Welcome to the *Trissolcus* workshop!

Introduction to the Hymenoptera

Smithsonian Institution

USDA

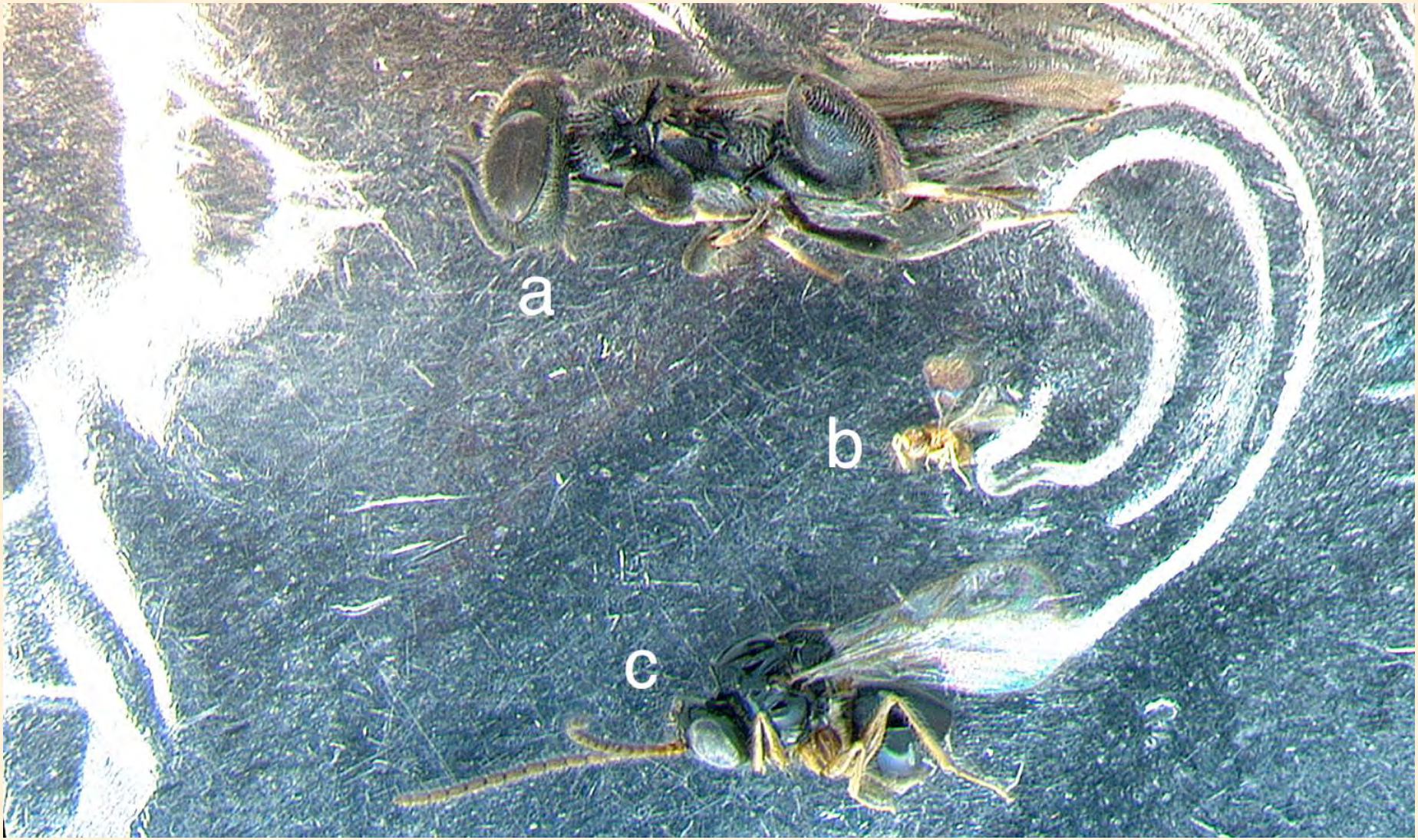
What we hope you get from this workshop…

- **An introduction to the diversity the order offers, and guidance on identification**
- **How to collect Hymenoptera, and specifically *Trissolcus***
- **How to handle samples from the field**
- **How to correctly mount and label specimens**
- **New friends**
- **A challenge that could last your entire lifetime…**

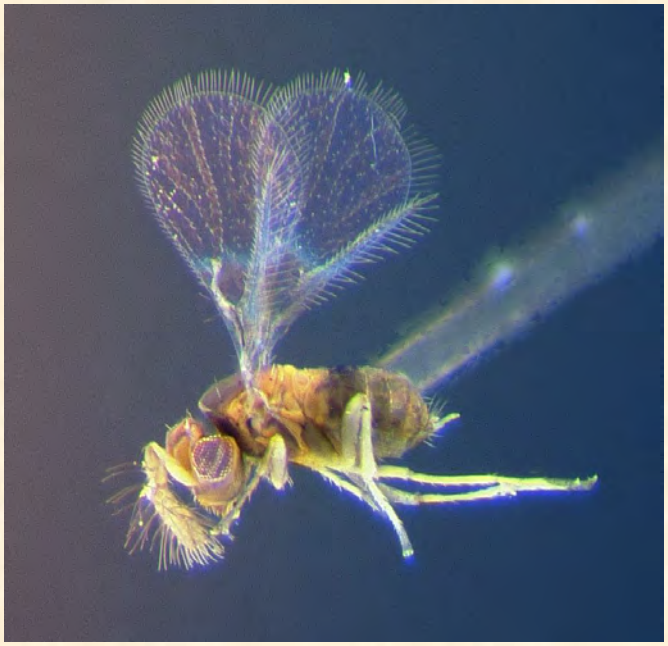

© Department of Entomology, UC Riverside


© Department of Entomology, UC Riverside

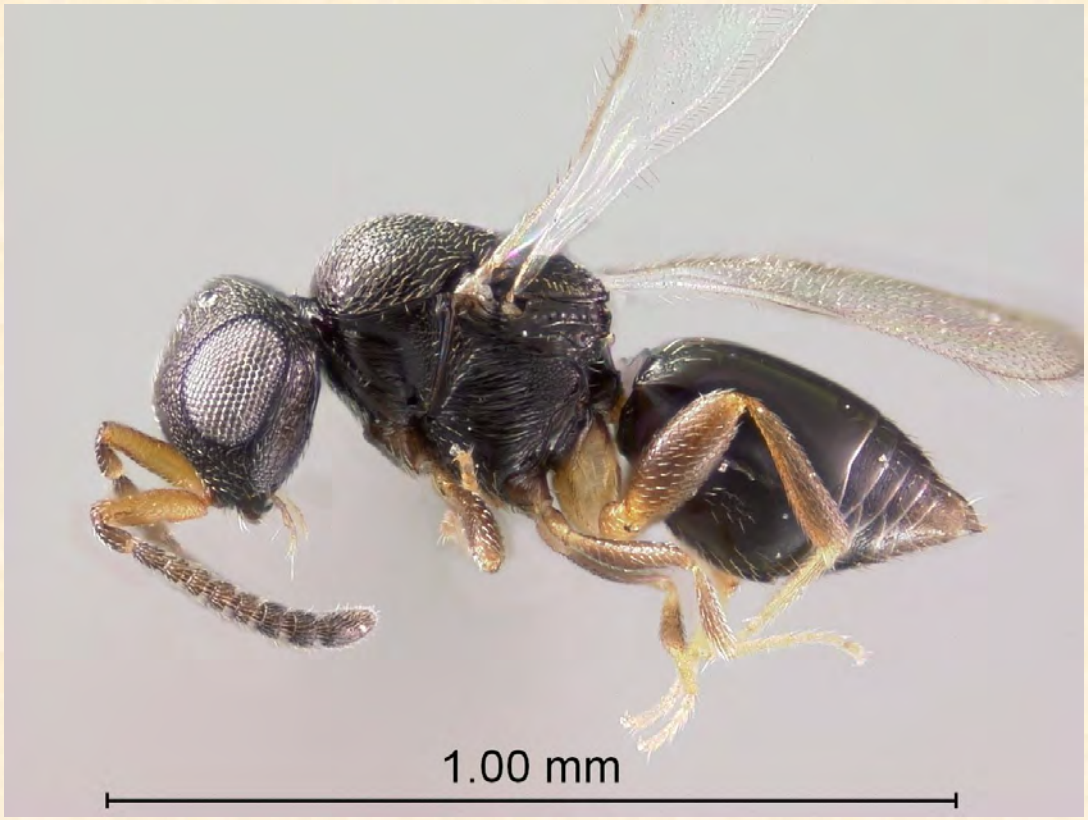

© Department of Entomology, UC Riverside



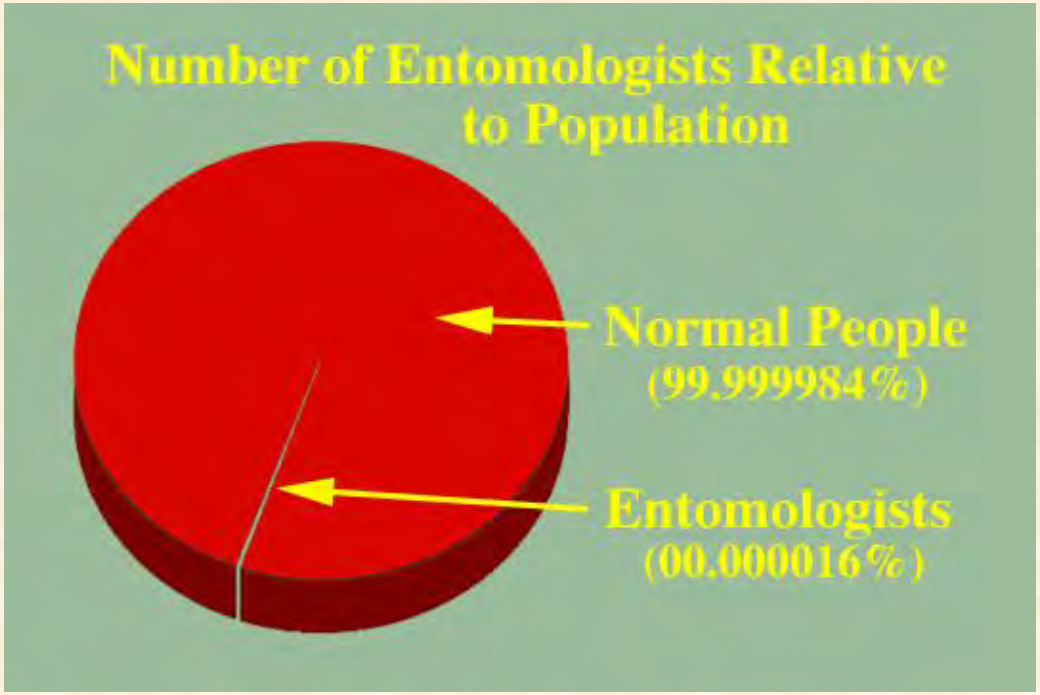
Challenging to work with: small, speciose, cryptic, ubiquitous

