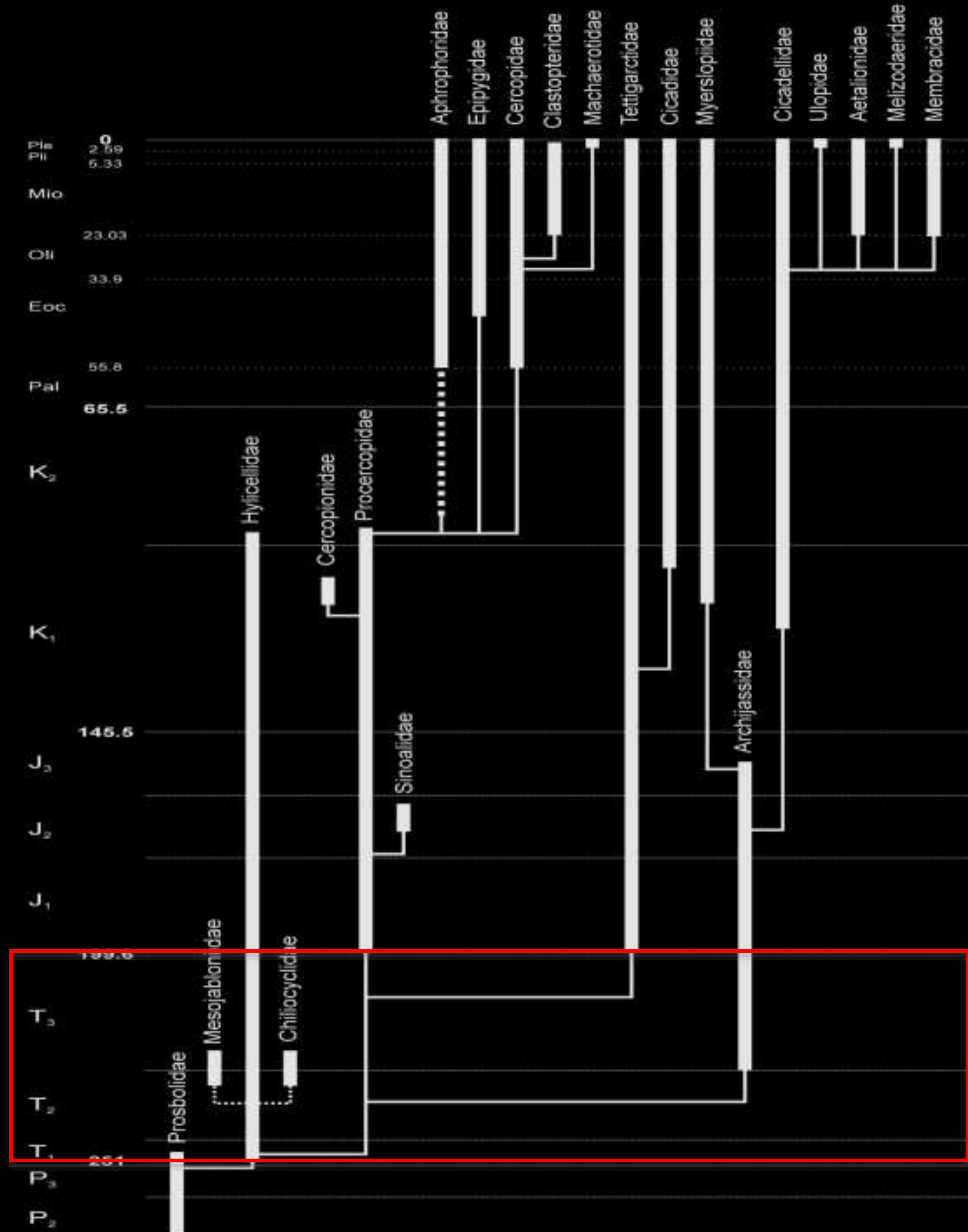
Why ancestors of Clypeata shifted their food-source?
New gymnosperm plants available as food source?
Development of defensive mechanisms in gymnosperm plants?
Change in food-plants physiology?
Competition with Sternorrhyncha?

Cicadomorpha: Clypeata

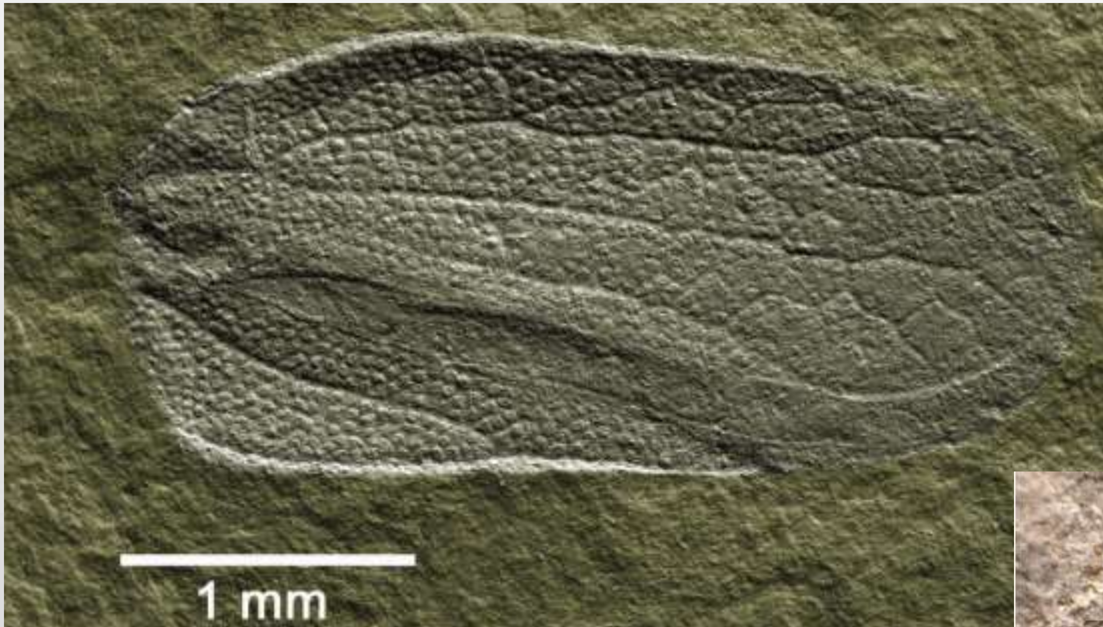
- The only surviving group of Cicadomorpha, present in the Recent fauna
- The recent groups are descendants of the Hylicelloidea
- Earliest Archijassidae in Australia

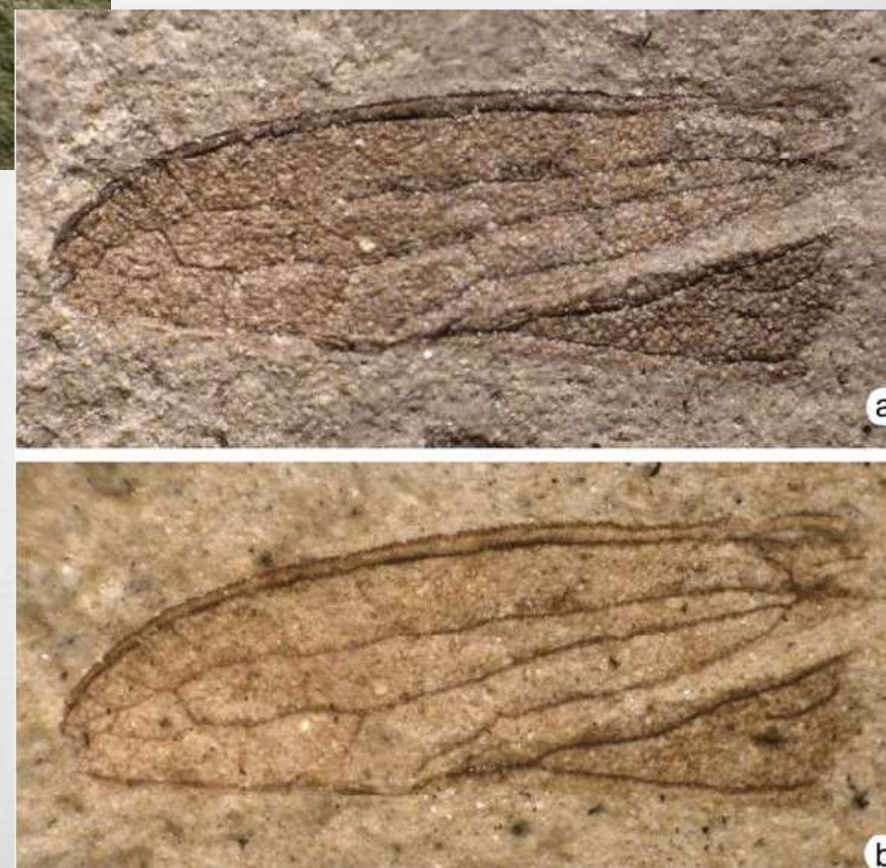
Mesojassus ipsviciensis

Triassojassus proavitus



Heseneuma hammelburgensis Brauckmann et Schlüter, 1993 – taxonomic position uncertain



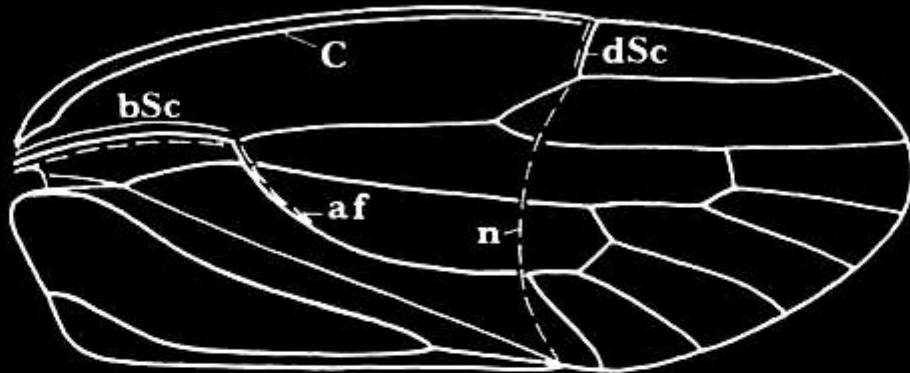


Ipsvicia langenbergensis Barth *et al.*, 2011

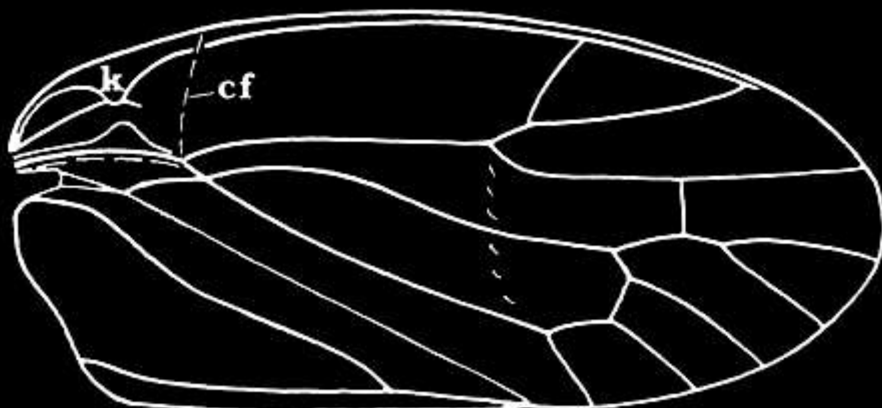
Ipsviciidae: Scytinopteromorpha

Episode 4

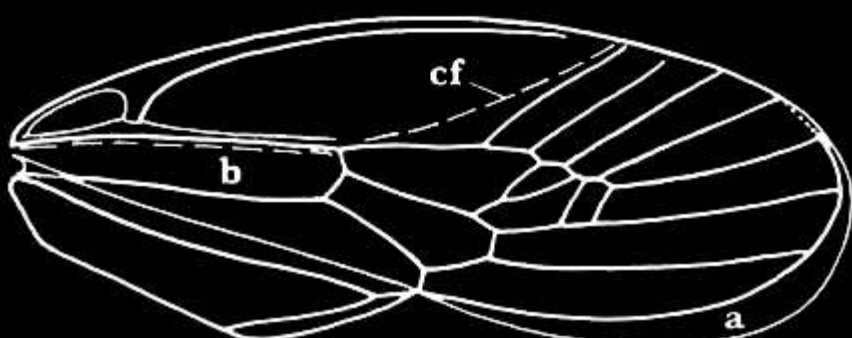
PREDATION



Prosbolopseidae (Cicadomorpha)

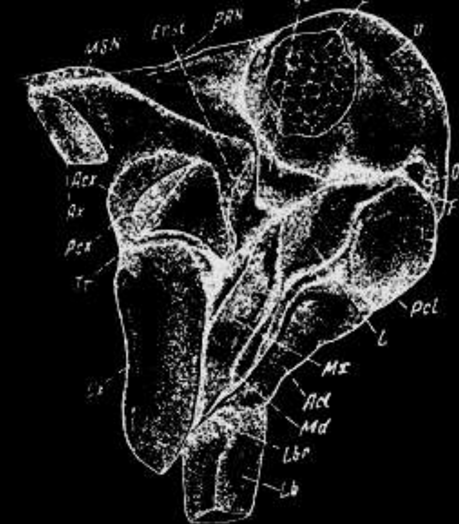


Scytinopteridae (Cicadomorpha s.l.)



Archegocimicidae (Leptopodomorpha)

Prosbolopseidae

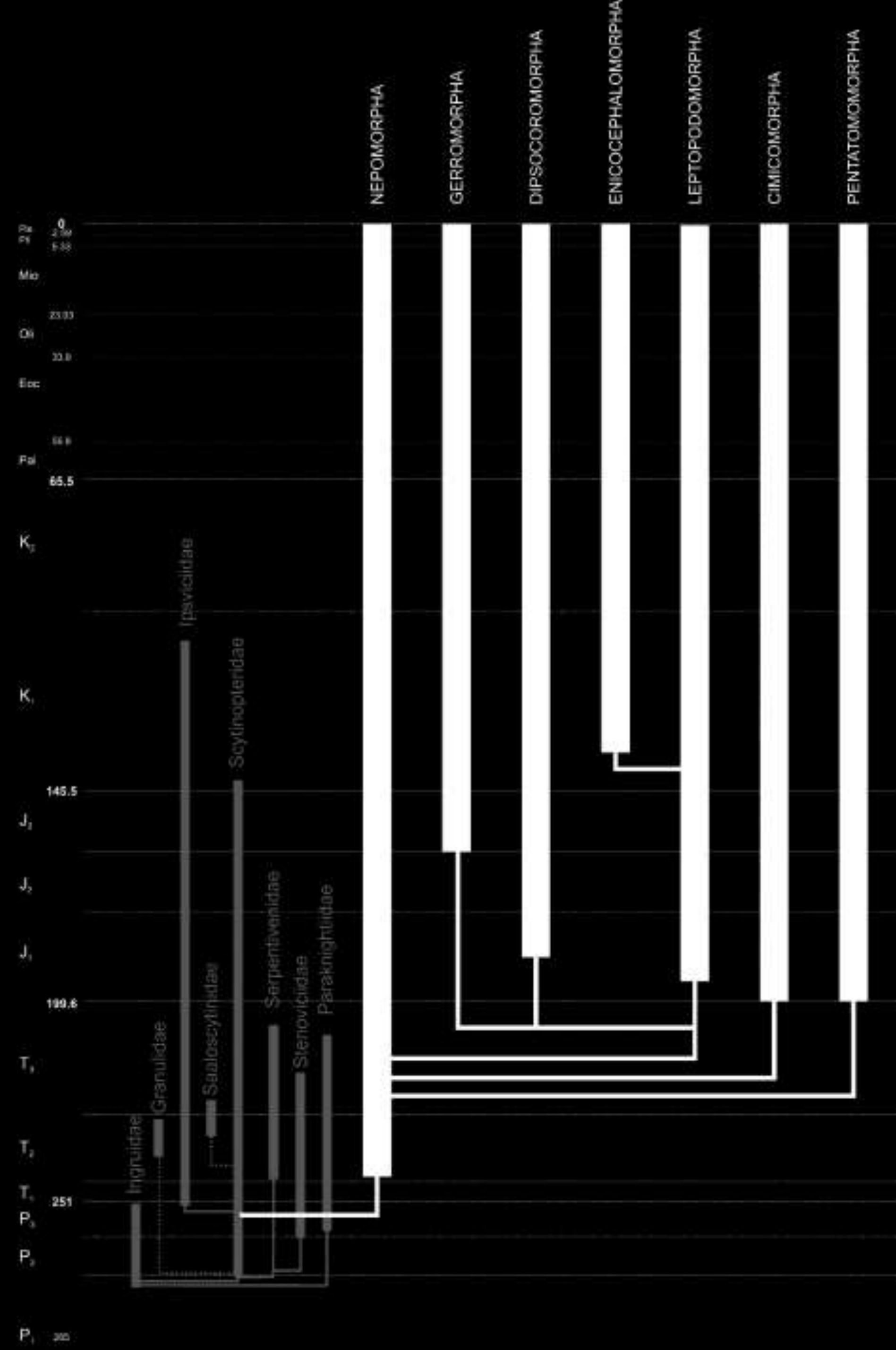


Scytinoptera sp.

