中山大學生物資優班
昆蟲學

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Outline

- OVERVIEW OF Arthropod DIVERSITY
- HEXAPODA
- Ectognaths: CLASS INSECTA
- Pterygotes—winged insects
- Neopteran Insects

How to read the terms in this class

Naturalreaders is your good friend…

https://www.naturalreaders.com

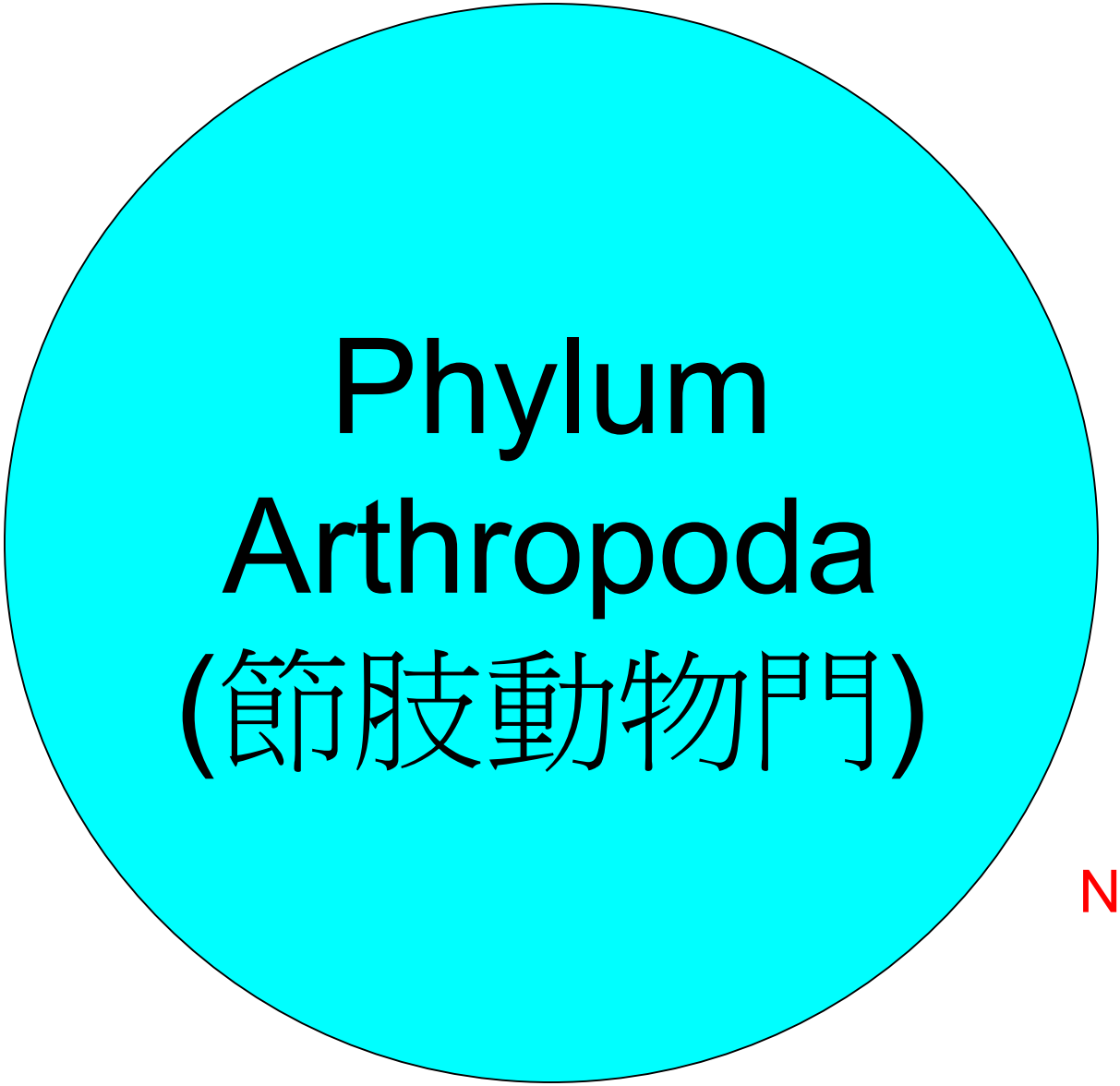
https://www.youtube.com/watch?v=0oWWOJW3948

國家教育研究院 專有名詞查詢:

https://terms.naer.edu.tw

節肢動物 生物多樣性簡介
OVERVIEW OF Arthropod DIVERSITY

Insects are arthropods



界 Kingdom
門 Phylum
綱 Class
目 Order
科 Family
屬 Genus
種 Species

Natural group!

TAXONOMIC CATEGORIES

Taxon Category	Suffix	Example
Order		Hymenoptera
Suborder		Apocrita
Superfamily	-oidea	Apoidea
Epifamily	-oidae	Apoidae
Family	-idae	Apidae
Subfamily	-inae	Apinae
Tribe	-ini	Apini
Genus		*Apis*
Subgenus		
Species		*A. mellifera*

Obligatory categories are shown in **bold** text.

Major groups within the Arthropoda

Pycnogonida
(海蜘蛛)

Chelicerates
(螯肢類)

Hexapods
(六足類)

ancestor

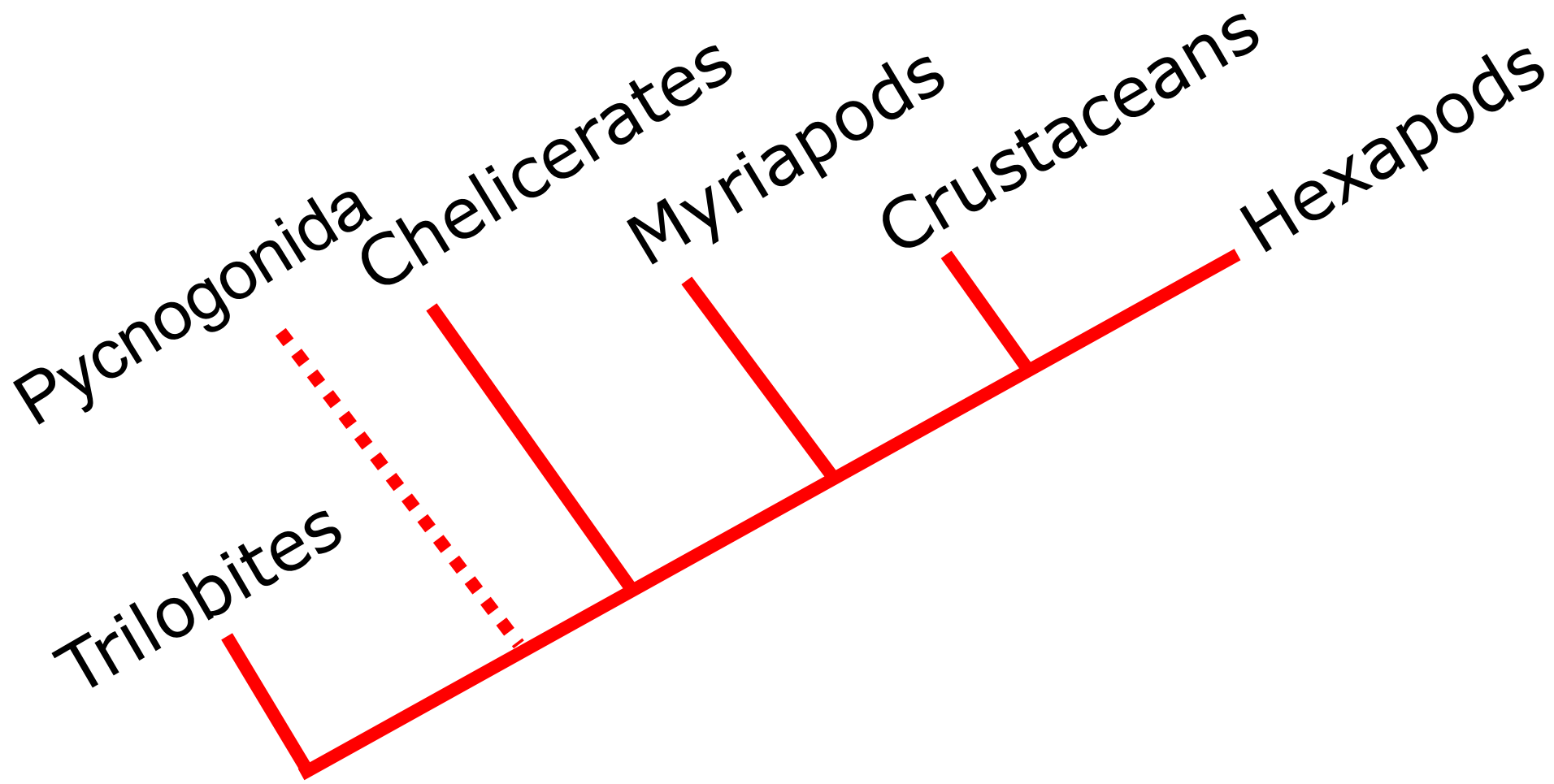
Crustaceans
(甲殻類)

Myriapods
(多足類)

Trilobites
(三葉蟲)

Extinct

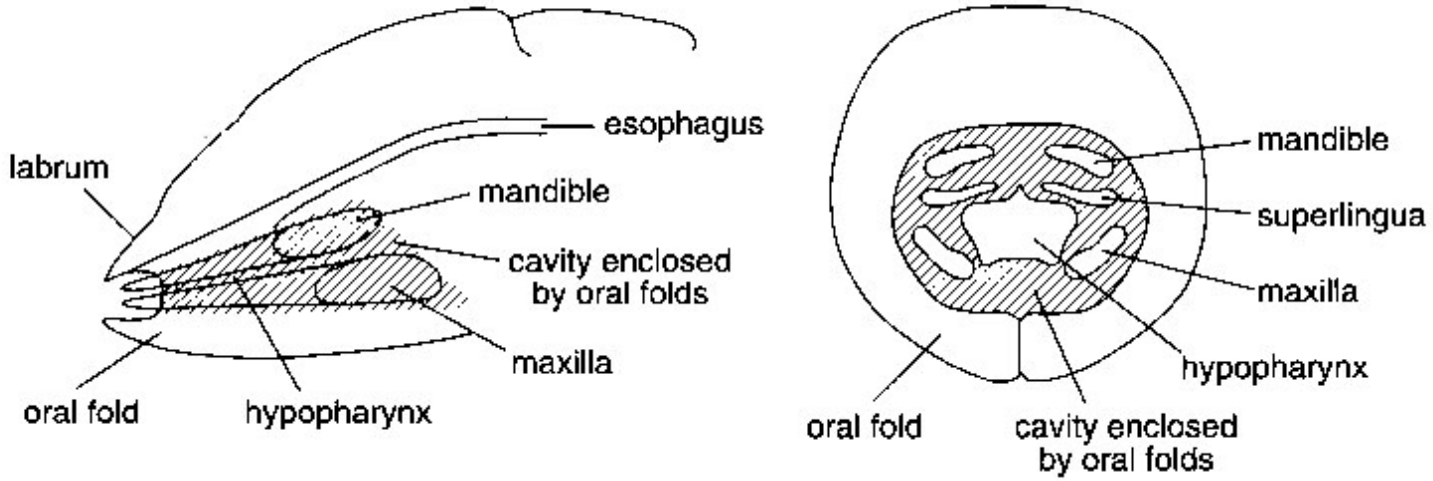
節肢動物可能的演化關係



HEXAPODA
(都是六隻腳的動物，但並不是都是昆蟲)

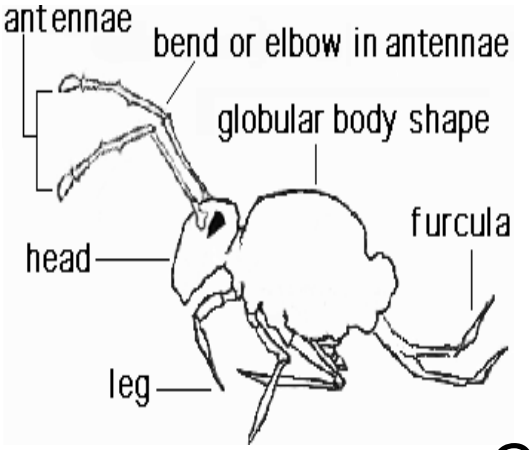
Entognaths(內口類) and Ectognaths(外口類)
(稱「類」而不稱「綱」-演化觀念之適用)

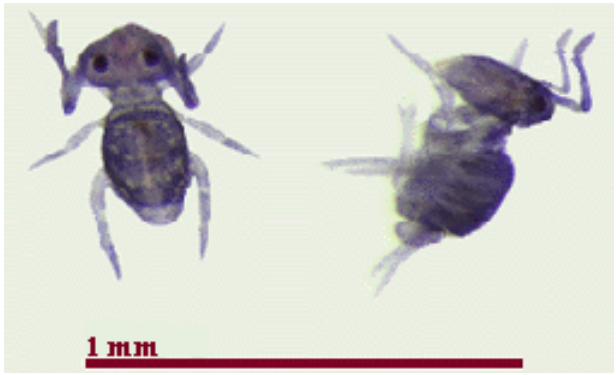
- Entognaths (內口類): Mouthparts "pulled up" into head capsule



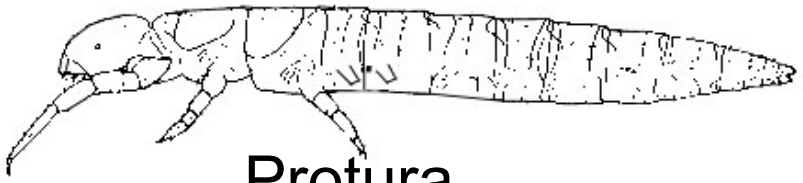
THE ENTOGNATHS
Orders Protura, Collembola, Diplura

- 小型生物、住在落葉及表土層中

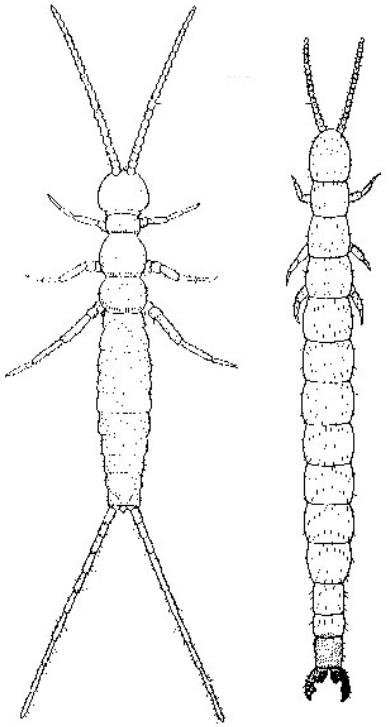




Collembola

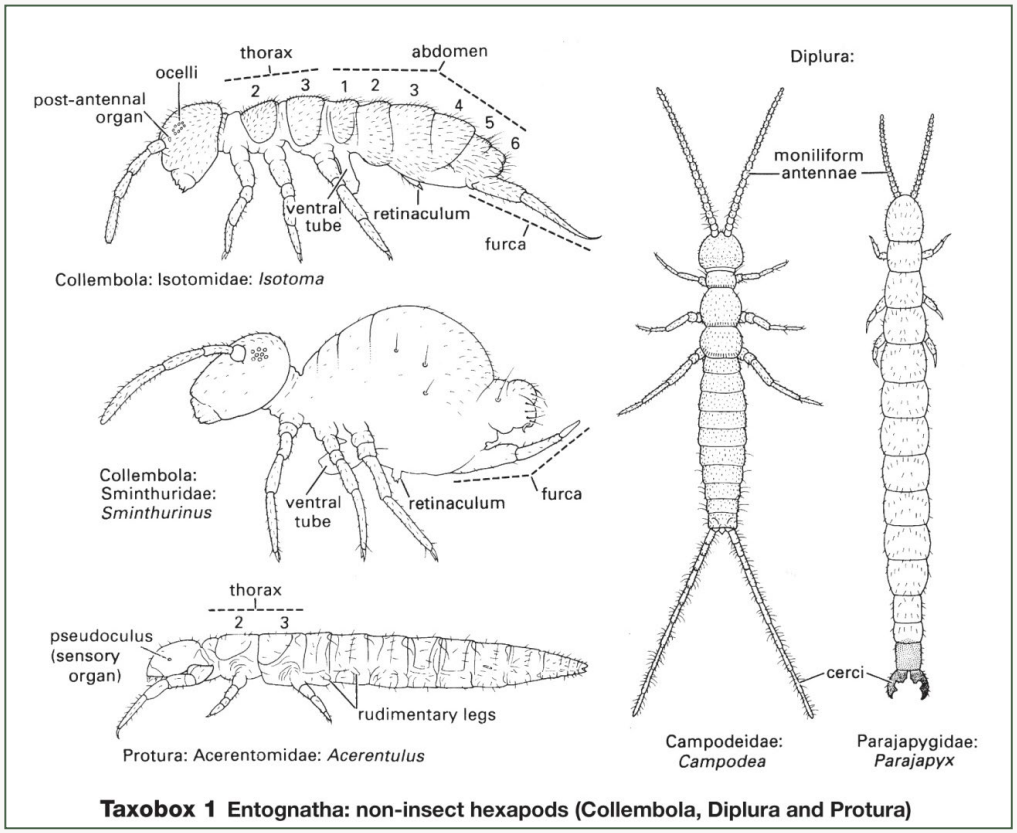


Protura



Diplura

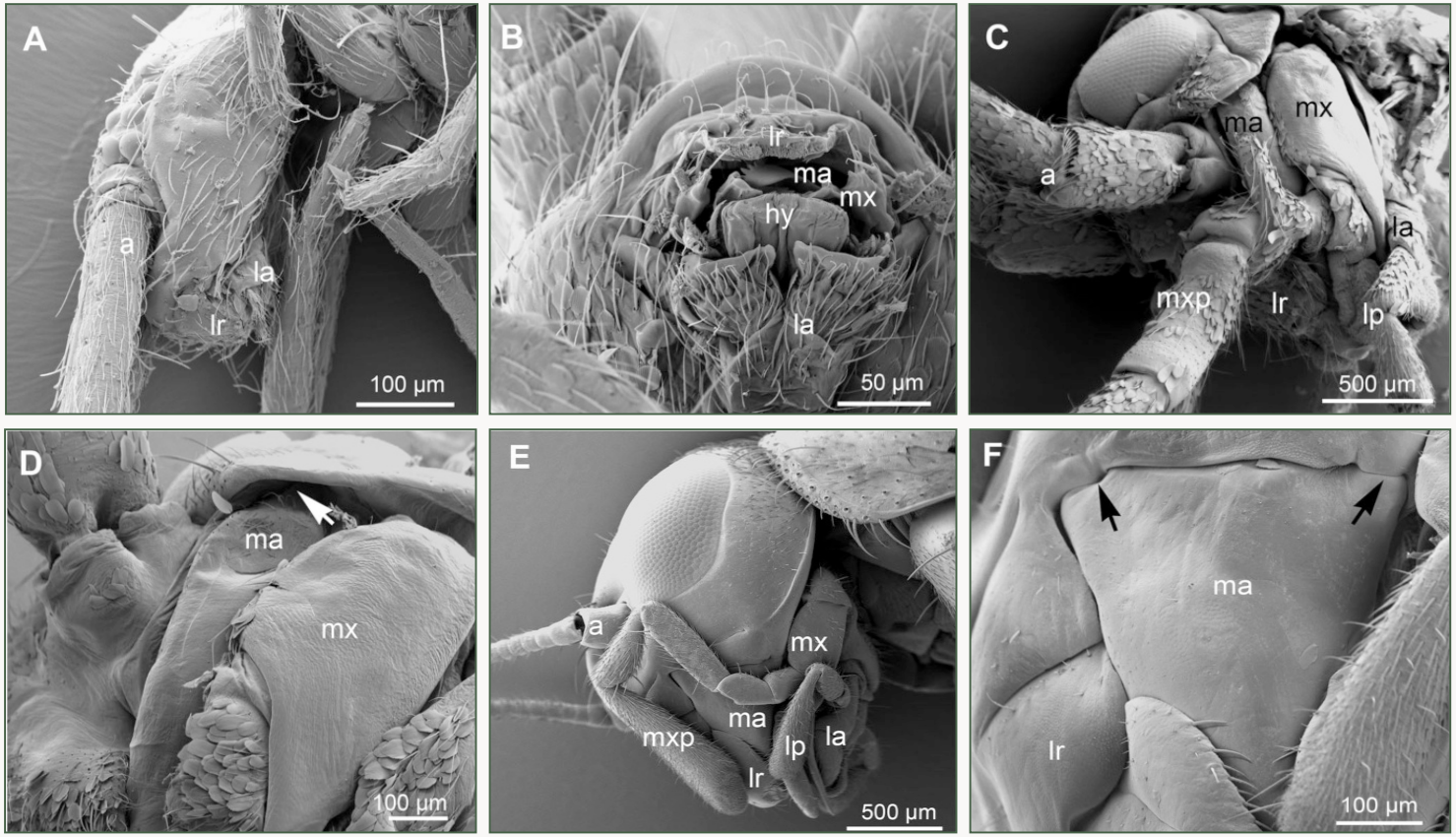
ENTOGNATHA (內口類)

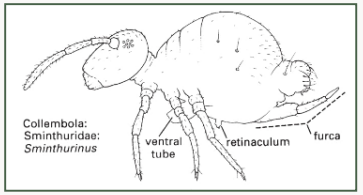


Taxobox 1 Entognatha: non-insect hexapods (Collembola, Diplura and Protura)

Mueggejapyx brehieri

Sendra et al. (2021)





Collembola

Archaeognatha

Cricket

Fig. 2.1 Principal morphology of mouthparts in Hexapoda (scanning electron microscope images). (a) Entognathous head of noninsect Hexapoda *Entomobrya* sp. (Entomobryidae, Collembola), lateral view. (b) Mouthparts of *Entomobrya* sp. are concealed in the head, ventral view. (c) Ectognathous mouthparts and head of *Machilis* sp. (Machilidae, Archaeognatha), fronto-lateral view. (d) Mandible has one external condyle (arrow) to the head (*Machilis* sp.), lateral view. (e) Head of pterygote insect *Nemobius sylvestris* (Gryllidae, Orthoptera), mouthparts in orthognathous position, lateral view. (f) Dicondylic mandible has two external condyles (arrows) to the head (*Nemobius sylvestris*), lateral view. a antenna, hy hypopharynx, la labium, lp labial palpus, lr labrum, ma mandible, mx maxilla, mxp maxillary palpus

Krenn (2019)

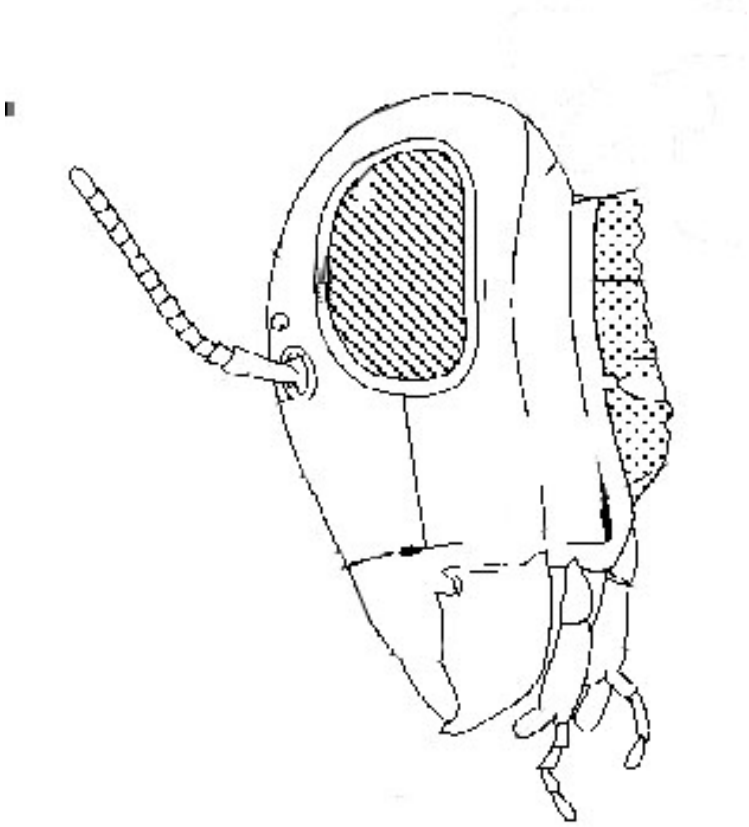
Springtails take jumps

https://www.youtube.com/watch?v=MXeSnWY6DNc

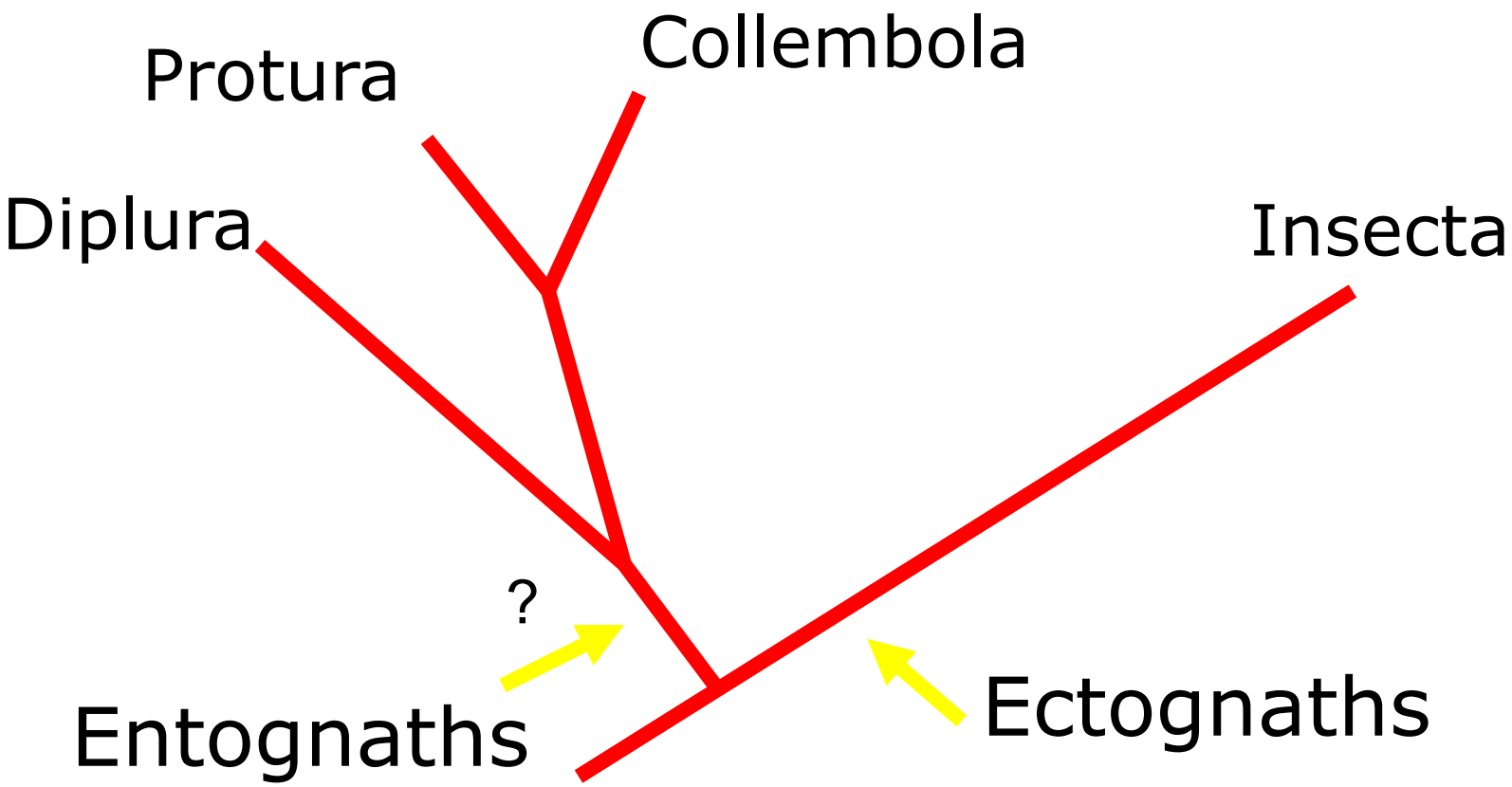
Entognaths(內口類) and Ectognaths(外口類)