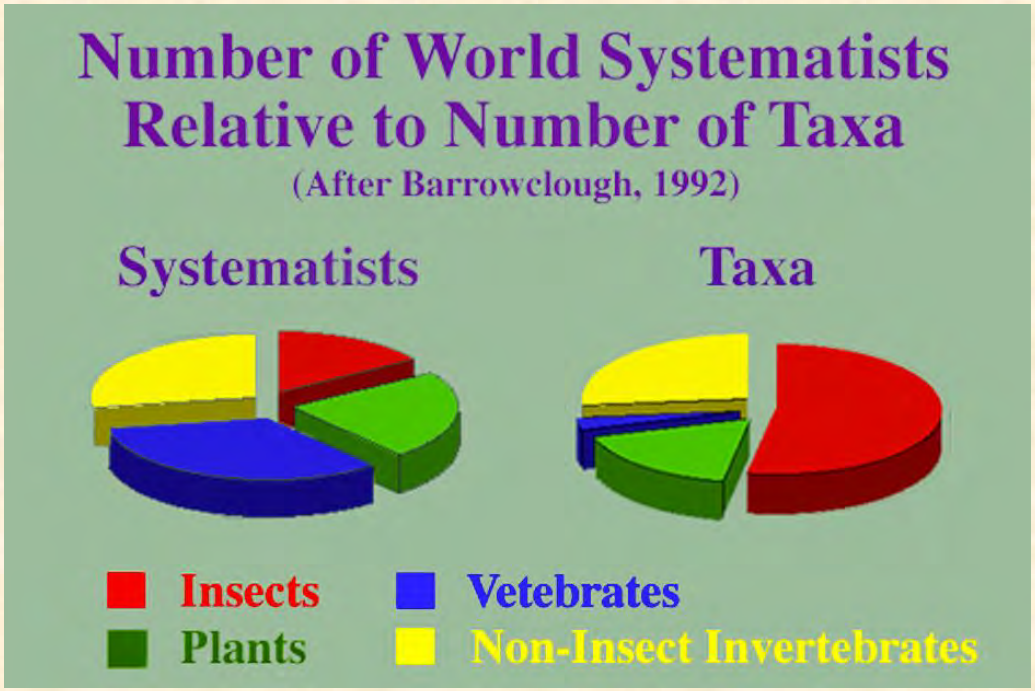


Trichogramma kaykai on a human hair



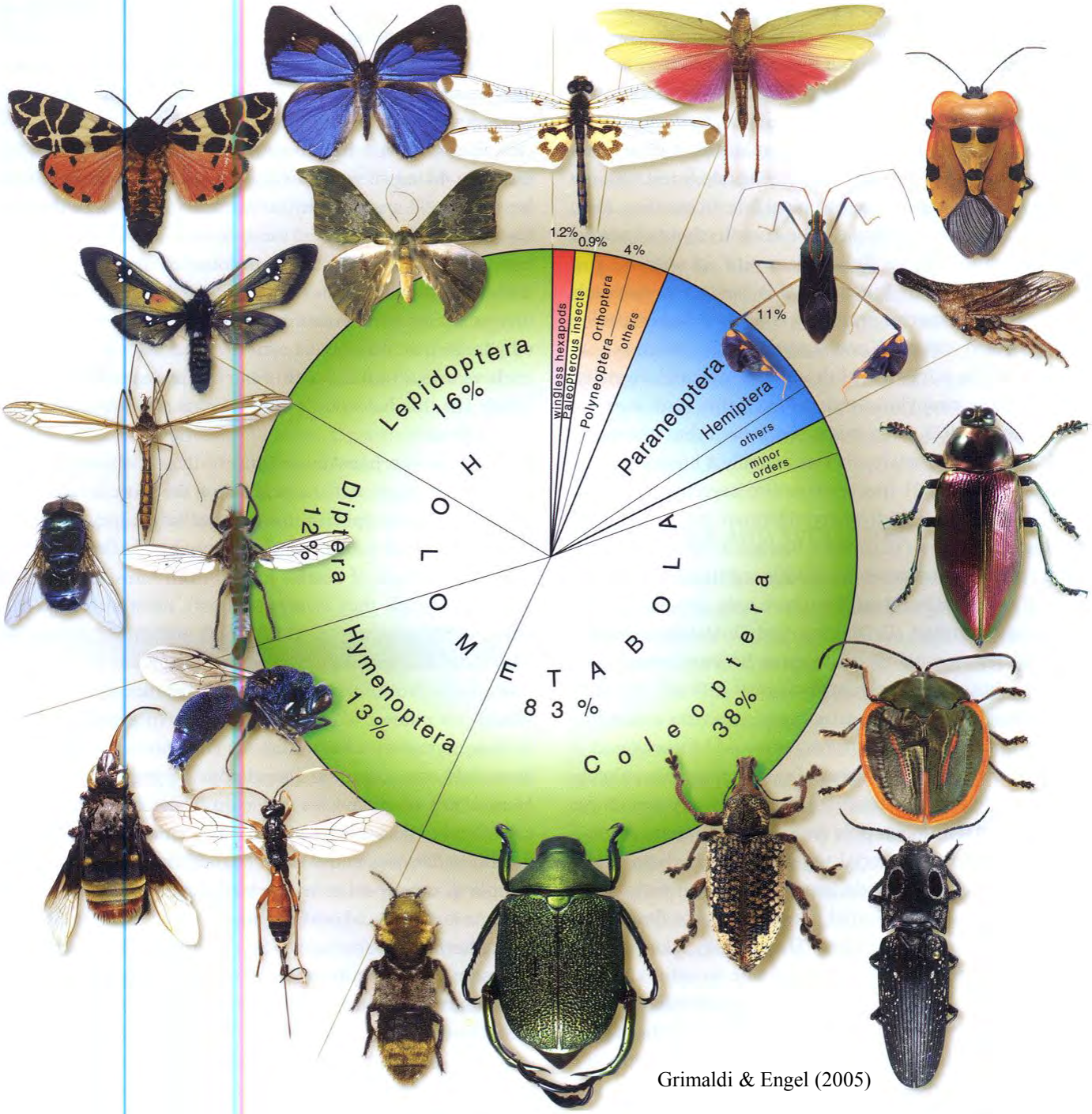
Aphanogmus dictynna on minuten





Grissell, 1999

Hymenoptera



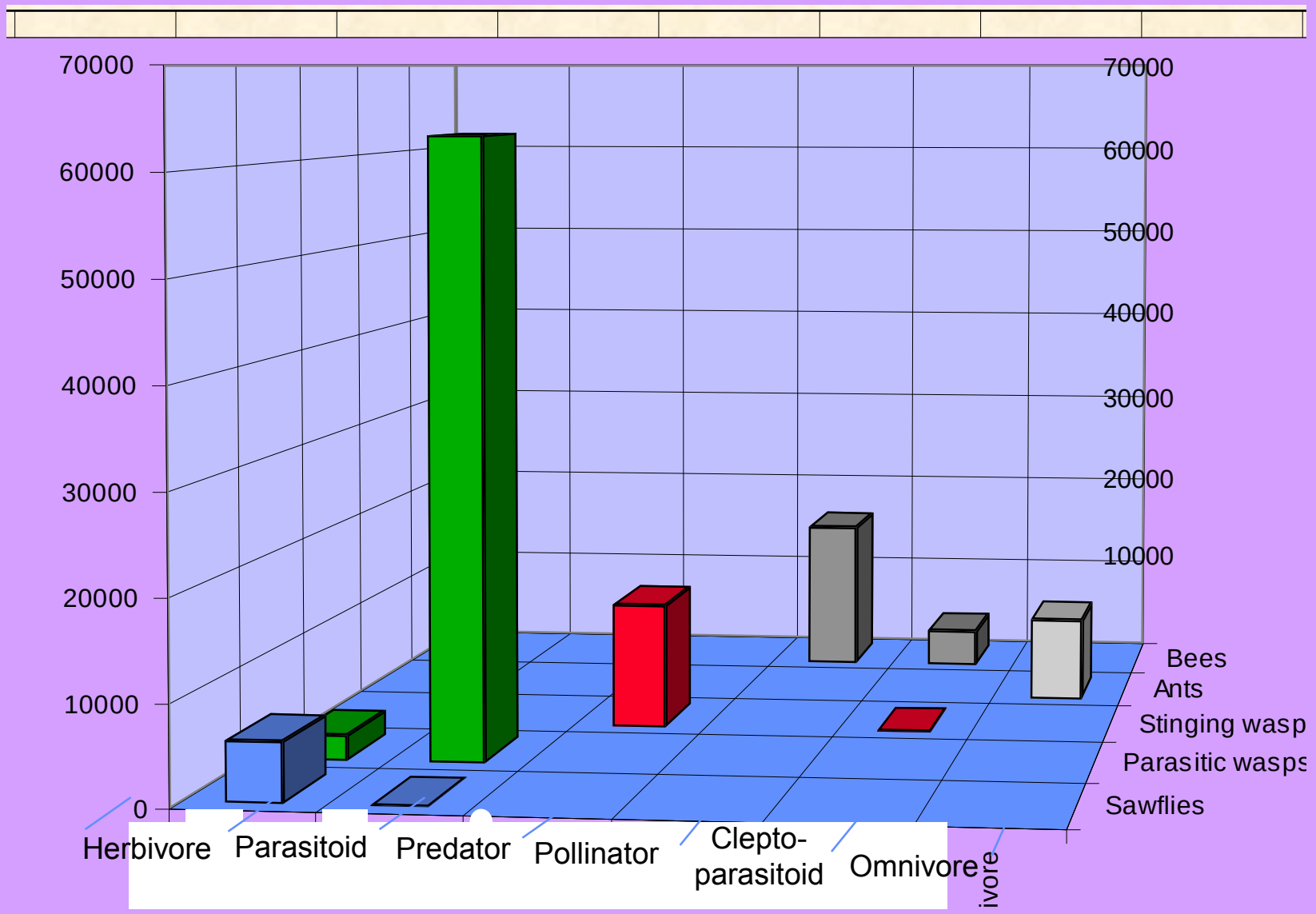
Grimaldi & Engel (2005)

Importance of Hymenoptera

- Fascinating units of evolution, especially if one is interested in co-evolution, social insects, etc.
- Hyper-diverse; conservative estimates within parasitic species suggest for every host species of insect, somewhere between 3 and 8 Hymenoptera can successfully reproduce on it.
- Sensitive to environmental changes; can be used to address ecological questions
- Food web architecture
- Arguable the MOST important force shaping other insect population dynamics
  - This can be used for human benefit through IPM and biological control

