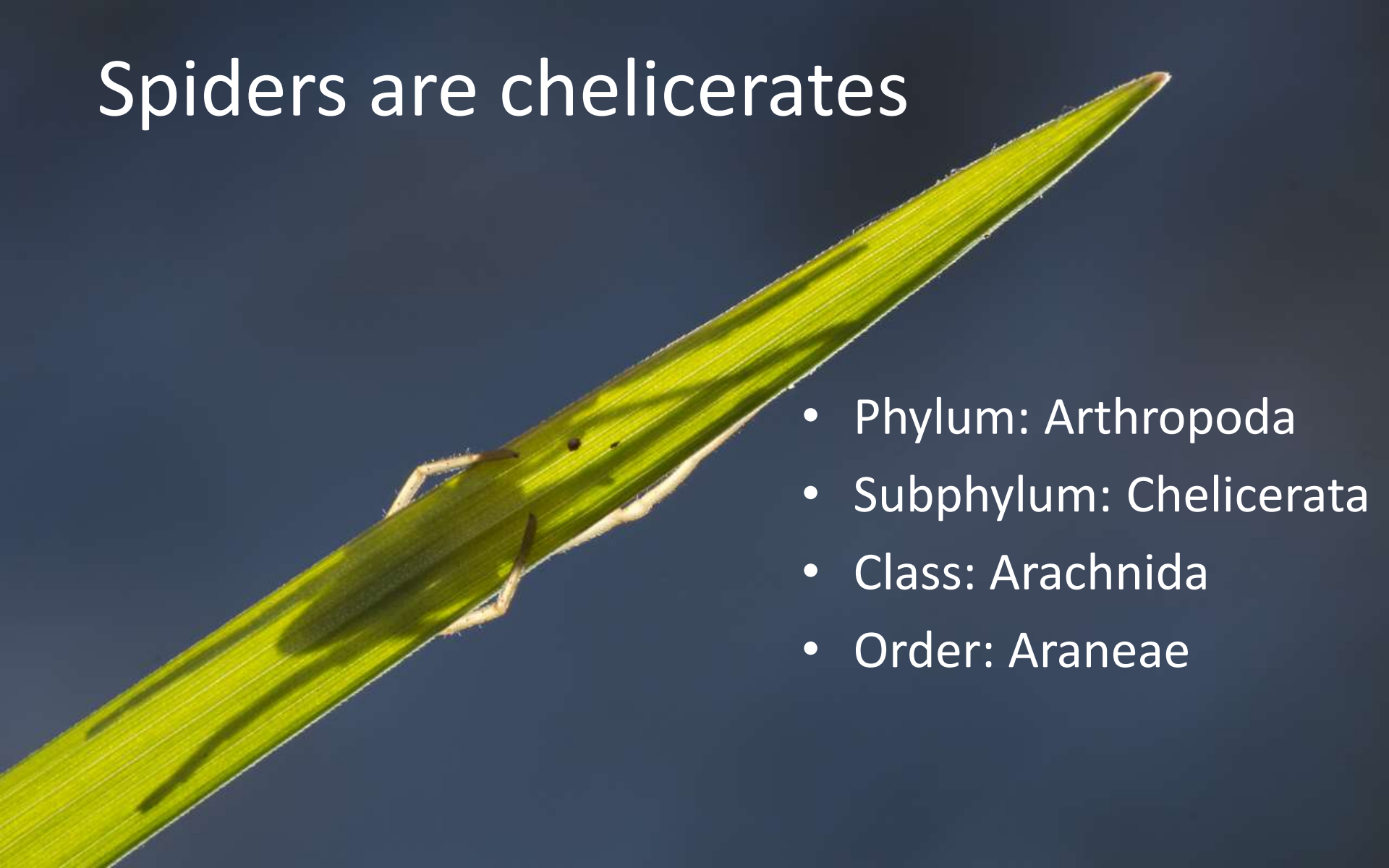
Spiders: an introduction

Spiders are chelicerates



- Phylum: Arthropoda
- Subphylum: Chelicerata
- Class: Arachnida
- Order: Araneae