六足類的早期分化

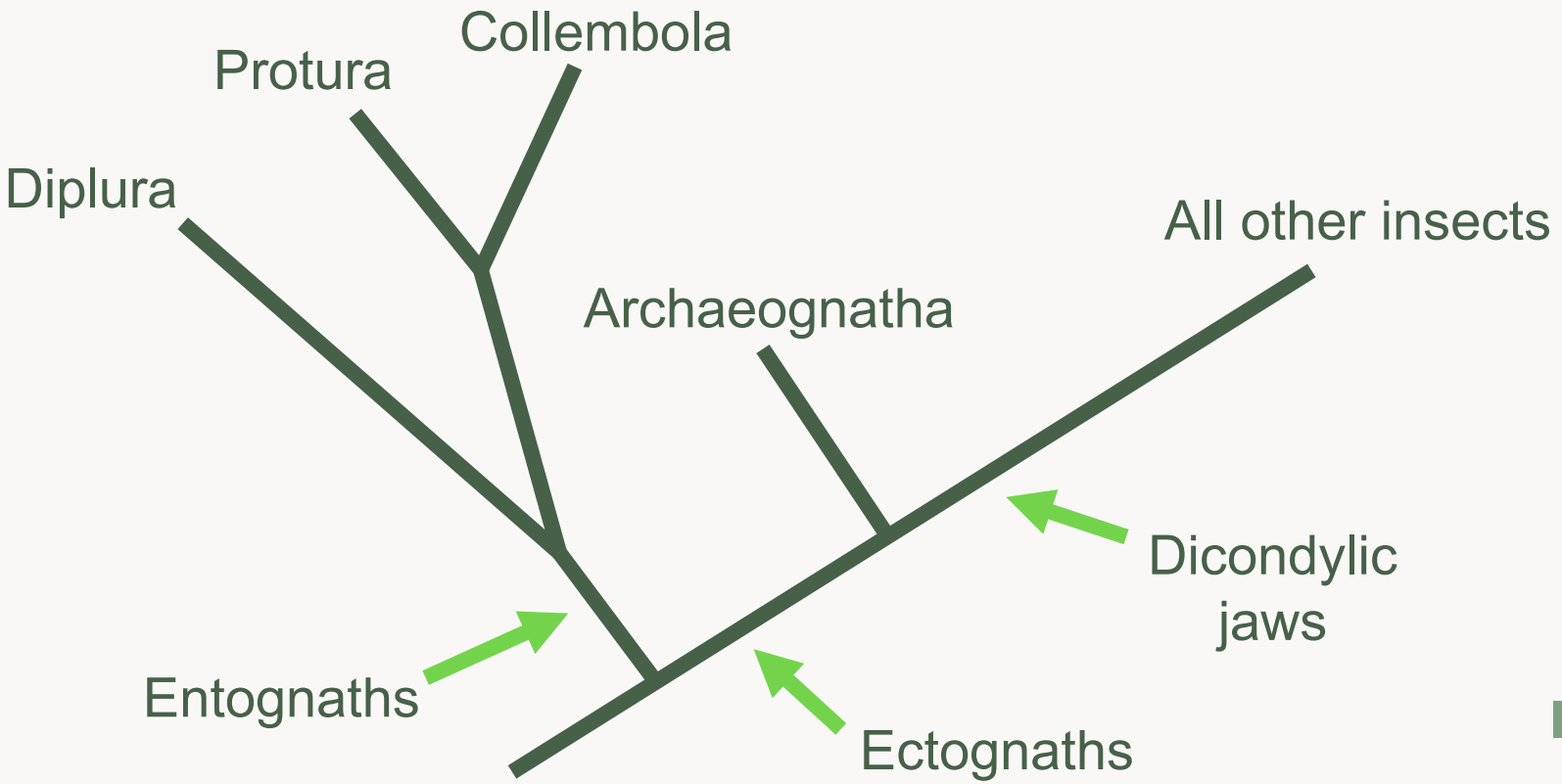
- Ectognathous hexapods: Mouthparts not covered by head capsule(口器外露)

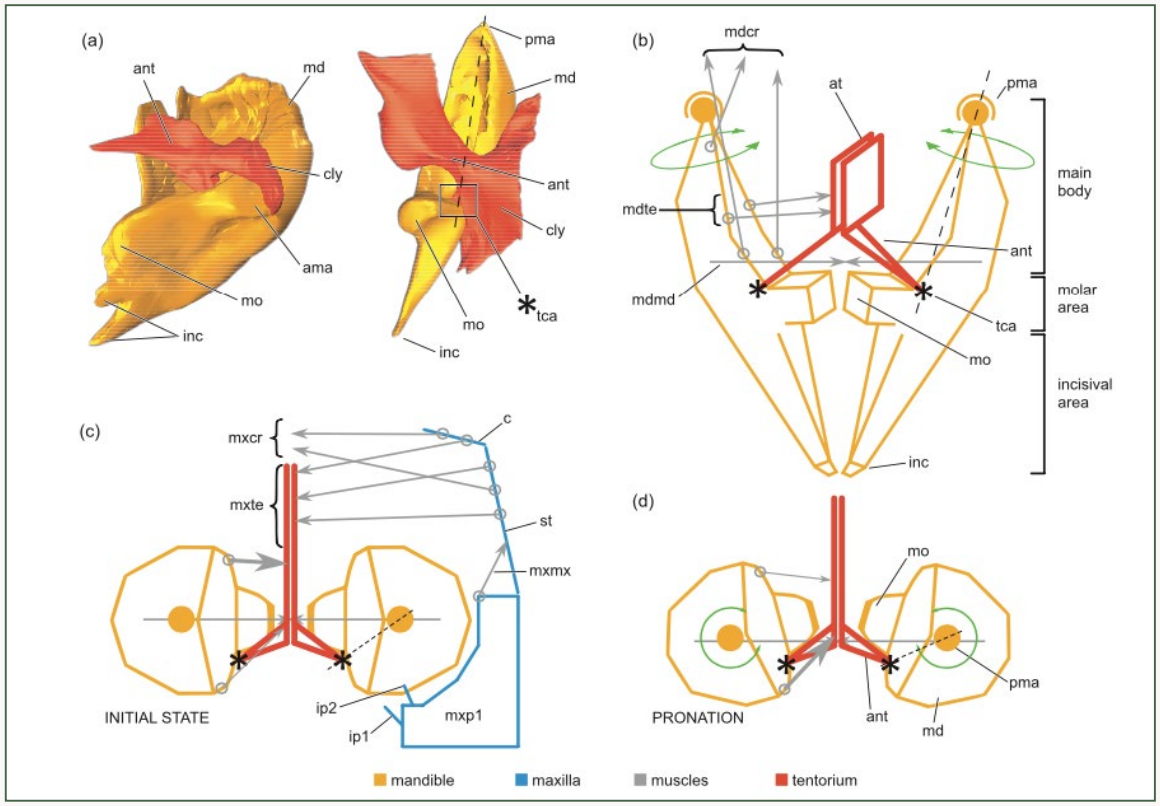


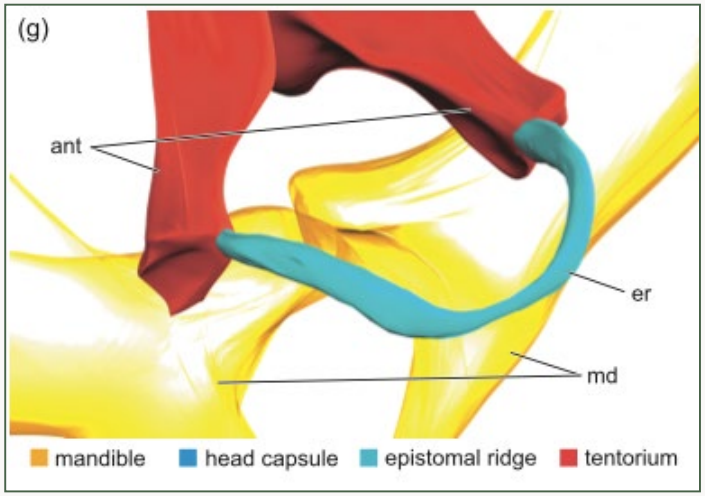
六足類的演化樹


Protura
Collembola
Diplura
Insecta
?
Entognaths
Ectognaths

TREE OF HEXAPOD GROUPS

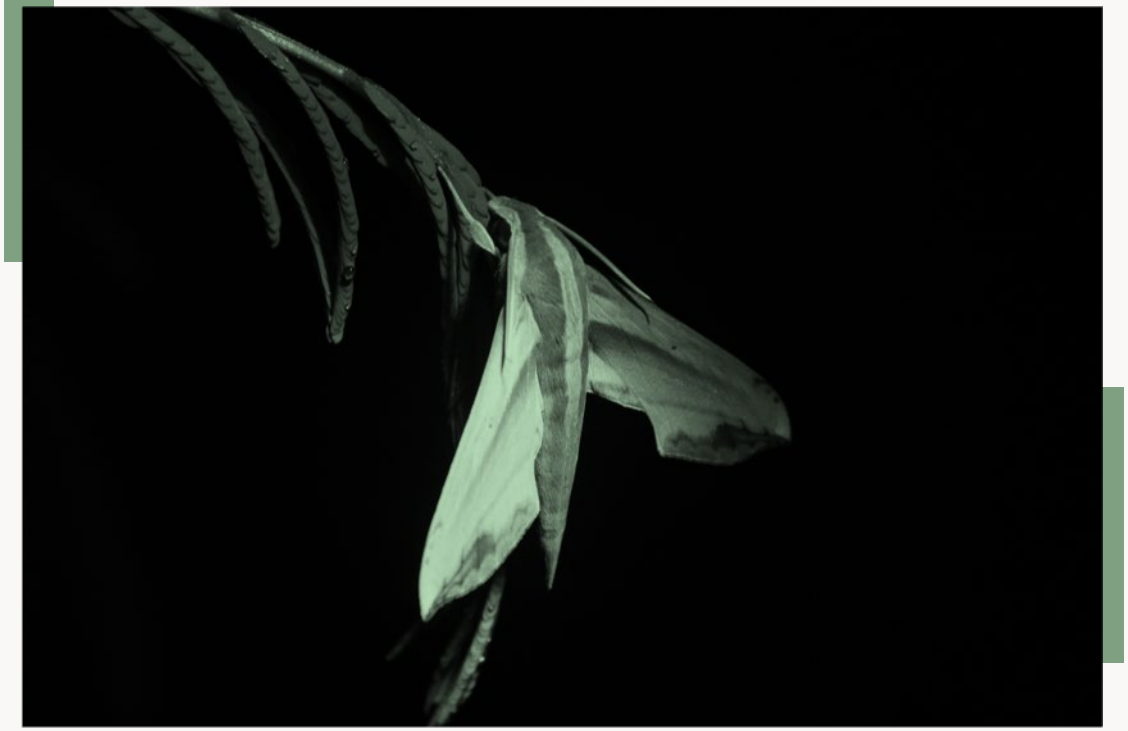


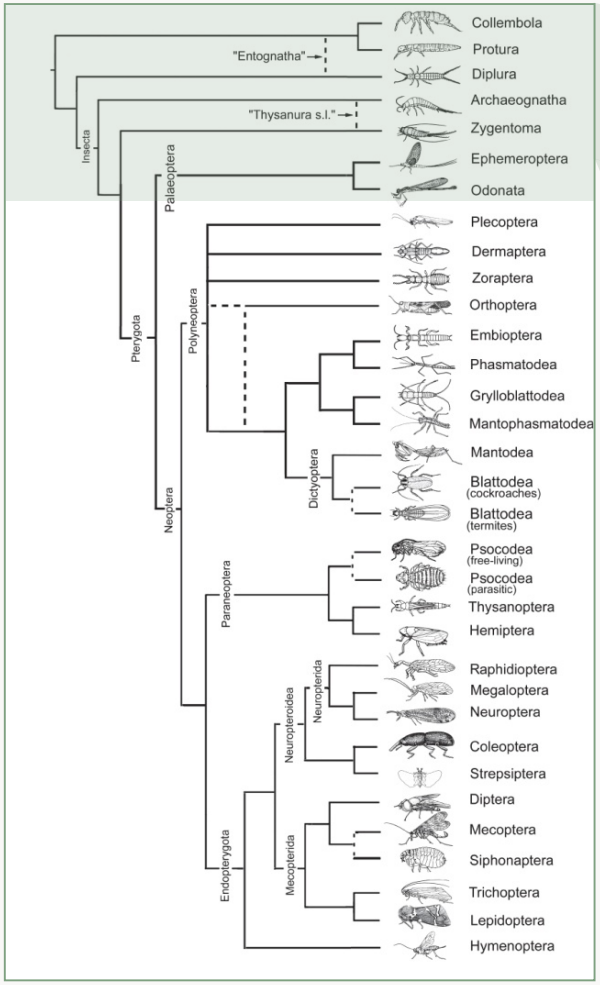


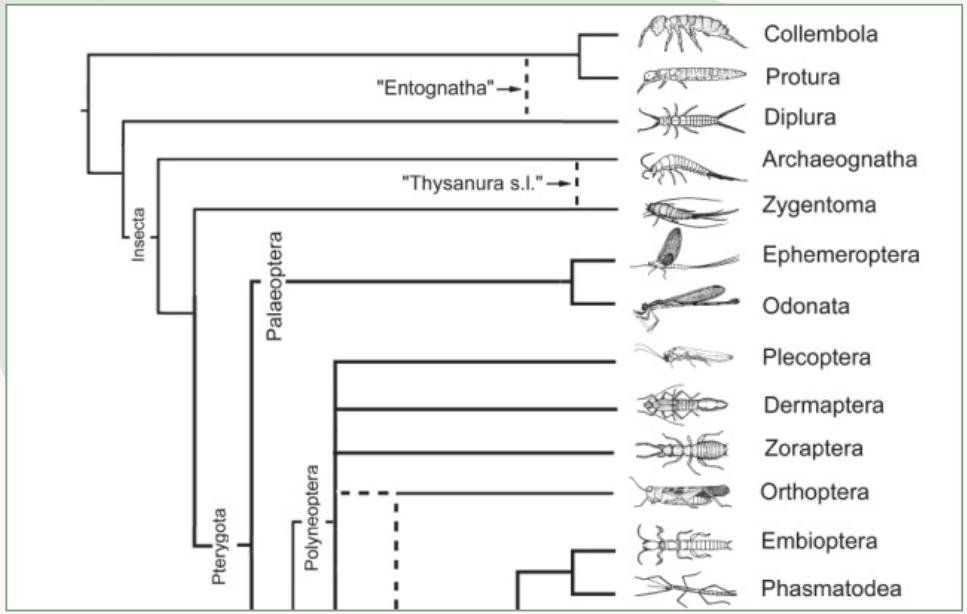


Blanke et al. (2014)

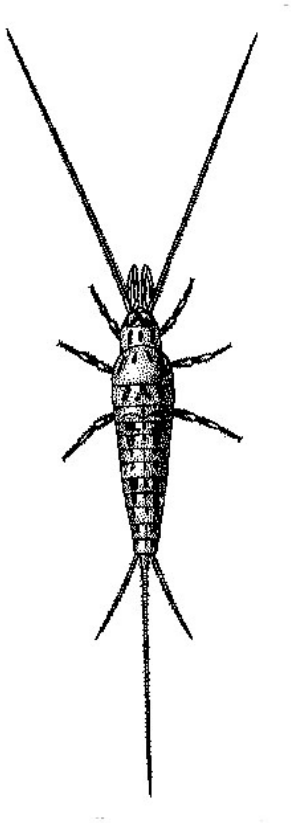
ECTOGNATHA (外顎類)



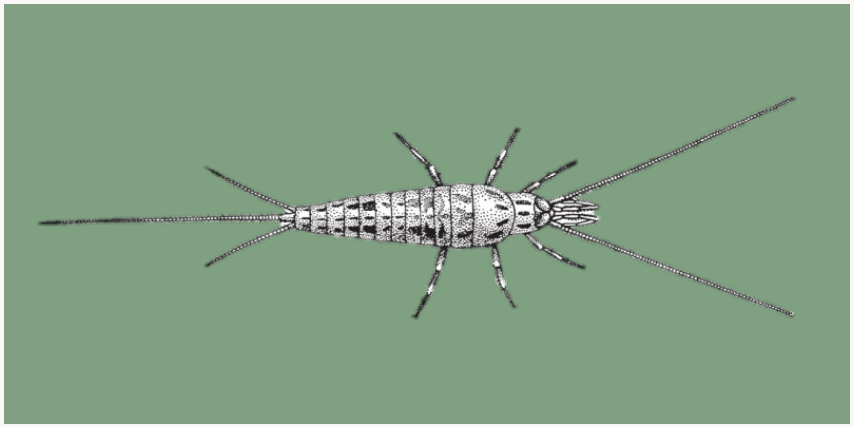

Collembola
Protura
Diplura
Archaeognatha
Zygentoma
Ephemeroptera
Odonata
Plecoptera
Dermaptera
Zoraptera
Orthoptera
Embioptera
Phasmatodea
Grylloblattodea
Mantophasmatodea
Mantodea
Blattodea (cockroaches)
Blattodea (termites)
Psocodea (free-living)
Psocodea (parasitic)
Thysanoptera
Hemiptera
Raphidioptera
Megaloptera
Neuroptera
Coleoptera
Strepsiptera
Diptera
Mecoptera
Siphonaptera
Trichoptera
Lepidoptera
Hymenoptera
"Entognatha"
"Thysanura s.l."
Insecta
Pterygota
Palaeoptera
Neoptera
Polyneoptera
Dictyoptera
Paraneoptera
Endopterygota
Neuropterida
Neuropteroidea
Mecopterida


Collembola
Protura
Diplura
Archaeognatha
Zygentoma
Ephemeroptera
Odonata
Plecoptera
Dermaptera
Zoraptera
Orthoptera
Embioptera
Phasmatodea
"Entognatha"
"Thysanura s.l."
Insecta
Palaeoptera
Pterygota
Polyneoptera

- Order Archeognatha (古口目"ancient jaws")
- Only 1 mandibular condyle (大顎接點一個)



Archaeognatha (Microcoryphia, Bristletails)



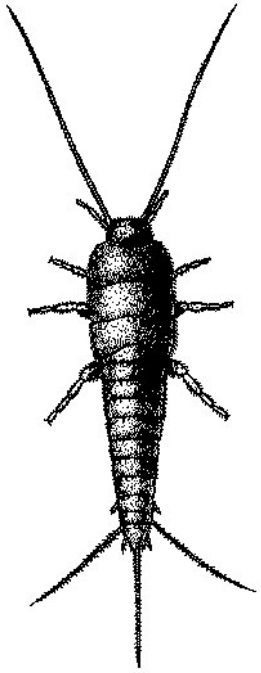
Taxobox 2 Archaeognatha (Microcoryphia; archaeognathans or bristletails)

~350 species

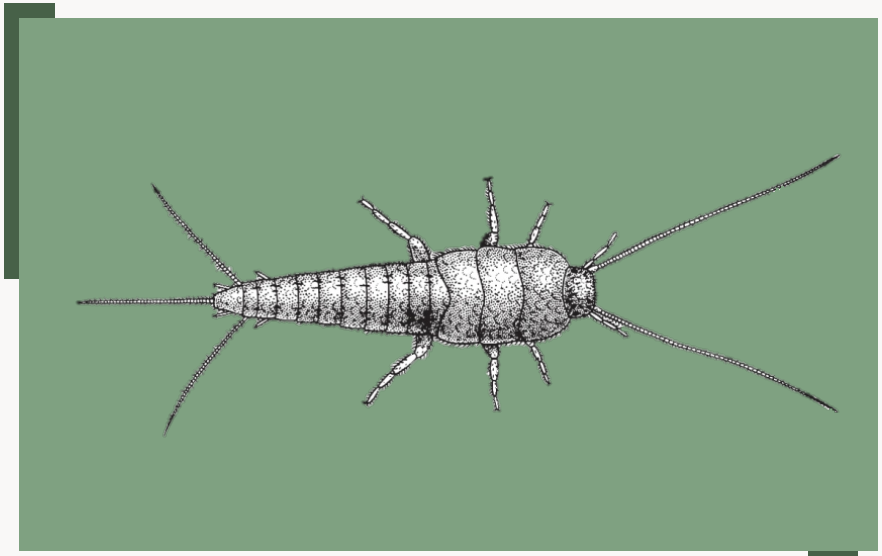
Fancy Bristletail, Washington, USA

Order Thysanura (衣魚目、銀魚目)
Silverfish and firebrats

- New invention:
  dicondylic jaws (大顎接點兩個、見模型)



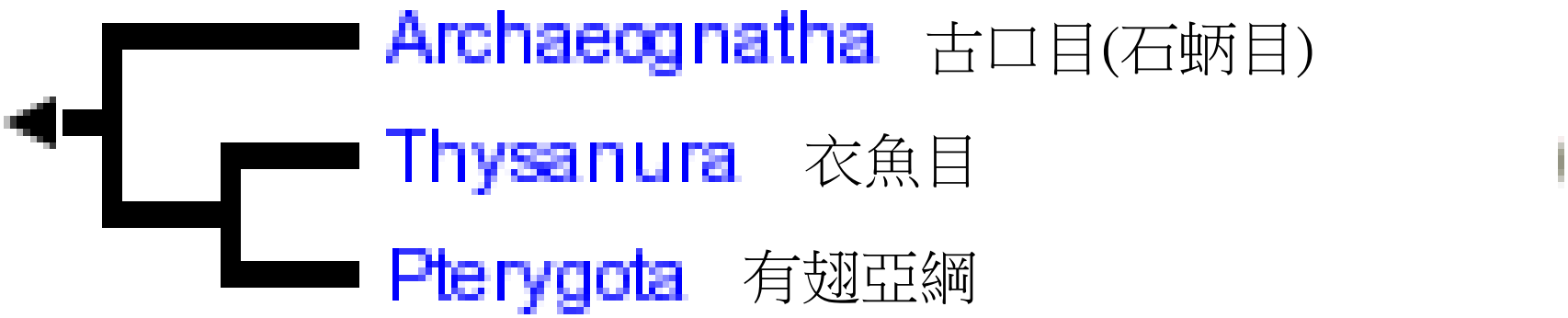
Zygentoma (Thysanura, Silverfish)



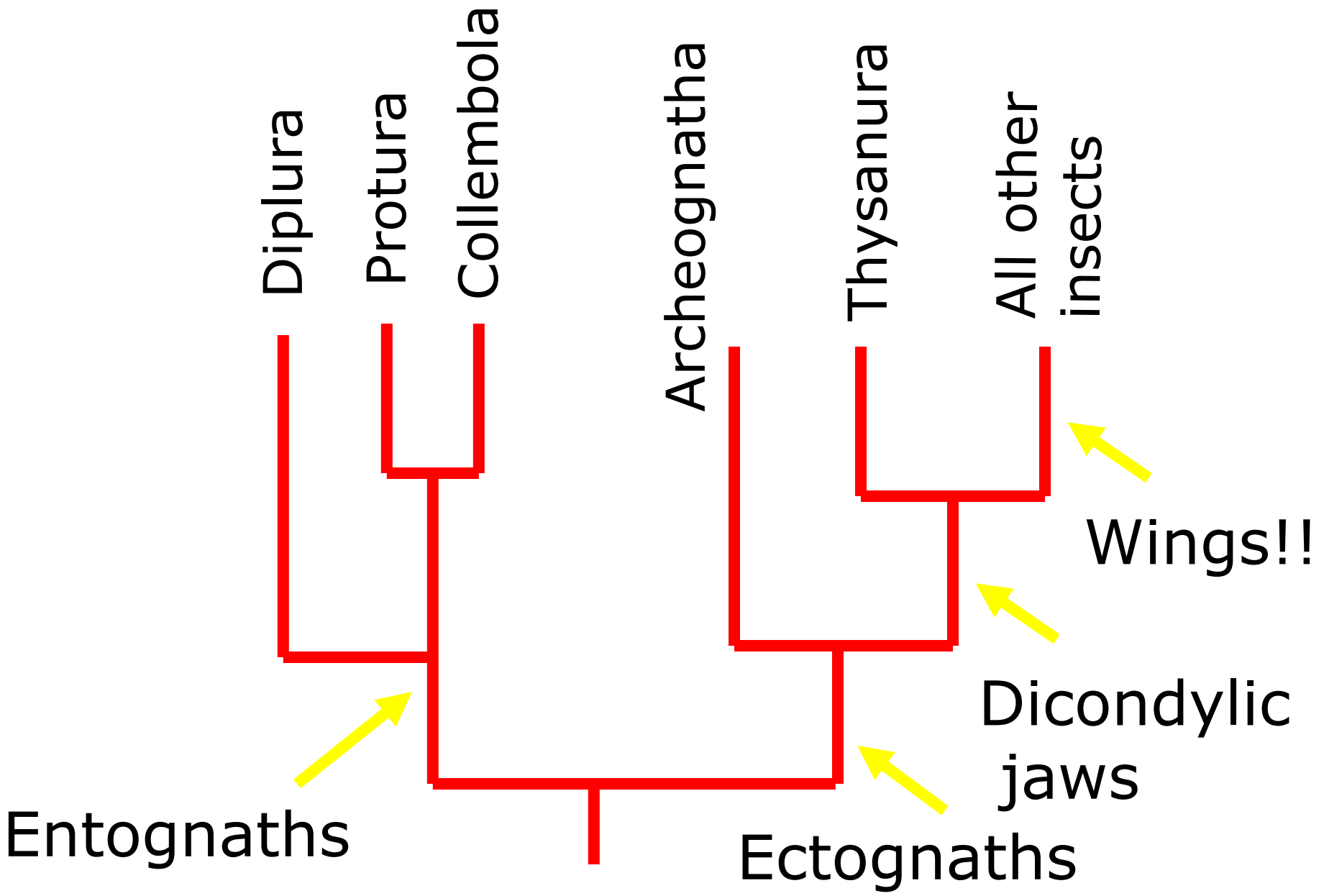
Taxobox 3 Zygentoma (silverfish)