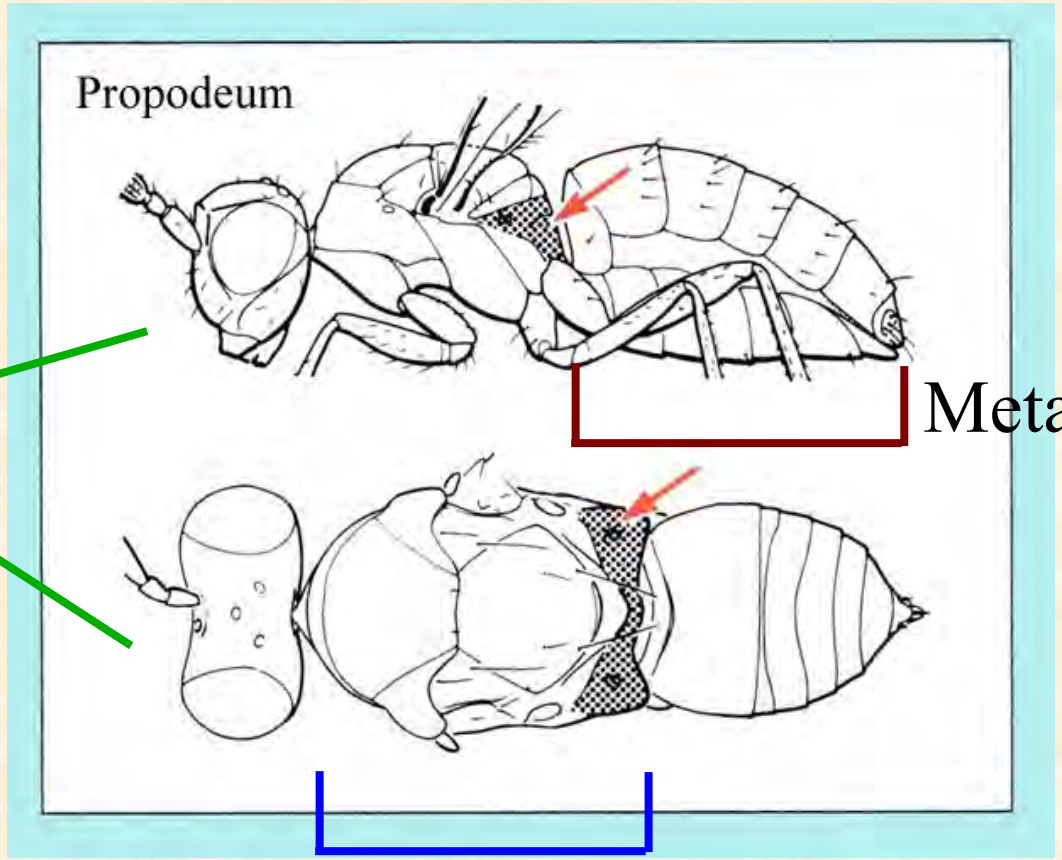
KEY ADAPTATIONS AND SPECIES DIVERSITY

Numbers and Categories of Described Hymenoptera by Feeding Type

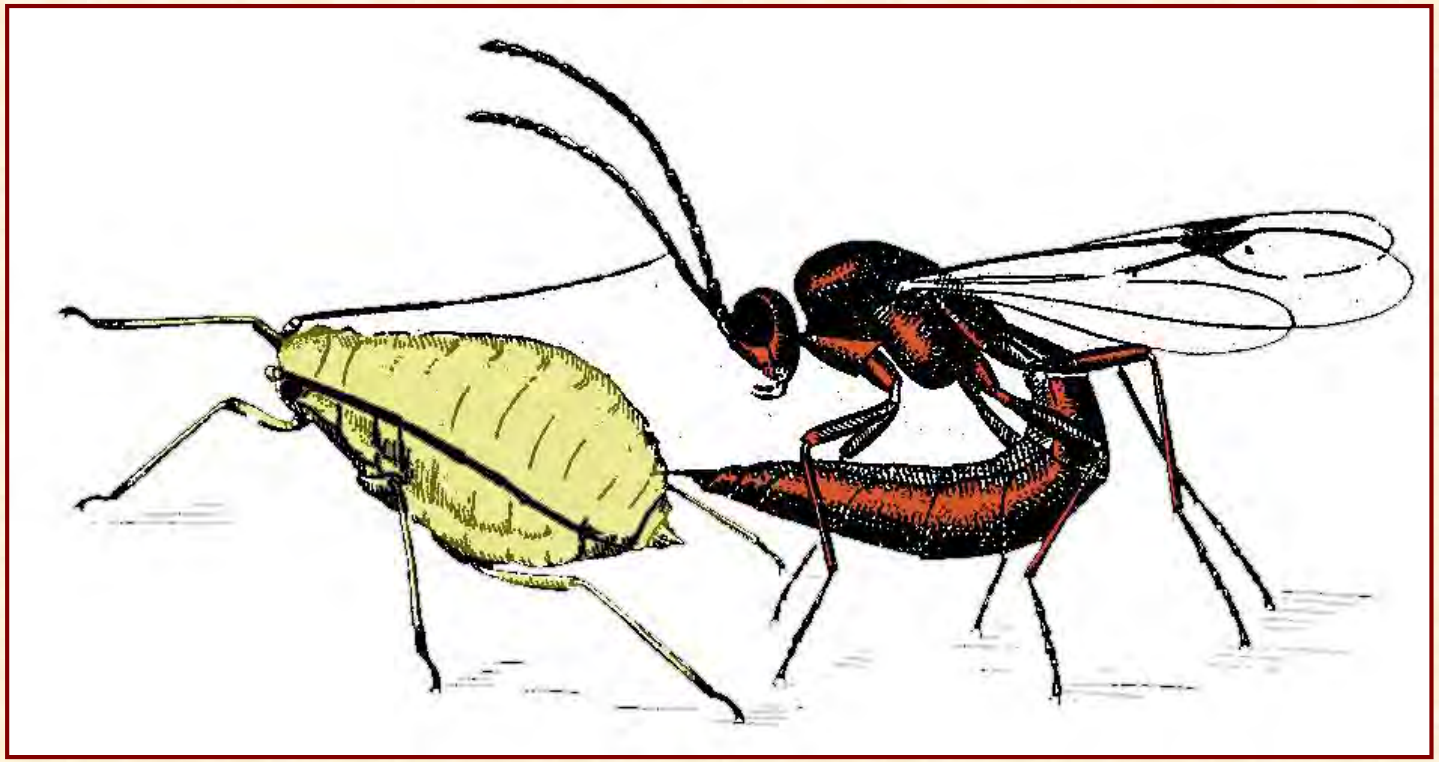


(Modified from LaSalle and Gauld 1993, Gaston 1993)