Saldula sp.

Heteroptera

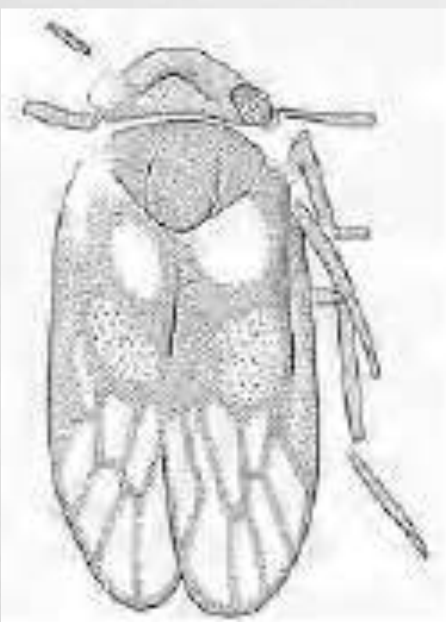
- fossil record since Middle Triassic;
- neotenic Scytinopteridae (?);
- nymphal features retained;
- body flattened;
- shift of feeding through saprophagy (?), scavenging to carnivory;
- antennae 5 (4)-segmented;
- increased mobility of head;
- shift of rostrum to front of head; head opistognathous;
- additinal sclerite – gula;
- tegmina with costal fracture;
- Druckknopfsystem – clip holding tegmen at repose;
- shortened clavus, membranes of tegmina overlapped
- distinct elongation of basal cell;
- membrana tegminis softer;
- secondary herbivory / carnivory / blood-sucking



Appearance of the Heteroptera from scytinopteroids

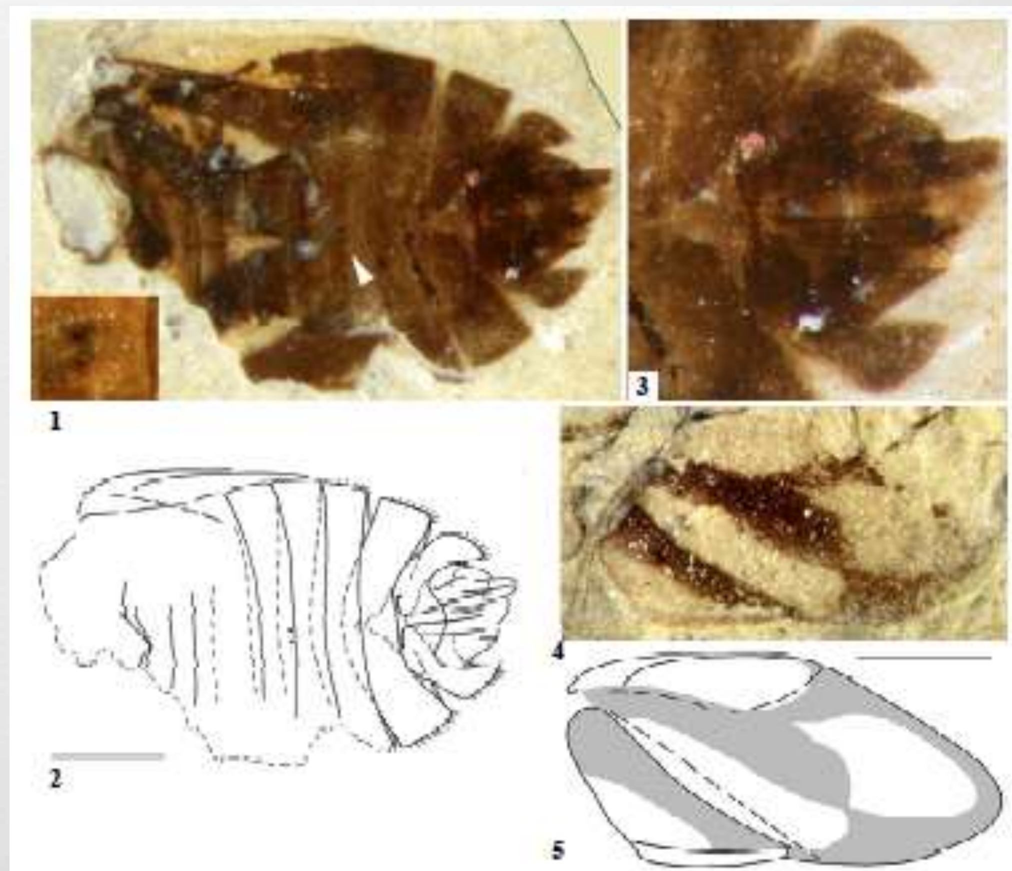
- neoteny and structural simplification
- transition from 3D environment to 2D environments – shores and floating mats
- scavenging to predation
- development of costal fracture at apex of basal cell (substituting nodal flexion line), hypocostal pit mounting mesepimeral knob in repose (Druckknopfsystem)

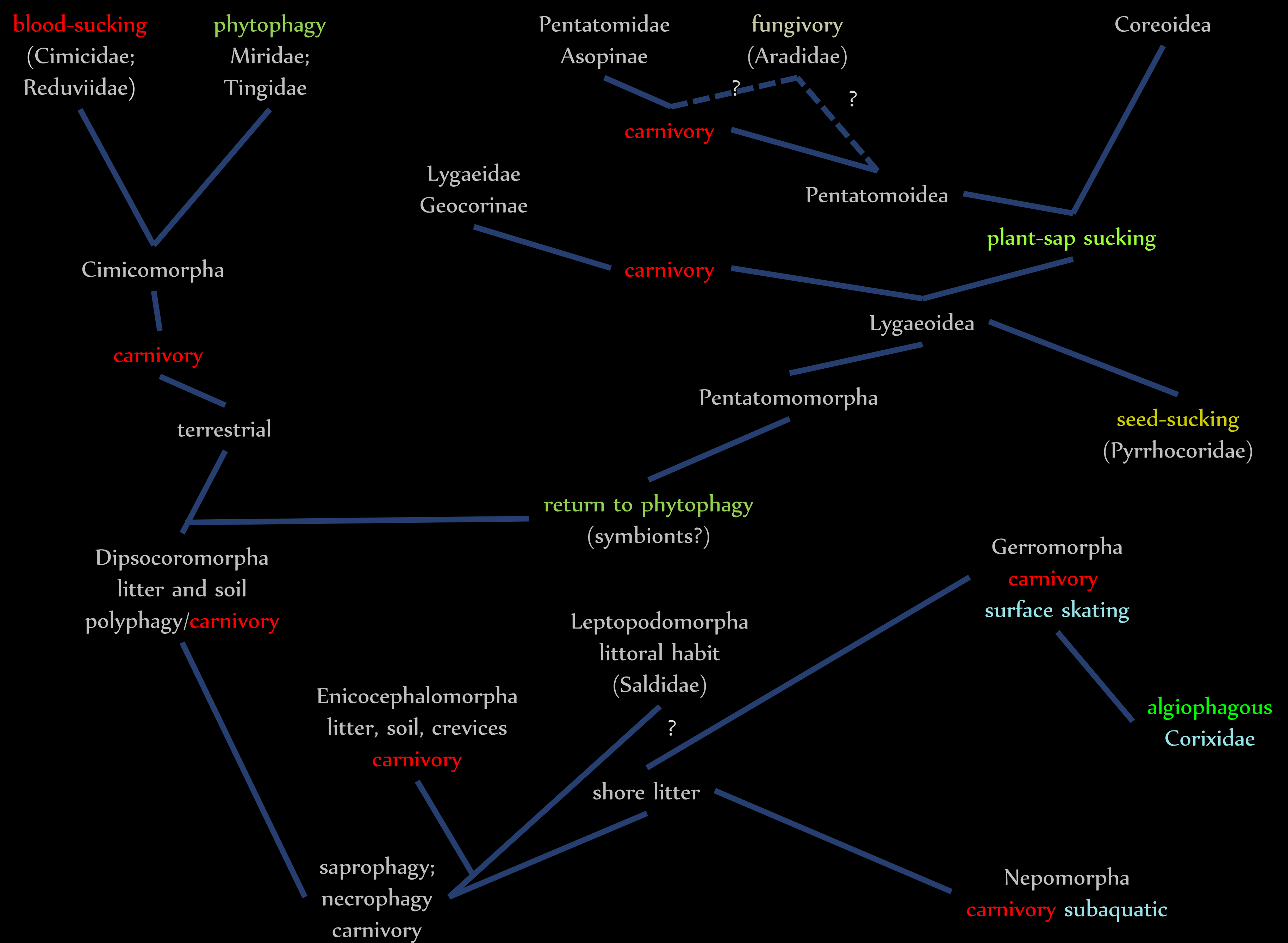
Heteroptera: Dipsocoromorpha?

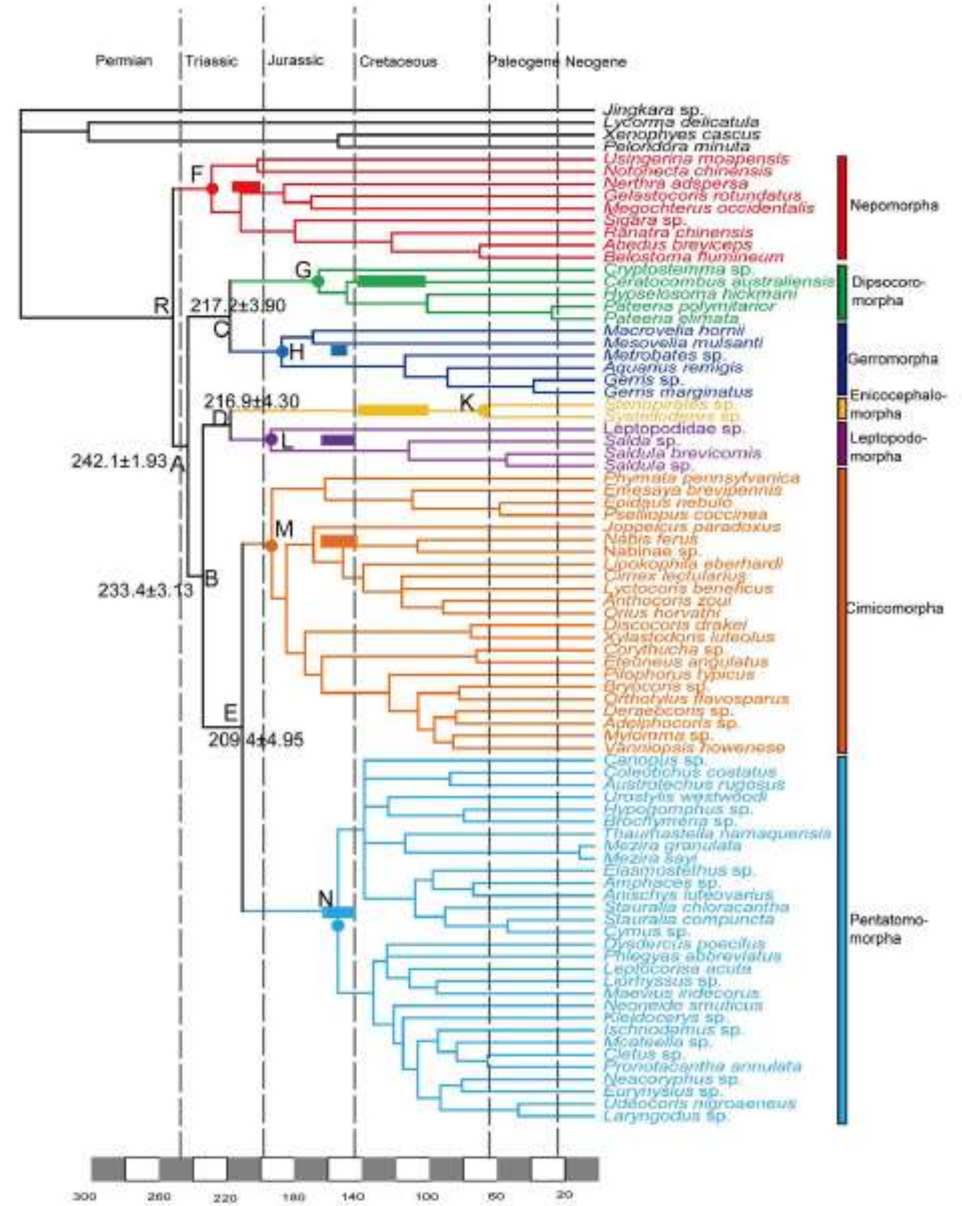


Arlecoris louisi Shcherbakov, 2012

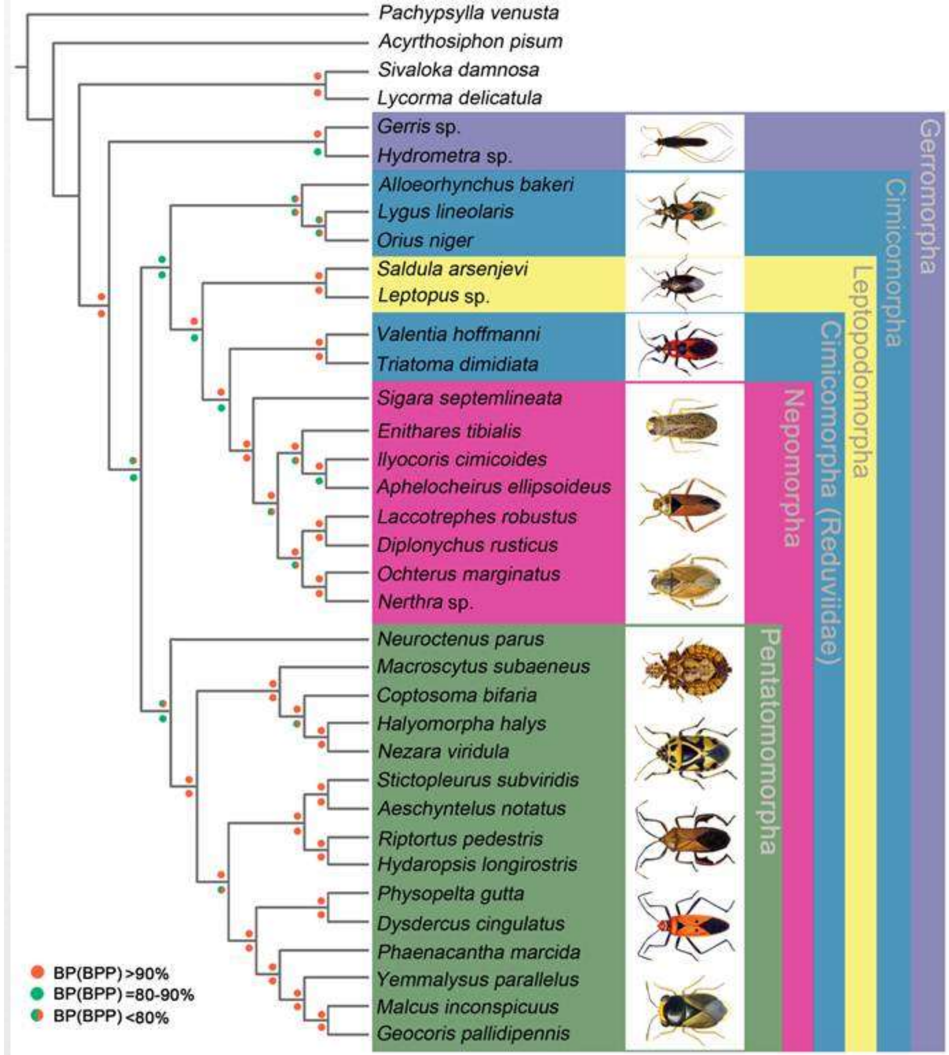
Heteroptera: Nepomorpha: Naucoroidea: Triassocoridae




blood-sucking
(Cimicidae;
Reduviidae)
phytophagy
Miridae;
Tingidae
Pentatomidae
Asopinae
fungivory
(Aradidae)
?
?
Coreoidea
carnivory
Pentatomoidea
Lygaeidae
Geocorinae
plant-sap sucking
carnivory
Cimicomorpha
Lygaeoidea
carnivory
Pentatomomorpha
terrestrial
seed-sucking
(Pyrrhocoridae)
return to phytophagy
(symbionts?)
Gerromorpha
carnivory
surface skating
Dipsocoromorpha
litter and soil
polyphagy/carnivory
Leptopodomorpha
littoral habit
(Saldidae)
Enicocephalomorpha
litter, soil, crevices
carnivory
?
algiophagous
Corixidae
shore litter
saprophagy;
necrophagy
carnivory
Nepomorpha
carnivory subaquatic