~320 species

外口類=昆蟲綱
Ectognaths: CLASS INSECTA



Order Achaeognatha (古口目) and Order Thysanura (衣魚目) sometimes referred to as the apterygotes (無翅亞“類”) — primitively wingless.
Pterygota (有翅亞綱)are the winged insects


Diplura
Protura
Collembola
Archeognatha
Thysanura
All other insects
Wings!!
Dicondylic jaws
Entognaths
Ectognaths

Brizard mouth part of dragonfly nymph

https://www.facebook.com/DeepLookPBS/videos/808009412716973/

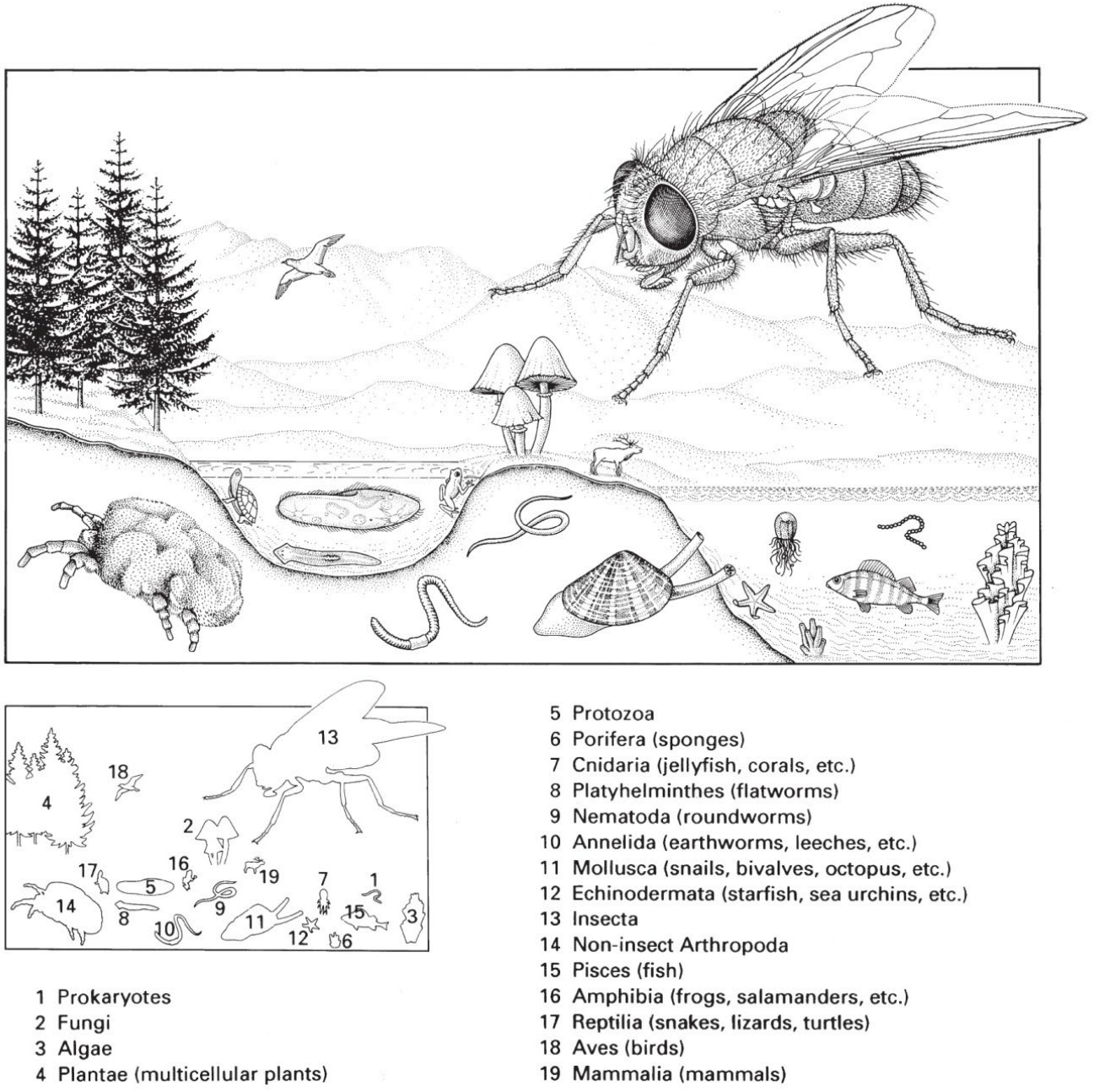


Fig. 1.1 Speciescape, in which the size of individual organisms is approximately proportional to the number of described species in the higher taxon that it represents. (After Wheeler 1990.)

Pterygotes—winged insects

Ephemeroptera (蜉蝣目) and Odonata (蜻蜓目) sometimes called the Paleoptera (古生翅群 Old wings)

Orders Ephemeroptera (蜉蝣目) and Odonata (蜻蛉目)

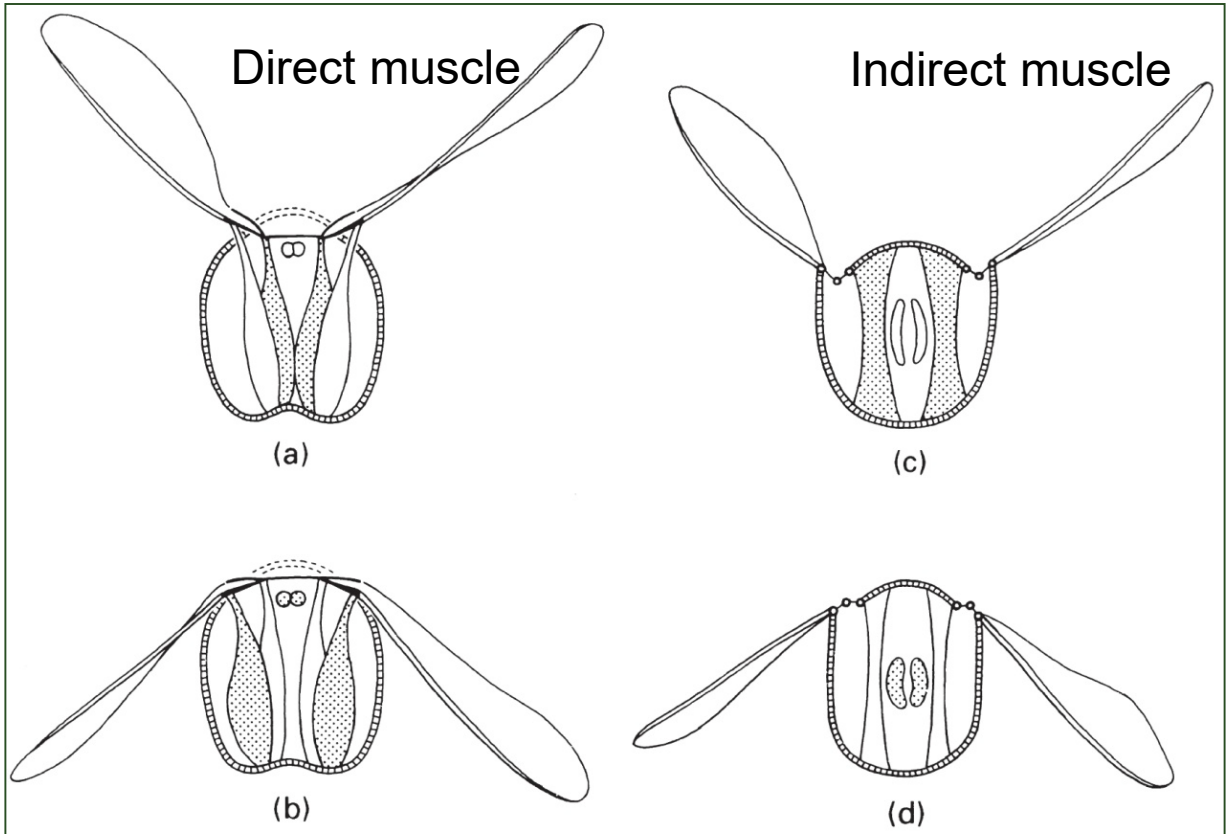
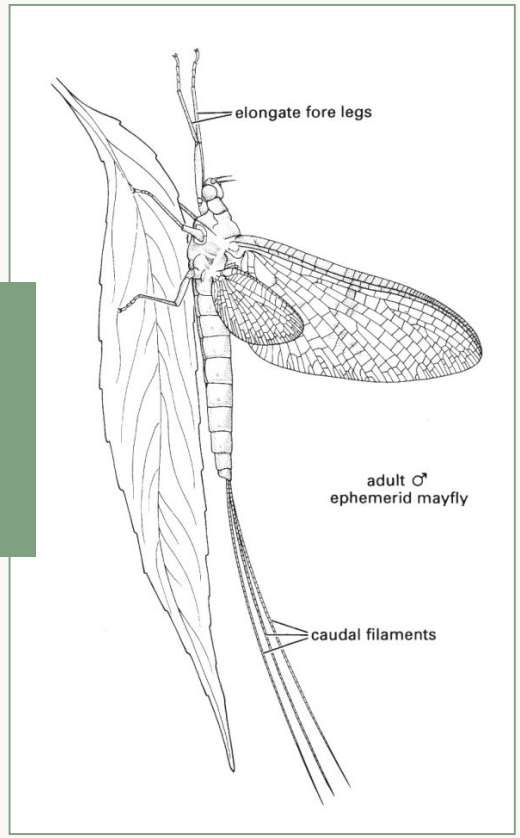
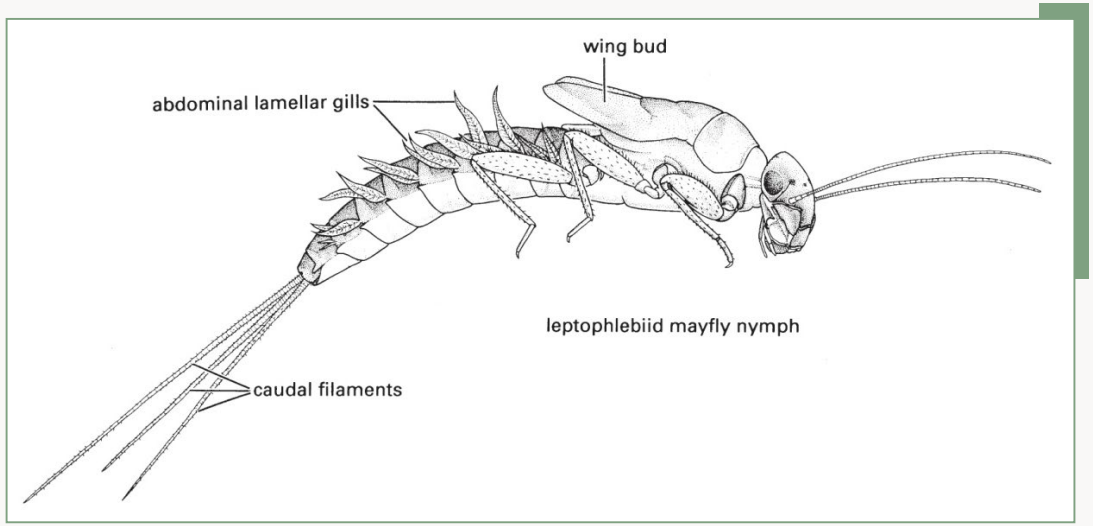


Fig. 3.4 Direct flight mechanisms: thorax during (a) upstroke and (b) downstroke of the wings. Indirect flight mechanisms: thorax during (c) upstroke and (d) downstroke of the wings. Stippled muscles are those contracting in each illustration. (After Blaney 1976.)

Ephemeroptera (Mayflies)
Use indirect flight muscle

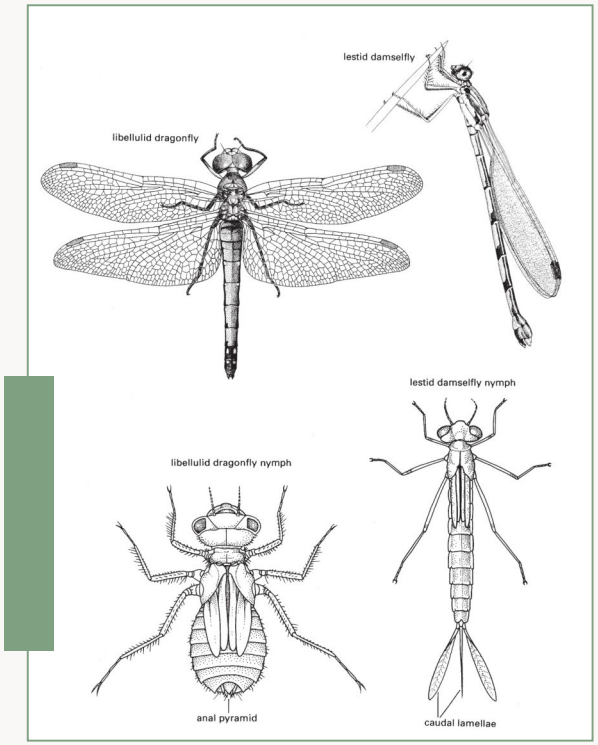




Taxobox 4 Ephemeroptera (mayflies)

~3,000 species

Odonata (Dragonflies and Damselflies)
Use direct flight muscle



Taxobox 5 Odonata (damselflies and dragonflies)

~5,000 species

Neopteran Insects (新翅群)

- Most of the insect orders
- Special wing-folding mechanism
- Can fold wings flat over back (可以將翅折與腹部平行)

Dictyoperan orders

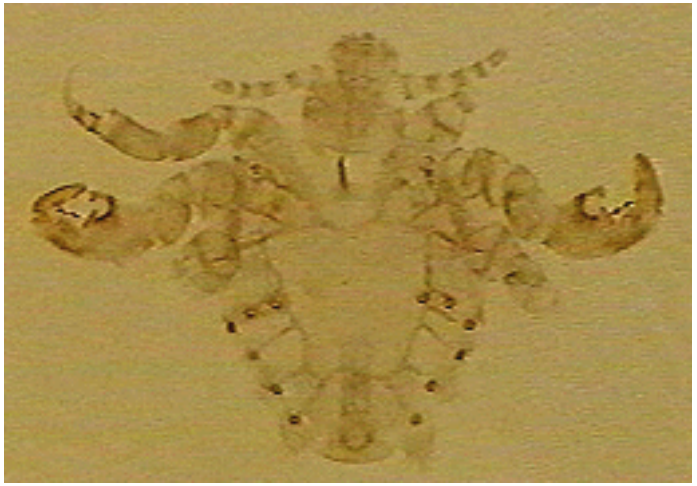
- Blattodea(蜚蠊目)
- Blatteria-Roaches
- Isoptera-Termites
- Mantodea-Mantises

Order Orthoptera:Two big groups:

- Ensifera: “long horned”
- Crickets, katydids and weta

- Caelifera: “Short-horned”
- grasshoppers, locusts and their relatives

Hemipteroid Orders

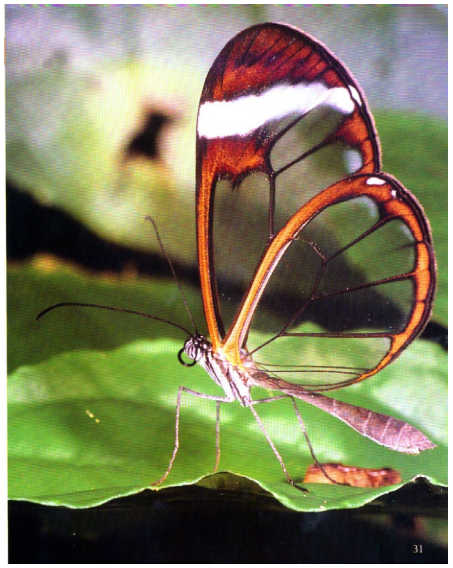


Crab louse-Phthiraptera

A thrips
Thysanoptera

Hemiptera/
Homoptera

Lacewing-Neuroptera



Butterfly-
Lepidoptera

Flea-Siphonaptera

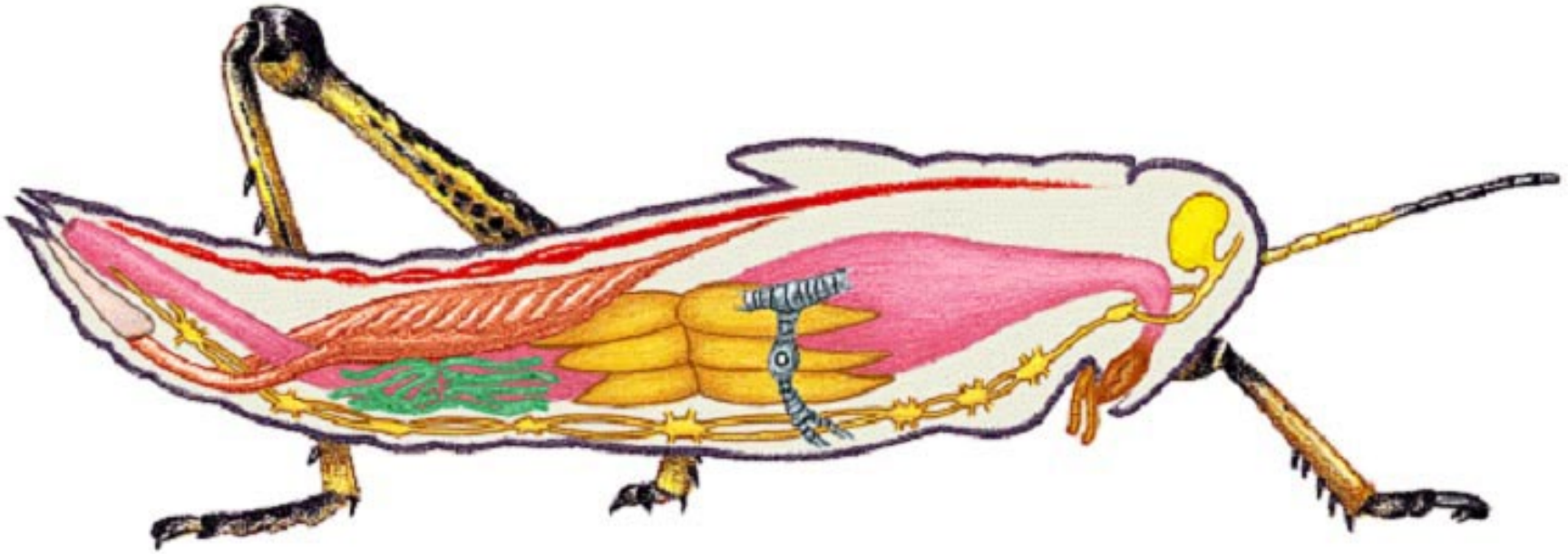
Beetle-Coleoptera

Bee-Hymenoptera

Mosquito-Diptera

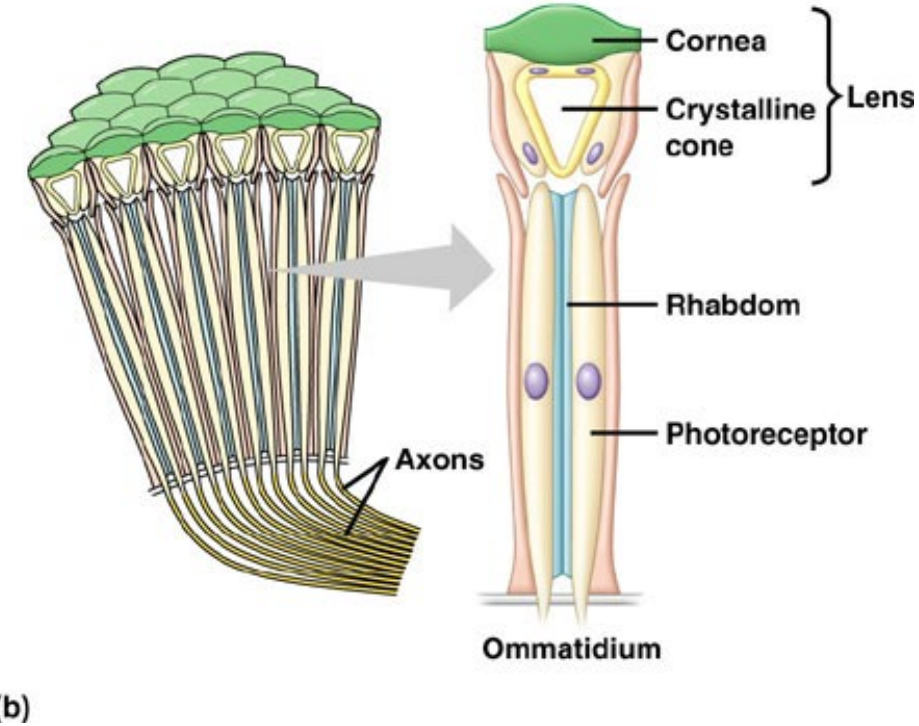
Phylum Arthropoda:
the jointed-foot animals

- Many basic features shared with other animal phyla
- SEGMENTED BODY (身體分節)
- DORSAL HEART (心位於背部)
- PAIRED VENTRAL NERVE CORDS (成對的神經索位於腹部)



https://www.facebook.com/ScientificAmerican/videos/10159107115145246/

Phylum Arthropoda



- COMPOUND EYES (複眼)
- many small units, OMMATIDIA (複眼單元)
- OMMATIDIUM has lens, visual pigments

Phylum Arthropoda
unique characters

- Coelom greatly reduced (體腔退化)
- Instead, open circulatory system (半開放體循環)

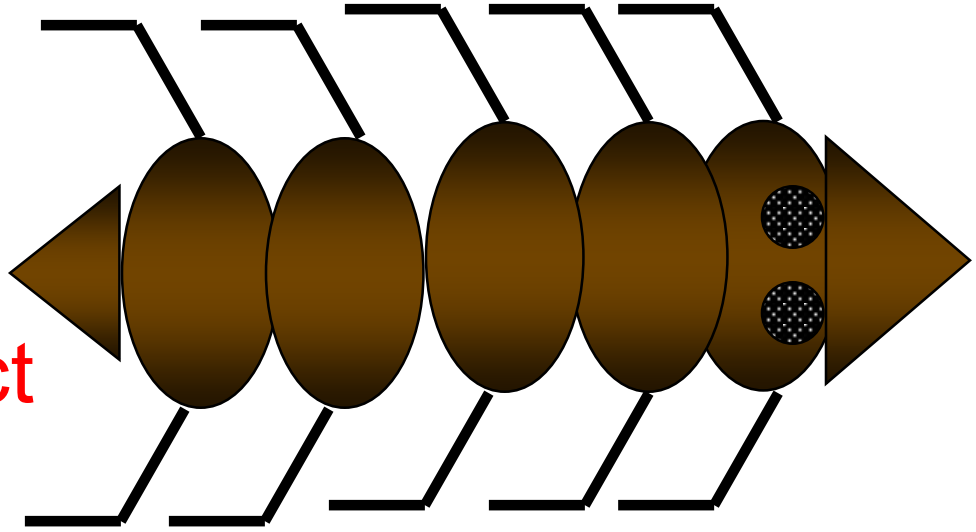
Phylum Arthropoda
unique characters

- Hard, jointed exoskeleton (硬的外骨骼)
  - Cuticle= protein and CHITIN, a polysaccharide
  - Sclerotization of cuticle:

  tanning of protein to form hard plates
- Jointed, segmented appendages on each body segment (外骨骼及附肢分節)

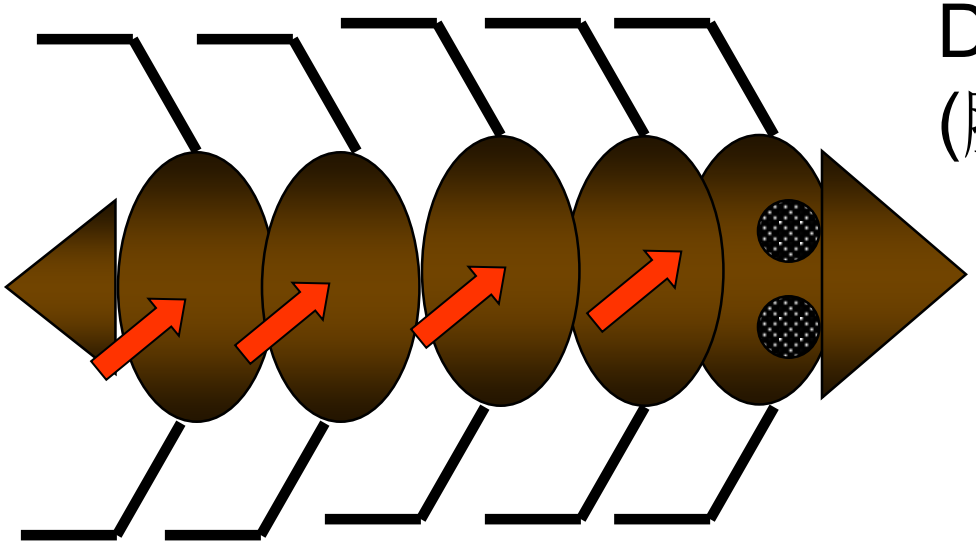
Segmented body plan, Jointed exoskeleton