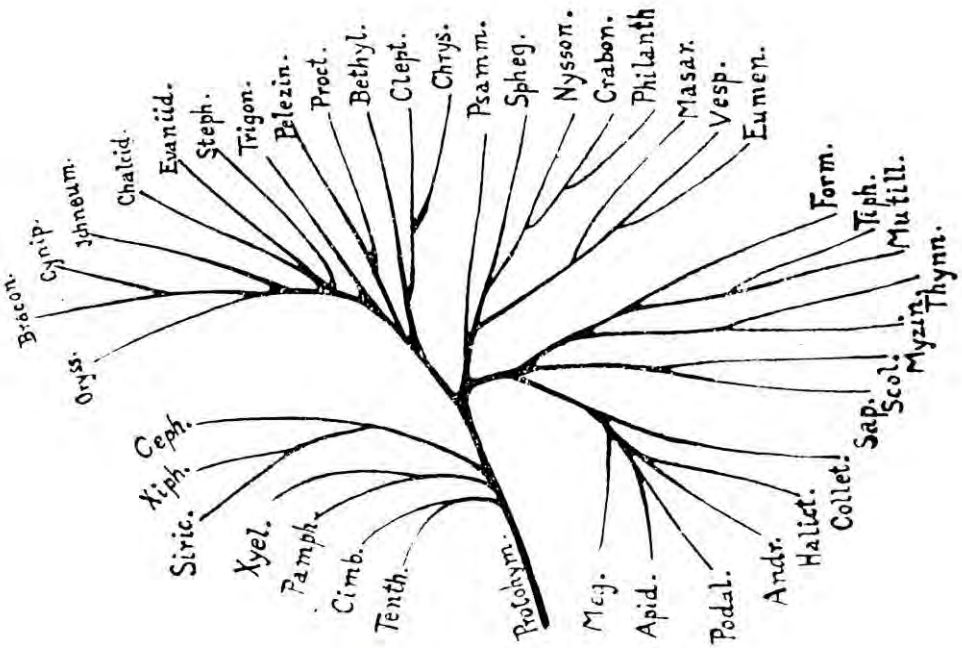
The Wasp Waist



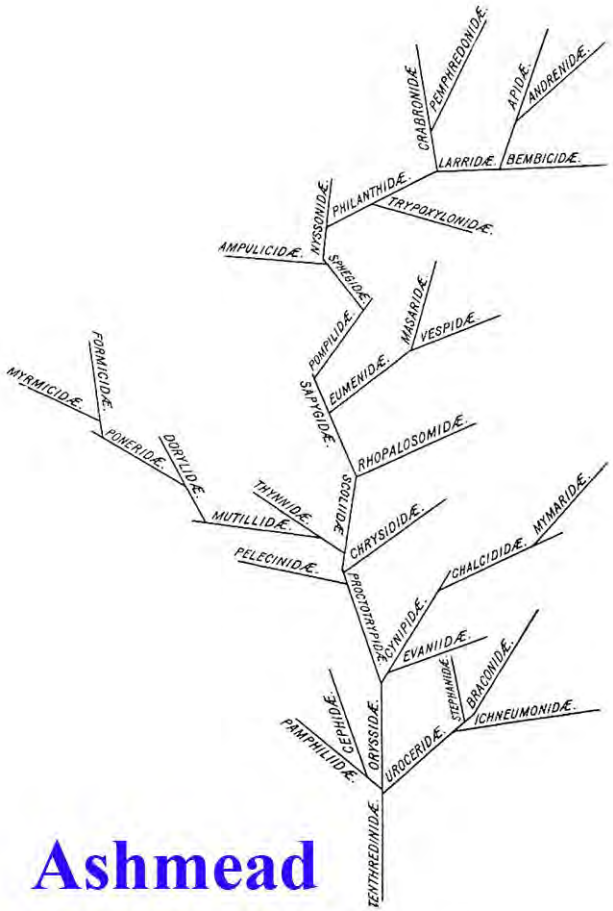
Wasp waist in action



Phylogenetics of the Hymenoptera: the early years

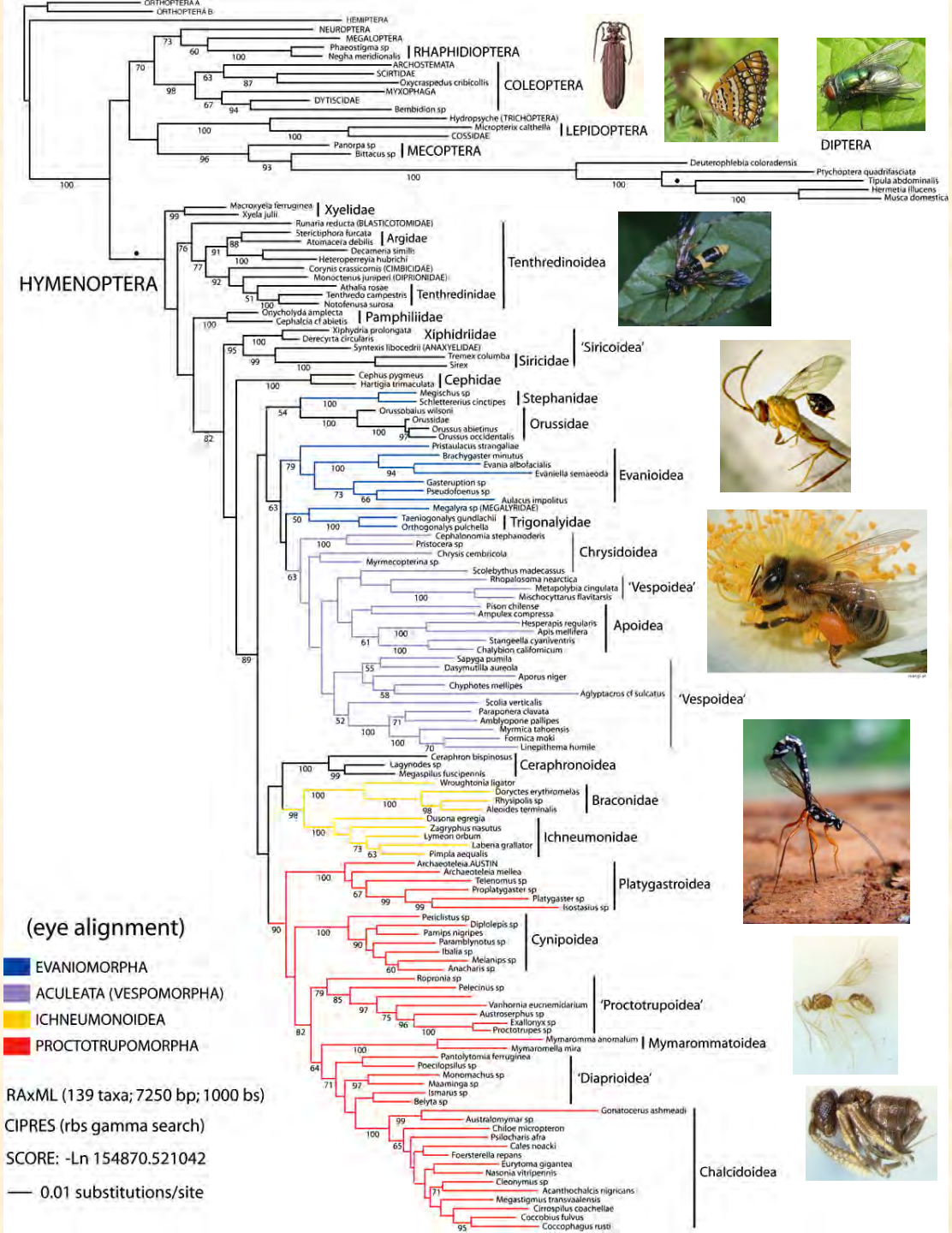


Borner



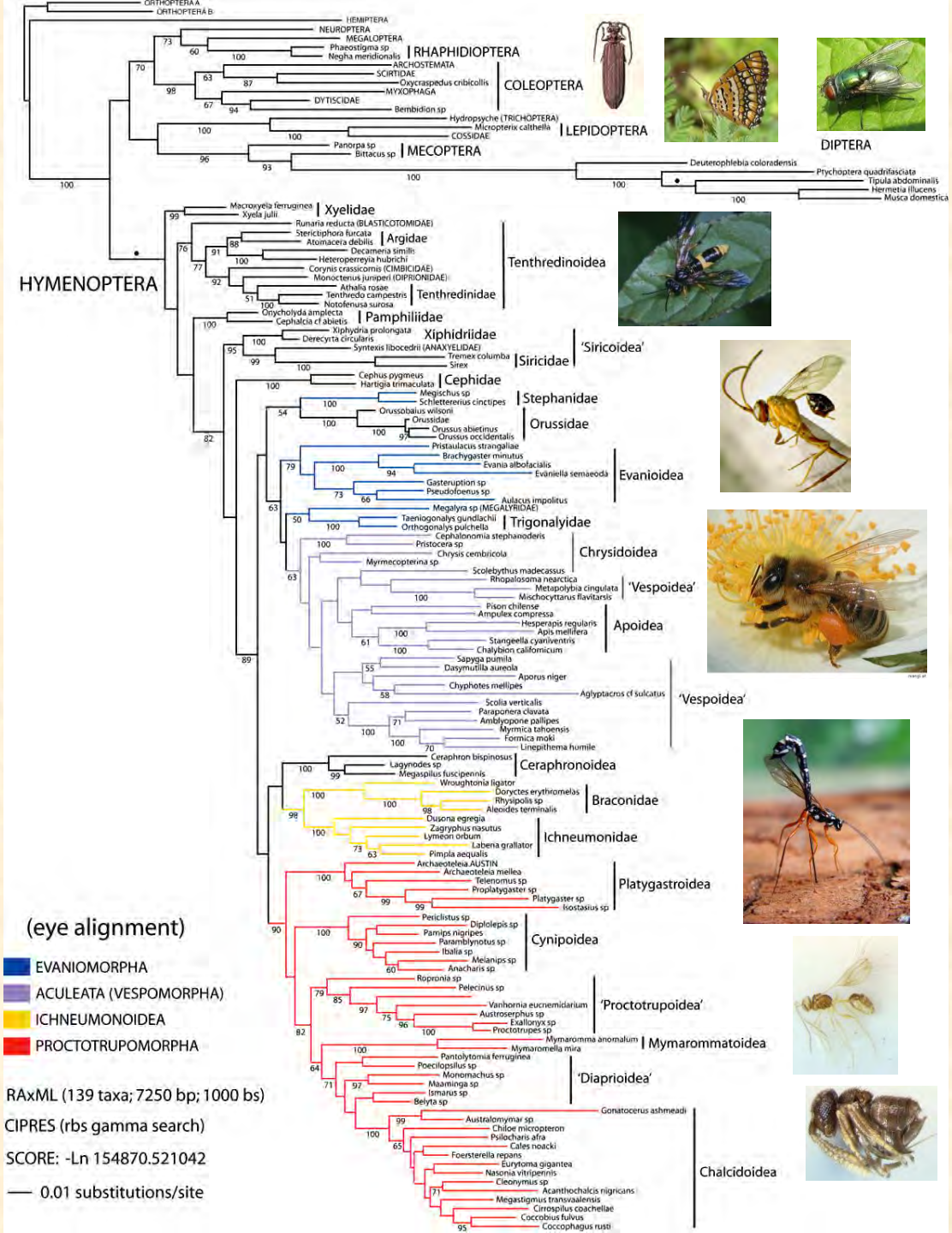
Ashmead

Phylogeny of the Hymenoptera.

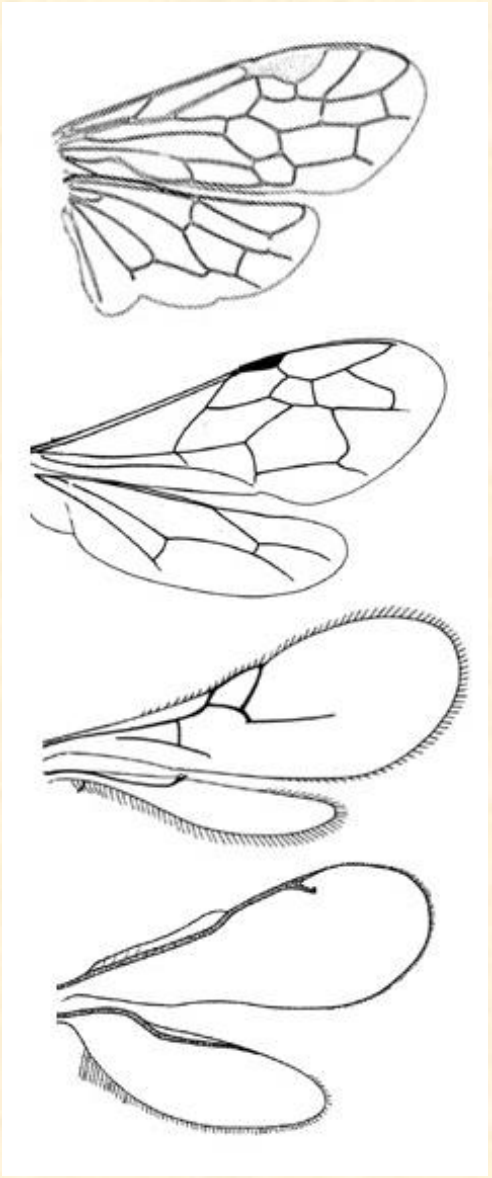


Hymenoptera- Tree of life

- 18S, 28S, EF1, COI
- ss and eye alignment
- 7250 / 7204 aligned
- RAxML / Bayes
- 139 taxa, 23 outgroups