Order Scorpiones

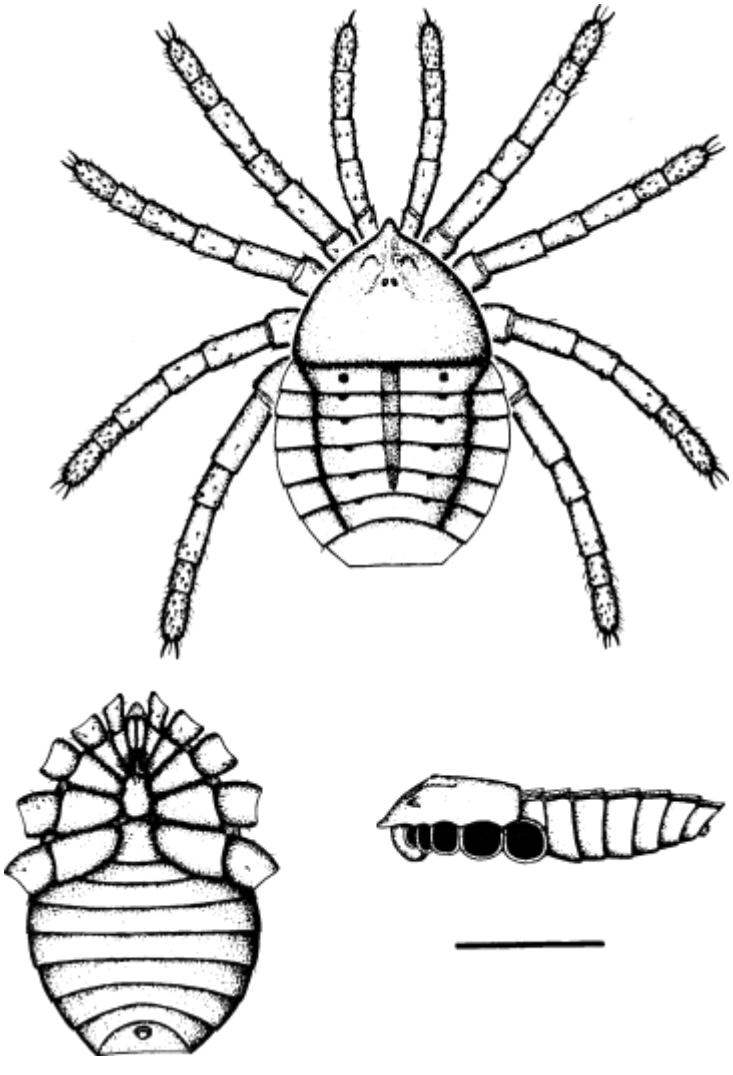
Order Opiliones

Order Solifugae


Subclass Acari, Order Ixodida

Subclass Acari, Order Trombidiiformes

Spiders are an ancient order…



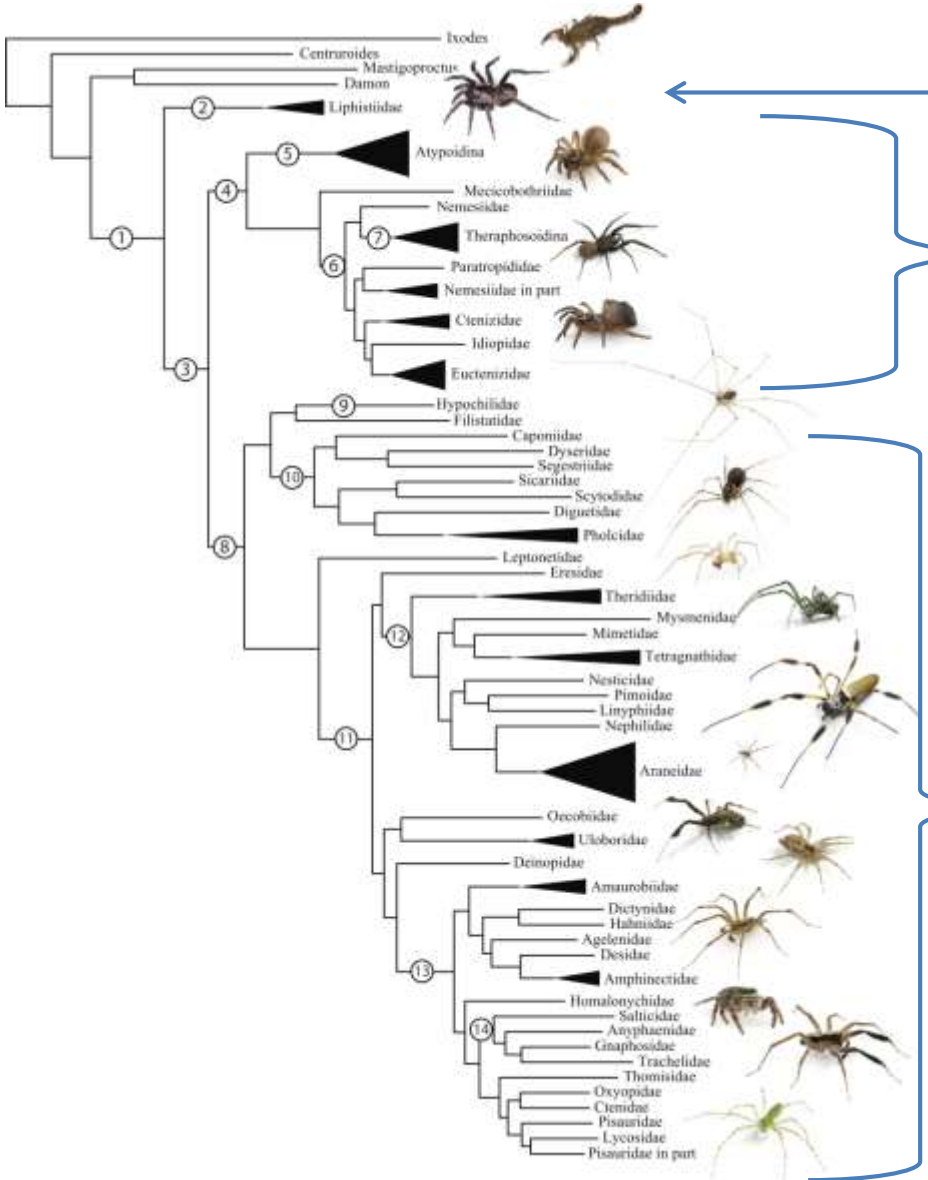
Proto-spiders present in Silurian and Devonian periods

Figure from:
Dunlop, Jason A. 1996. “A Trigonotarbid Arachnid from the Upper Silurian of Shropshire.” *Palaeontology* 39 (3): 605–14.

First true spiders resemble modern Mesothelae, and are found from Carboniferous deposits (360-299 MYA)

Modern spiders: diversity and distribution

- c. 40,000 species in 111 families
- Found in almost every terrestrial habitat



Suborder Mesothelae

Infraorder Mygalomorphae

Suborder Opisthothelae

Infraorder Araneomorphae

Garrison et al. 2016. "Spider Phylogenomics: Untangling the Spider Tree of Life." *PeerJ* 4 (February): e1719. doi:10.7717/peerj.1719.

Suborder Mesothelae

Infraorder Mygalomorphae

Avicularia versicolor

Therapohosa blondii
(world's largest spider!)


a spider

Infraorder Araneomorphae

A brief survey of some Canadian spiders

Habronattus ophrys

- Starting with mygalomorphs and then some common araneomorph families

Ontario mygalomorph fauna (n=1)

Family Atypidae, (purseweb weavers), *Sphodros niger*

Canadian fauna

Antrodiaetidae
Antrodiaetus pacificus

Mecicobothriidae
Hexura picea

Mecicobothriidae
Hexura picea

Salticidae
(jumping spiders)
c. 4400 sp.

Habronattus americanus

Ontario fauna

Phidippus audax

Phidippus clarus
By David Hill

Habronattus decorus

Salticus scenicus (Zebra jumper)

Myrmarachne formicaria

Linyphiidae

(sheetweb weavers and dwarf spiders)

c. 400 genera, 3700 sp.

Araneidae

(orb weavers)

c. 160 genera, 2600 sp.

Ontario Fauna

Argiope aurantia

Argiope trifasciata

Araneus diadematus

Theridiidae (cobweb weavers, comb-footed spiders)

c. 50 genera, 2200 sp.

Enoplognatha ovata


Latrodectus hesperus

Rhomphaea fictilium

Lycosidae (wolf spiders)

c. 100 genera, 2200 sp.

Pardosa sp.