Anterior to mouth:
non-segmental acron
or prostomium



Just posterior to anus:
non-segmental tail,
or telson or periproct

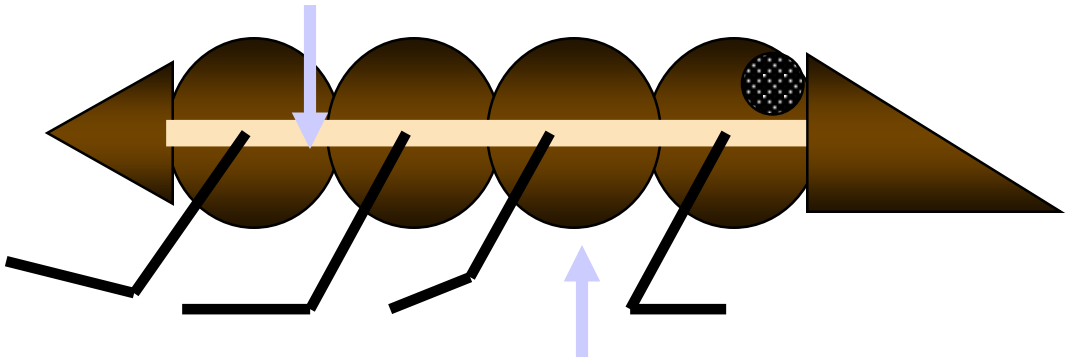
Paired, jointed limbs on each body segment



DORSAL VIEW
(腹面)

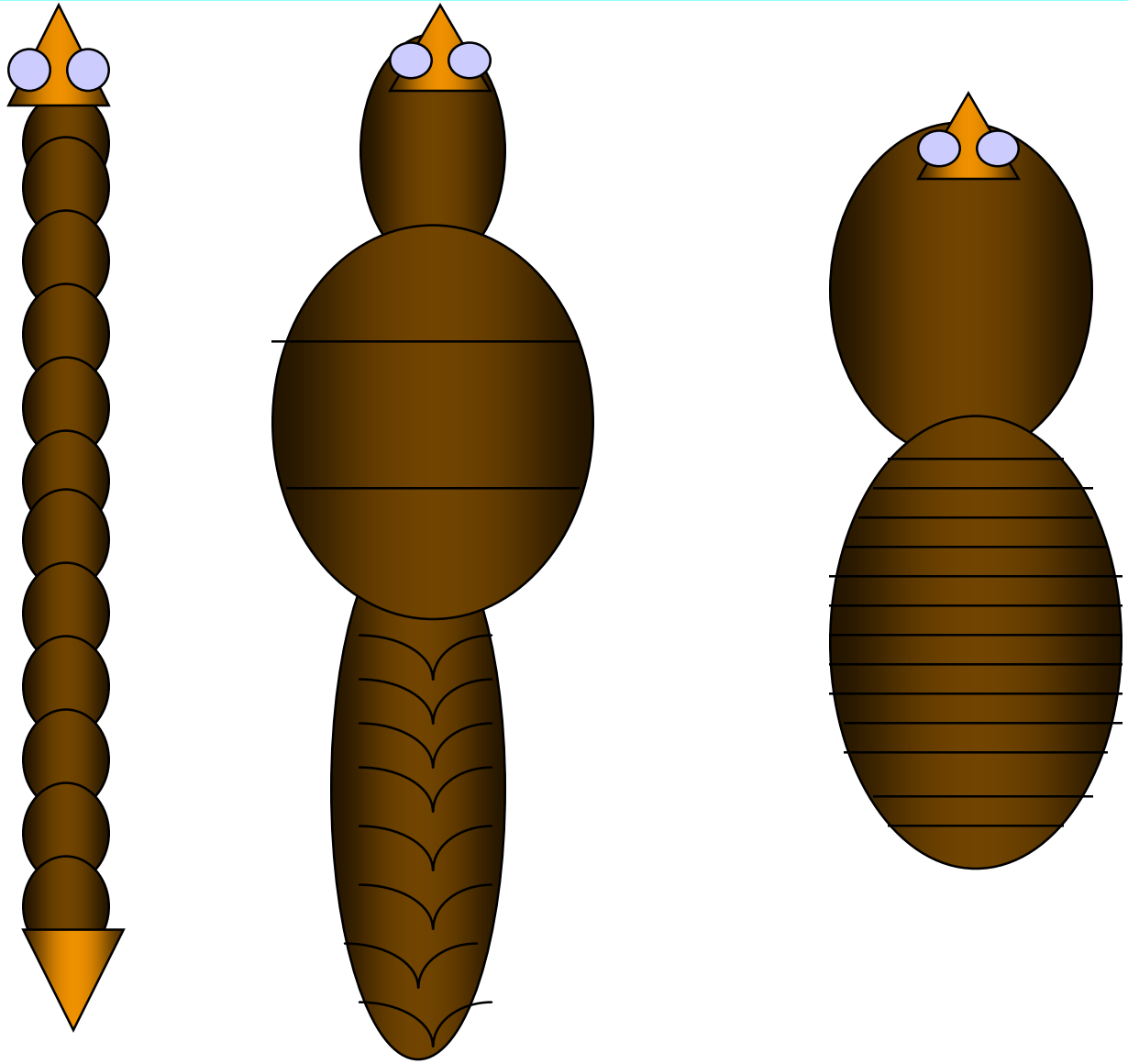
Tergites(背片): hard dorsal plates

Soft, thin pleural membrane

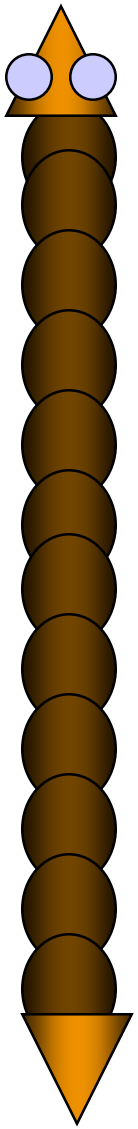


hard ventral plates: sternites(腹片)

Tagmosis (分節特化):
Fusion, specialization of body segments



Modification of limbs



Head or head region

limbs → mouthparts, antennae.

Other limbs →

walking, swimming, (運動)

sperm transfer,

holding eggs, (生殖)

Limbs may be lost

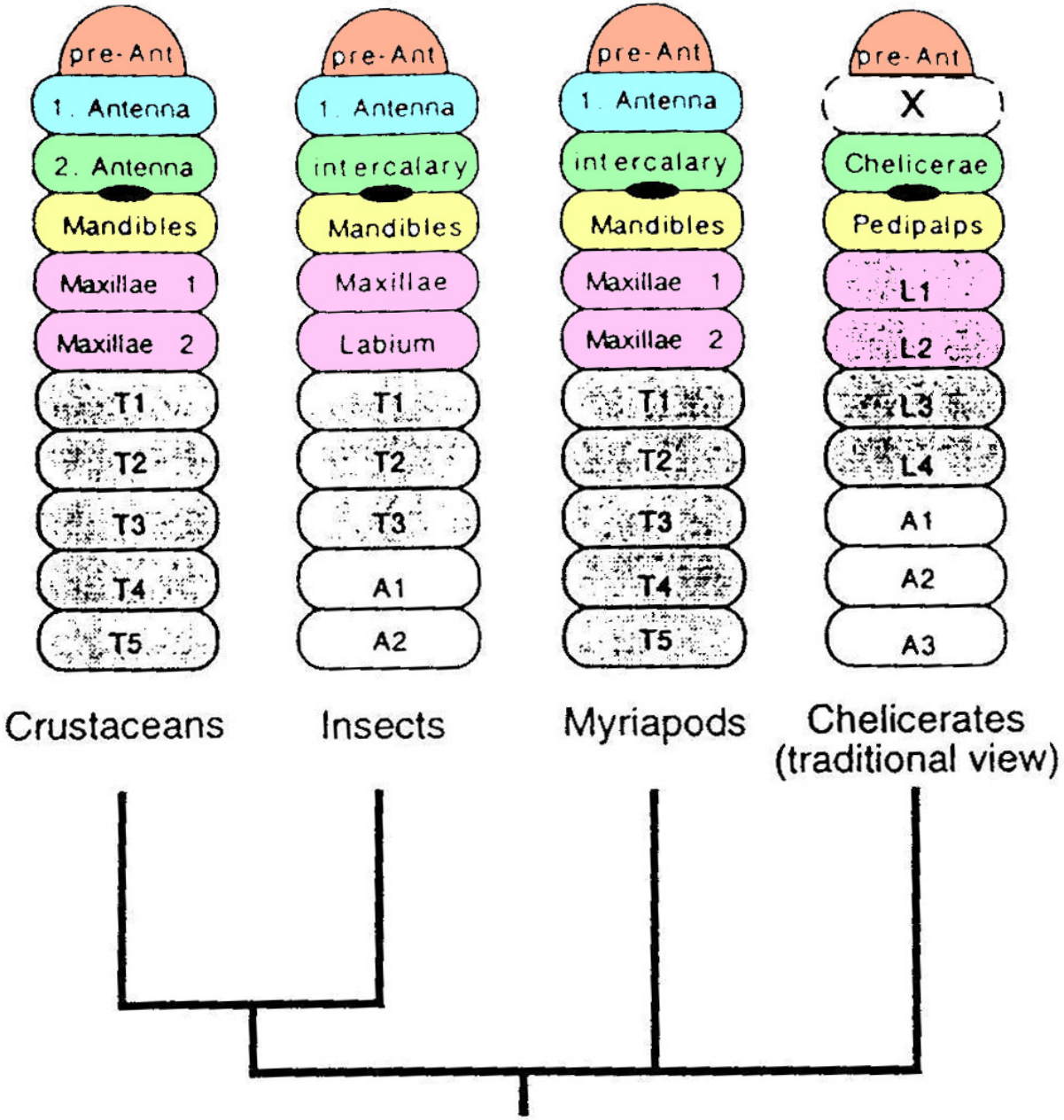
Insects: 3 body regions or tagmata

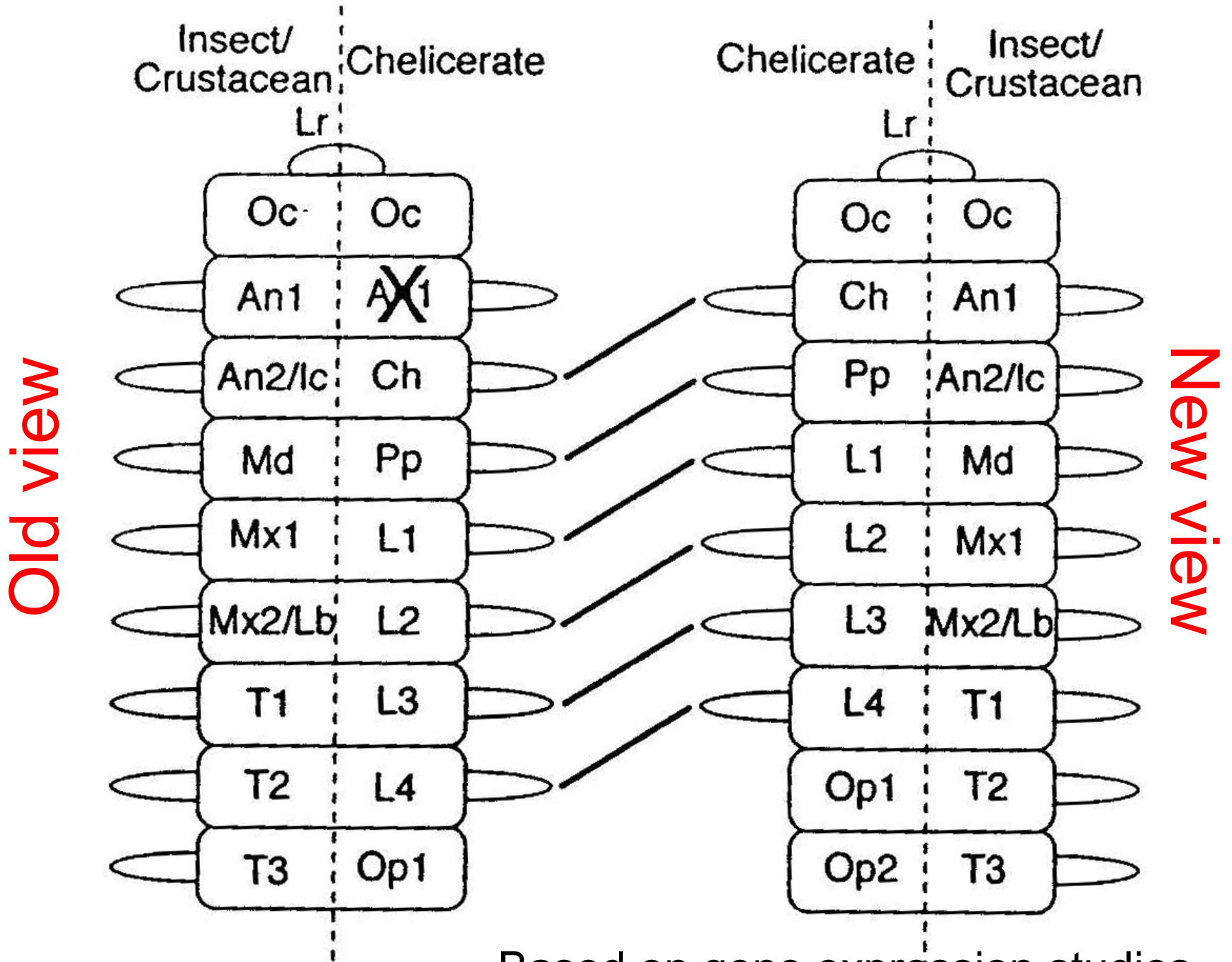
- Abdomen(腹), thorax(胸), head (頭)

Segmentation (分節)– how do we know(如何知道分幾節)?

- Count appendages (計算附肢)
  - Each pair of appendages (or things derived from the appendages) indicates a segment
- Count pairs of nerve ganglia (計算神經節)
  - (one pair per segment)
- Examine limb buds in embryos (由胚胎)
- (分子生物學的方法) Use labeled antibodies or other method to determine where gene for “front edge of a segment” is turned on in developing embryo

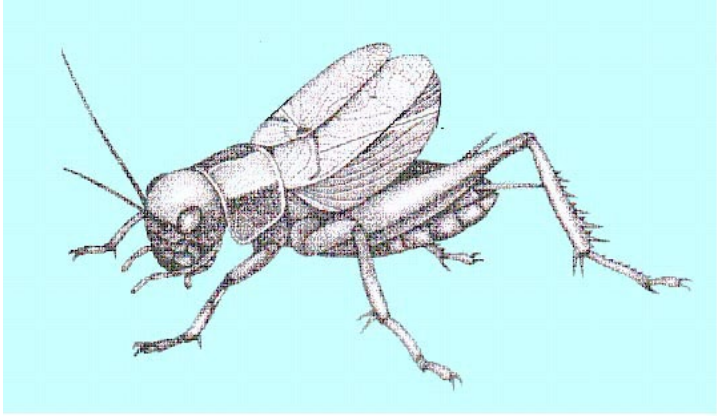
“Traditional” view



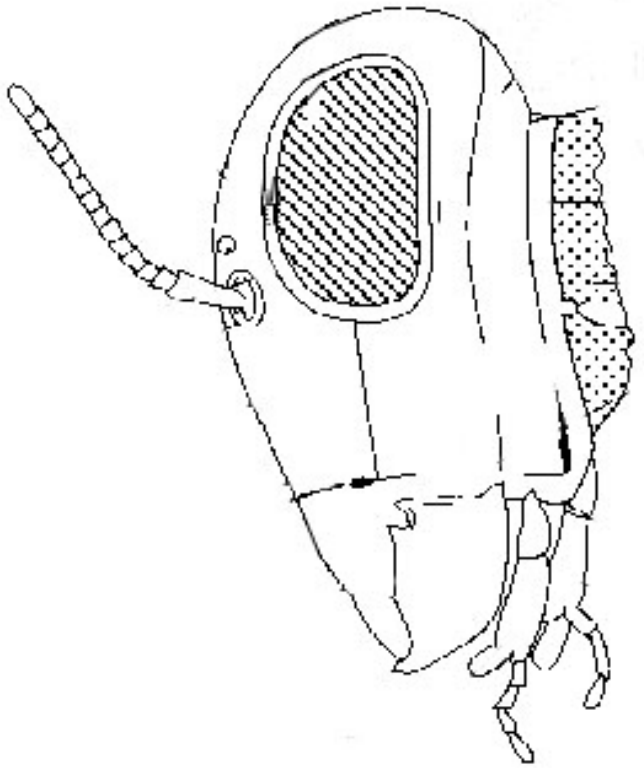


Based on gene expression studies

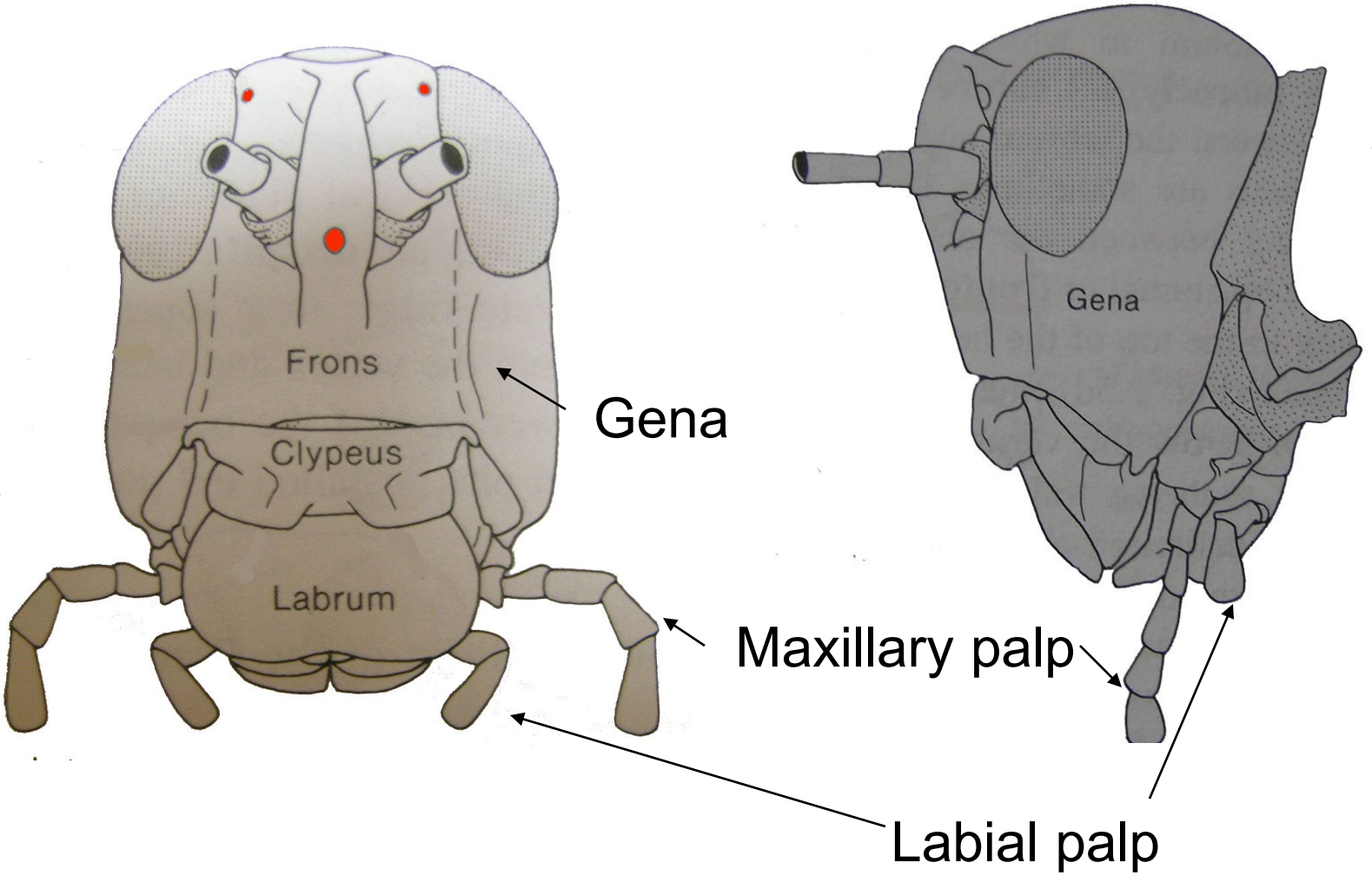
Basic insect head



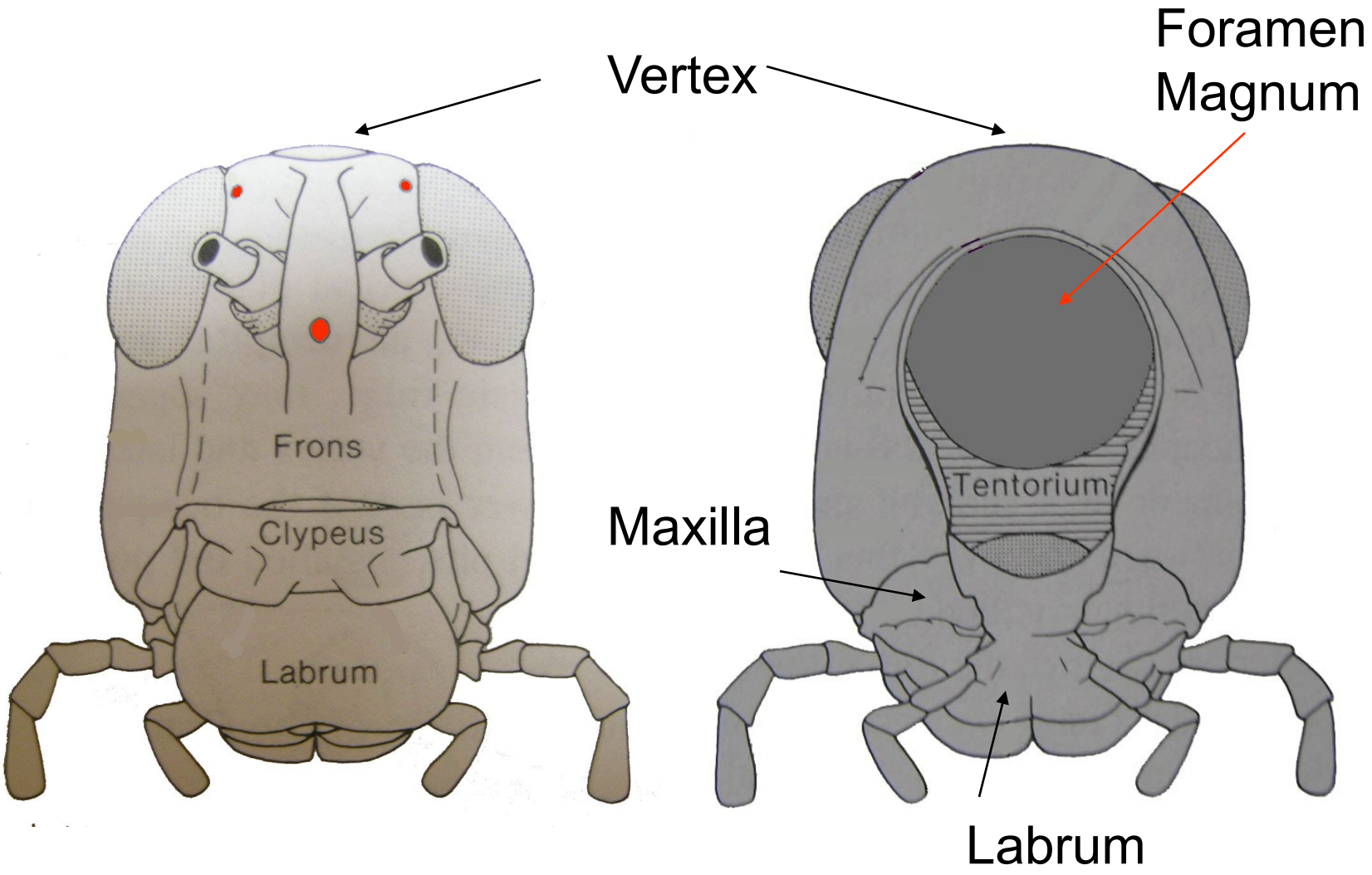
- Head capsule
- 1 pair compound eyes(複眼)
- 3 simple eyes-ocelli (單眼)
- 1 pair antennae (觸角)
- 3 pair mouthparts (口器)
  - Mandibles(大顎)
  - Maxillae(小顎)
  - Labium (唇)