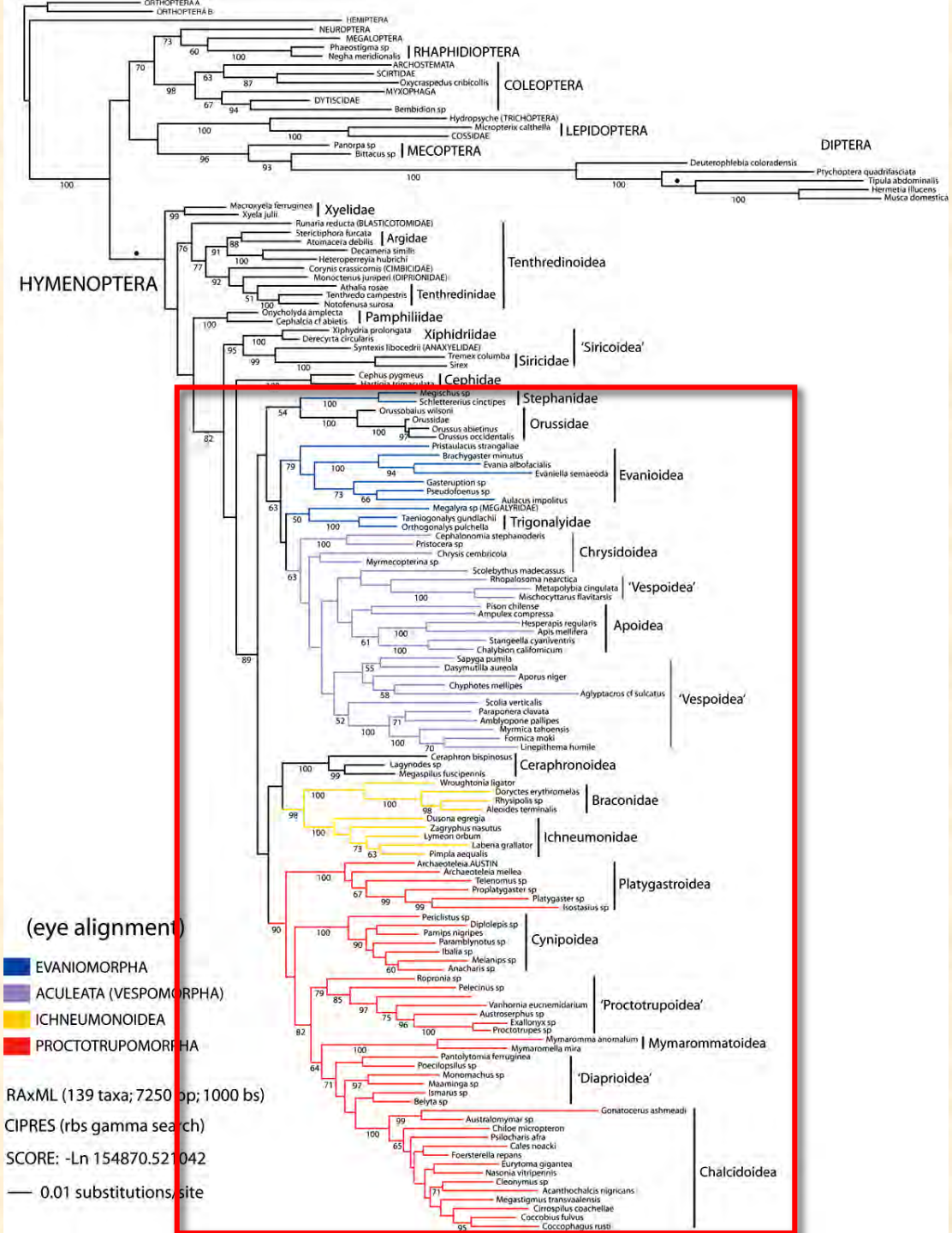


Wing vein reduction



Evolution of Parasitism

Predation, phytophagy and hyperparasitism secondarily derived

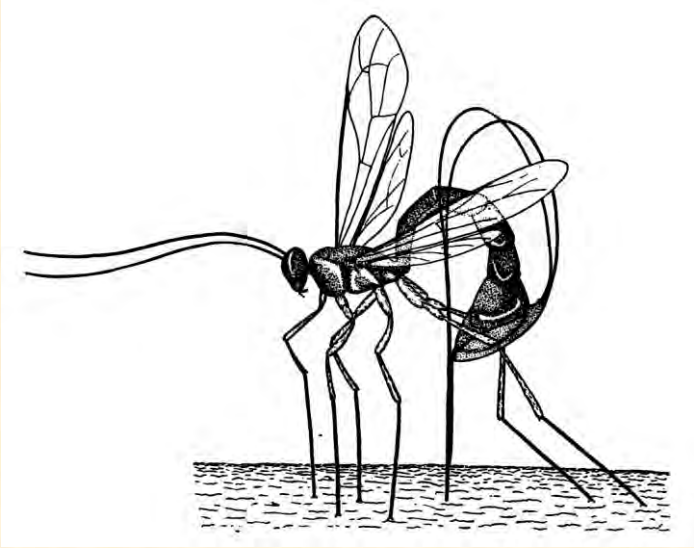


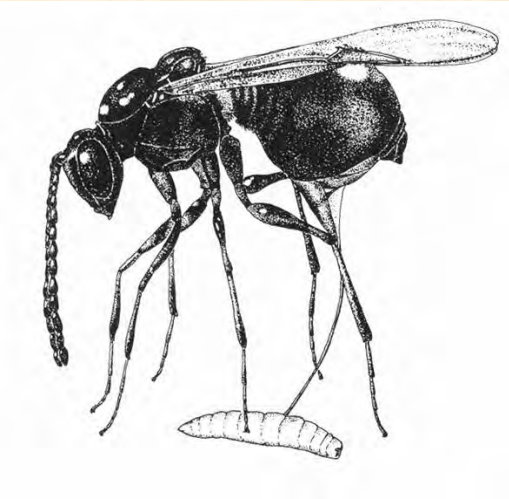
Biological Definitions

- **Phytophagy** - 'plant eating', including pollen, gall tissue, leaf tissue, etc.
- **Predatation**- carnivore that requires *more than one individual* victim for complete reproduction
- **Parasitoidism** - special case of parasitism where host is killed in order to parasite to successfully reach adulthood - a *predator* that only needs *one* victim to complete reproduction
- **Meconium** - type of waste stored within parasitoid larva until final molt; don't s&*t where you sleep…

Lines between predator and parasitoid frequently hard to distinguish

The Finer Points of Parasitism



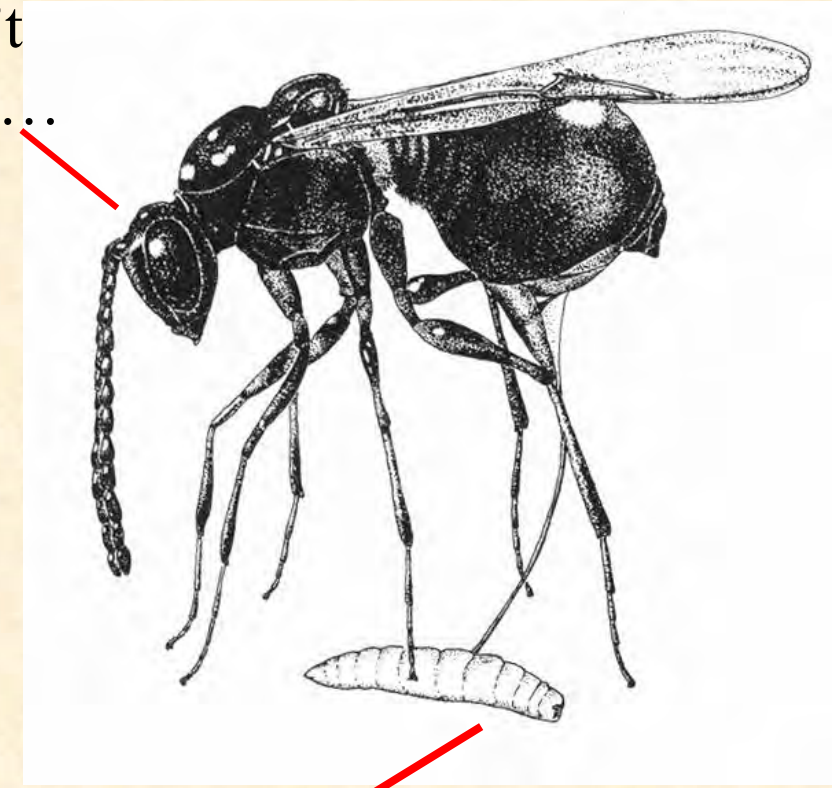


Koinobiont
Idiobiont
Endoparasitism
Ectoparasitism

Also to consider the *stage* attacked and *stage* of emergence: egg, larval prepupa, pupa, adult

The Finer Points of Parasitism

Hold still, this won't hurt a bit…



Ouch!

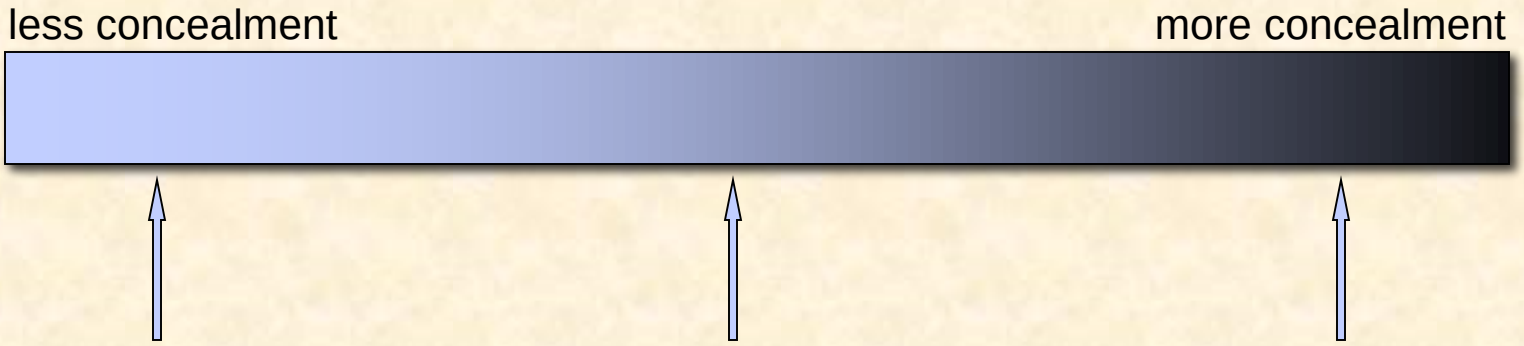
Hosts do not like to be parasitized: they *hide*, have immune systems, etc.

Parasitoids *find* their hosts by cueing in on host plants, salivary compounds…. and use 'chemical warfare' to overcome the host immune system…viruses, paralysis, etc….evolutionary arms race!

Parasitic Hymenoptera: Generalized steps of oviposition

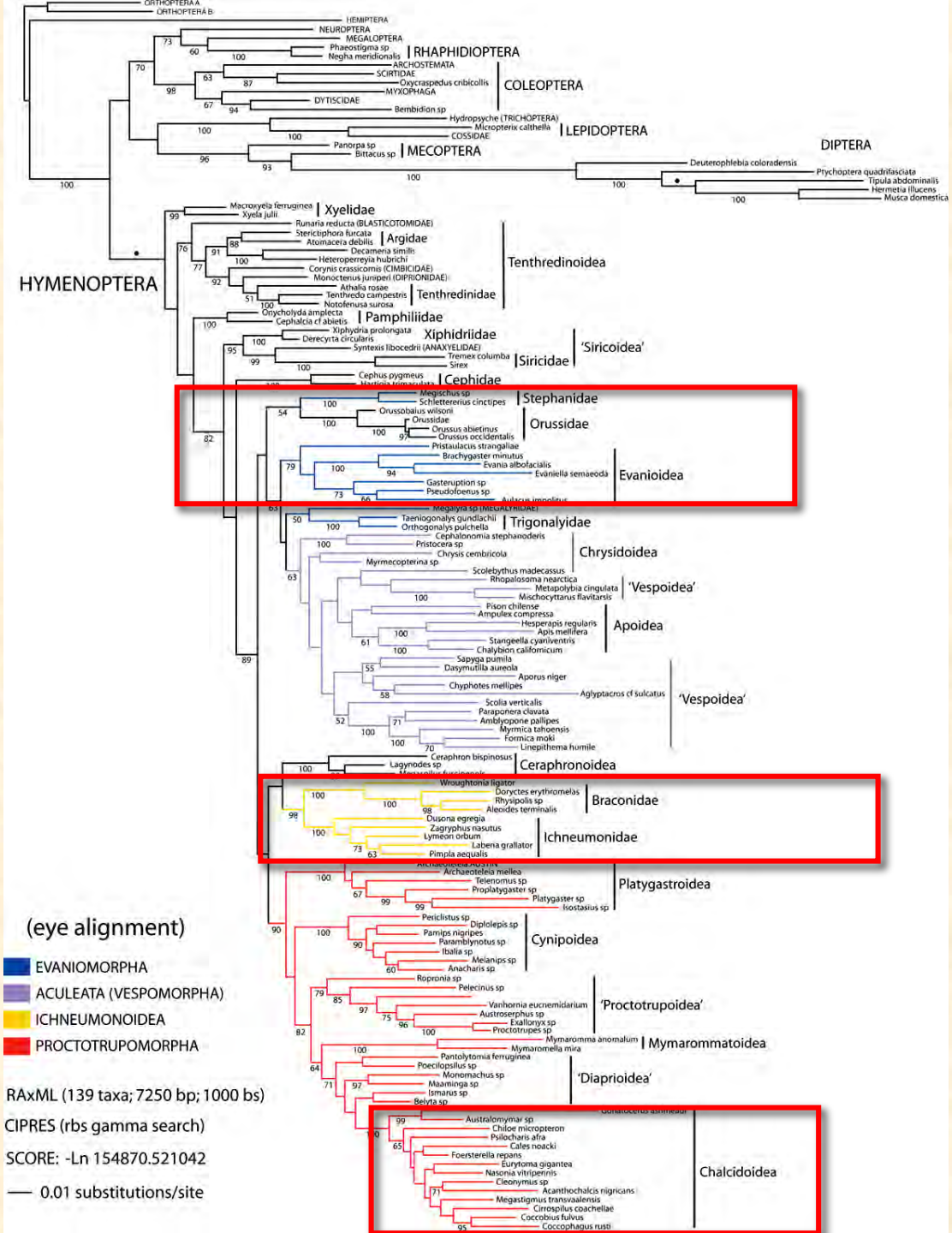
- Locate host (not trivial)
- Constrain host
  - Invenomization
  - Mechanical
  - Structural
- Successfully develop within/on host
  - Polydnavirus, ‘virus-like’ particles
  - Strategic placement of eggs
  - Gregarious species
  - Alter host behavior
  - Koinobiontism, idiobiontism
- See Godfray (1994) for more information