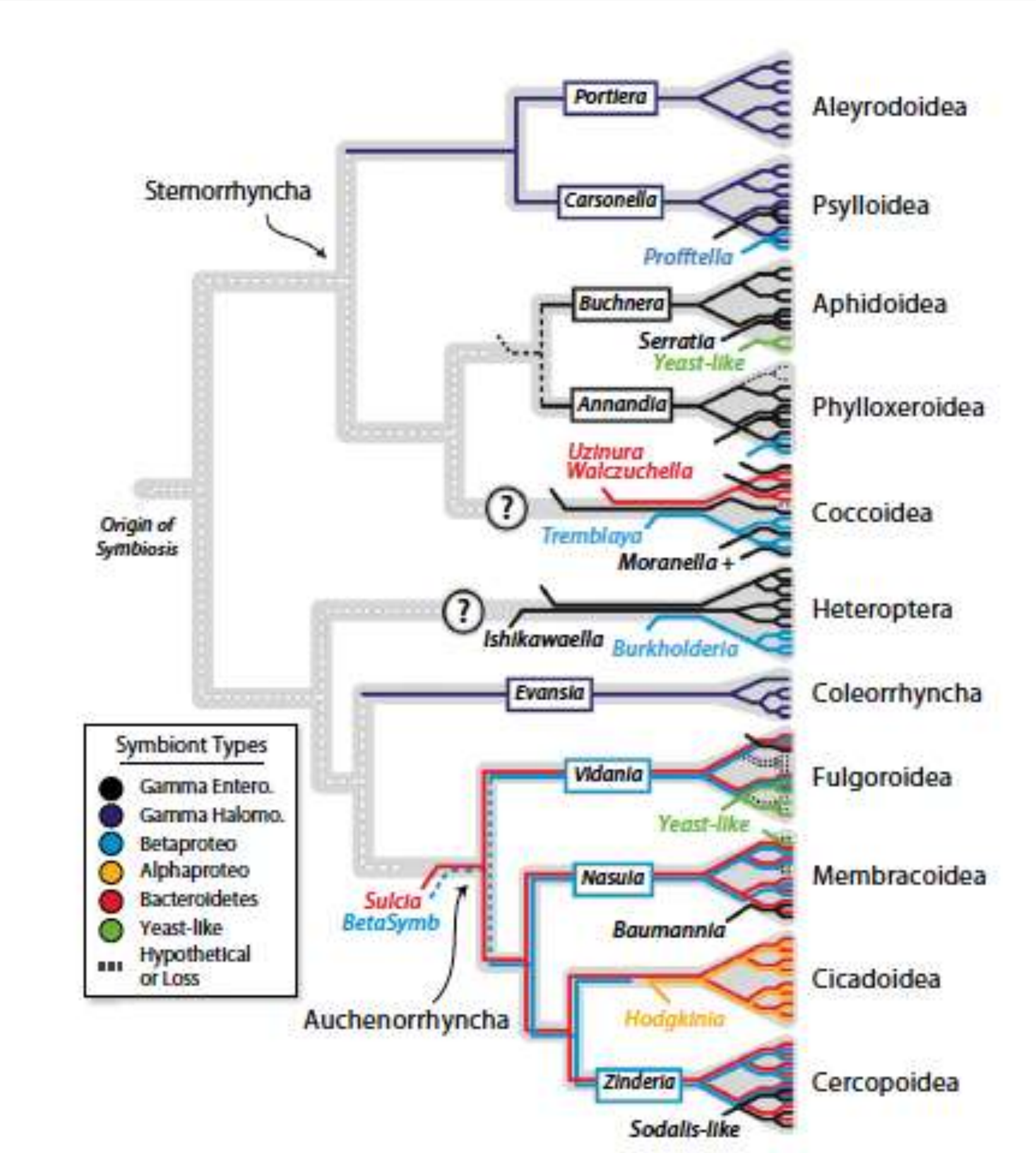
Li M. *et al.* 2012
nuclear DNA



Li H. *et al.* 2012
mitochondrial DNA

Episode 5

JURASSIC DIVERSIFICATION

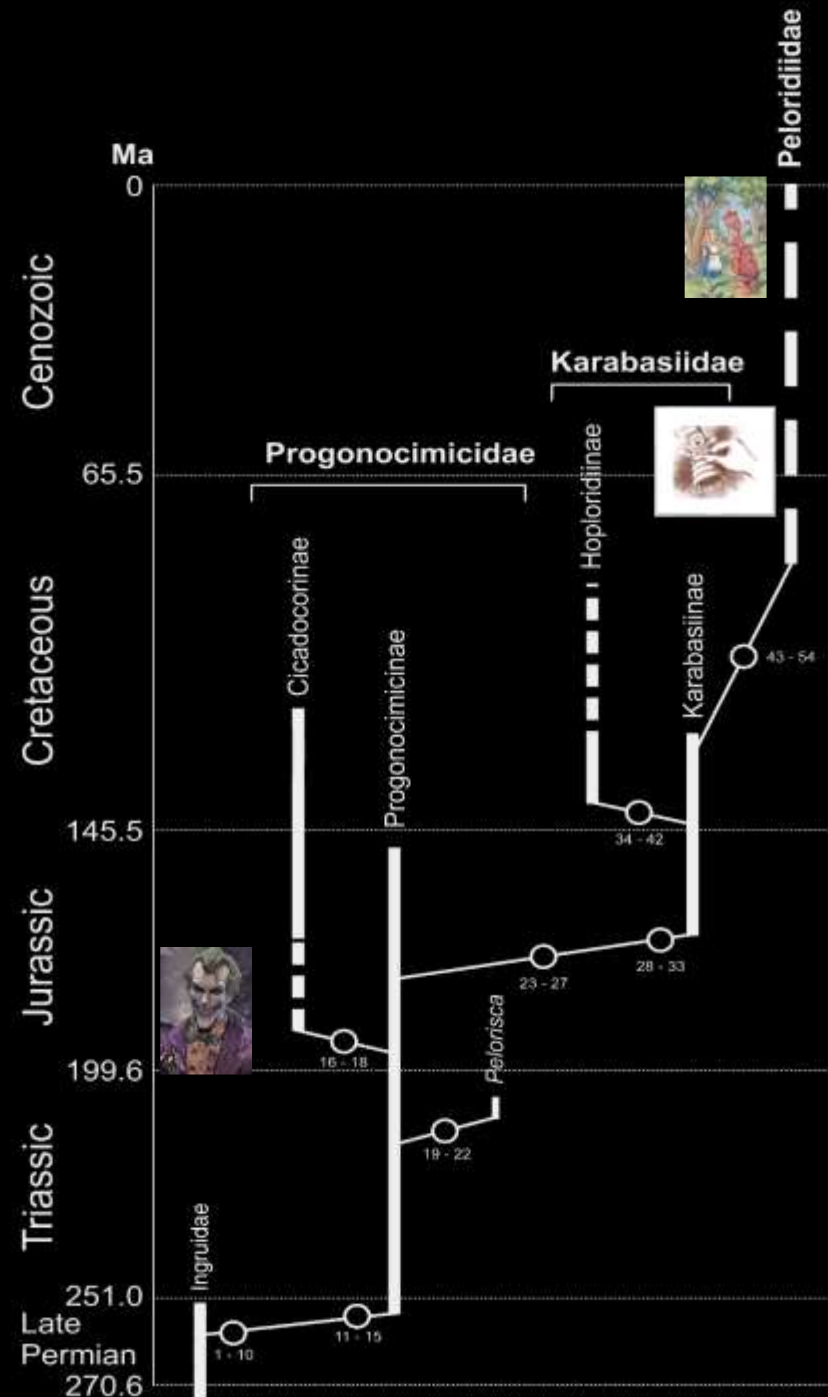


Summary of the acquisitions and losses of heritable endosymbionts across sap-feeding insects in the order Hemiptera.

Bennett & Moran 2015

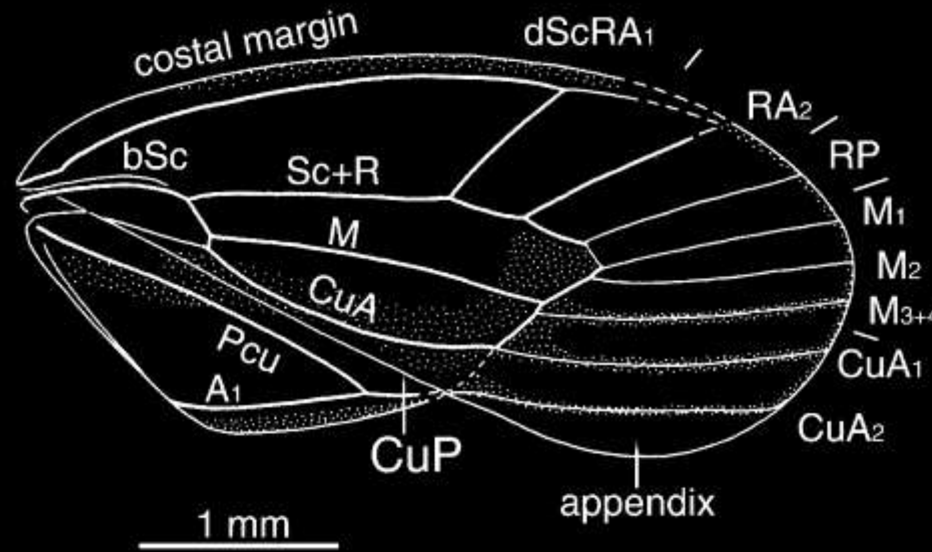
Coleorrhyncha

- originated in the Late Permian from Ingruidae (Scytinopteroidea);
- feeding on phloem of gymnosperms;
- flattened body;
- changes of head capsule structure (alveolarisation)
- supraantennal ledges fused over frontoclypeus;
- pronotum with paranota;
- asymmetry of tegmina due to overlapping of left over right – enlargement of membrane;
- membrane with appendix;
- wing-coupling apparatus of Heteroptera type;
- fore and mid tarsi 2-segmented;
- pygofer barrel-shaped, styli bent
- nymph flattened, cryptic, non jumping;
- imagines jumping;
- modern forms secondary in moss and litter
  - feeding on mosses (?) or fungi (?);