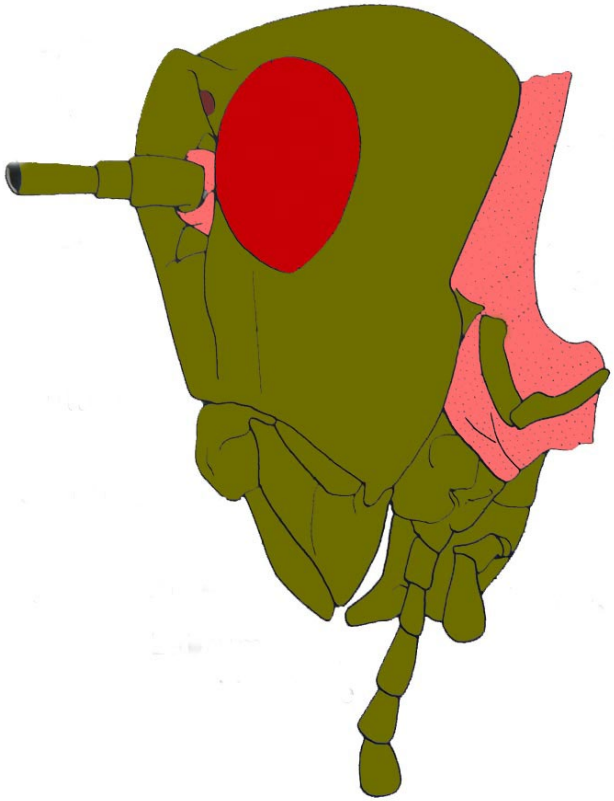
Parts of the head

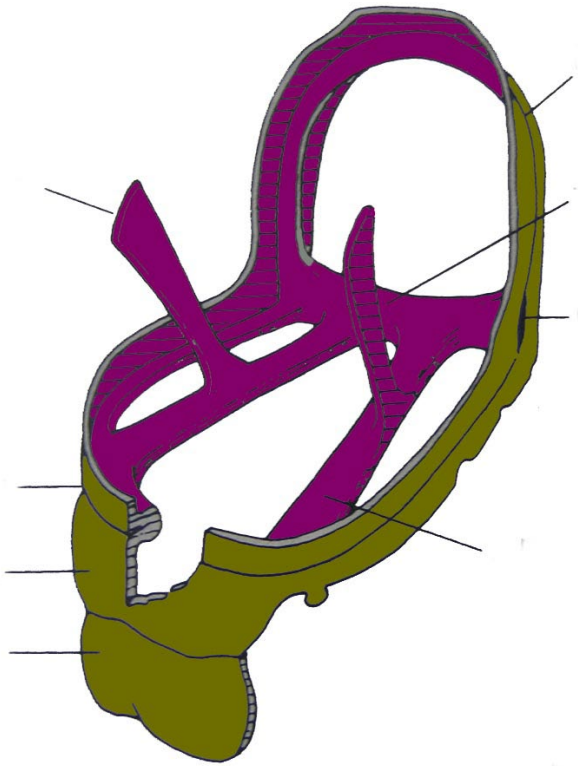


Parts of the head



Internal bracing in insect head

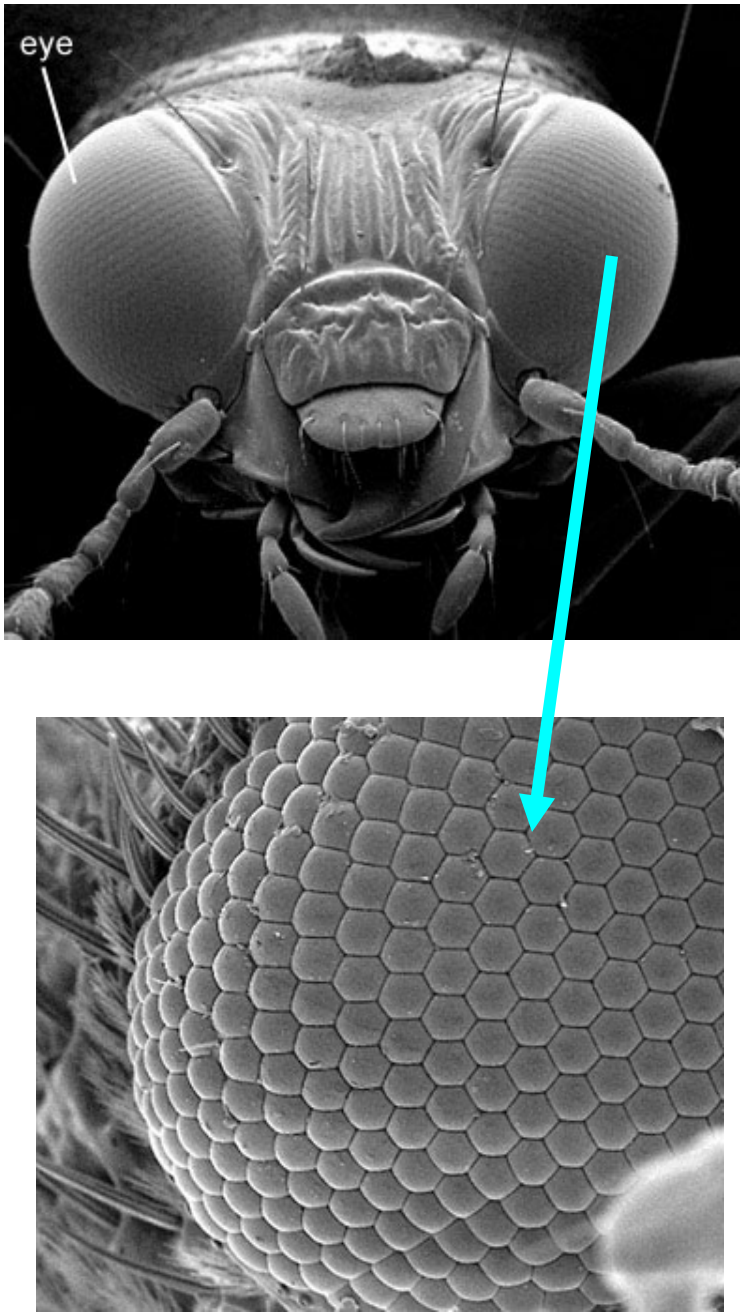




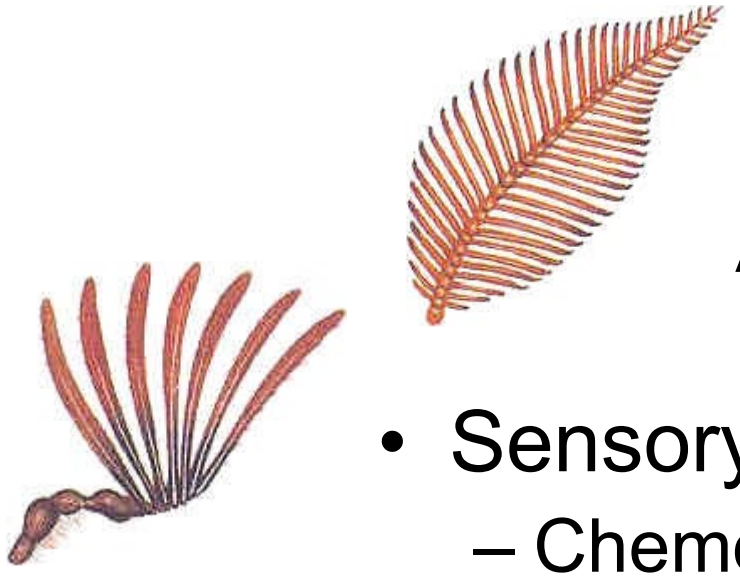
Tentorium

Eyes

- Compound eyes
- Up to 3 simple eyes or ocelli
- More on eyes later



Eyes of praying mantis

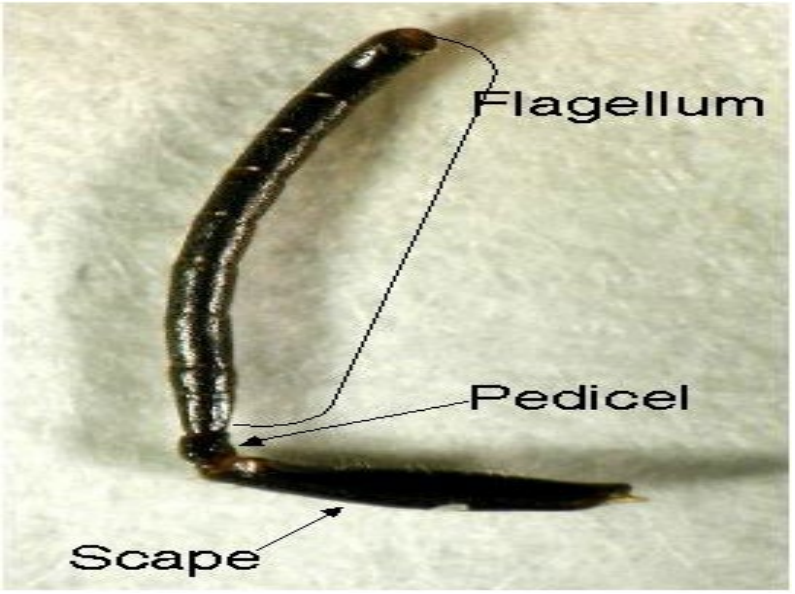


Antennae

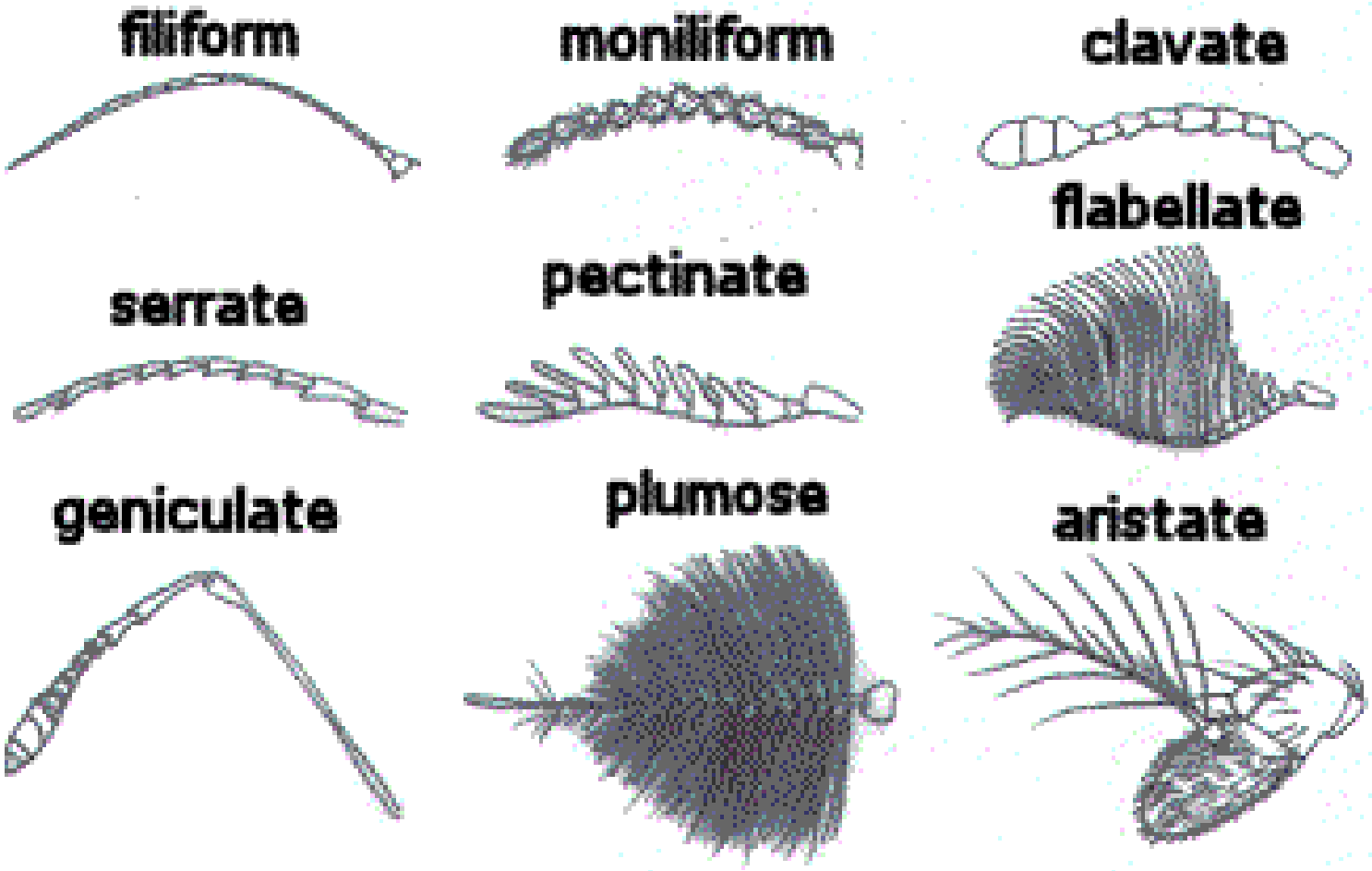
- Sensory
  - Chemoreception(化學接受器)
  - Touch(觸覺接受器)
- Parts
  - Scape (基)
  - Pedicel (軸)
  - Flagellum (with many small flagellomeres)(羽)

Antennae

- Honey bee
- (*Apis mellifera*)

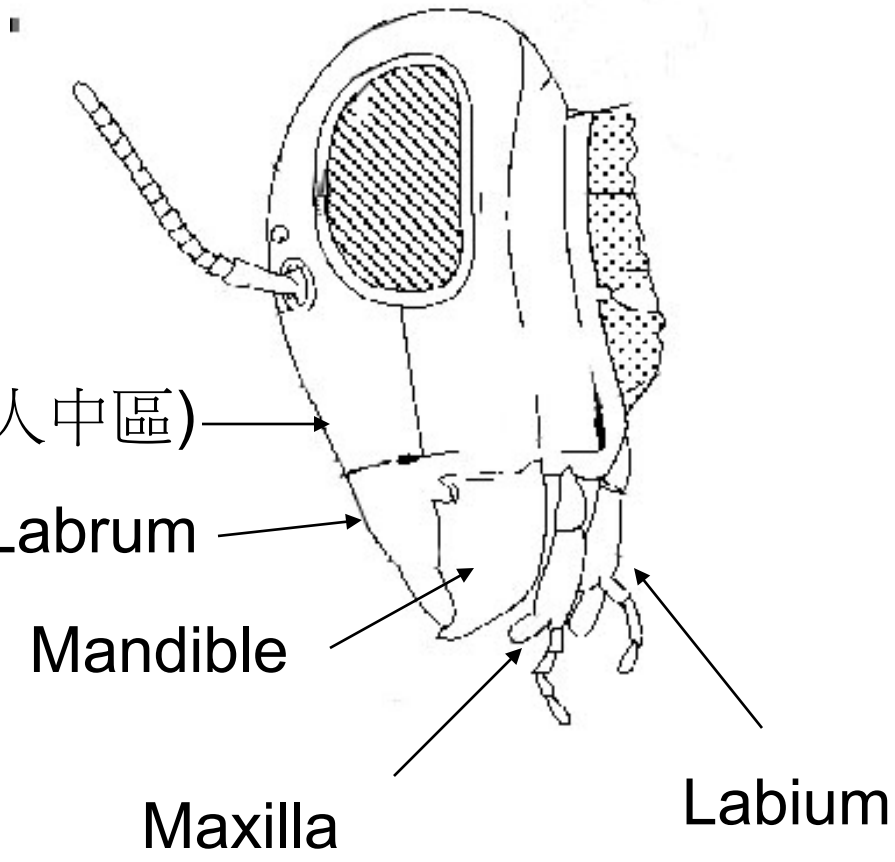


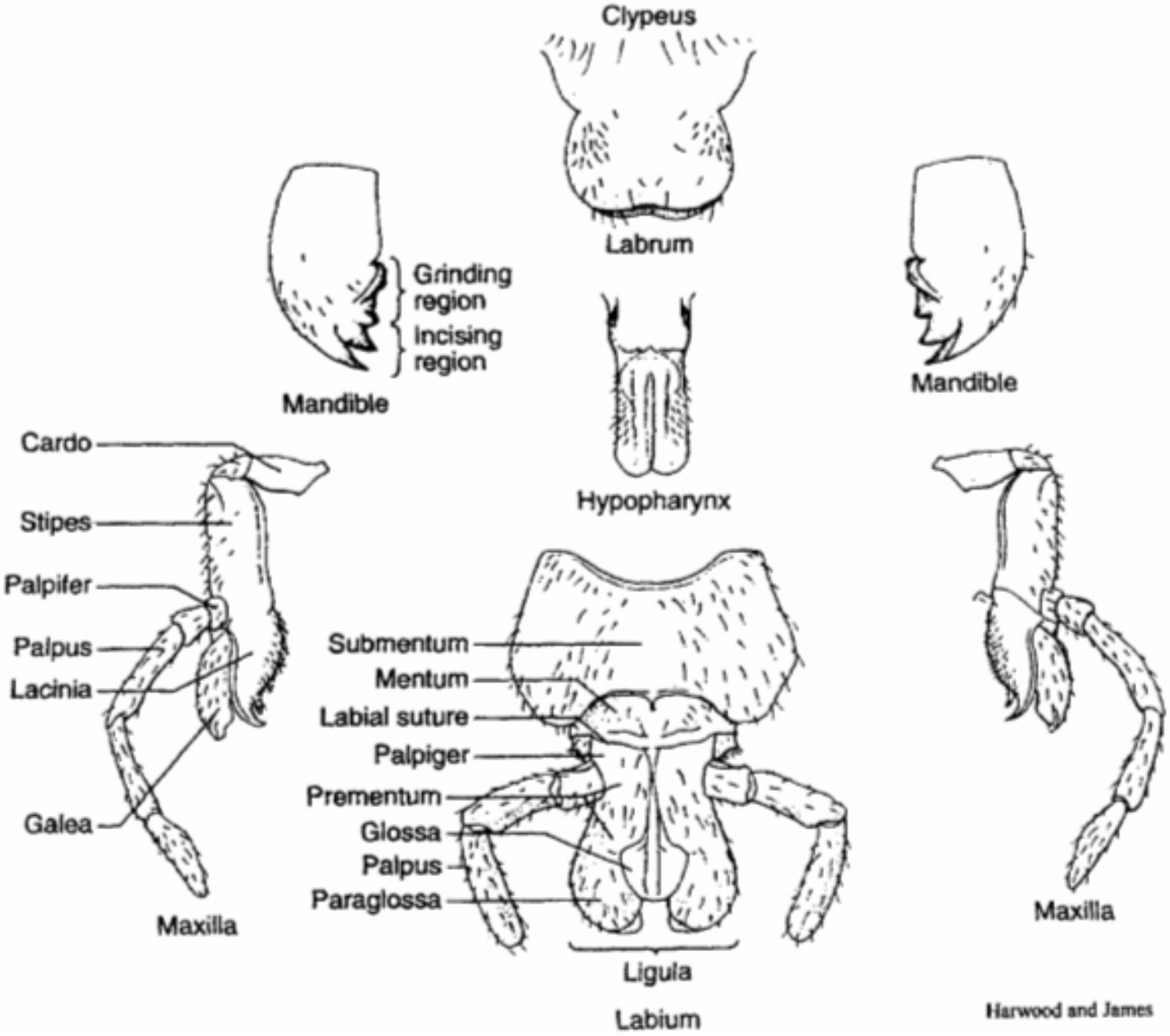
Many modifications



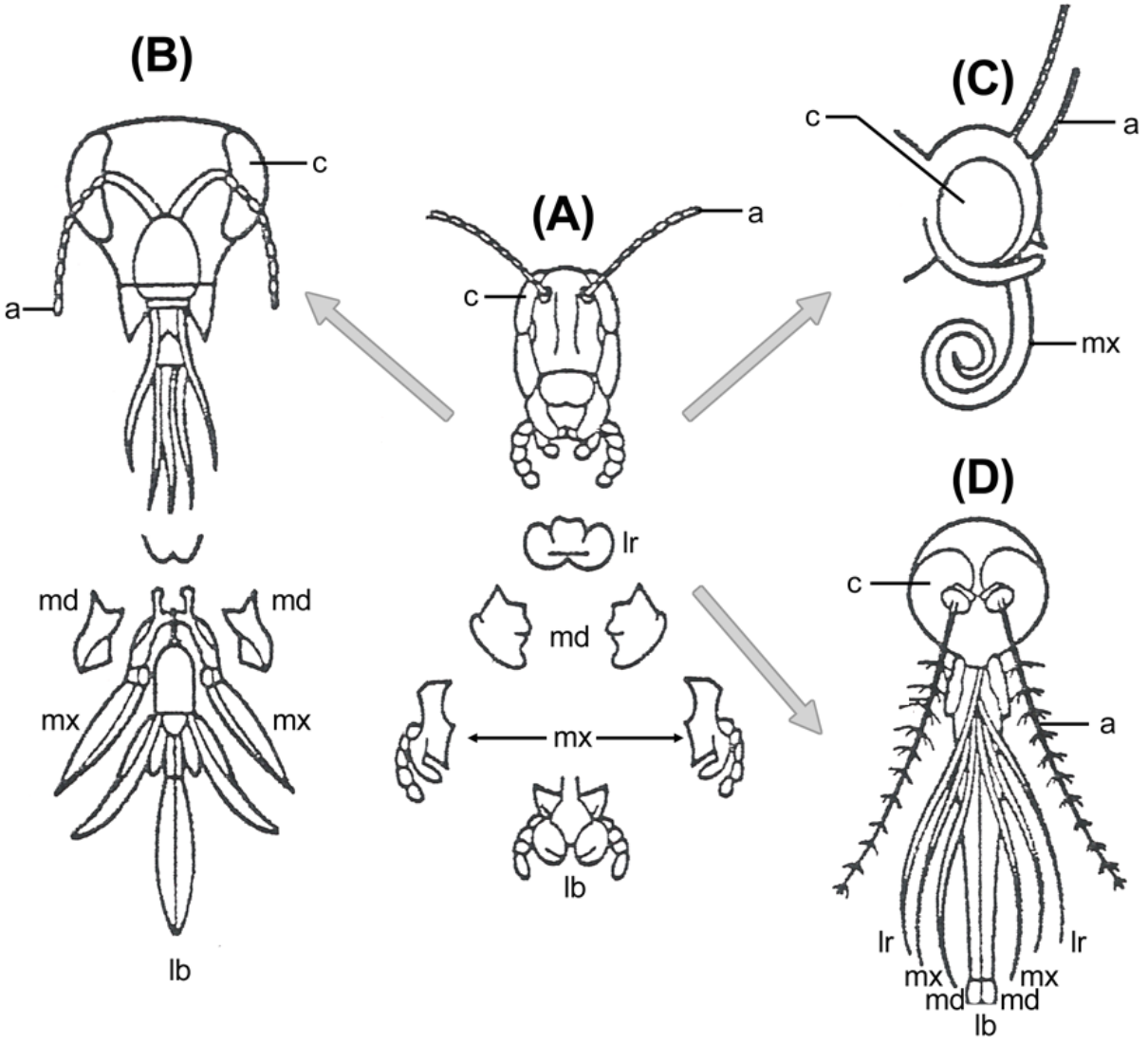
Mouthparts

- Labrum
  - “upper lip”
  - May or may not be derived from limbs
- Mandible (2)
- Maxilla (2)
- Labium
  - formed of fused left and right limbs




Clypeus
Labrum
Grinding region
Incising region
Mandible
Mandible
Hypopharynx
Cardo
Stipes
Palpifer
Palpus
Lacinia
Galea
Maxilla
Submentum
Mentum
Labial suture
Palpiger
Prementum
Glossa
Palpus
Paraglossa
Ligula
Labium
Maxilla
Harwood and James

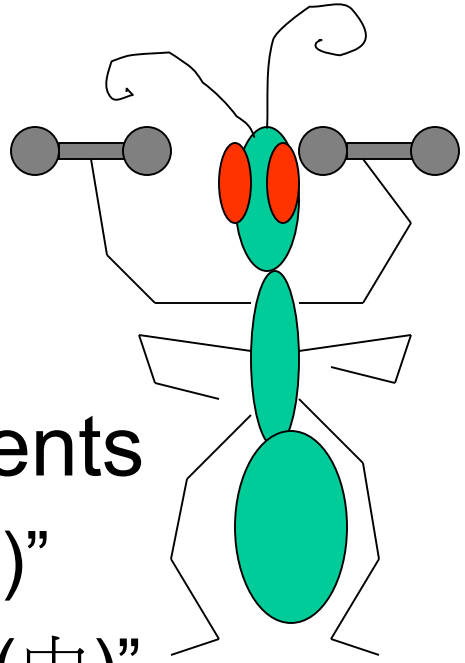
Modified Mouthparts



The “needle” of mosquitos

https://www.facebook.com/DeepLookPBS/videos/912356292282284/

Insect thorax



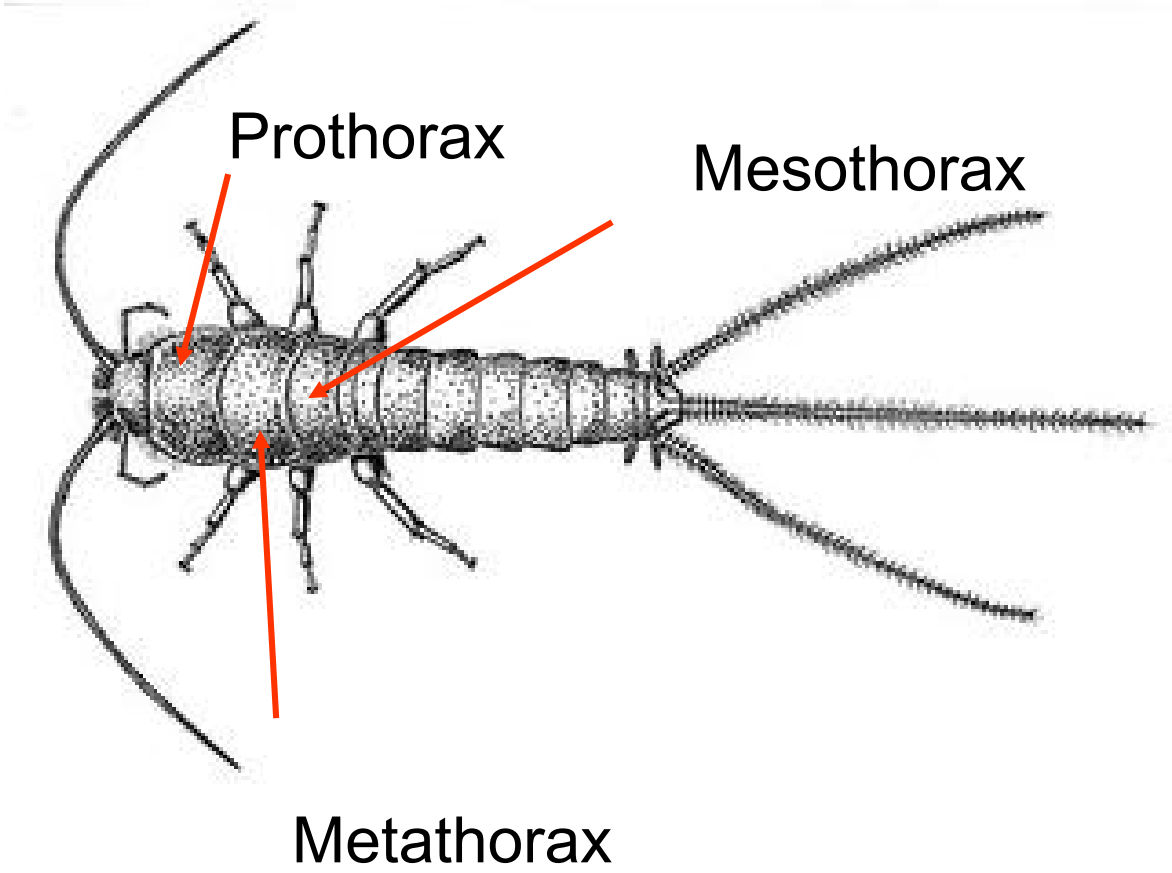
- Formed from three body segments
  - 1st referred to with prefix “pro (前)”
  - 2nd “meso (中)”
  - 3rd “meta (後)”
- Three pairs of walking legs
- In winged (pterygote) insects, 2 pairs of wings