Host Preference Spectrum



Evolution of Parasitism

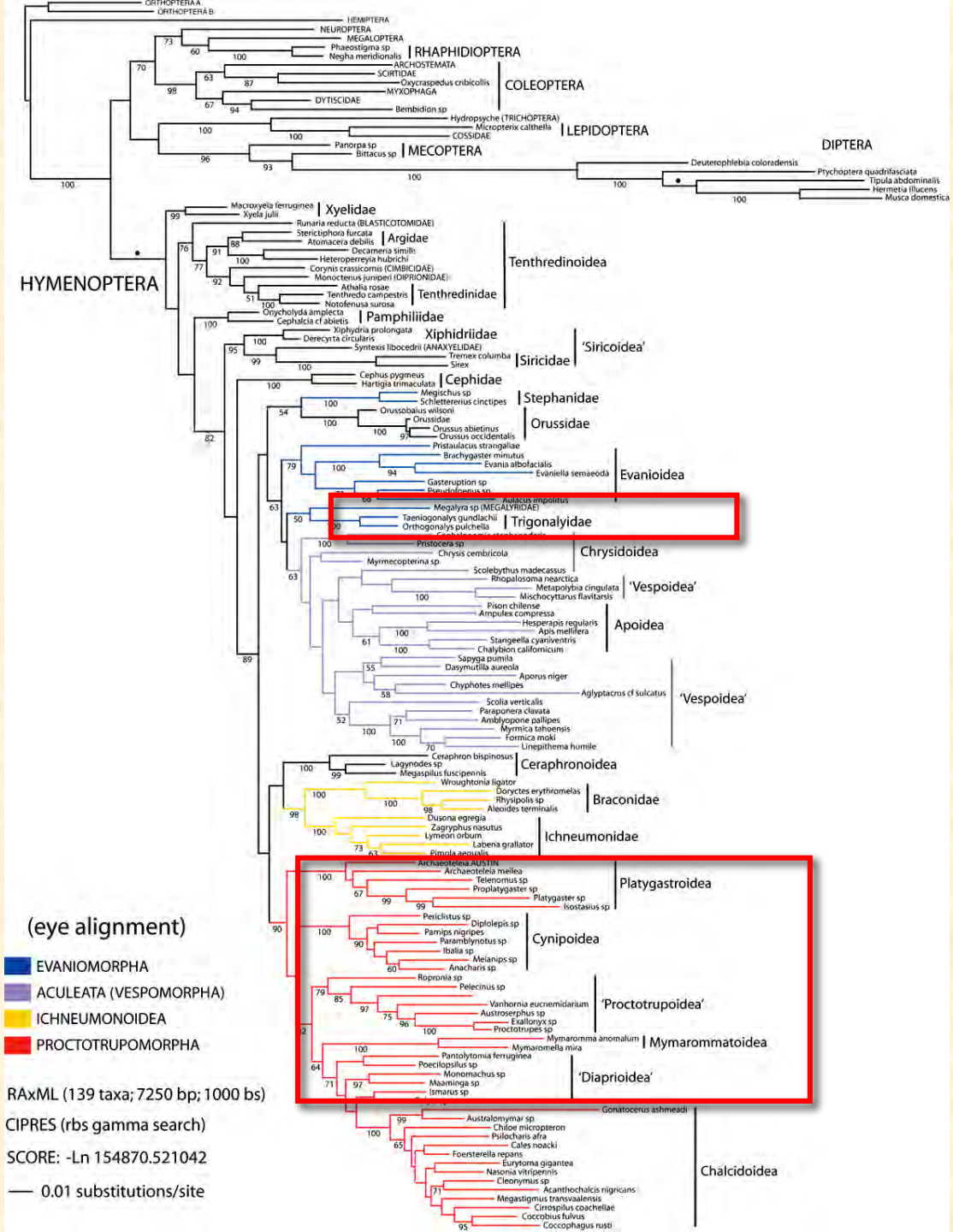
Ground Plan
Ectoparasitism



Evolution of Parasitism

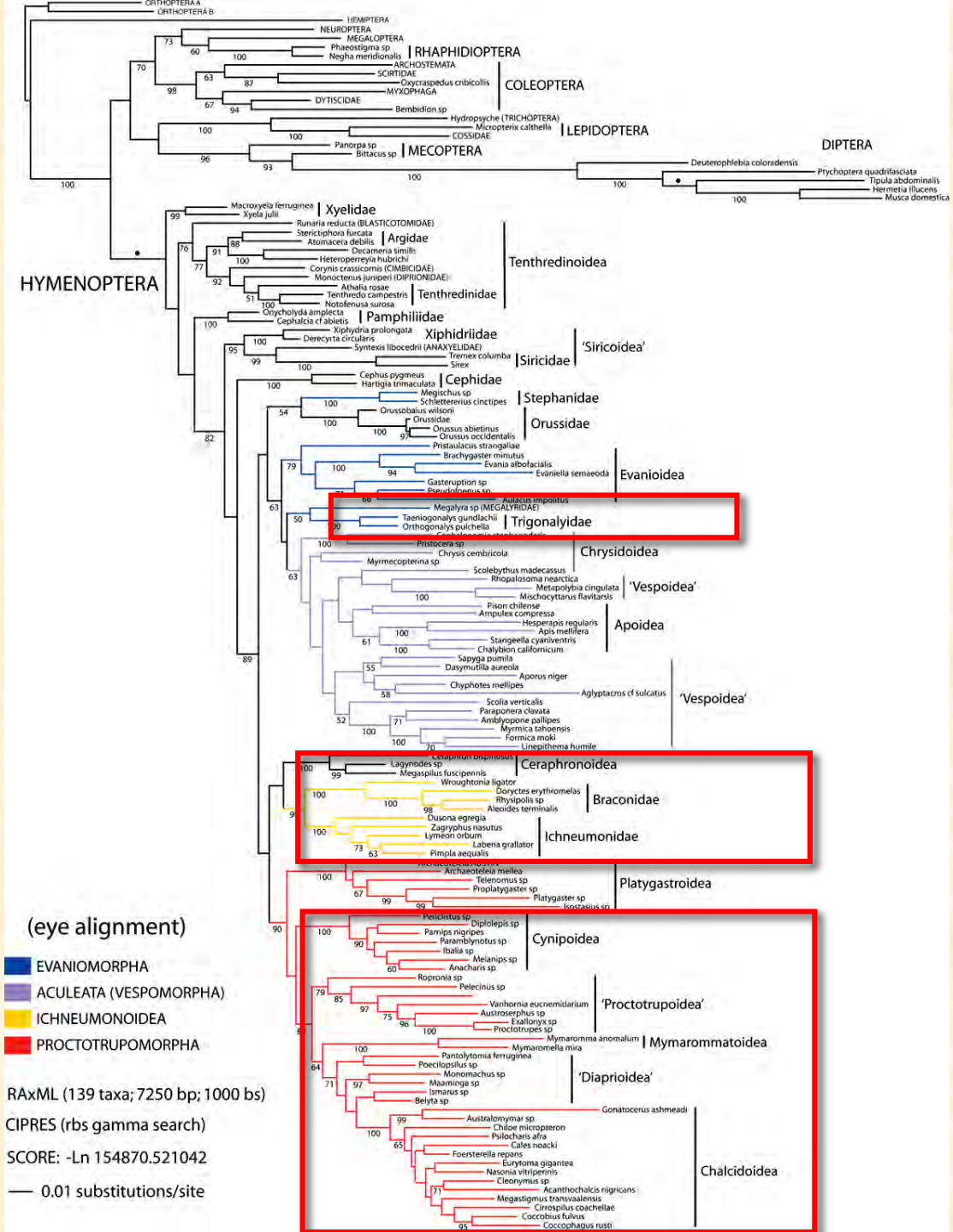
Ground Plan Endoparasitism

Koino vs Idio spread throughout the tree!