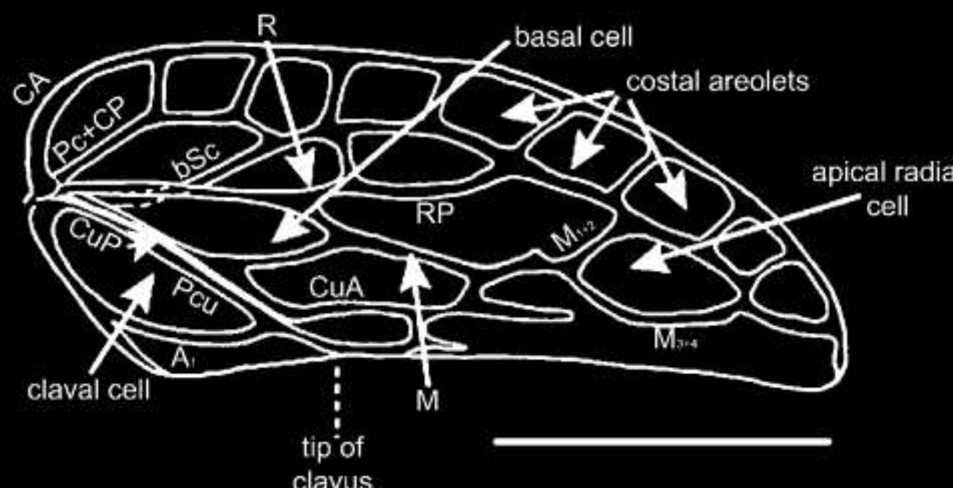
Mesocimex lini

Karabasia plana

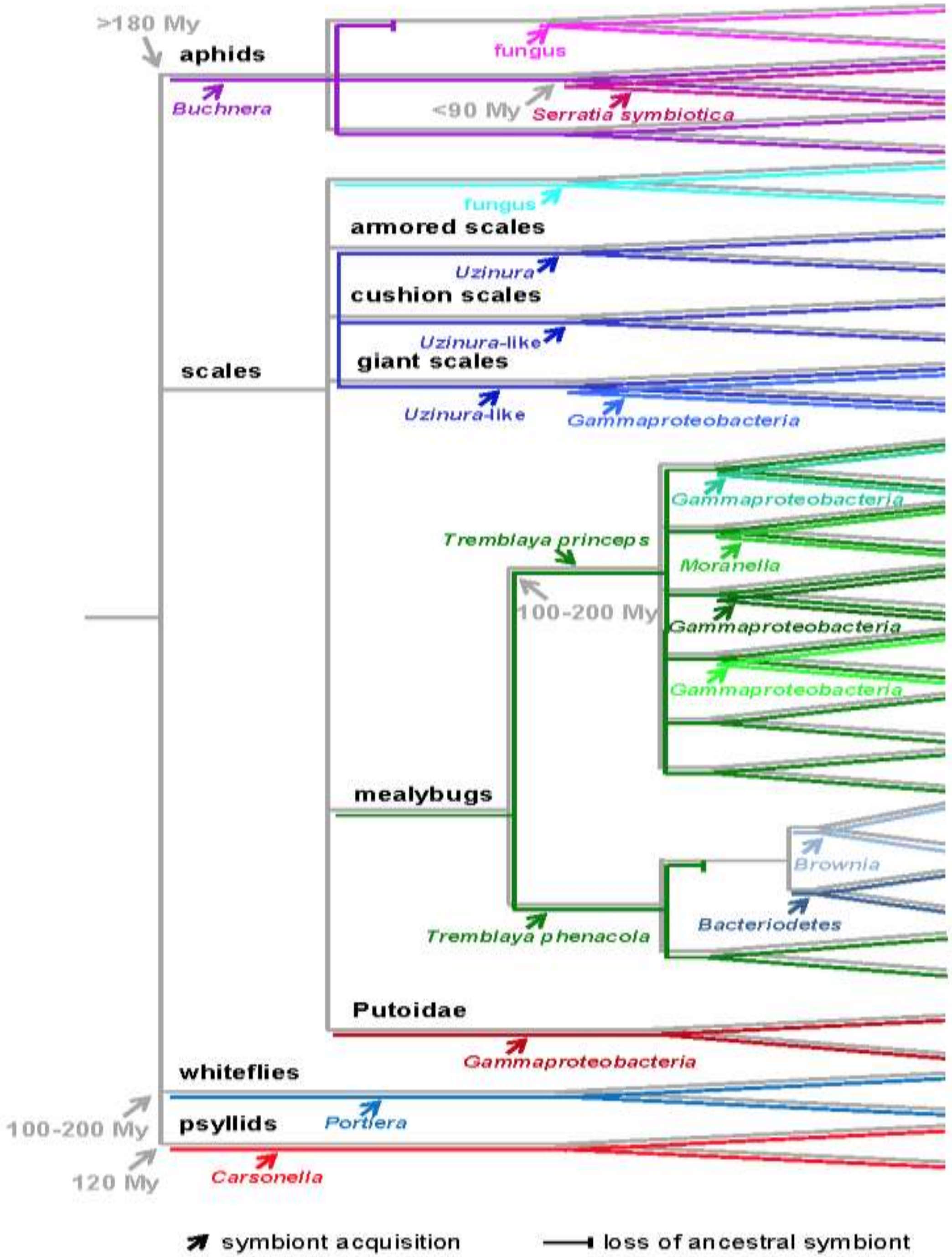


Eocercopis similis

Hackeriella veitchi



Peloridium hammoniorum



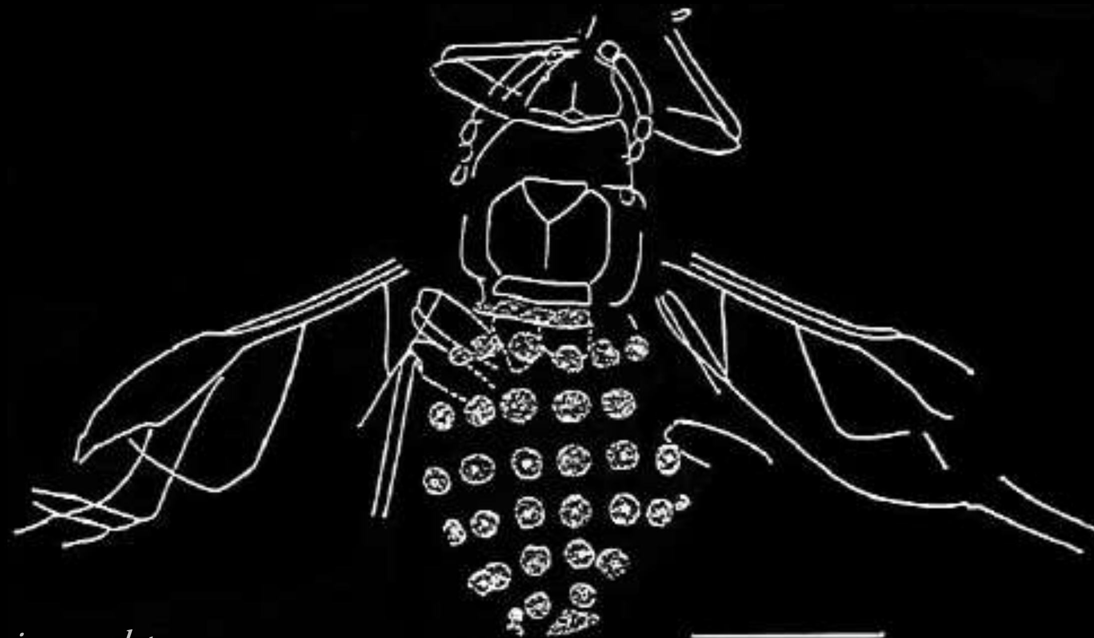
Multiple acquisitions and losses of symbionts among Sternorrhyncha

How strong is the influence of **Red King on evolutionary traits among various sternorrhynchan groups?**

Which are the advantages and perils of an evolutionary rabbit hole of heritable symbiosis?

If and how strong this effect interferes with Red Queen and Court Jester activites?

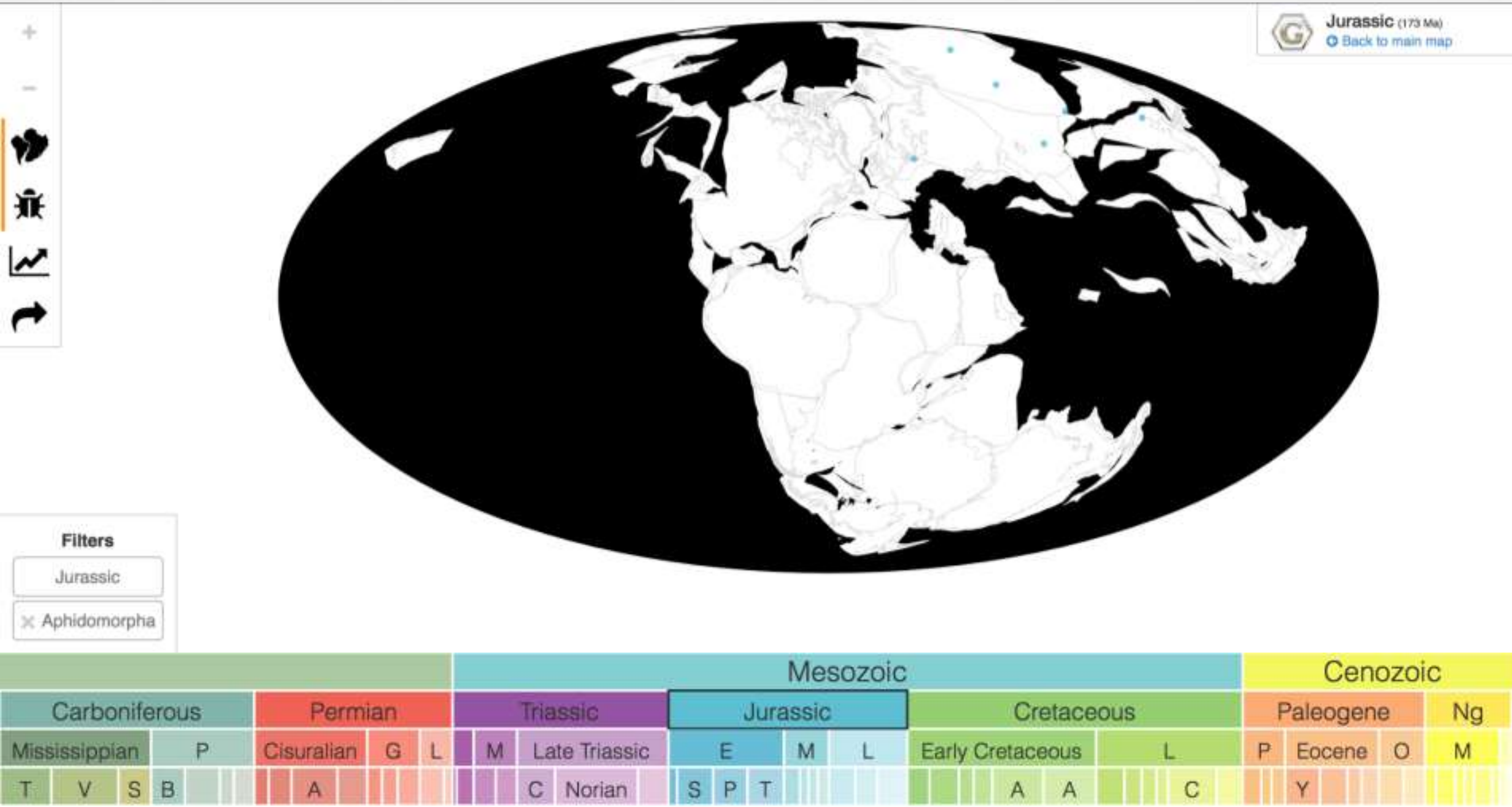
Toenschoff 2012



Szelegiewiczia maculata
Szelegiewicziidae

Aphis nerii (Aphididae) - cornicles

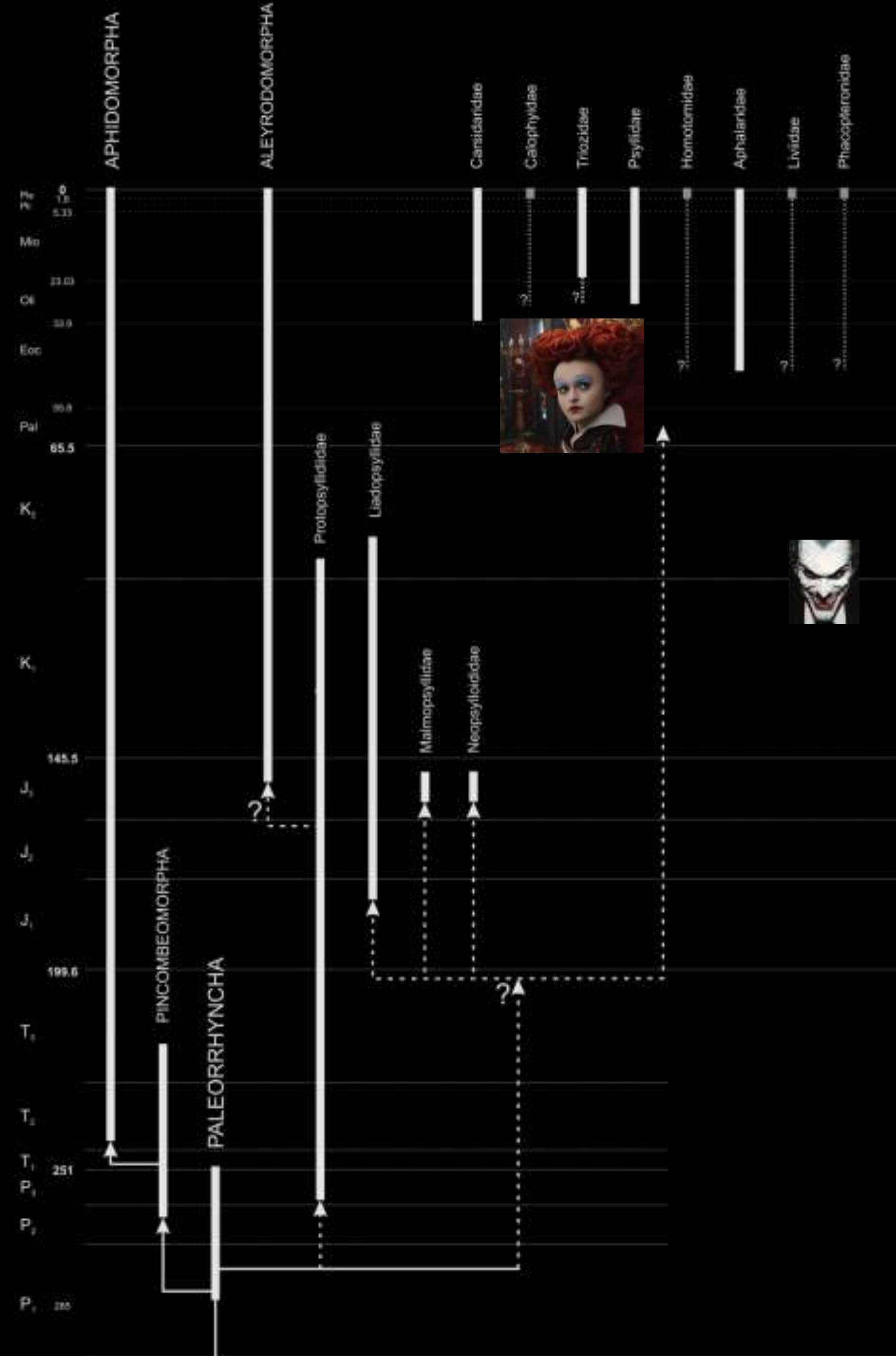
Pineus boerneri (Adelgidae) - ovipositor



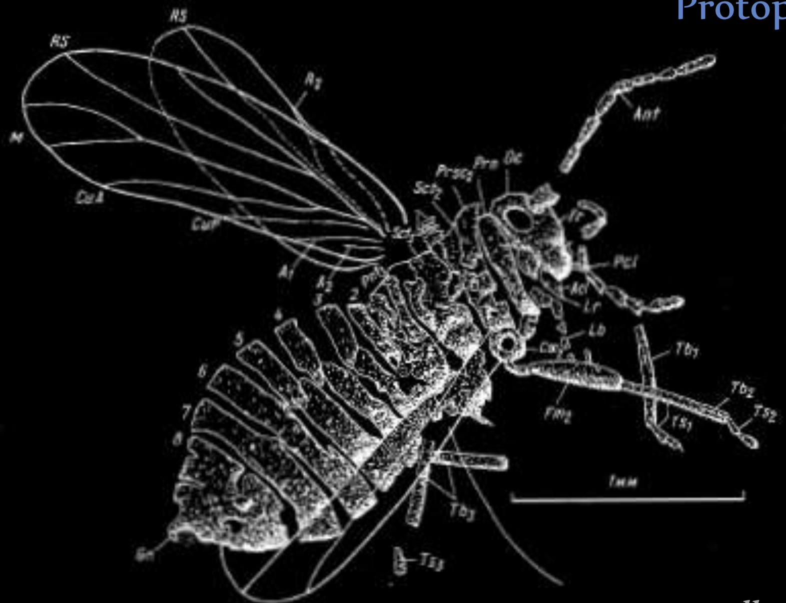
Aphidomorpha of the Jurassic are not very common, but their taxonomic diversity is relatively high, with several families: Juraphididae, Szelegiewicziidae, Palaeoaphididae, Oviparosiphidae,

Sternorrhyncha: Psyllaeformia

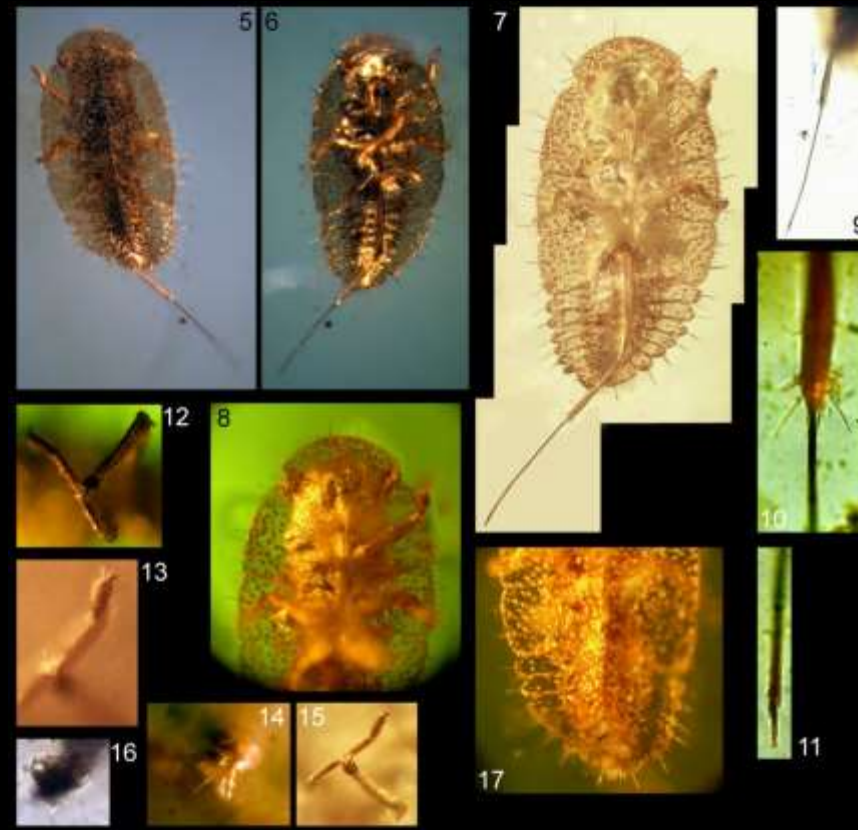
- separation in the Permian (?);
- retention of numerous features shared with Archescytinidae;
- diversification of Protopsyllidiidae in the Jurassic;
- origins of modern fauna related to Palaeogene radiation in concordance with angiosperms diversification;
- retained venational model;
- retained 10-segmented antennae;
- hind legs jumping;
- flattened nymphs;
- nymphs of Psylloidea with specialized setation;
- nymphs more strictly related to host-plants than imagines;