Apterygotes: Archeognatha & Thysanura

Legs similar

Thoracic segments clearly visible

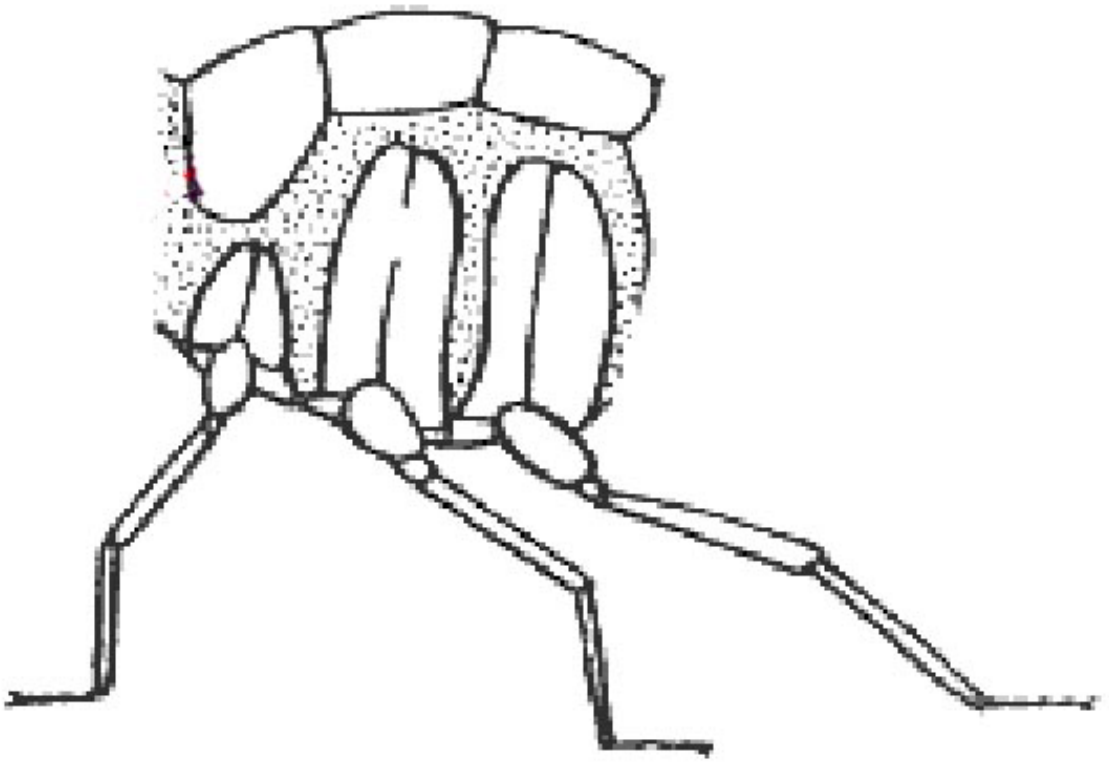
Three segments clearly visible



Thoracic segments often fused or modified

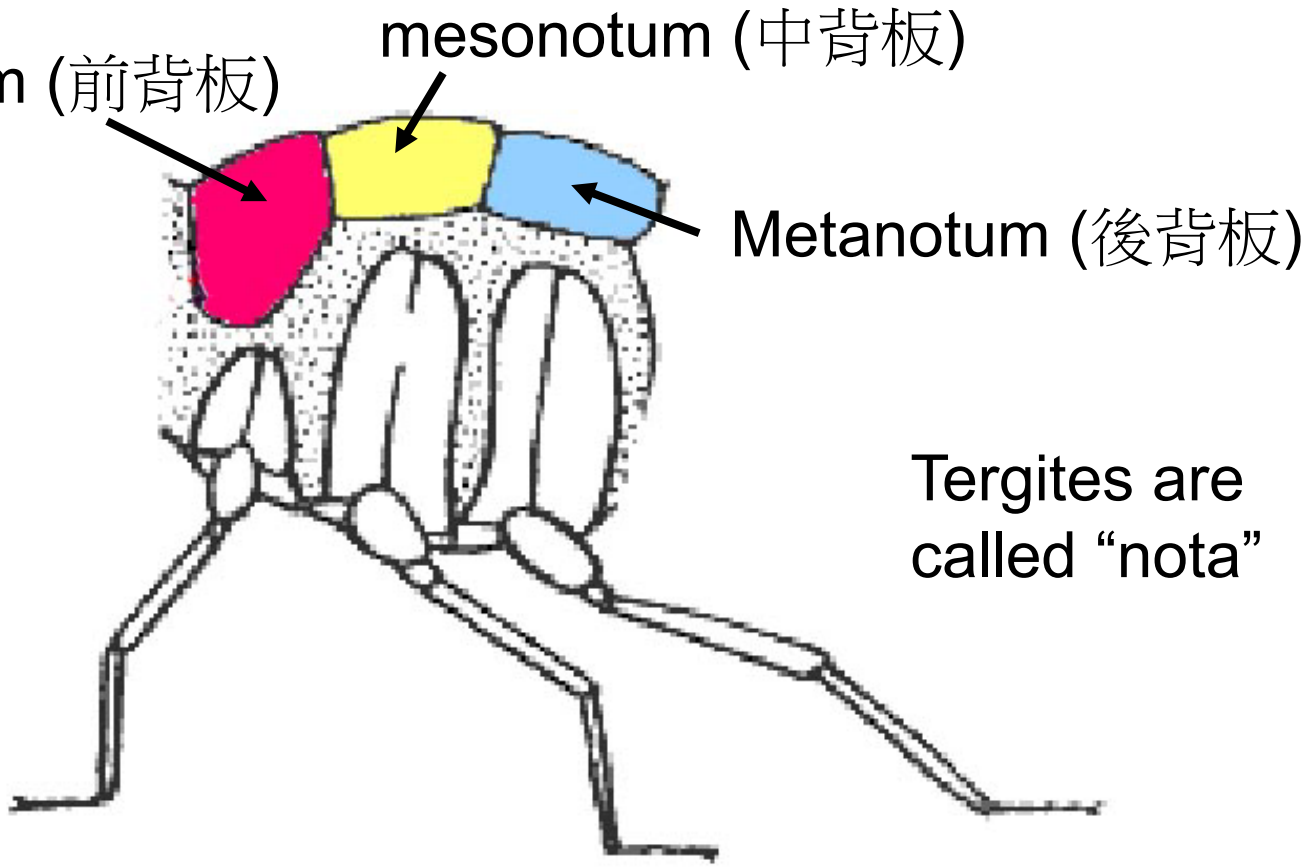
Larva of a trichopteran

Basic thoracic sclerites



Larva of a trichopteran

Basic thoracic sclerites

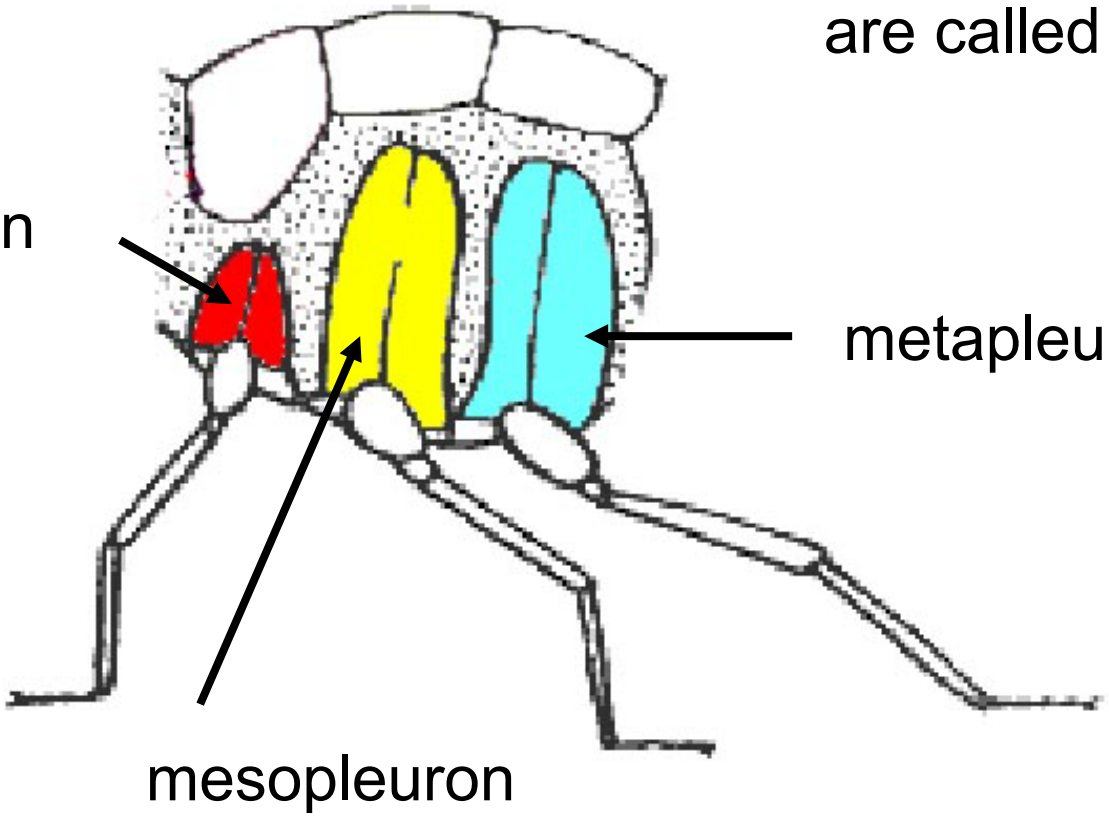


Tergites are called “nota”

Larva of a trichopteran

Basic thoracic sclerites

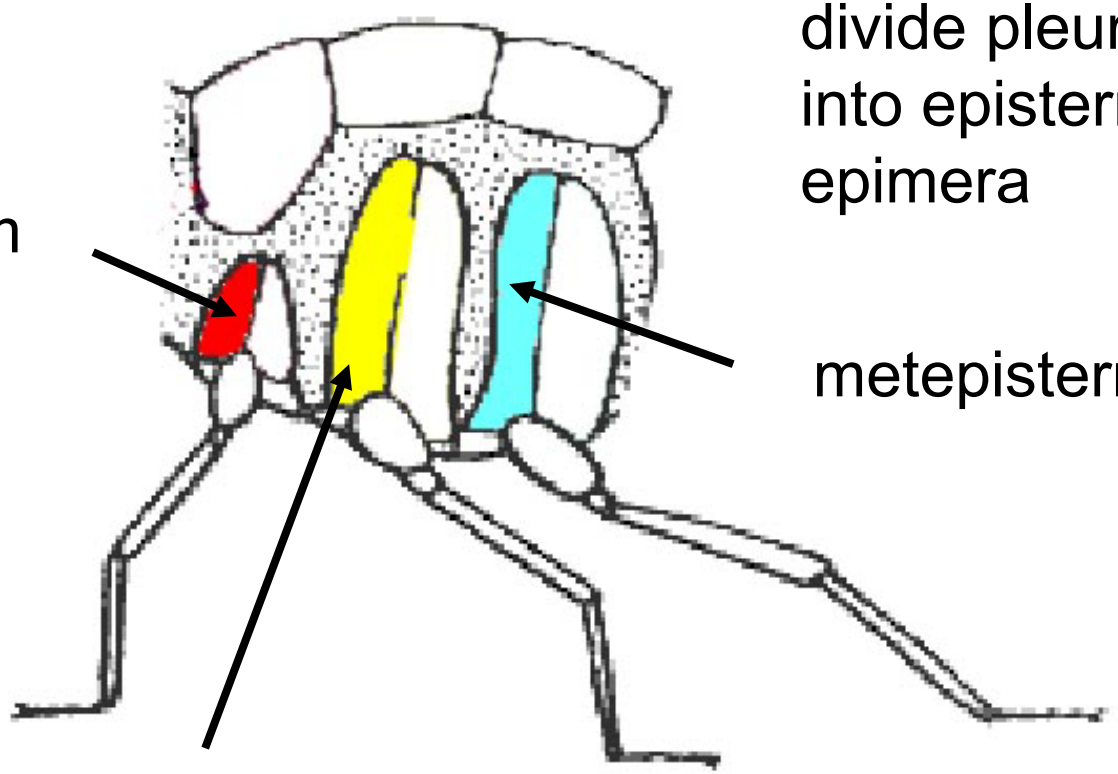
Lateral sclerites are called “pleura”