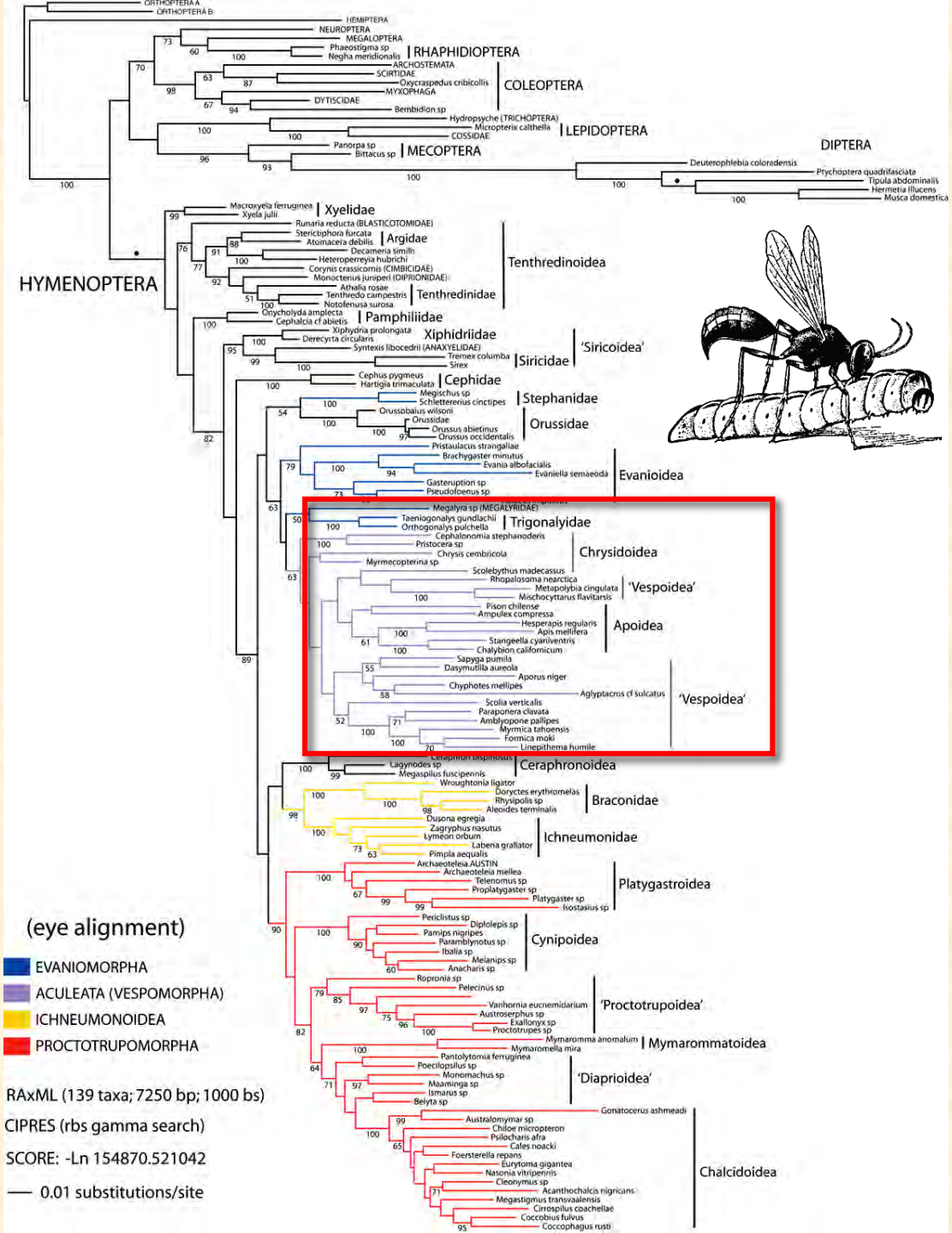
Evolution of Parasitism

Hyperparasitism

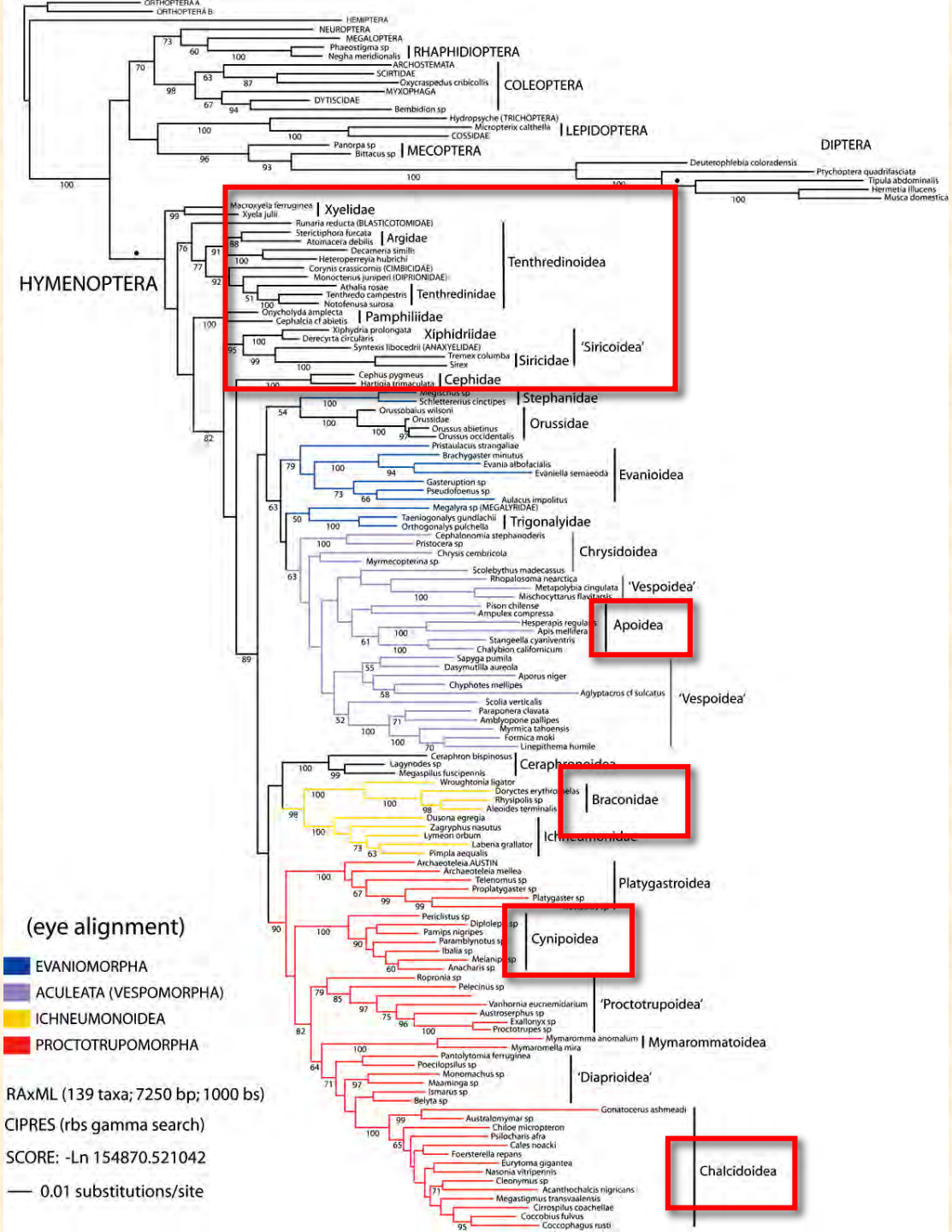


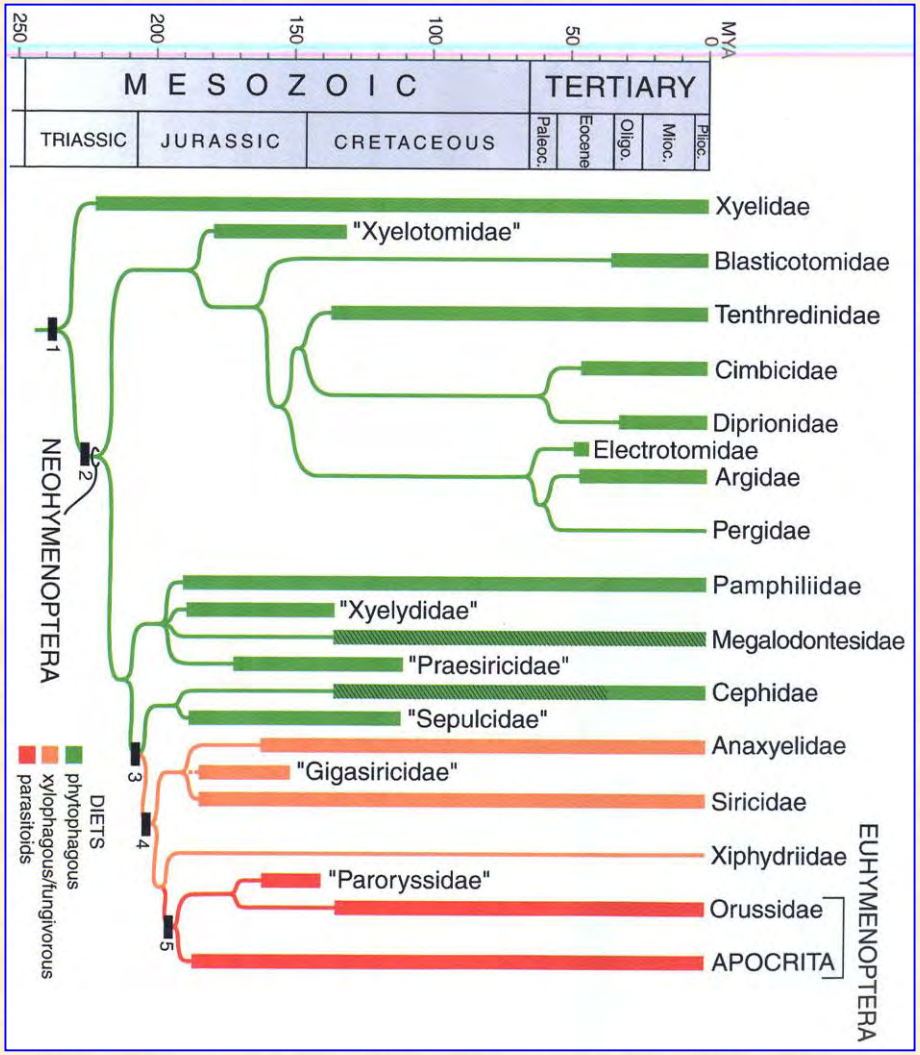
Predators


© Steven Corbett 2006


HEMIPTERA
NEUROPTERA
MEGALOPTERA
Phaeostigma sp
Negha meridionalis
RHAPHIDIOPTERA
ARCHOSTEMATA
SCIRTIDAE
Dascraspedus cribicollis
MYXOPHAGA
DYTISCIDAE
COLEOPTERA
Bembidion sp
Hydropsyche (TRICHOPTERA)
Micropterix calthella
COSSIDAE
LEPIDOPTERA
Panorpa sp
Bittacus sp
MECOPTERA
DIPTERA
Deuterophlebia coloradensis
Ptychoptera quadrifasciata
Tipula abdominalis
Hermetia illucens
Musca domestica
HYMENOPTERA
Macroxyela ferruginea
Xyela julii
Xyelidae
Runaria reducta (BLASTICOTOMIDAE)
Stericiphora furcata
Atomacera debilis
Argidae
Decameria similis
Heteropereyia hubrichi
Corynis crassicornis (CIMBICIDAE)
Monoctenus juniperi (DIPRIONIDAE)
Athalia rosae
Tenthredo campestris
Tenthredinidae
Notofenusa surosa
Tenthredinoidea
Onycholyda amplecta
Cephalcia cf abietis
Pamphiliidae
Xiphydria prolongata
Derecyrta circularis
Xiphidriidae
Syntexis libocedrii (ANAXYELIDAE)
Tremex columba
Sirex
Siricidae
'Siricoidea'
Cephus pygmeus
Hartigia trimaculata
Cephidae
Megischus sp
Schlettererius cinctipes
Stephanidae
Orussobaius wilsoni
Orussidae
Orussus abietinus
Orussus occidentalis
Pristaulacus strangaliae
Brachygaster minutus
Evania albofacialis
Evaniella semaeoda
Evanioidea
Gasteruption sp
Pseudofoenus sp
Megalyra sp (MEGALYRIDAE)
Taeniogonalys gundlachii
Orthogonalys pulchella
Trigonalyidae
Cephalonomia stephanoderis
Pristocera sp
Chrysis cembricola
Chrysidoidea
Myrmecopterina sp
Scolebythus madecassus
Rhopalosoma nearctica
Metapolybia cingulata
Mischocyttarus flavitarsis
'Vespoidea'
Pison chilense
Ampulex compressa
Hesperapis regularis
Apis mellifera
Stangeella cyaniventris
Chalybion californicum
Apoidea
Sapyga pumila
Dasymutilla aureola
Aporus niger
Chyphotes mellipes
Aglyptacros cf sulcatus
Scolia verticalis
Paraponera clavata
Amblyopone pallipes
Myrmica tahoensis
Formica moki
Linepithema humile
'Vespoidea'
Ceraphron dispinosus
Lagynodes sp
Megaspilus fuscipennis
Ceraphronoidea
Wroughtonia ligator
Doryctes erythromelas
Rhysipolis sp
Aleoides terminalis
Braconidae
Dusona egregia
Zagryphus nasutus
Lymeon orbum
Labena grallator
Pimpla aequalis
Ichneumonidae
Archaeoteleia AUSTIN
Archaeoteleia miellea
Telenomus sp
Proplatygaster sp
Platygaster sp
Isostasius sp
Platygastroidea
Periclistus sp
Diplolepis sp
Pamips nigripes
Paramblynotus sp
Ibalia sp
Melanips sp
Anacharis sp
Cynipoidea
Ropronia sp
Pelecinus sp
Vanhornia eucnemidarium
Austroserphus sp
Exallonyx sp
Proctotrupes sp
'Proctotrupoidea'
Mymaromma anomalum
Mymarommatoidea
Mymaromella mira
Pantolytomia ferruginea
Poecilopsilus sp
Monomachus sp
Maaminga sp
Ismarus sp
Belyta sp
'Diaprioidea'
Gonatocerus ashmeadi
Australomymar sp
Chiloe micropteron
Psilocharis afra
Cales noacki
Foersterella repans
Eurytoma gigantea
Nasonia vitripennis
Cleonymus sp
Acanthochalcis nigricans
Megastigmus transvaalensis
Cirrospilus coachellae
Coccobius fulvus
Coccophagus rusti
Chalcidoidea
(eye alignment)
EVANIOMORPHA
ACULEATA (VESPOMORPHA)
ICHNEUMONOIDEA
PROCTOTRUPOMORPHA
RAxML (139 taxa; 7250 bp; 1000 bs)
CIPRES (rbs gamma search)
SCORE: -Ln 154870.521042
0.01 substitutions/site

Phytophages/pollen feeders





1. hamuli
2. forewing venation (Rs not furcate; Sc fused to R; Sc absent in hind wing); DNA content of flight muscles in males restored
3. reduction of posterior protibial spur
4. absence of larval eyes
5. parasitic larvae; loss of larval thoracic legs

Relationships of 'early' Hymenoptera

Grimaldi & Engel (2005)

based on analyses of:

Vilhelmson (2001)
Schulmeister (2003)

(only major difference with Rasnitsyn is monophyly of Siricidae+ Anaxyelidae)

A bit-o-nomenclature

Hymenoptera

Symphyta

Apocrita

Ceraphronoidea

Chalcidoidea

….

Platygastroidea

Platygastridae

Scelioninae

Trissolcus

T. japonicus Ashmead

=*T. halymorphae* Yang

Team *Trissolcus* research

Hoelmer Lab (BIIR; Newark, DE); foreign exploration quarantine rearing, host range testing, sentinel egg mass monitoring, phylogenetics (w/ Tim Hay and Marie Claude)

Systematic Entomology Lab (SEL, Washington DC); revisionary taxonomy of *Trissolcus*, key building, imaging of specimens, phylogenetics

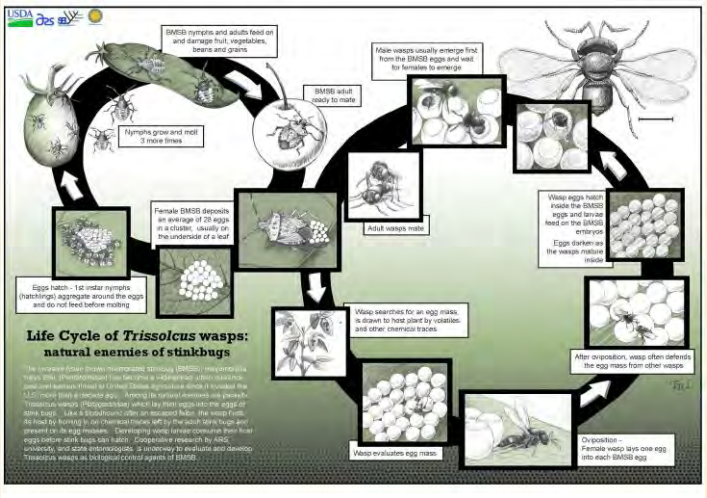
Current status of North American *Trissolcus* research

Products: synonymy of *Trissolcus halymorphae* with *T. japonicus* Ashmead; new synonymies of Kozlov species; Insect Zoo display, Smithsonian Institution; brochures

Additional research:
-study of Kozlov types in St. Petersburg
-acquisition of other relevant types from around the world's museums
-draft key to *Trissolcus* of N. America: where ya'll come in!
-initiation of Eastern Palearctic *flavipes* key
-study of fossil playgastroids entombed in amber, housed at USNM


No [one] can truly be called an entomologist, sir; the subject is too vast for any single human intelligence to grasp.
–Oliver Wendell Holmes,
The Poet at the Breakfast Table
Natural Enemy of the Brown Marmorated Stink Bug
Parasitic Wasp
Trissolcus japonicus
Connected Life Cycles: Parasitic Wasps and Stink Bugs
How Do We Know?
Behind the SCENES!


intelligence to grasp.
–Oliver Wendell Holmes,
The Poet at the Breakfast Table
Natural Enemy of the Brown Marmorated Stink Bug
Parasitic Wasp


USDA
BMSB nymphs and adults feed on and damage fruit, vegetables, beans and grains
Male wasps usually emerge first from the BMSB eggs and wait for females to emerge
BMSB adult ready to mate
Nymphs grow and molt 5 more times
Female BMSB deposits an average of 28 eggs in a cluster, usually on the underside of a leaf