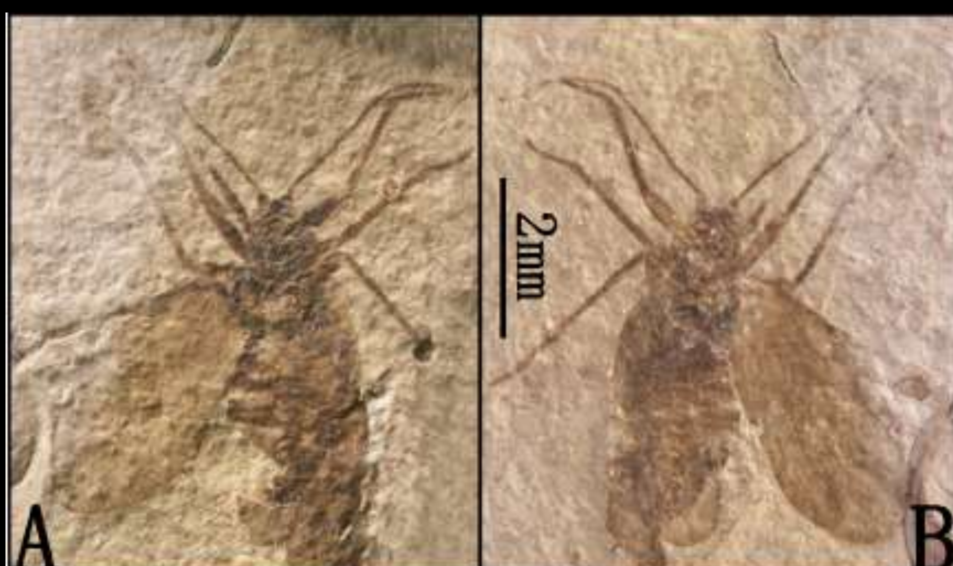
Protopsyllidiidae



Carpenterella pusilla

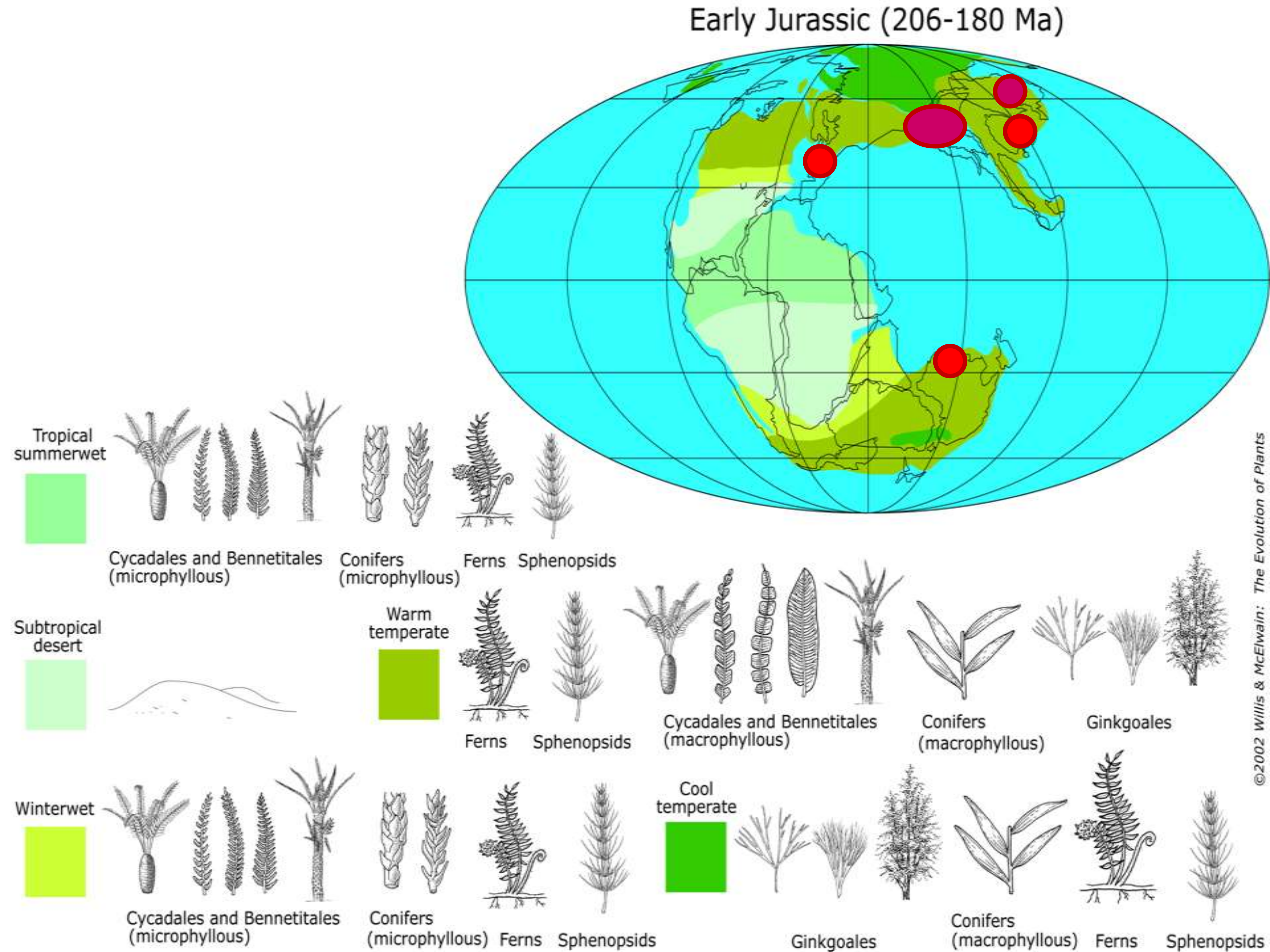


Talaya batraba

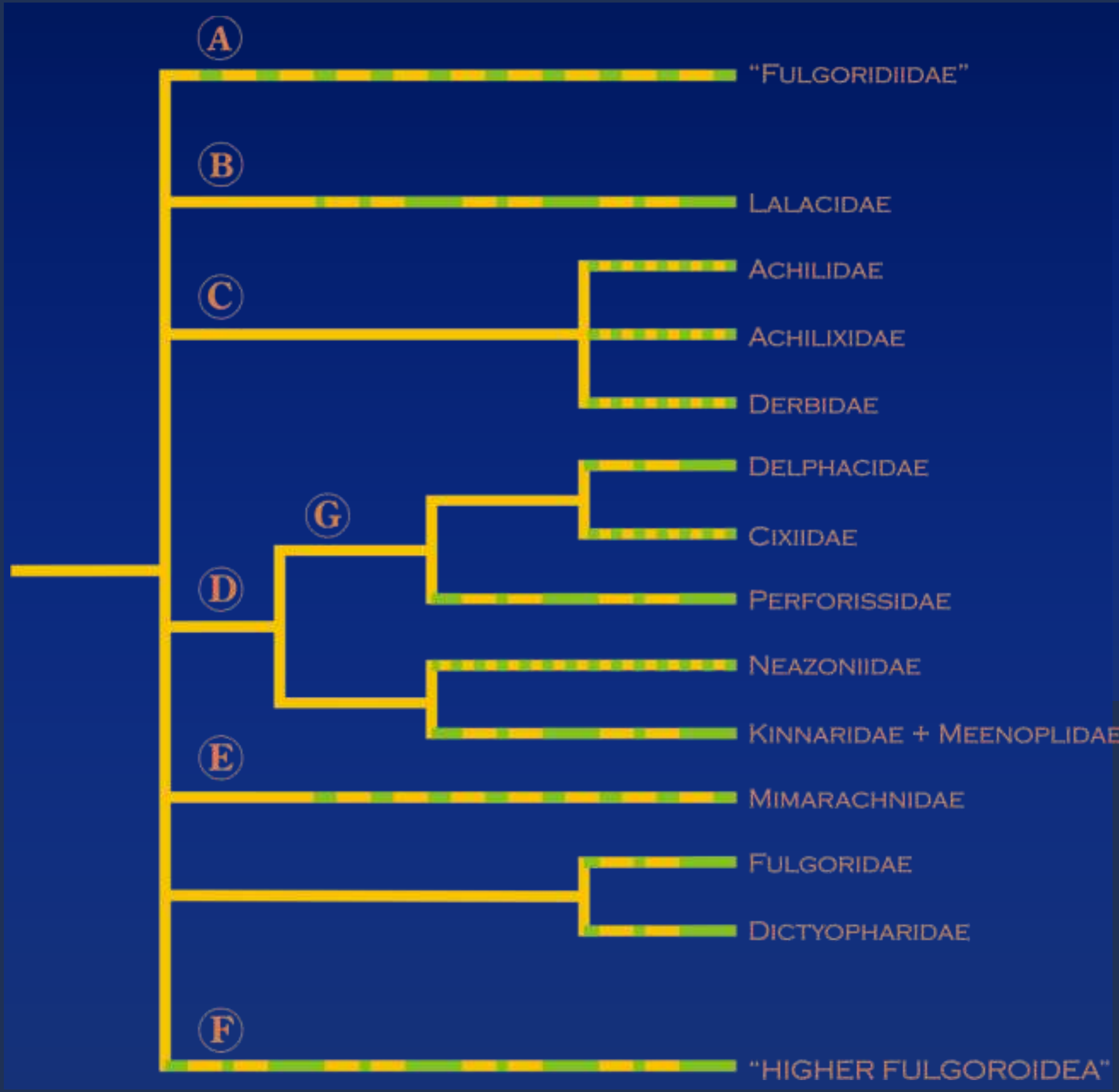


Poljanka hirsuta

Postopsyllidium emilyae



Early Jurassic (206-180 Ma)
Tropical summerwet
Cycadales and Bennetitales (microphyllous)
Conifers (microphyllous)
Ferns
Sphenopsids
Subtropical desert
Warm temperate
Ferns
Sphenopsids
Cycadales and Bennetitales (macrophyllous)
Conifers (macrophyllous)
Ginkgoales
Winterwet
Cycadales and Bennetitales (microphyllous)
Conifers (microphyllous)
Ferns
Sphenopsids
Cool temperate
Ginkgoales
Conifers (macrophyllous)
Ferns
Sphenopsids
©2002 Willis & McElwain: The Evolution of Plants

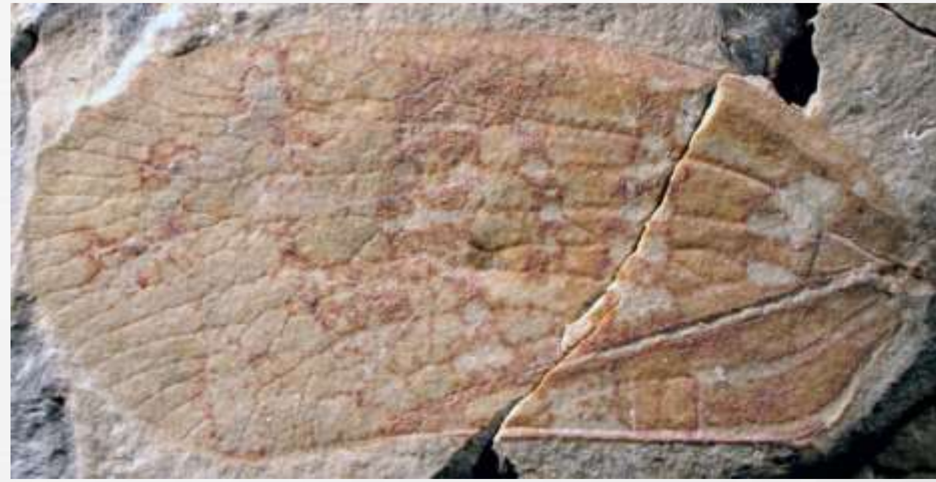


A – "Fulgoridiidae" - a paraphyletic unit, ancestral for other Fulgoroidea;
B – Lalacidae – one of the "short living" families from the times of Mid-Cretaceous biotic turnover;
C – Monophyletic clade with not-monophyletic families;
D – "Cixiidae-like" groups, monophyly is weakly supported;
E – Placement of Mimarachnidae is tentative;
F – So called "higher Fulgoroidea" seems to be not monophyletic clade;
G - Cixiidae could be not monophyletic.

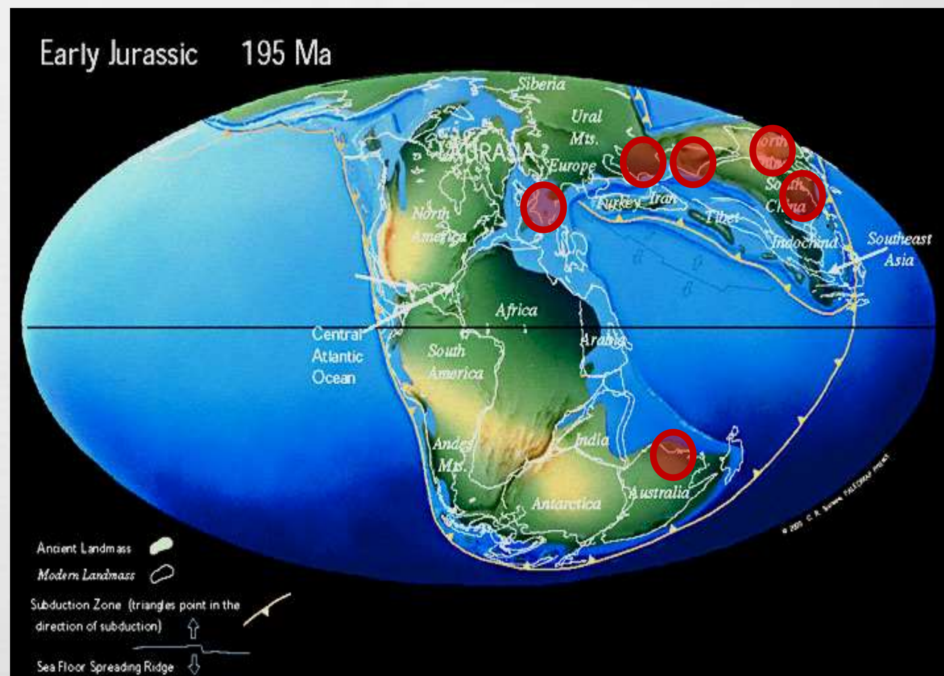
Jurassic Fulgoromorpha – variety, unity and ancestry for modern planthoppers