Basic thoracic sclerites

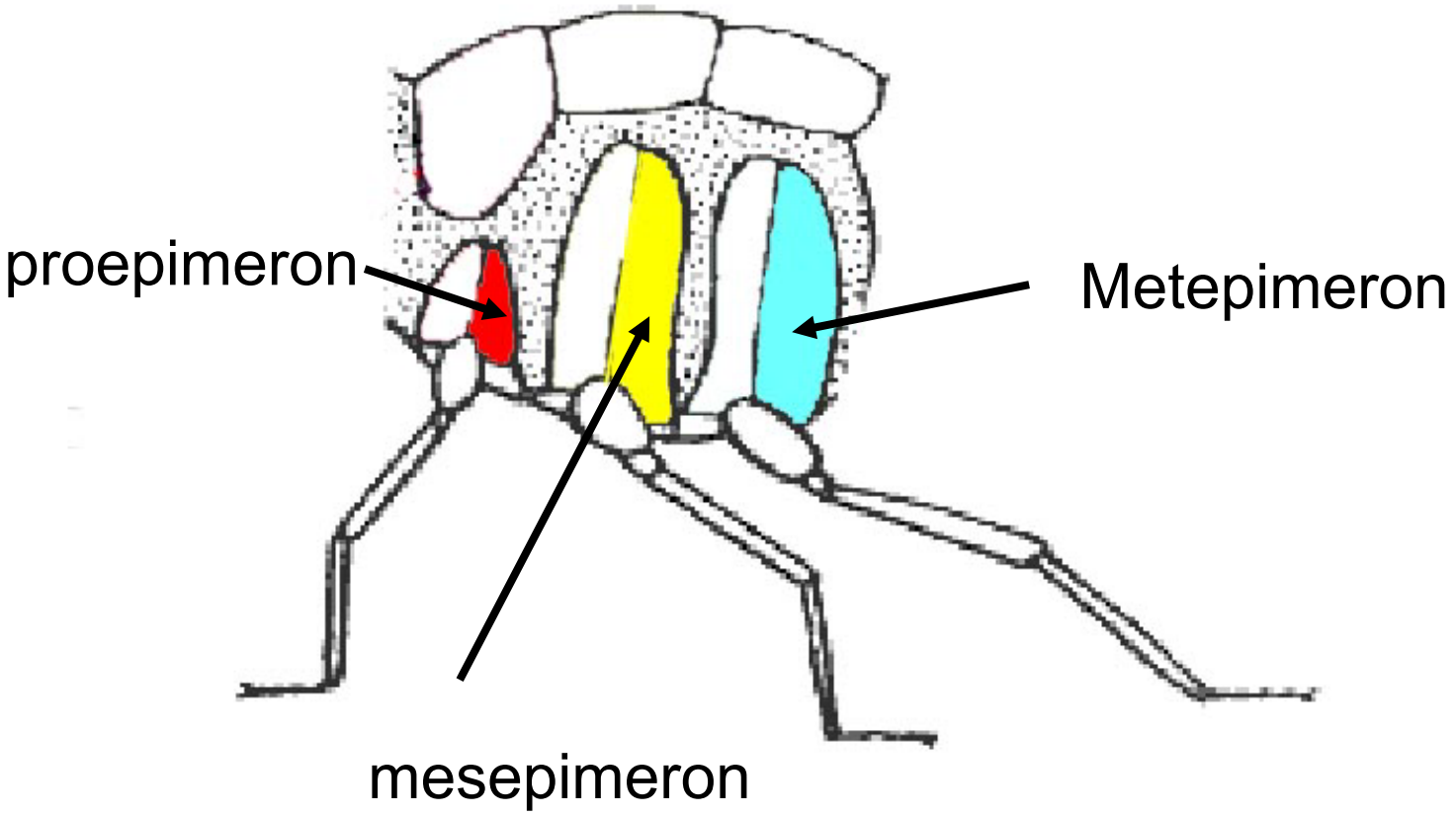
Larva of a trichopteran

Pleural sutures divide pleurons into episterna and epimera



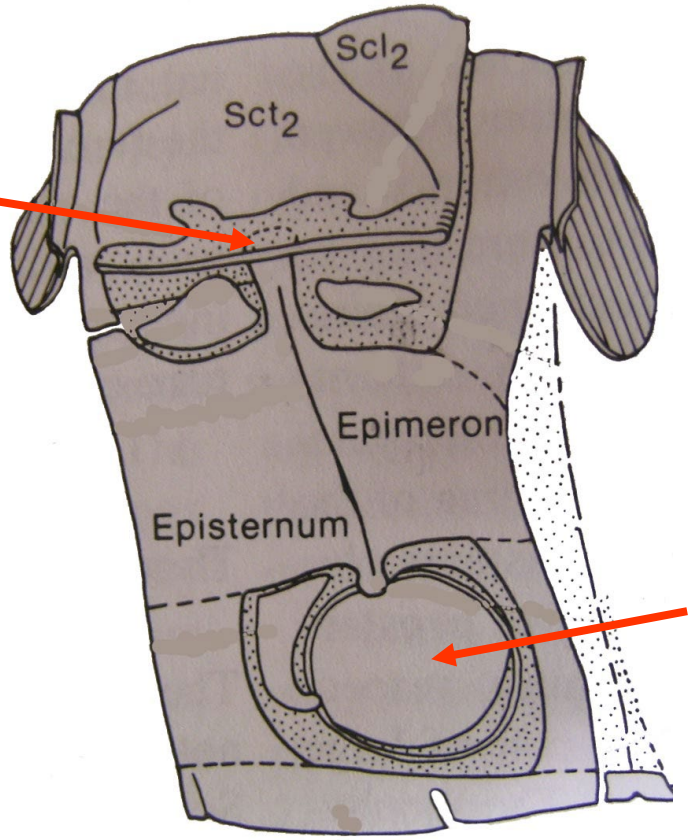
Larva of a trichopteran

Basic thoracic sclerites

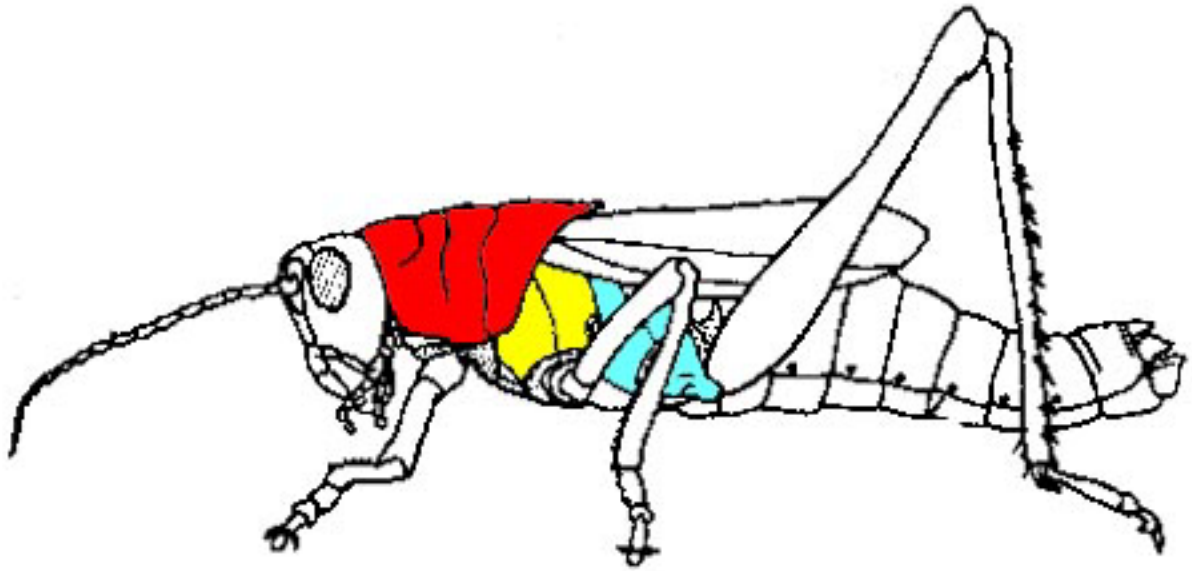


A more realistic mesothoracic segment

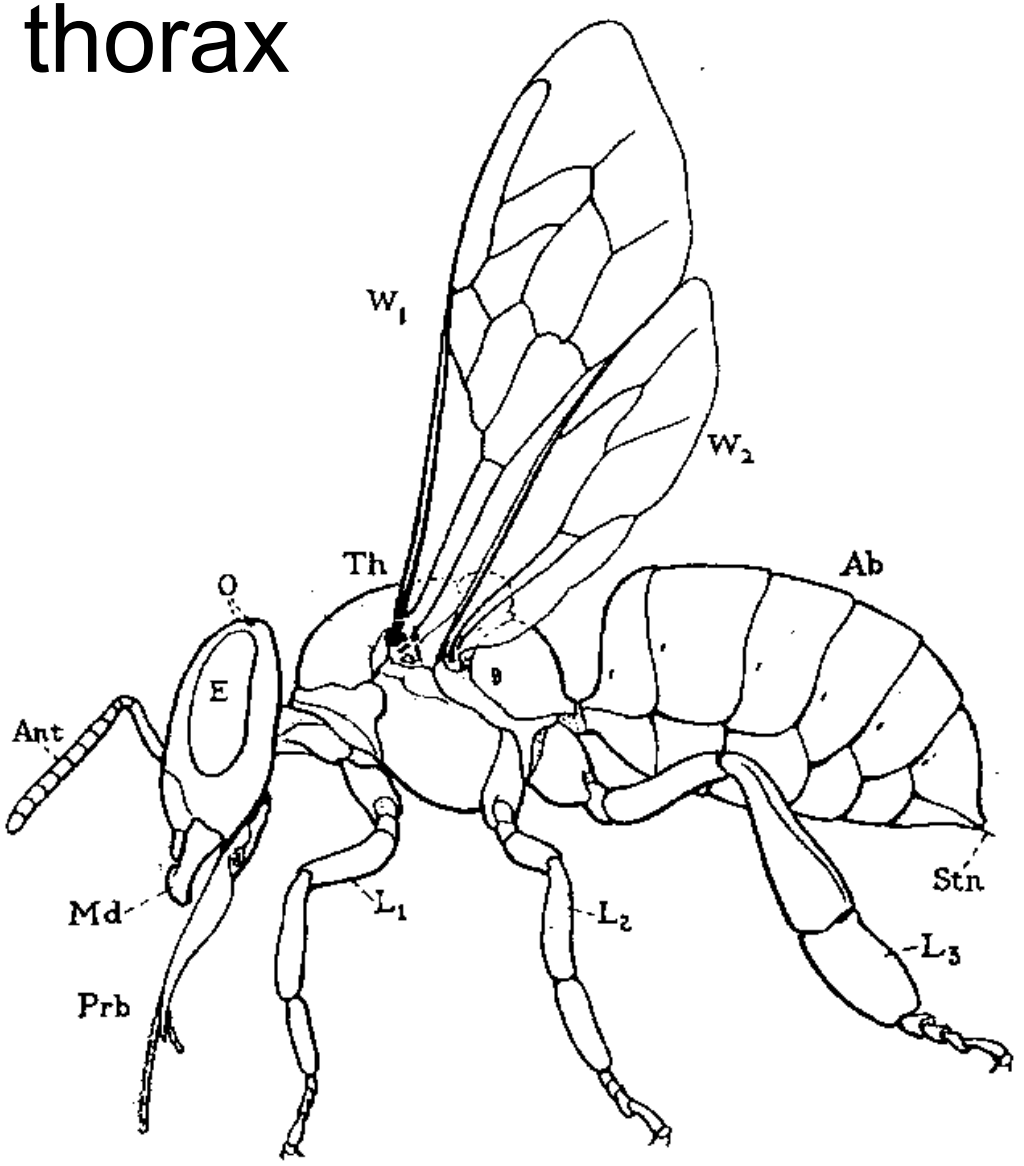
Wing articulates here



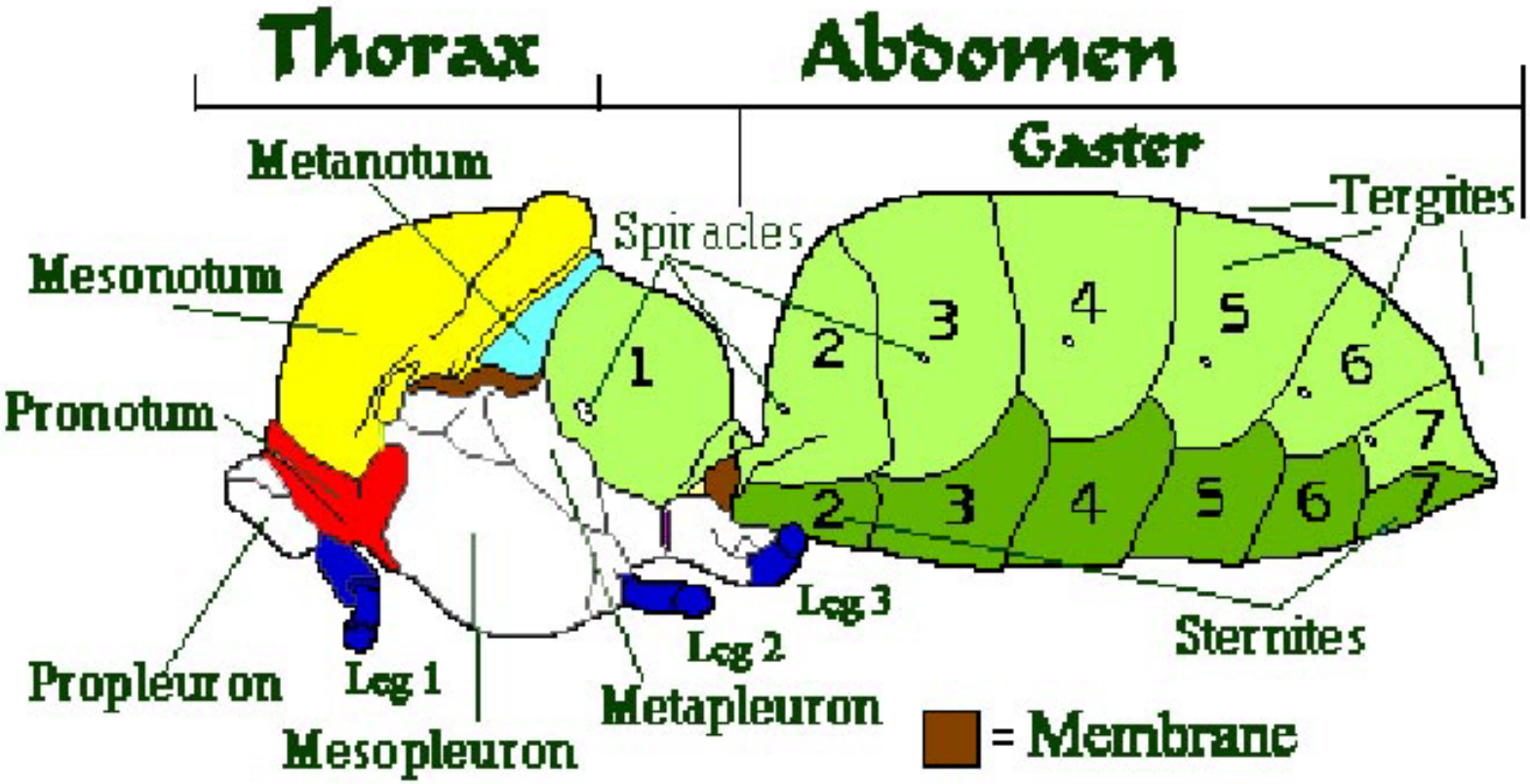
Leg attaches here



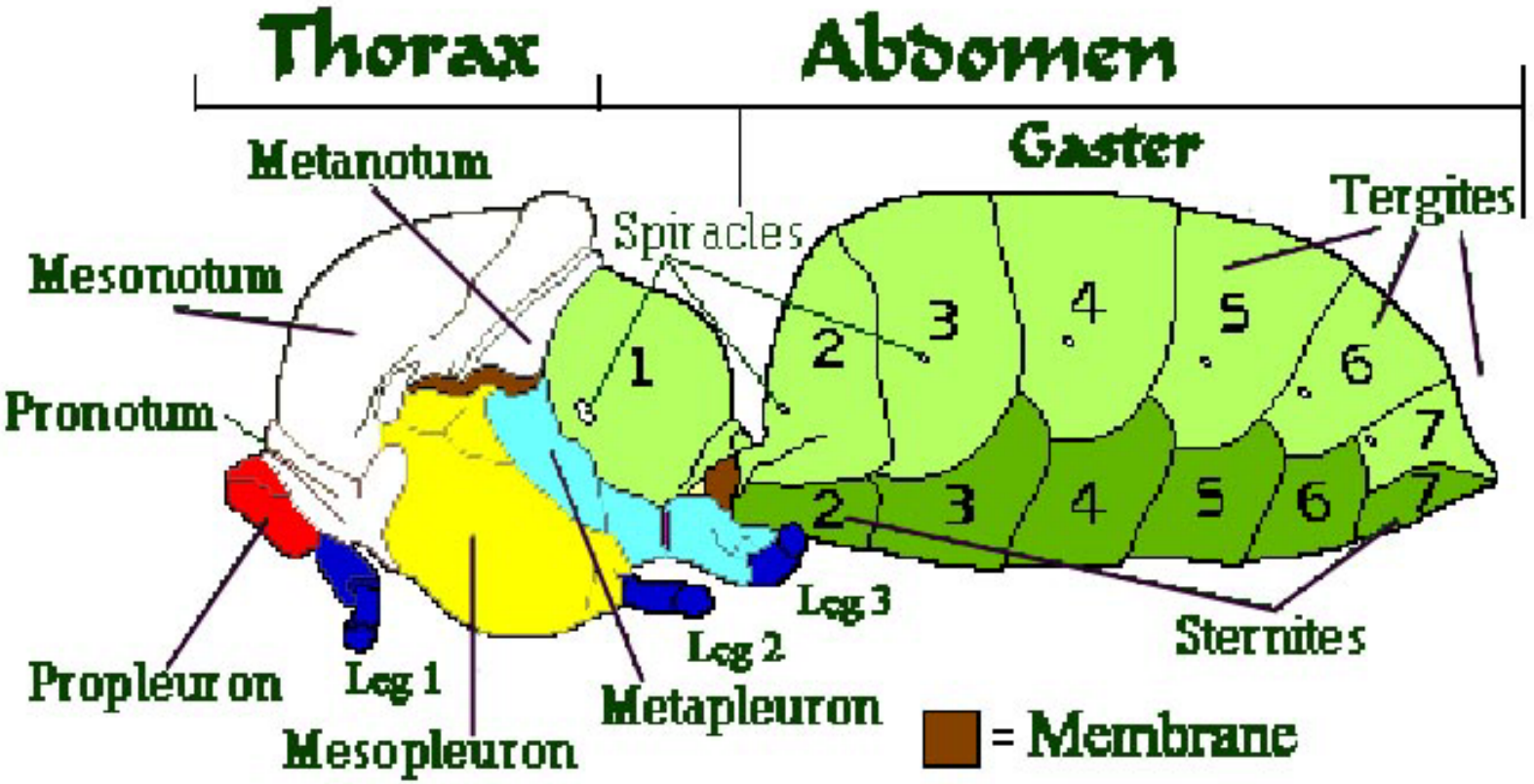
Honey bee thorax



Thorax highly modified in a bee



Thorax highly modified in a bee



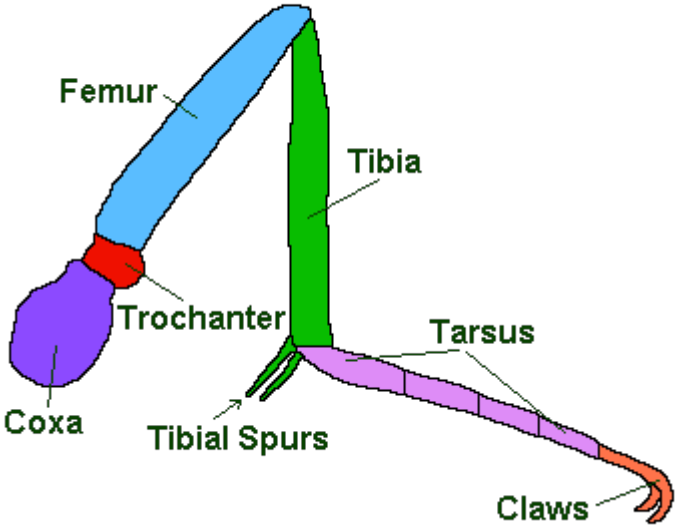
Inside of bee

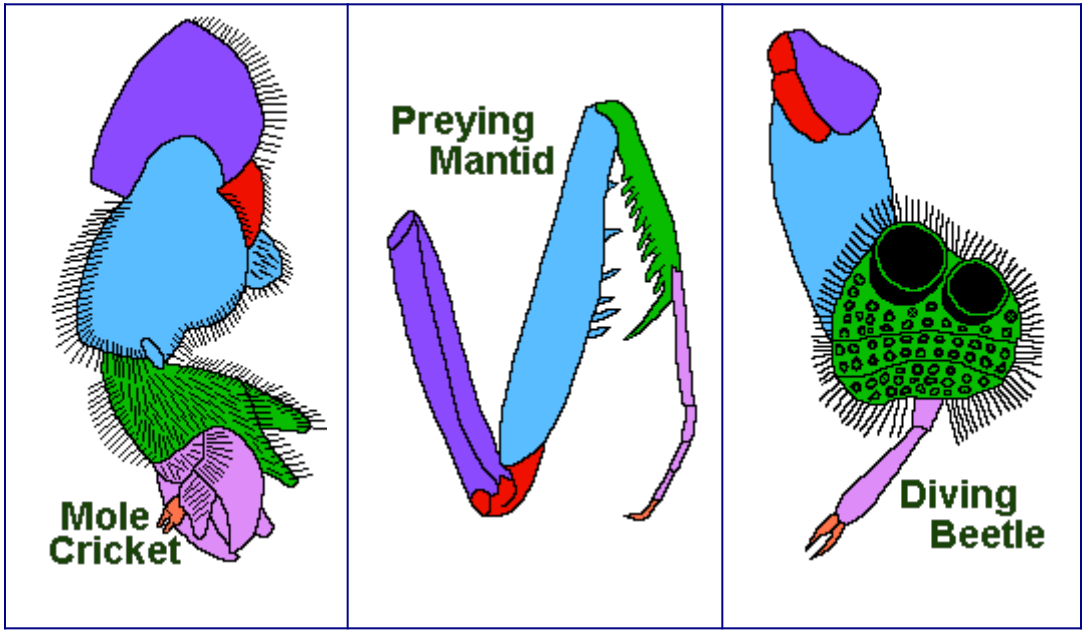
https://www.facebook.com/SeekerMedia/videos/10155233269088387/

Insects take fly

https://www.youtube.com/watch?v=Cnn9CfsYJqc

The Insect Leg



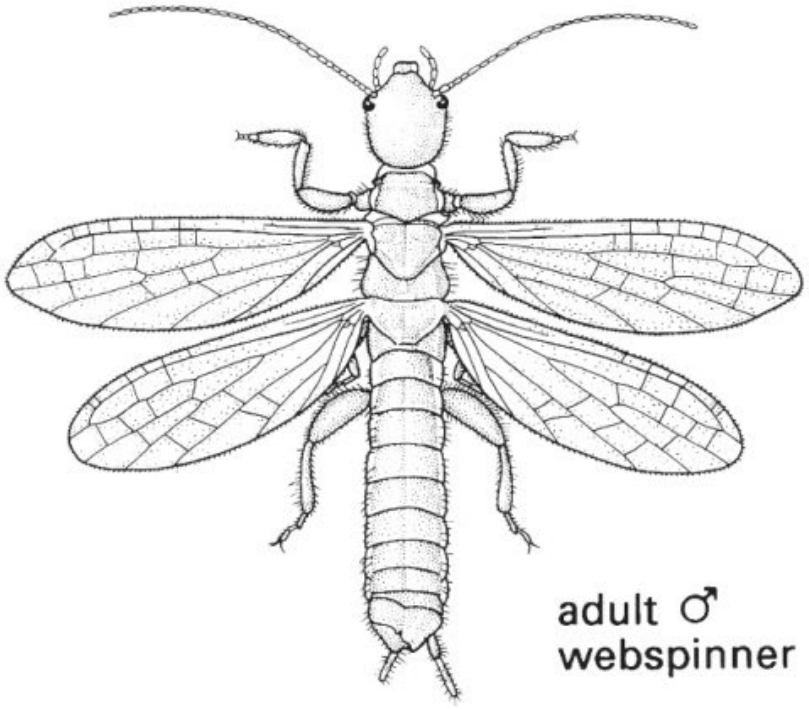


What about wings?

- Two pair
- On 2nd and 3rd thoracic segments
- Diptera (flies) have only anterior pair
- Second pair replaced by halteres

https://www.facebook.com/NatureNews/videos/1432573090146529/

Embioptera (紡足目)



Taxobox 10 Embioptera (Embiidina, Emboidea; embiopterans or webspinners)

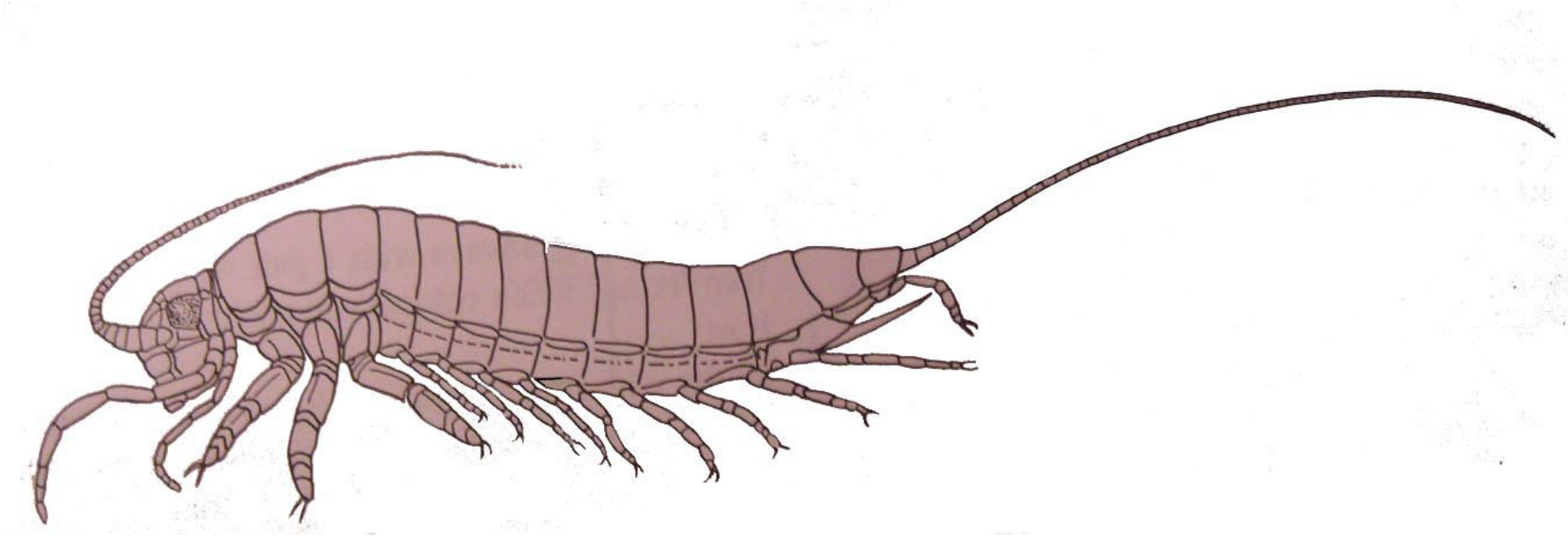
2000 species

External morphology- Abdomen

Abdominal segmentation

- Usually easy to observe
- 11 segments
- 9-10 easy to observe
- Specialized for digestion, fat storage, reproduction

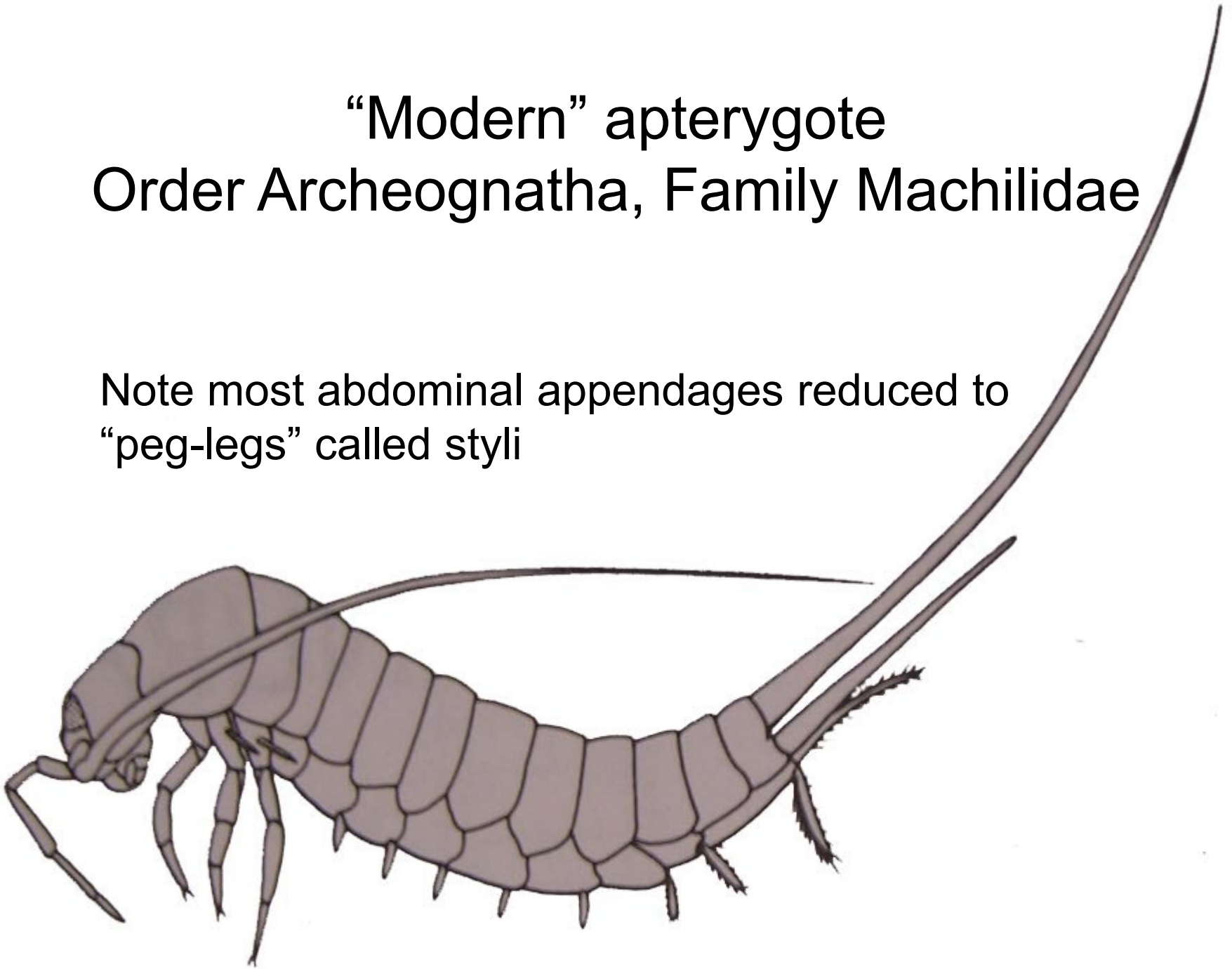
Dasyleptus- extinct apterygote from Carboniferous period



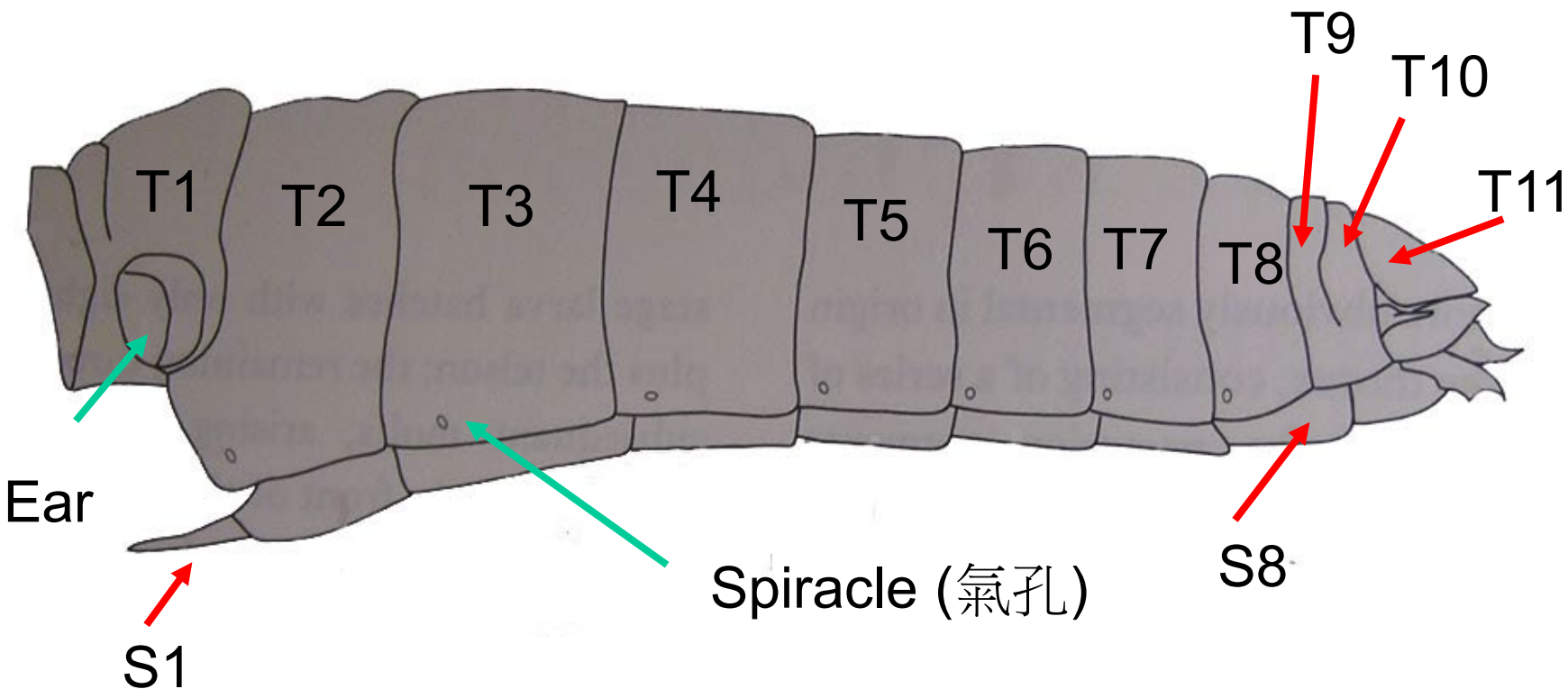
Note appendages on abdominal segments!

“Modern” apterygote
Order Archeognatha, Family Machilidae

Note most abdominal appendages reduced to “peg-legs” called styli



Modern *Nomadacris* (Orthoptera)



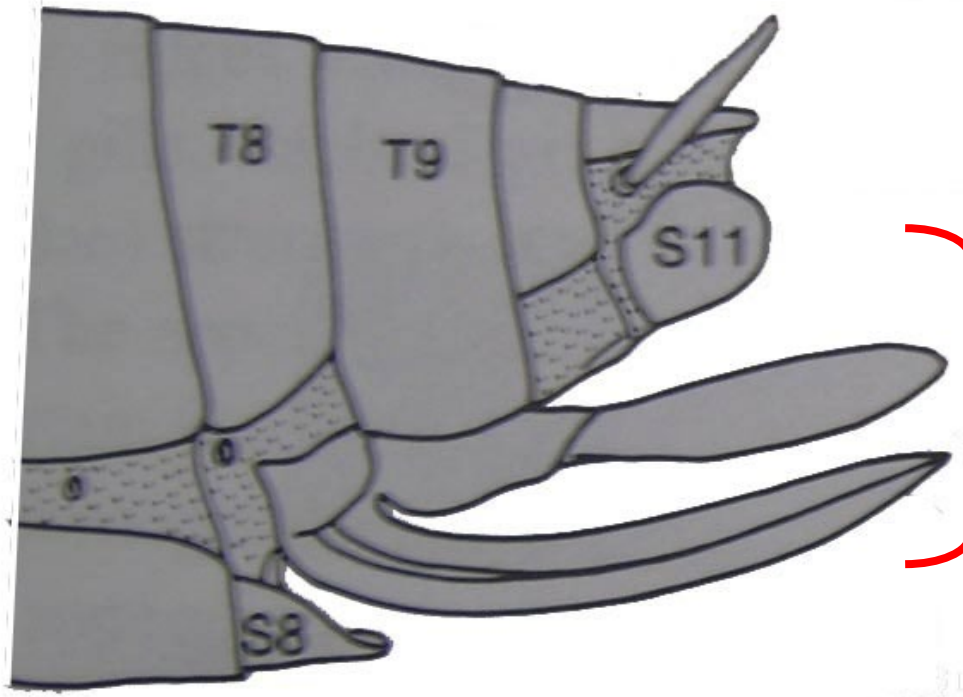
T = tergite, S = sternite

Ear = Tympanum

Where did all the abdominal appendages go?

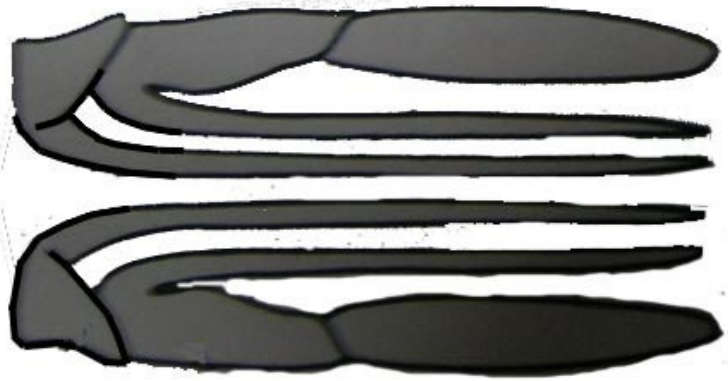
- Most lost without a trace
- Genitalia (生殖器)
  - 8th & 9th segments of females
  - 9th of males
- Cerci (one cercus) (觸毛)
  - 11th segment

Generalized female genitalia

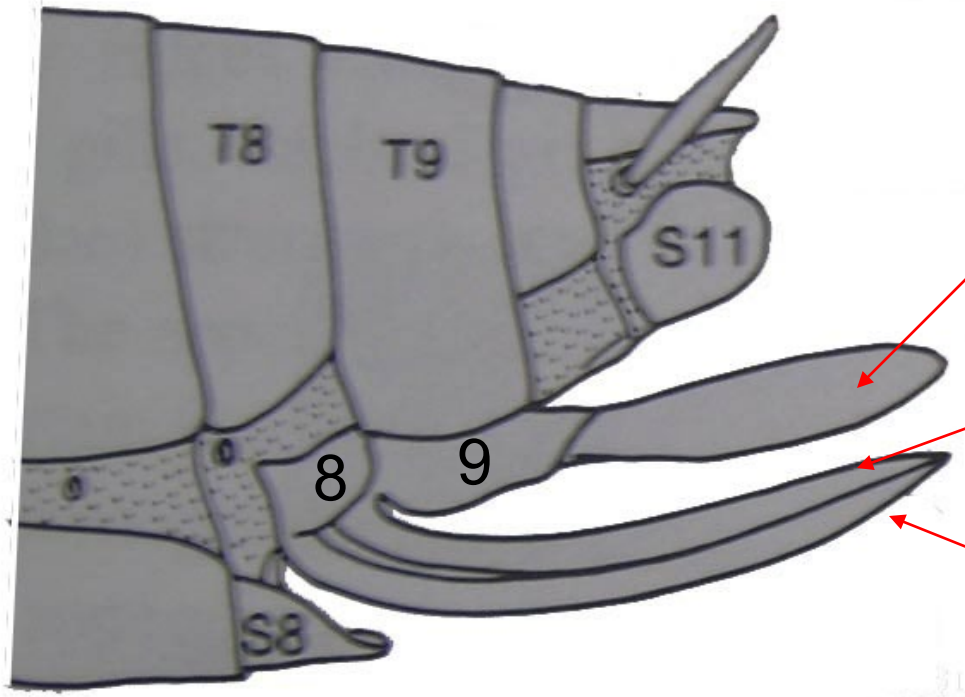


Ovipositor (產卵器)