Adult wasps mate
Wasp eggs hatch inside the BMSB eggs and larvae feed on the BMSB embryos
Eggs darken as the wasps mature inside
Eggs hatch - 1st instar nymphs (hatchlings) aggregate around the eggs and do not feed before molting
Wasp searches for an egg mass, is drawn to host plant by volatiles and other chemical traces
After oviposition, wasp often defends the egg mass from other wasps
Life Cycle of Trissolcus wasps: natural enemies of stinkbugs
Wasp evaluates egg mass
Oviposition - Female wasp lays one egg into each BMSB egg

‘Experts are In’, Apr 2013

The Agricultural Research Service (USDA), and cooperators nationwide, are researching safe and sustainable means of BMSB biological control.

Our hero, Trissolcus!

Species in this genus range from 2mm to just under 1mm in adult length. These tiny wasps are egg parasitoids; the female wasp lays her eggs in the eggs of shield bugs (Pentomidae), of which BMSB is a member. Trissolcus are particularly effective biological control agents since developing wasp larva consumes the entire hose prior hatching, precluding the feeding stages of earlier instars of BMSB. Trissolcus wasps can be found worldwide, and our native species have been bred from BMSB. However, Asian species of Trissolcus, which co-evolved with BMSB, are far more effective. Cooperative work is currently underway between the Systematic Entomology Laboratory (Washington DC), The Ohio State University (Columbus, OH), and the Beneficial Insect Introduction Research Unit (Newark, DE) to understand the species limits of Trissolcus wasps, their host range, and host specificity. This work is essential for the safe release of Trissolcus wasps for the future of biological control of BMSB.

Beneficial Insects Introduction Research Unit (BIIR) Mission:

To develop comprehensive classification systems for insects and mites on a world basis based on structural, biological and molecular characteristics.

To furnish taxonomic services to Federal, state, and private organizations.

To cooperate with the Smithsonian Institution on a daily basis in the continuing development and maintenance of the National Collection of insects as a working tool to support systematic studies and identification.

To develop digital information, storage, and retrieval systems for systematic and biological information.

Systematic Entomology Laboratory (SEL) Mission

Addresses pest problems of regional and national importance including Russian wheat and soybean aphids, brown marmorated stink bug, emerald ash borer, tarnished plant bug, and Asian longhorned beetle.

Imports new natural enemies into the U.S. to solve pest problems, using environmentally friendly and self-sustaining biological control methods.

Studies the biology and ecology of parasites and predators of insect pests.

Evaluates establishment and impact of natural enemies.

BIIR
Dr. Kim Hoelmer
Dr. Christine Dieckhoff
USDA,REE,ARS,NAA
501 South Chapel Street, Newark, DE, 19713-3814
Voice 302-737-7330, ext 242

SEL
Dr. Matthew Buffington
Dr. Elijah Talamas
10th & Constitution Ave NW
PO Box 37012 MRC-168, Washington DC 20560
Voice 202-633-4552

The Ohio State University
Dr. Norm Johnson
1220A Museum of Biological Diversity©
1316 Kinnear Rd., Columbus, OH 43212

Effective natural control of an invasive species:

***Trissolcus* wasps**

egg parasitoids of the Brown Marmorated Stink Bug

0.02 inches

What is BMSB?

The invasive Asian brown marmorated stink bug (BMSB), Halyomorpha halys Stål, (Pentatomidae) has become a widespread urban nuisance pest and serious threat to United States agriculture since it invaded the U.S. more than a decade ago. Adult bugs are 5/8" and dark mottled brown. They emerge from overwintering sites from late March through June depending on location. They immediately begin to feed. Females lay clusters of light green, barrel-shaped eggs on the undersides of leaves from June to August. There are 5 stages or instars. While this species has become a major pest in the Mid Atlantic Region, it has recently been recorded from California, Oregon, and Washington, where it poses a major threat to agriculture on the West Coast. During 2010, BMSB caused an estimated $37 million worth of damage throughout the mid-Atlantic region.

What are parasitoid wasps and biological control?

Often considered the perfect killing machine, these typically tiny (2mm) wasps cannot harm humans. Female parasitoid wasps lay their eggs in the larval or egg stage of a host insect. The wasp larva feeds internally on the host, eventually killing the host. Because the immature wasp must kill its host to complete its own lifecycle, we use the term parasitoid (instead of parasite, which needs to keep its host alive). This intimate relationship between wasp and host has taken millions of years of evolutionary time to achieve, resulting in species of wasps possessing a very high degree of specificity; most species of wasp can only exploit a single species of host. We can use this specificity in agriculture to reunite a pest insect with its natural enemy. We call this process biological control.

(Please see me to receive copies of this brochure.)

Future Prospects

Products: N. American Key; Eastern Palearctic key; additional nomenclatural stability

Phylogeny utilizing penalized liklihood and divergence estimation, calibrated by fossil data: insight into the ‘best’ natural enemy?

Conducting additional behavioral studies in quarantine at the Insect Zoo, in conjunction with those already underway in DE.

Release of biological control agent(s): hell yeah!