Fulgoridiidae

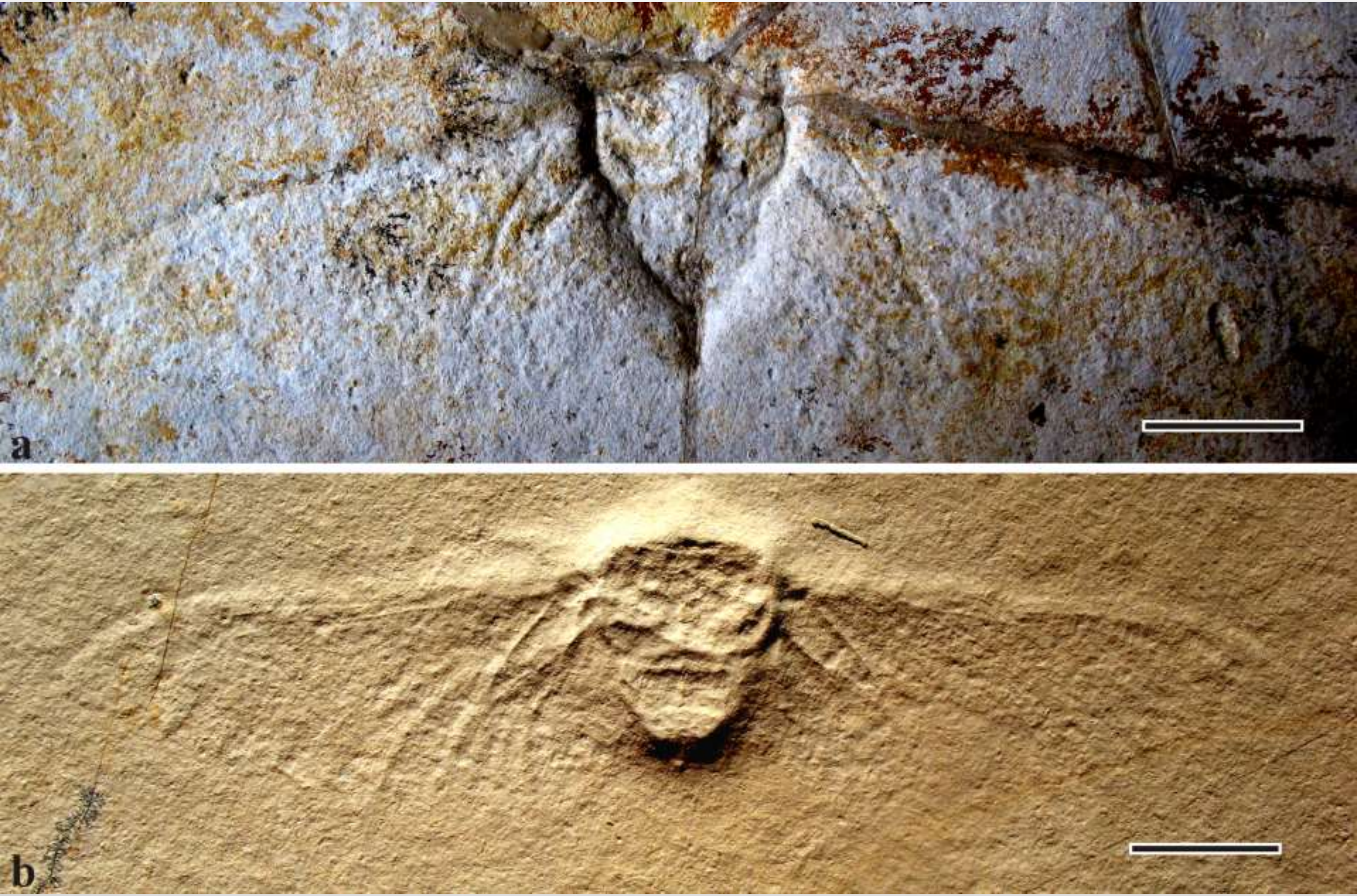
Auliezidium, Cixiites, Compactofulgoridium, Conofulgoridium, Eofulgoridium, Fulgoridiella, Fulgoridium, Fulgoridulum, Fulgoropsis, Margaroptilon, Metafulgoridium, Parafulgoridium, Procercofulgoridium, Productofulgoridium, Tetragonidium, Valvifulgoria



Qiyangiricaniidae: *Qiyangiricania cesta*



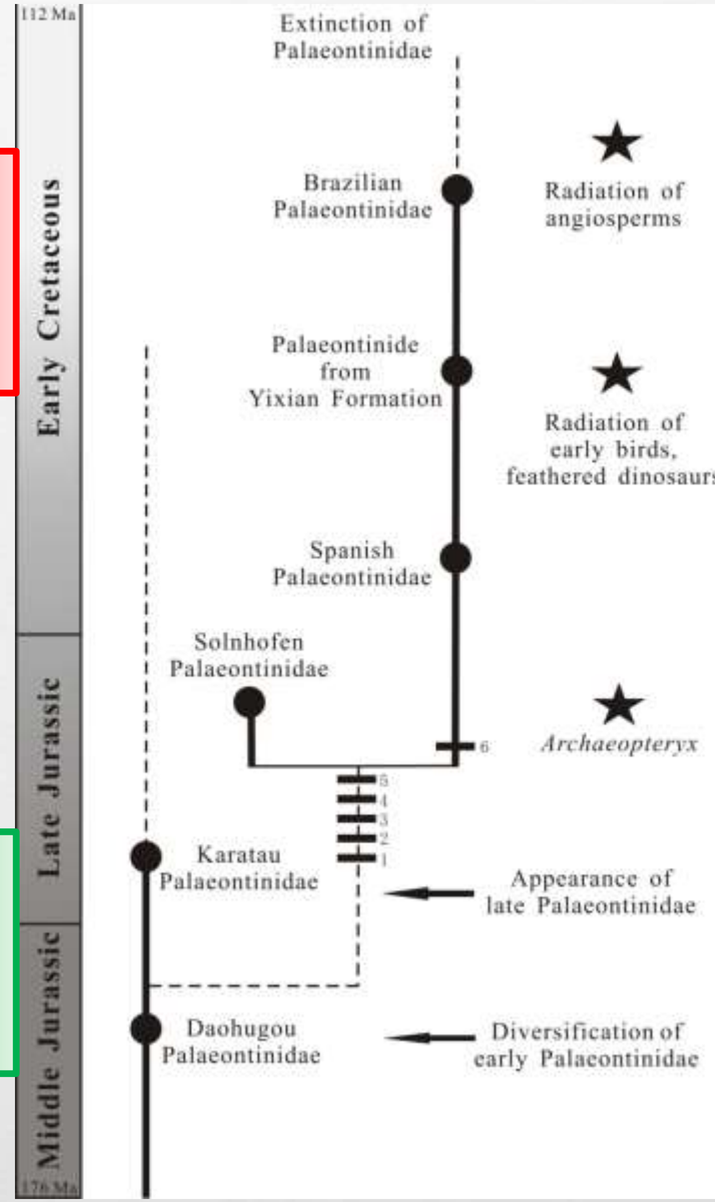
Jurassic Palaeontinidae – spectacular success

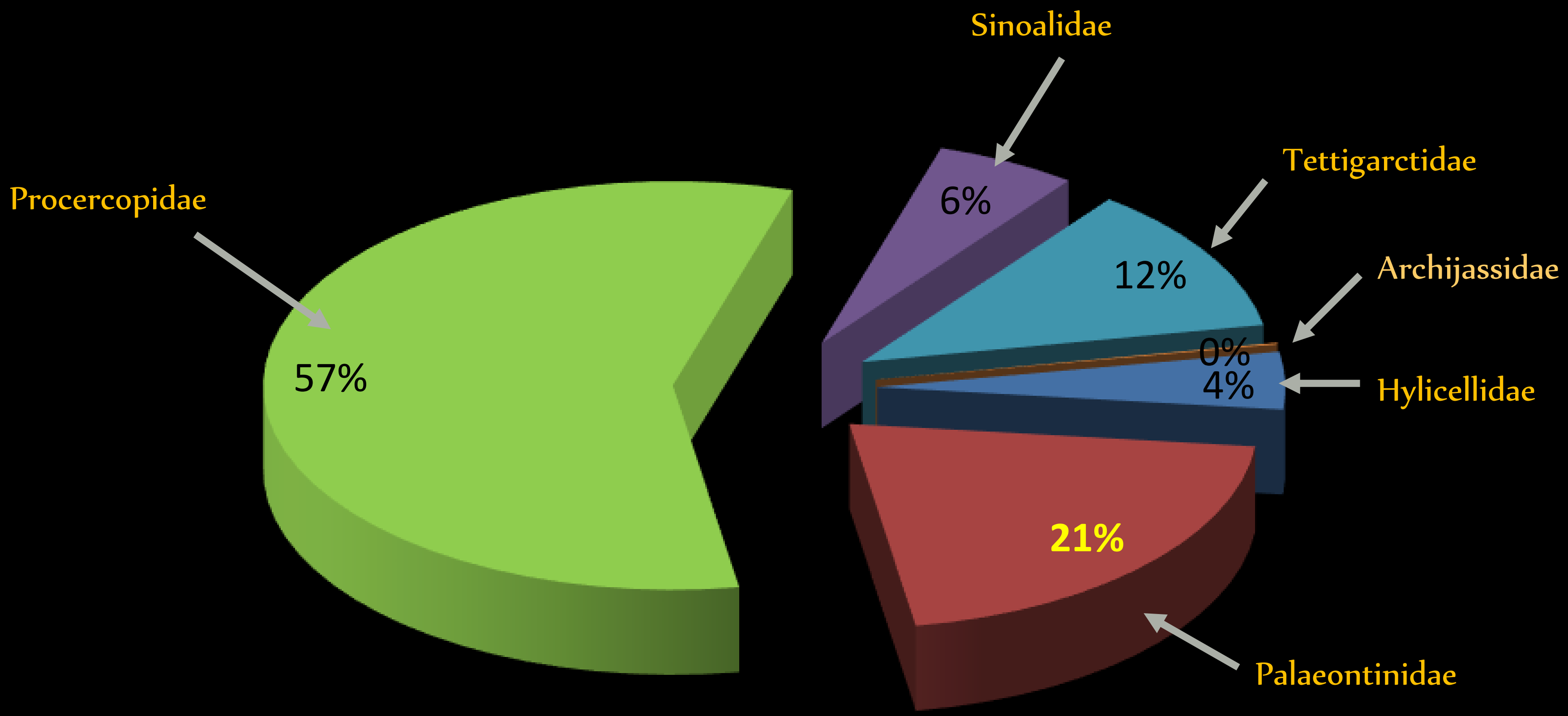


Palaeontinoidea Handlirsch, 1906

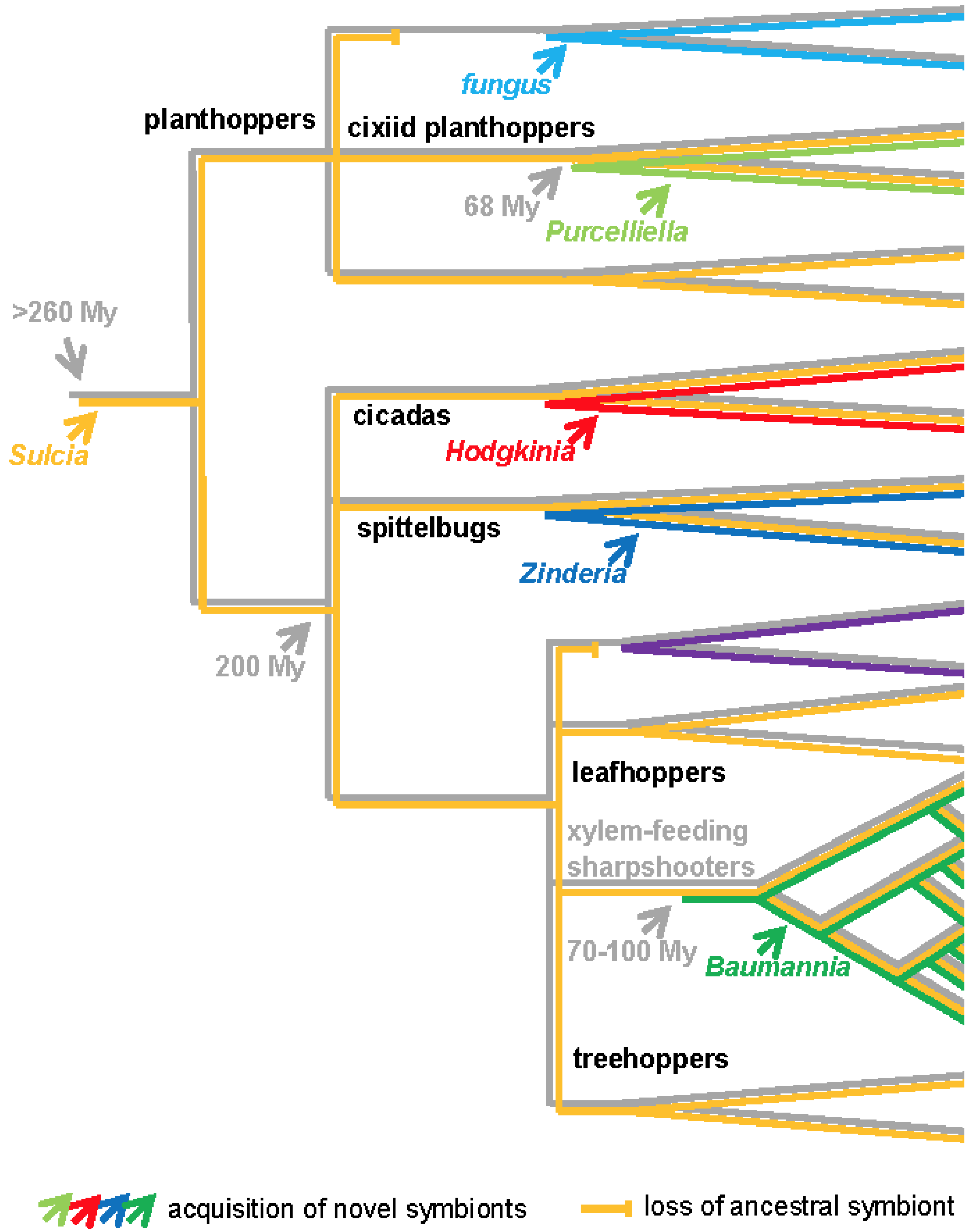
11 genera

22 genera





Jurassic reign of Procercopidae



Acquisition of symbionts among Euhemiptera

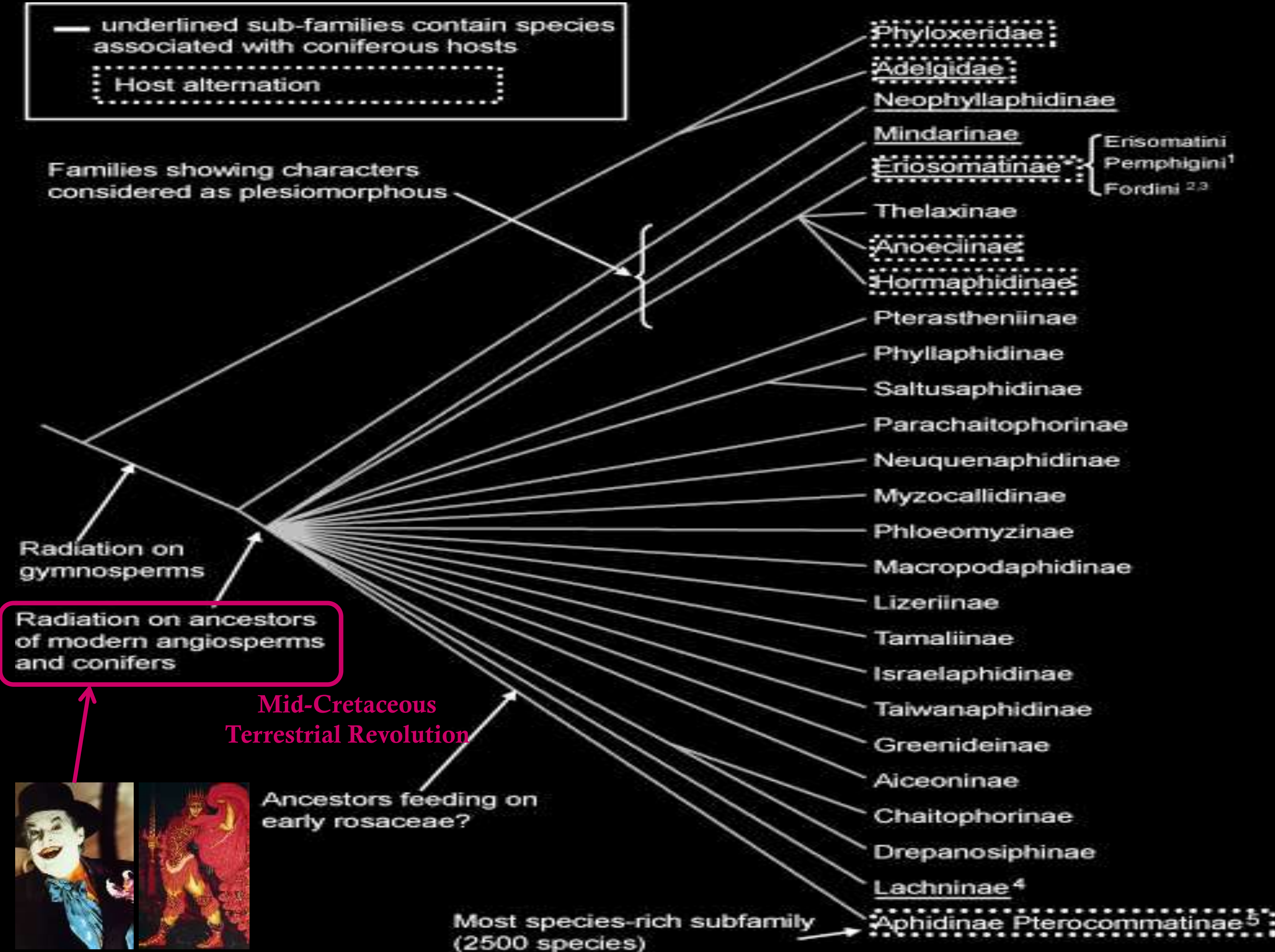
Euhemiptera

- known since the Carboniferous
- variable symbiotic systems
- phloem-feeding
- xylem-feeding (various adaptations)
- mesophyll-feeding (loss of symbionts)
- predators
- blood-feeders
- secondary plant-feeding