Genital opening on 8th segment



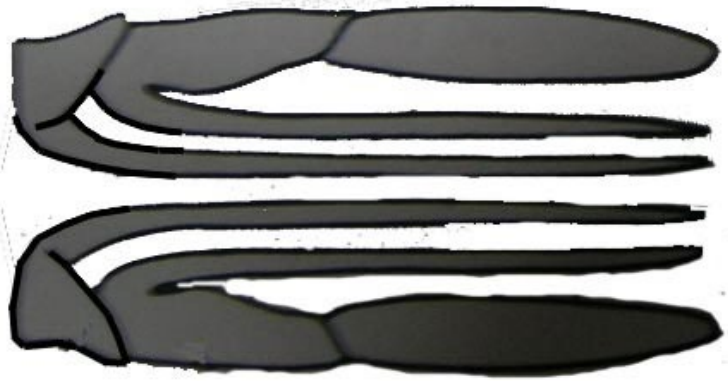
Generalized female genitalia



3rd valvula

2nd valvula

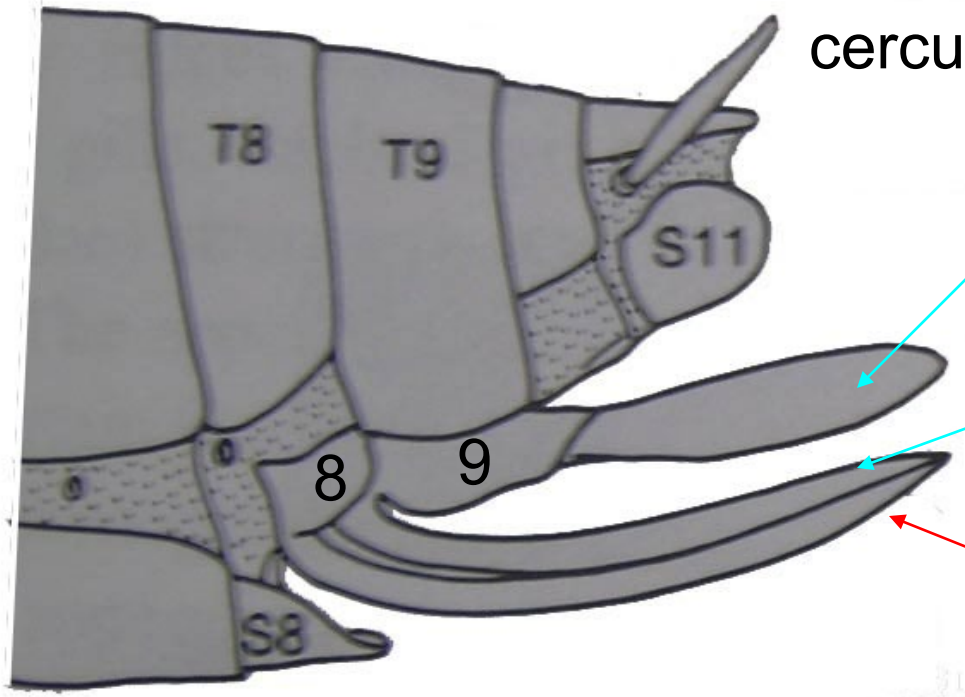
1st valvula



1st and 2nd valvulae may form a tube for egg-laying

3rd valvulae may form protective sheath

Generalized female genitalia

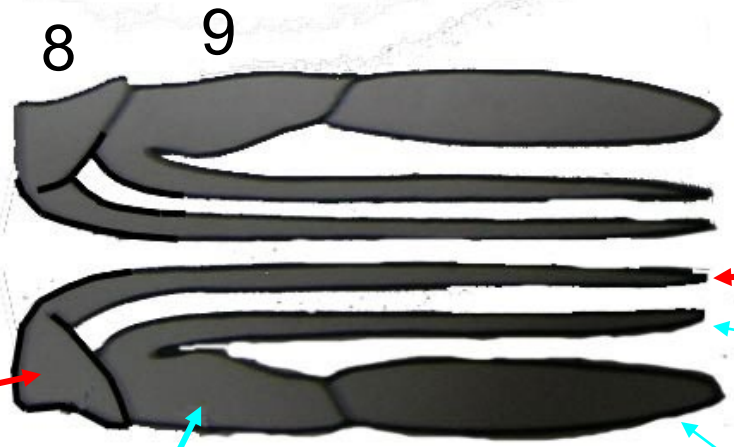


cercus

3rd valvula

2nd valvula

1st valvula



1st valvifer

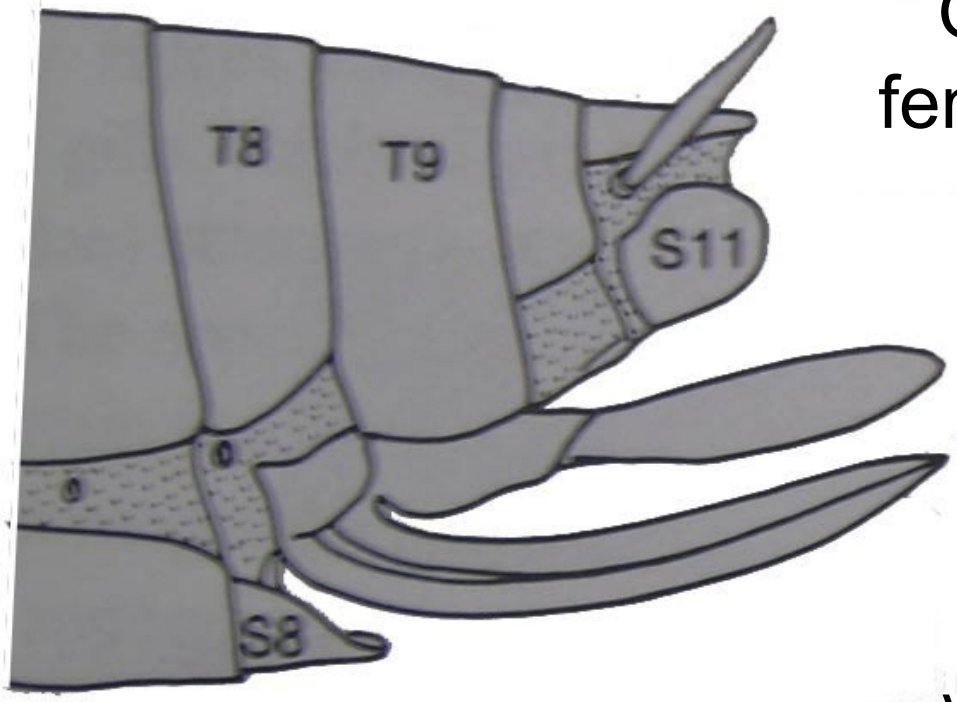
2nd valvifer

1st valvula

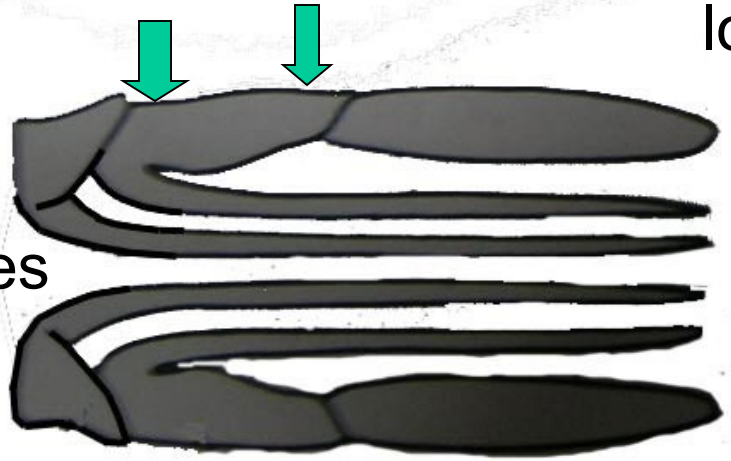
2nd valvula

3rd valvula

Generalized female genitalia

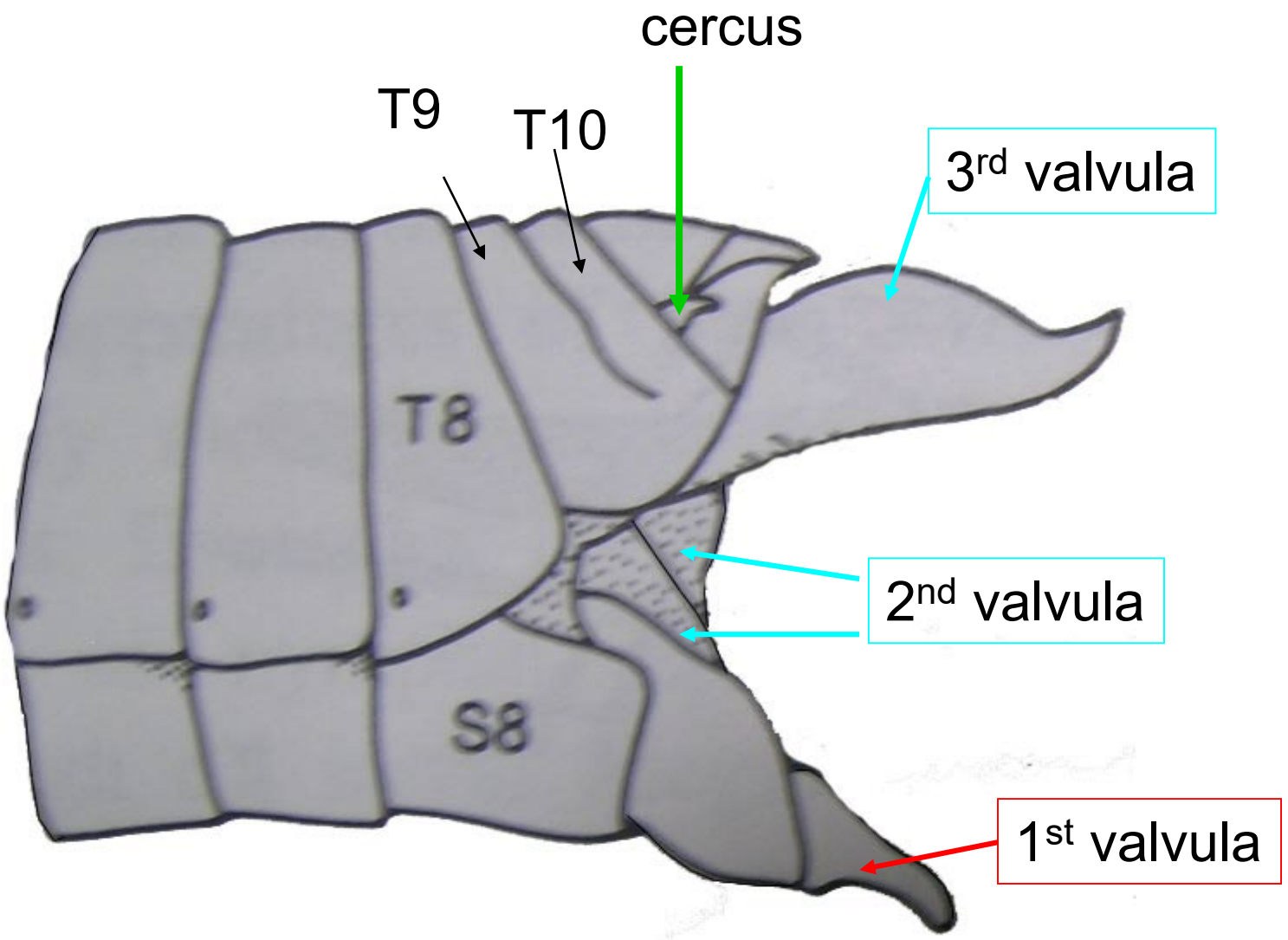


Valvulae = lobes on coxae



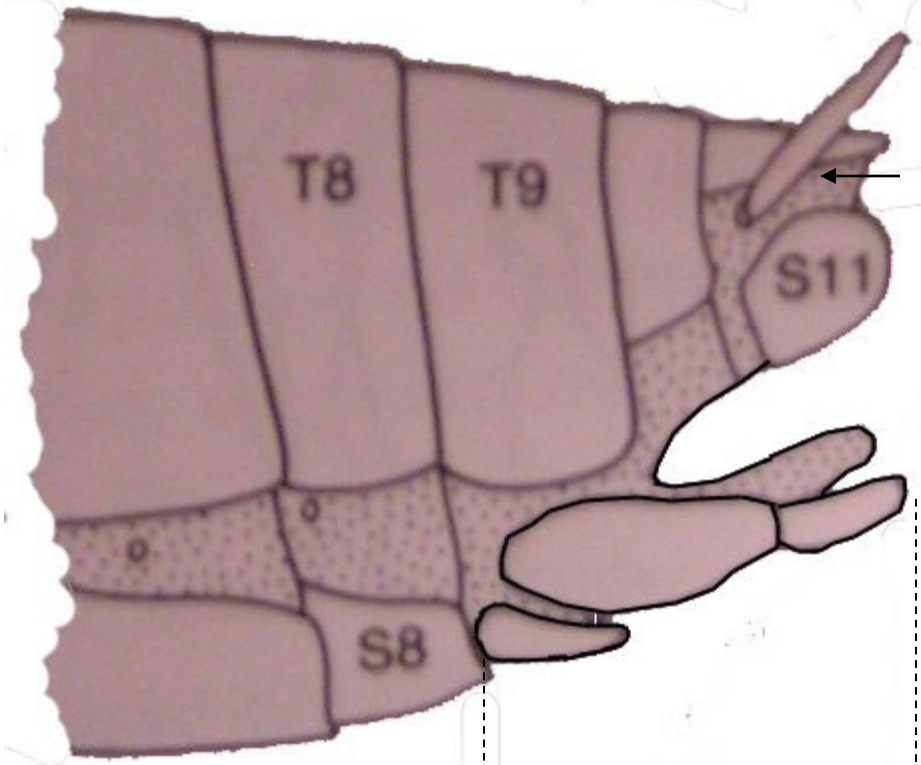
Valvifers = coxae of Modified appendages

Female of *Romalea microptera* (Orthoptera)



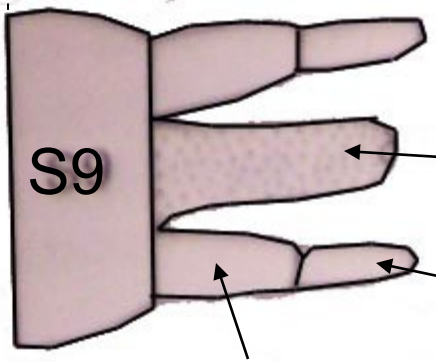
Genitalia of most insects highly modified from basic plan

Generalized male genitalia



anus

Paramere =
Gonostylus+gonocoxite

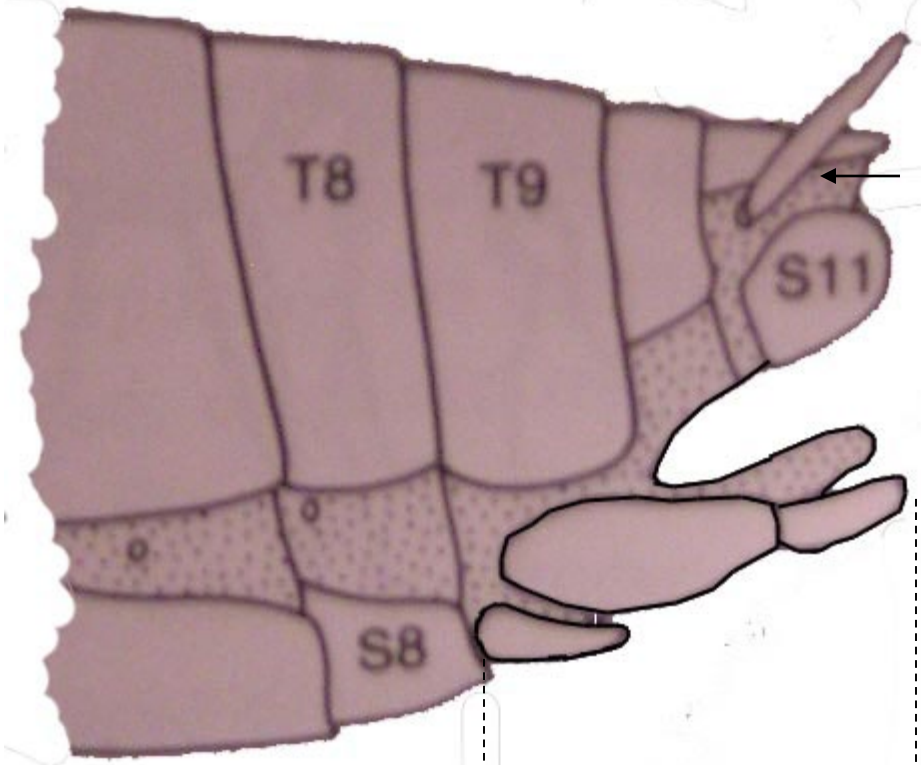


Aedeagus (= penis)

gonostylus

gonocoxite

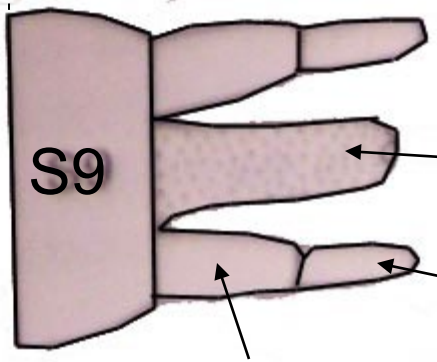
Generalized male genitalia



anus

Gonostylus+gonocoxite (or paramere) = modified leg

Aedeagus = fused lobes from coxae of 9th appendages

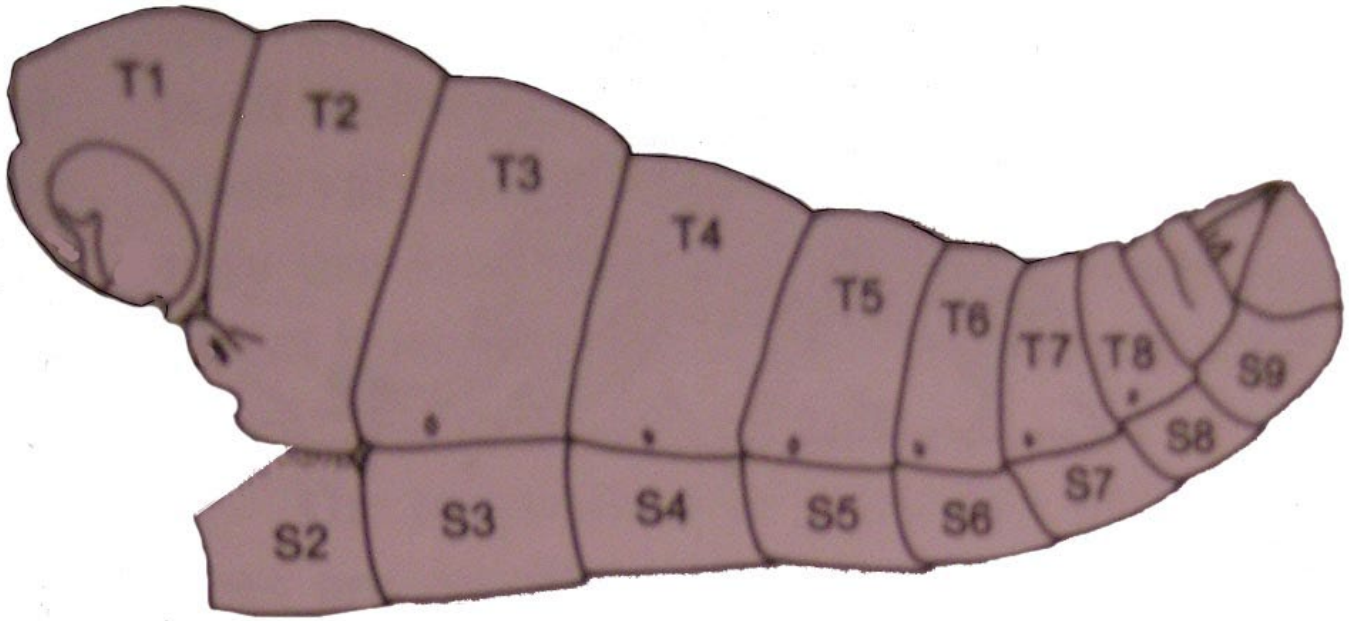


Aedeagus (= penis)

gonostylus

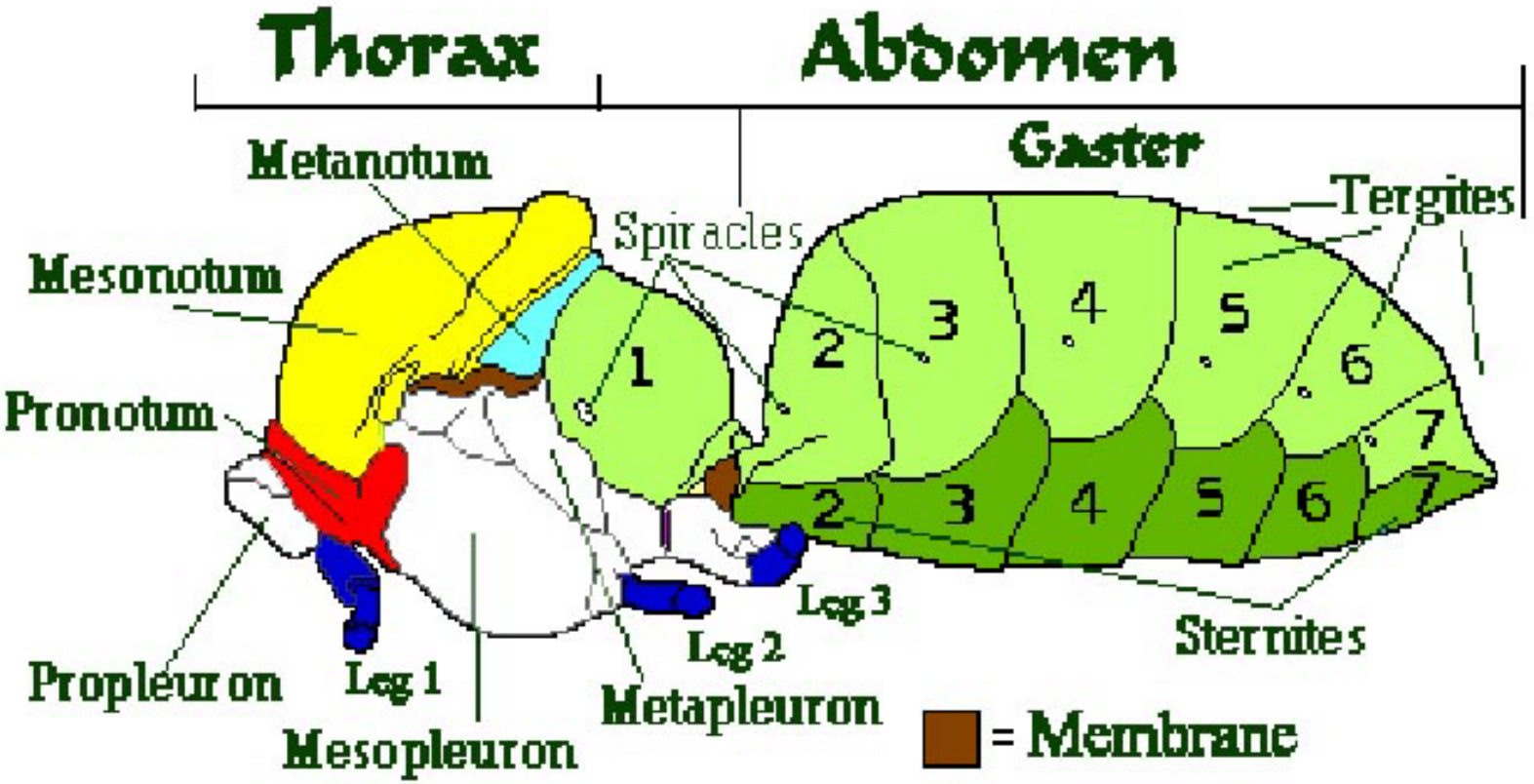
gonocoxite

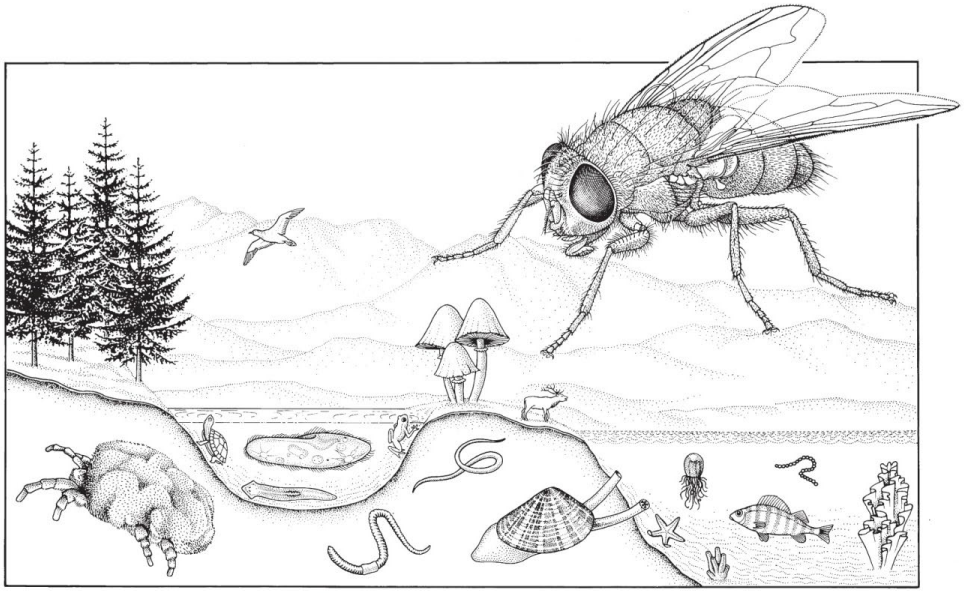
Male of *Romalea microptera* (Orthoptera)

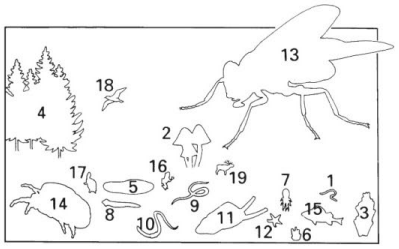


Not much to see from the outside

Abdomen highly modified in a bee







1 Prokaryotes
2 Fungi
3 Algae
4 Plantae (multicellular plants)
5 Protozoa
6 Porifera (sponges)
7 Cnidaria (jellyfish, corals, etc.)
8 Platyhelminthes (flatworms)
9 Nematoda (roundworms)
10 Annelida (earthworms, leeches, etc.)
11 Mollusca (snails, bivalves, octopus, etc.)
12 Echinodermata (starfish, sea urchins, etc.)
13 Insecta
14 Non-insect Arthropoda
15 Pisces (fish)
16 Amphibia (frogs, salamanders, etc.)
17 Reptilia (snakes, lizards, turtles)
18 Aves (birds)
19 Mammalia (mammals)

Fig. 1.1 Speciescape, in which the size of individual organisms is approximately proportional to the number of described species in the higher taxon that it represents. (After Wheeler 1990.)

Mosquitos kill one million people/ year

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjqvvWw5PLvAhW-wosBHQT3D_4QFjACegQICBAD&url=https%3A%2F%2Fwww.mosquito.org%2Fpage%2Fdiseases&usg=AOvVaw0_T1Rqk_Co25TwJ3mSJ6Rm

Bees and flies are important pollinators

A bacterium (*Yersinia pestis*) spread by fleas killed **25 million people**, more than a quarter of the European population, in 14 th century Europe. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjxg-vA5PLvAhWjHqYKHXcYDTEQFjAAegQIAhAD&url=http%3A%2F%2Fwww.idph.state.il.us%2Fenvhealth%2Fpcfleas.htm&usg=AOvVaw1Grfi84B_kHGM5s91IUxJf