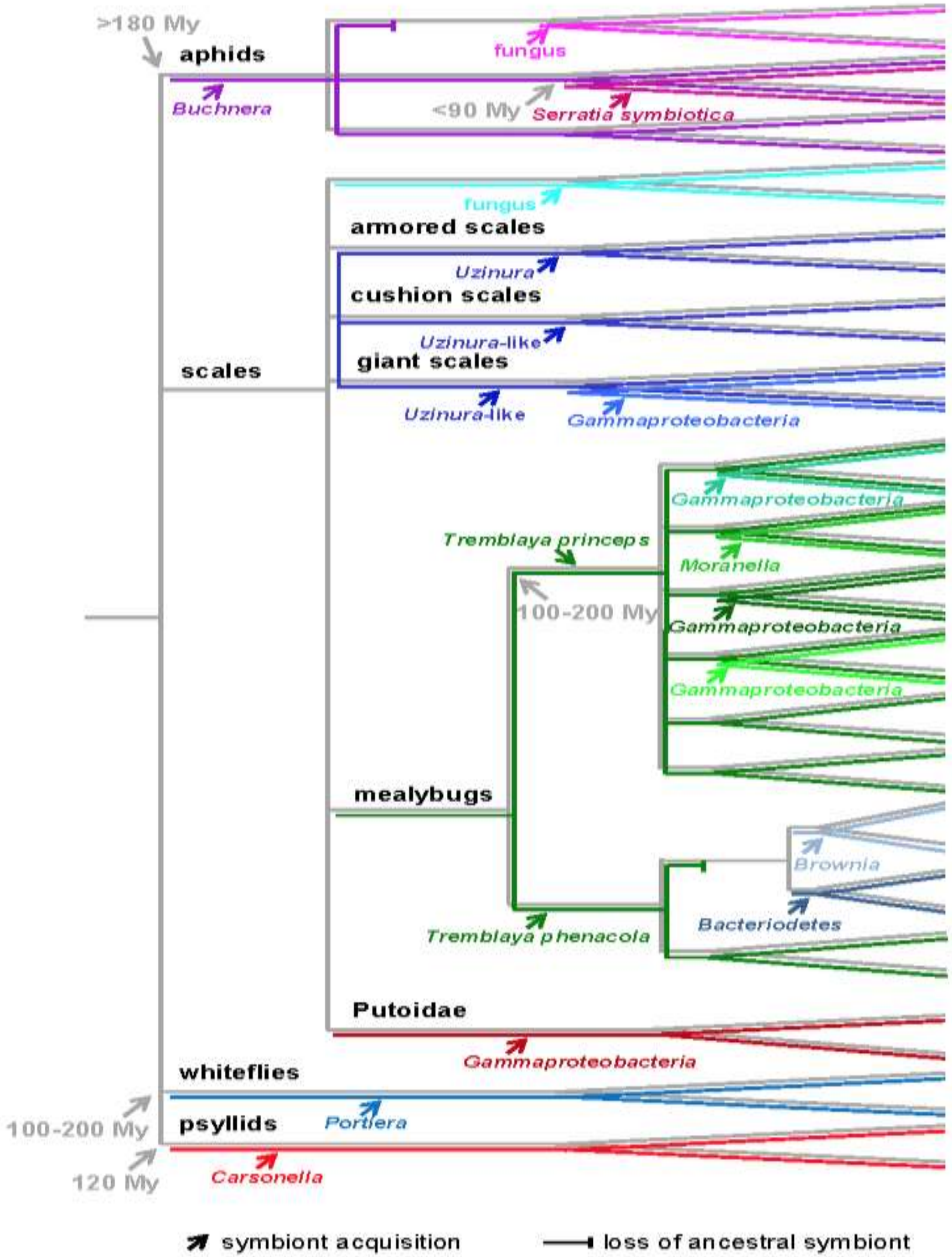
Toenschoff 2012

Episode 6

CRETACEOUS BIOTIC RE-ORGANIZATION AND CAINOZOIC DIVERSIFICATION



underlined sub-families contain species associated with coniferous hosts
Host alternation
Families showing characters considered as plesiomorphous
Radiation on gymnosperms
Radiation on ancestors of modern angiosperms and conifers
Mid-Cretaceous Terrestrial Revolution
Ancestors feeding on early rosaceae?
Most species-rich subfamily (2500 species)
Phyloxeridae
Adelgidae
Neophyllaphidinae
Mindarinae
Eriosomatinae
Erisomatini
Pemphigini[1]
Fordini [2,3]
Thelaxinae
Anoeciinae
Hormaphidinae
Pterastheniinae
Phyllaphidinae
Saltusaphidinae
Parachaitophorinae
Neuquenaphidinae
Myzocallidinae
Phloeomyzinae
Macropodaphidinae
Lizeriinae
Tamaliinae
Israelaphidinae
Taiwanaphidinae
Greenideinae
Aiceoninae
Chaitophorinae
Drepanosiphinae
Lachninae[4]
Aphidinae Pterocommatinae[5]



Multiple acquisitions and losses of symbionts among Sternorrhyncha

How strong is the influence of **Red King on evolutionary traits among various sternorrhynchan groups?**

Which are the advantages and perils of an evolutionary rabbit hole of heritable symbiosis?

If and how strong this effect interferes with Red Queen and Court Jester activites?

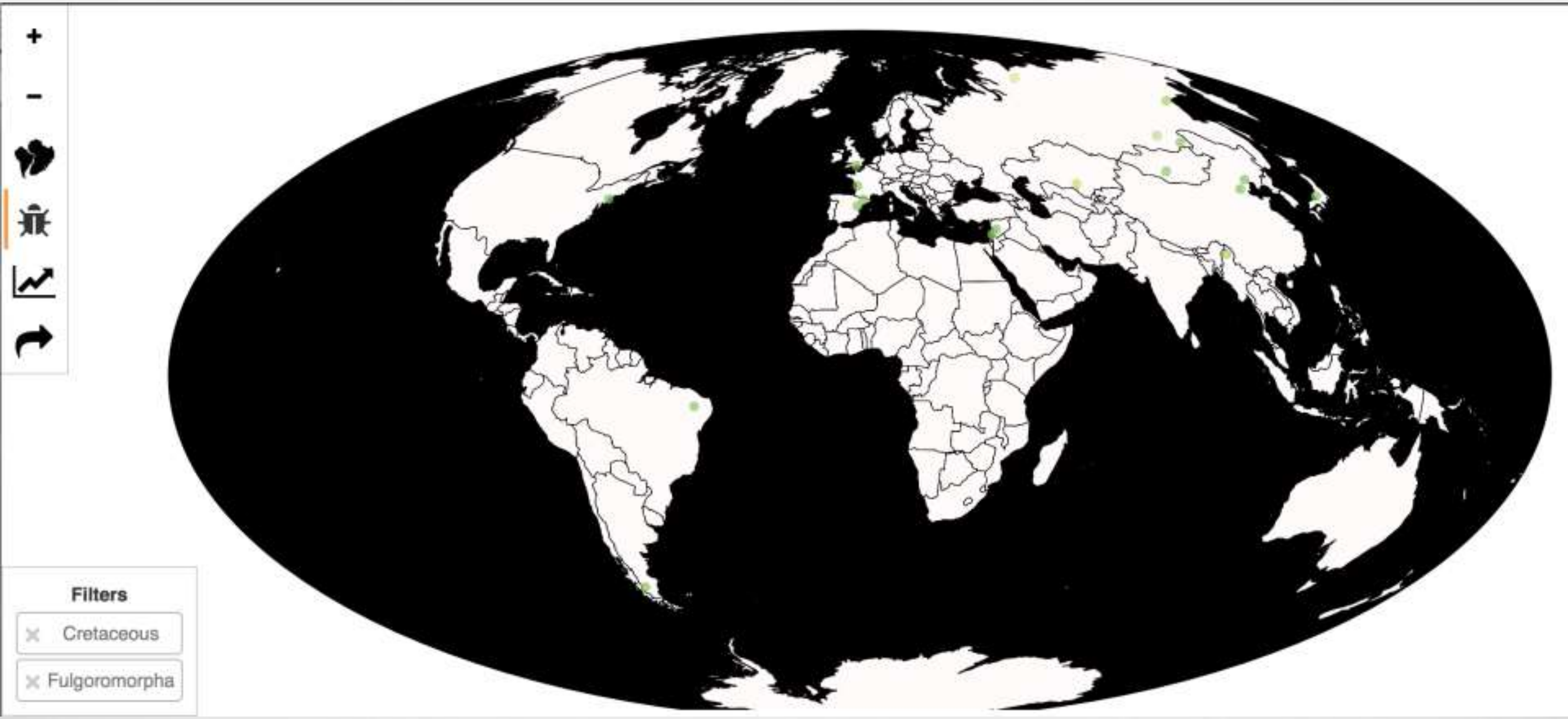
Toenschoff 2012

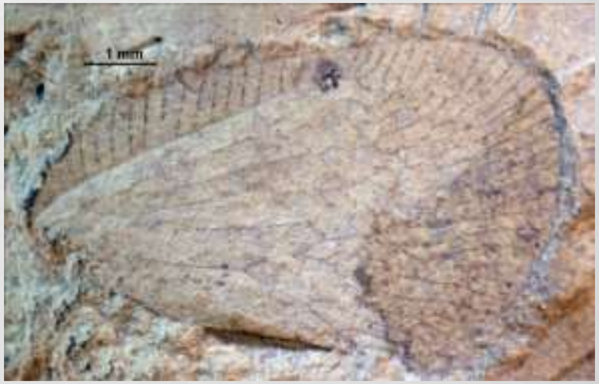










Filters
Cretaceous
Fulgoromorpha


1 mm

Mid-Cretaceous reorganization of biosphere

◆extinction of Paleozoic and many Mesozoic groups (e.g. Palaeontinidae, some Fulgoroidea, some Sternorrhyncha)

◆modern groups appear and diversify due to new host plants (angiosperms) radiation

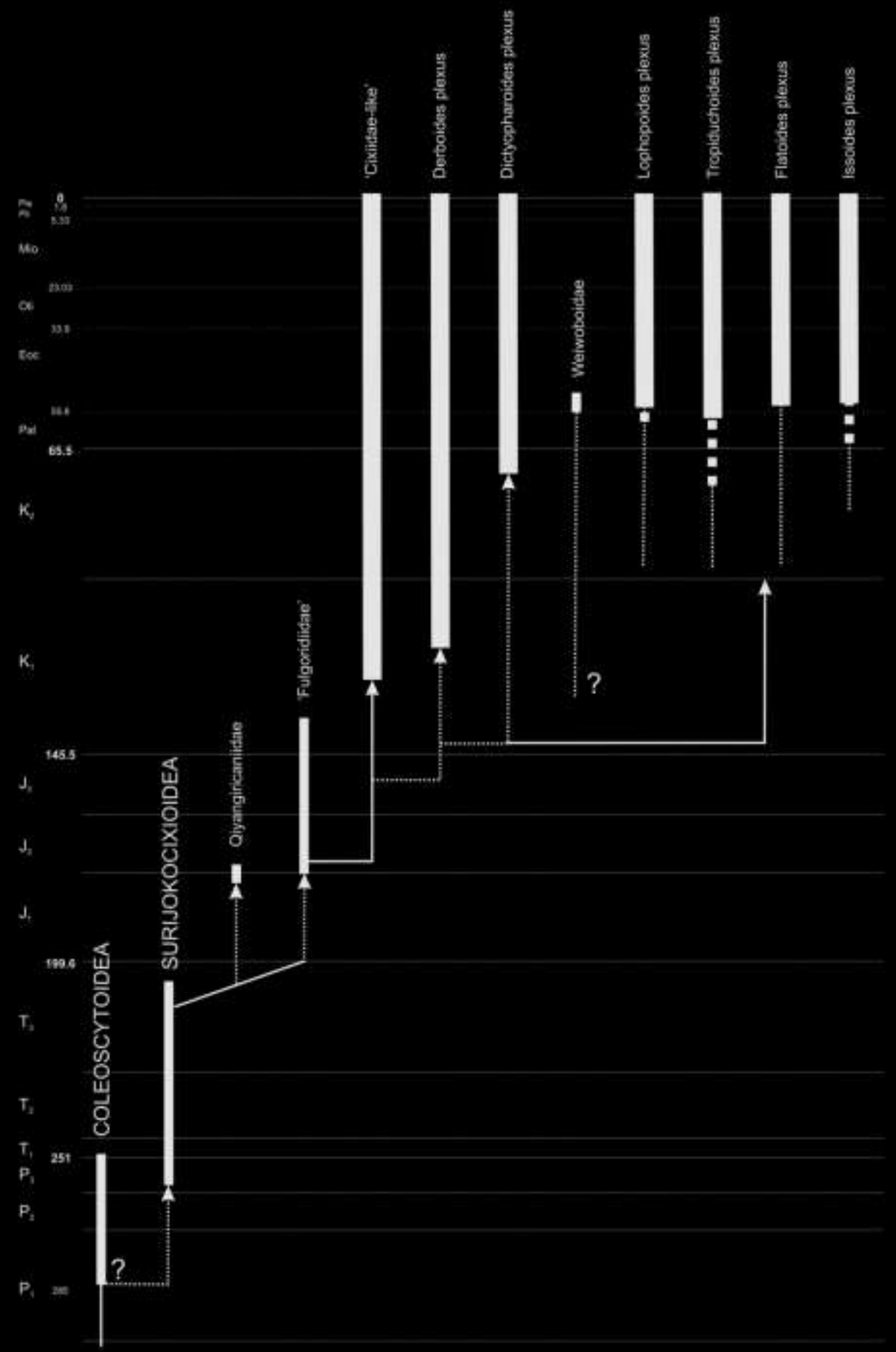
◆new endosymbiotic relationships? (as answer to host plant challenges)

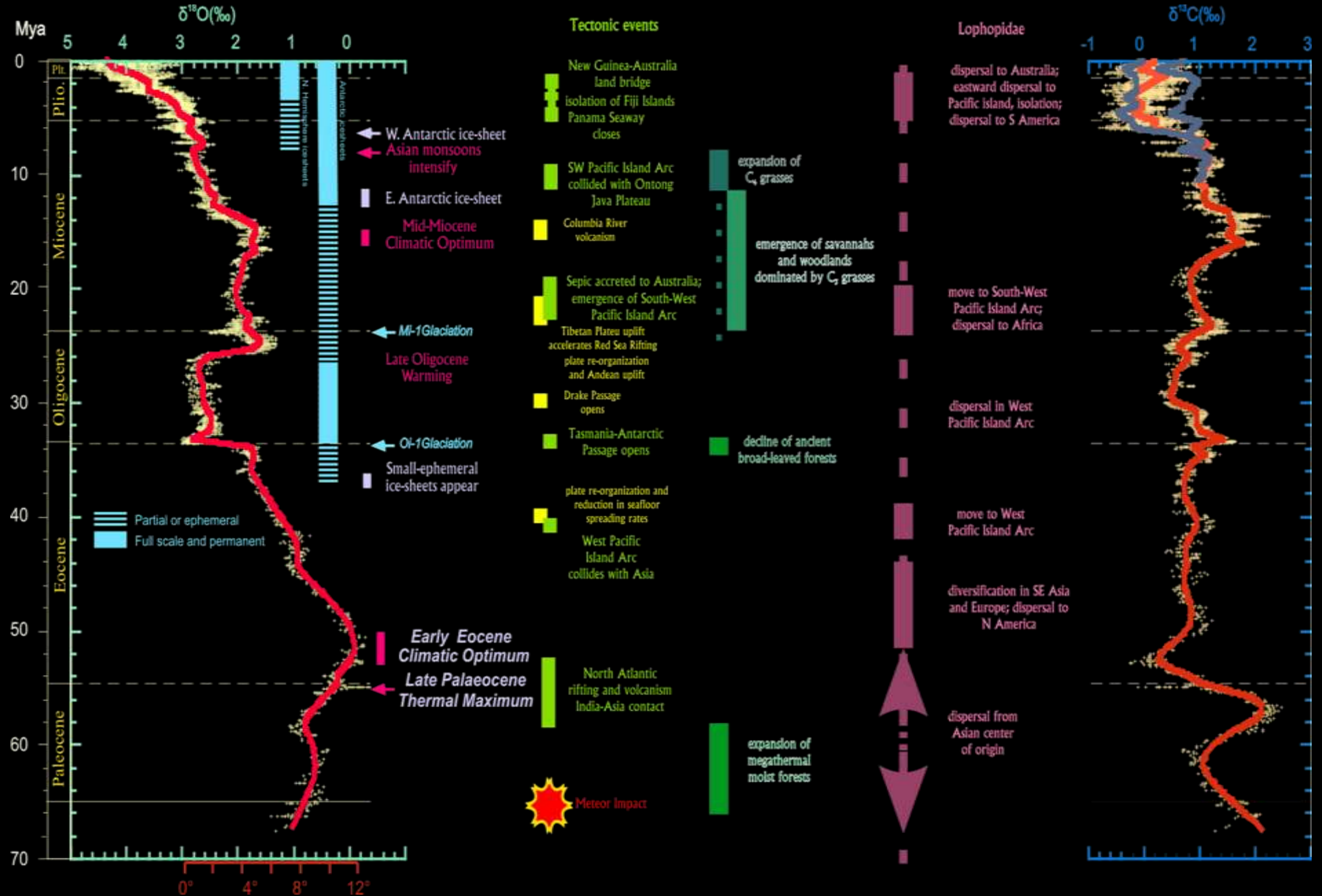
◆climatic changes – drying and cooling in Neogene

◆grassland expansion and grassland related lineages radiations

Fulgoromorpha: Fulgoroidea

- base of tegmen covered with enlarged tegula;
- tegminal basicubital triangle shortened;
- head with carinae;
- mesonotum with longitudinal carinae;
- metanotum with longitudinal carinae;
- 2nd and 3rd coxae stretched out;
- 2nd and 3rd coxae separated basally, remaining contiguous apically;
- nymphal 'gears'?
- jumping, free living nymphs

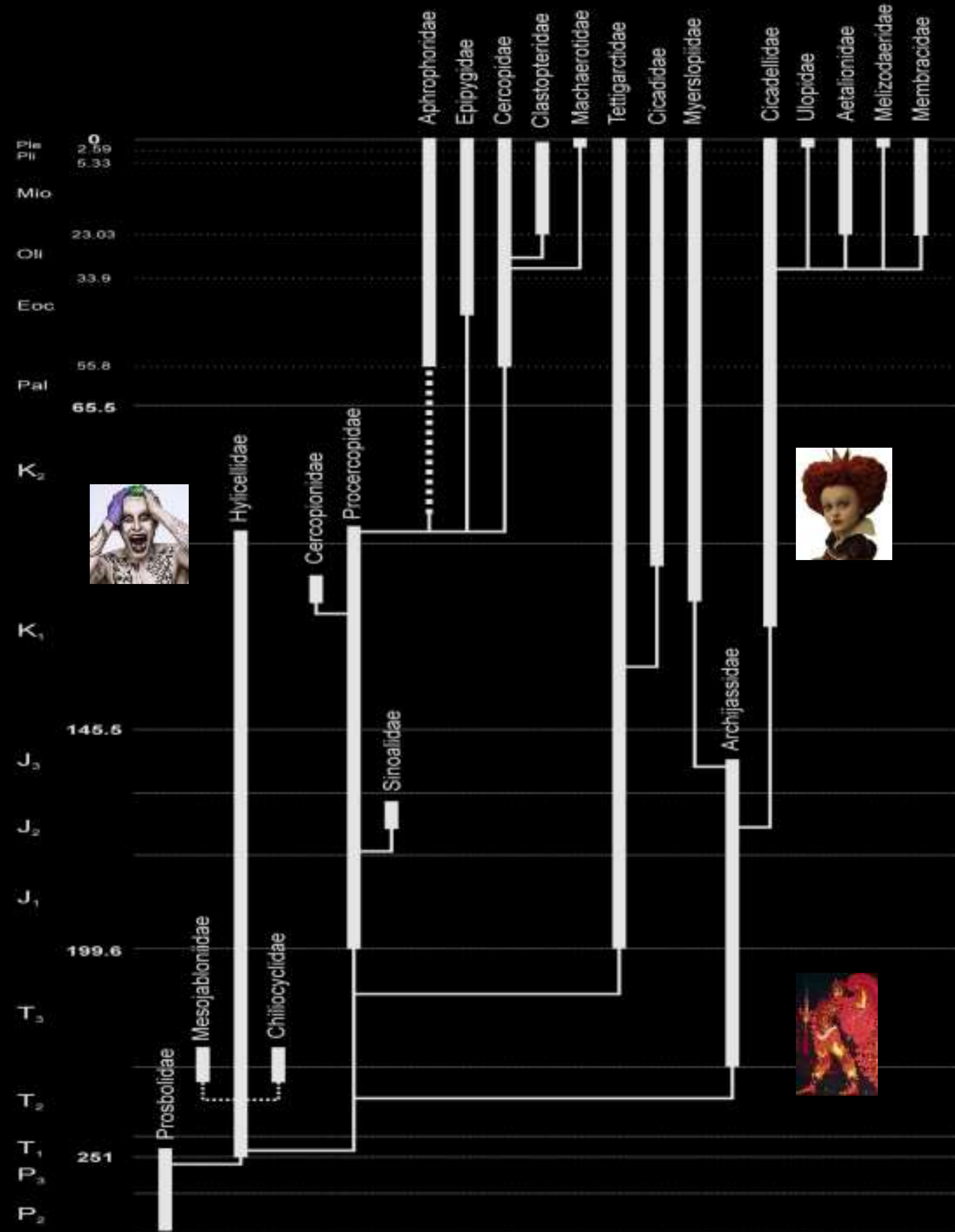




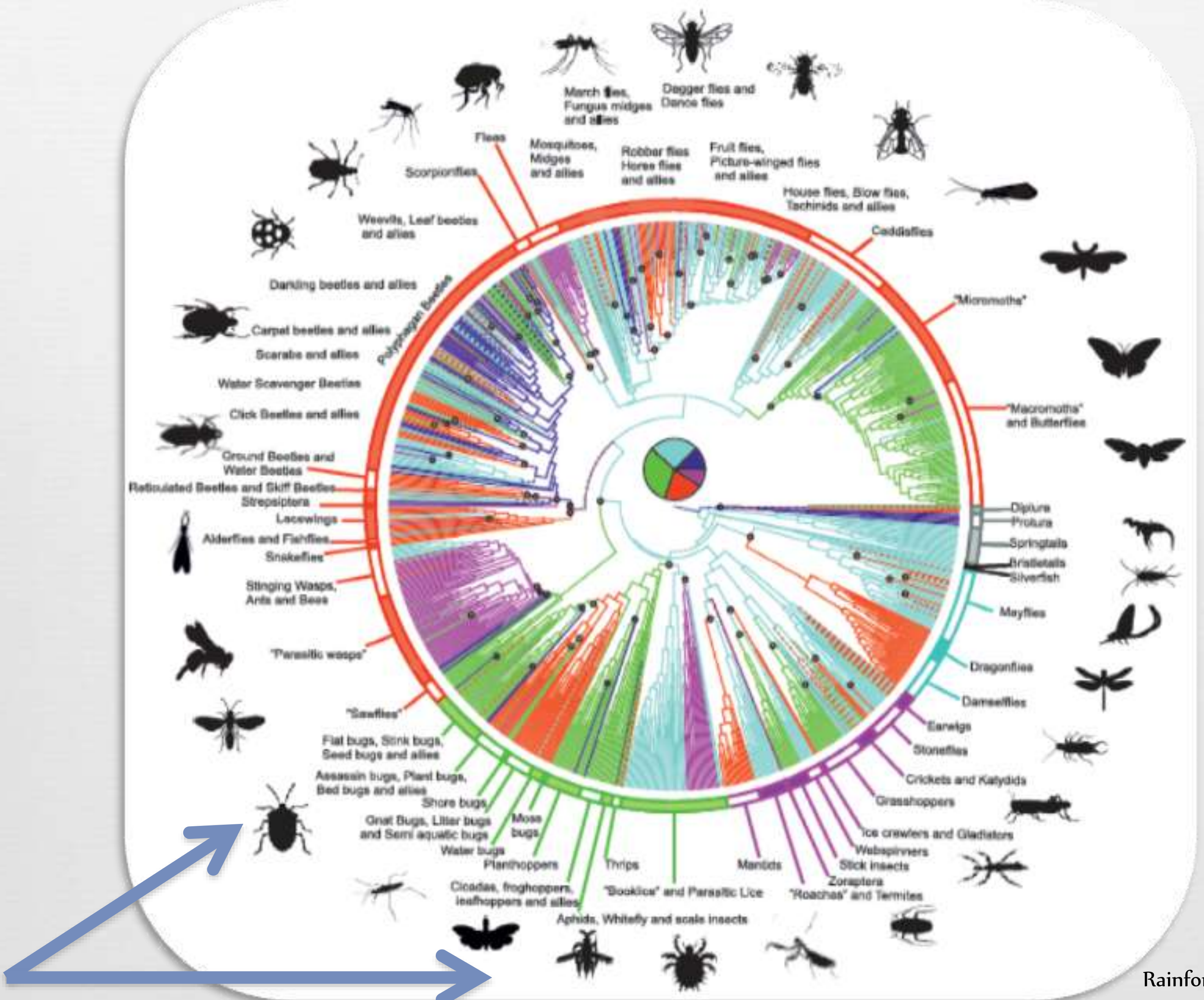
Mya
δ18O(‰)
Tectonic events
Lophopidae
δ13C(‰)
Plt.
Plio.
Miocene
Oligocene
Eocene
Paleocene
N. Hemisphere ice-sheets
Antarctic ice-sheets
W. Antarctic ice-sheet
Asian monsoons intensify
E. Antarctic ice-sheet
Mid-Miocene Climatic Optimum
Mi-1Glaciation
Late Oligocene Warming
Oi-1Glaciation
Small-ephemeral ice-sheets appear
Partial or ephemeral
Full scale and permanent
Early Eocene Climatic Optimum
Late Palaeocene Thermal Maximum
New Guinea-Australia land bridge
isolation of Fiji Islands
Panama Seaway closes
SW Pacific Island Arc collided with Ontong Java Plateau
Columbia River volcanism
Sepic accreted to Australia; emergence of South-West Pacific Island Arc
Tibetan Plateau uplift accelerates Red Sea Rifting
plate re-organization and Andean uplift
Drake Passage opens
Tasmania-Antarctic Passage opens
plate re-organization and reduction in seafloor spreading rates
West Pacific Island Arc collides with Asia
North Atlantic rifting and volcanism India-Asia contact
Meteor Impact
expansion of C4 grasses
emergence of savannahs and woodlands dominated by C4 grasses
decline of ancient broad-leaved forests
expansion of megathermal moist forests
dispersal to Australia; eastward dispersal to Pacific island, isolation; dispersal to S America
move to South-West Pacific Island Arc; dispersal to Africa
dispersal in West Pacific Island Arc
move to West Pacific Island Arc
diversification in SE Asia and Europe; dispersal to N America
dispersal from Asian center of origin

Clypeata

- The only surviving group of Cicadomorpha, present in the Recent fauna
- The recent groups are descendants of the Hylicelloidea
- Modern Cercopoidea diversified in the late Cretaceous
- Modern Cicadoidea diversified in the Cenozoic
- Membracoidea diversified in the late Jurassic/early Cretaceous
- Explosive diversification of Cicadellidae related to floristic and climatic changes in the Palaeogene
- Membracidae could be neotenous offshot of Cicadellidae, with origins influenced by the global cooling and drying events in the Oligocene/Miocene





Rainford and Mayhew 2015

Ecologies are denoted as follows: dark blue - fungivory, cyan - detritivory, green - phytophagy, red - predatory, magenta - parasitoids, and yellow - ectoparasites

The Red Queen Hypothesis suggests that continuing adaptation is needed in order for a species to survive and thrive. Everything else surrounding the species- the environment and the species' competitors – is changing. In one use of this hypothesis, every individual becomes an experiment. Every individual must find the way by adapting to changes.

The Court Jester Hypothesis suggests that environmental factors provide the drive for evolution in species. Big examples such as meteors and storms are often used to explain these environmental factors, but even day-to-day things like temperature can initiate a species to change or adapt.

Interestingly, the Red Queen and the Court Jester can work together. They explain different parts of a complex whole and they don't necessarily step on each other's toes.

…but there is another player in this evolutionary game - The Red King

Coevolution of two species is typically thought to favour the evolution of faster evolutionary rates helping a species keep ahead in the Red Queen race. In contrast, if species are in a mutualistic relationship, it was proposed that the Red King effect may act, where it can be beneficial to evolve slower than the mutualistic species. The Red King hypothesis proposes that the species which evolves slower can gain a larger share of the benefits.

How the Red King effect is involved and how it has influenced the evolutionary traits of the Hemiptera – this question remains open. However, the Hemiptera present number of internal symbiotic relationships as well as symbiotic relationships with external partners. Hence, this effect shold not be neglected in reconstruction of the evolutionary history of the Hemiptera.

However, this is fascination and frustration of research resolving the long-stanging puzzle of evolution.

Thank you!

Credits: Lewis Carroll, Leigh Van Valen, Anthony D. Barnosky, Carl T. Bergstrom, Michael Lachmann, Michael Benton, Helen Bonham-Carter, Jack Nicholson, Heath Ledger, Jared Leto, Tim Burton, Chris Nolan, David Ayer, Charles Darwin, Alfred R. Wallace, Claude Combes, Richard Dawkins, David M. Raup. Steven M. Stanley, Jan Koteja, Elżbieta Sontag, Barbara Kosmowska-Ceranowicz, Róza Kulicka, Karol Sabath, Jerzy Dzik, Zofia Pleń, International Commision on Zoological Nomenclature, International Commission on Stratigraphy, Adam Stroiński, Ryszard Szadziewski, Karol Szawaryn, Teresa Szklarzewicz, Anna Michalik, Aleksandra Urbanek, Elena R. Toenschoff, Nancy A. Moran, Gordon Bennett, James L. Rainford, Peter J. Mayhew, Peter A. Allison, David J. Bottjer, Peter Ax, Alexandr P. Rasnitsyn, Alexandr G. Ponomarenko, Alexandr F. Emeljanov, Dimitri E. Shcherbakov, Kiril Yu. Eskov, Vladimir V. Zherikhin, Rolf G. Beutel, Viktor Hartung, Bo Wang, Łukasz Rostkowski, Anja Orthodox, Maynard J. Keenan, Alison Goldfrapp, Will Gregory, Max Richter, Mark Hollis, Aleksandra Kaczkowska, Derek E.G. Briggs, Eric Buffetaut, Dave Penney, Andre J. Ross, Dany Azar, Andre Nel, Nikita Yu. Kluge and many, many others….

The talk presents unpublished results and interpretations

Episodes in history of the Hemiptera