Hogna carolinensis
By Fritz Flohr Reynolds

Gnaphosidae (ground spiders)

c. 140 genera, 2200 sp.

Herpyllus ecclesiasticus

Thomisidae (crab spiders)

c. 160 genera, 2000 sp.

Misumena vatia

Coriarachne sp.

Other notable families

Loxosceles reclusa (Sicariidae)

Pisauridae (nursery web spiders)

Dolomedes tenebrosus

Philodromidae (running crab spiders)

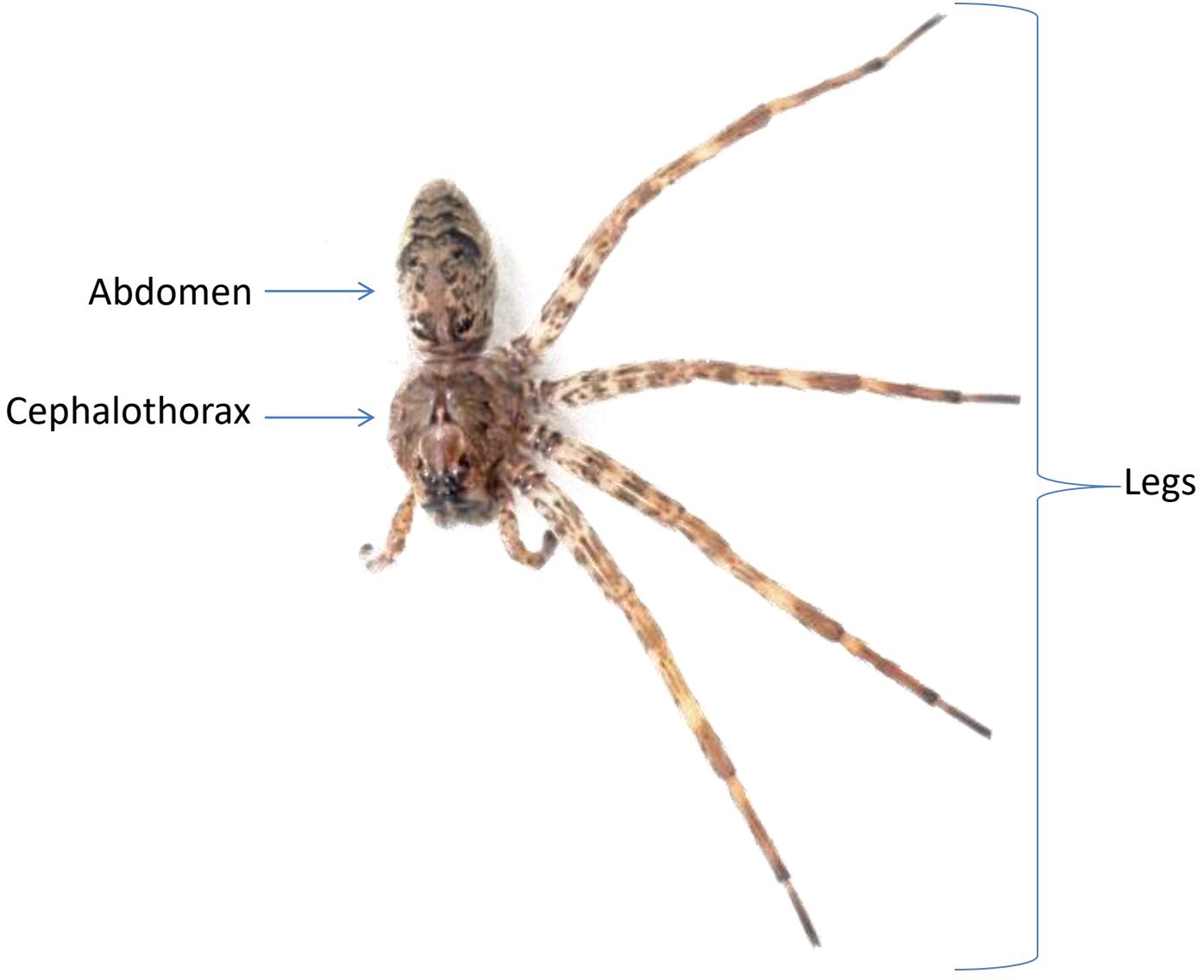
Tibellus sp.

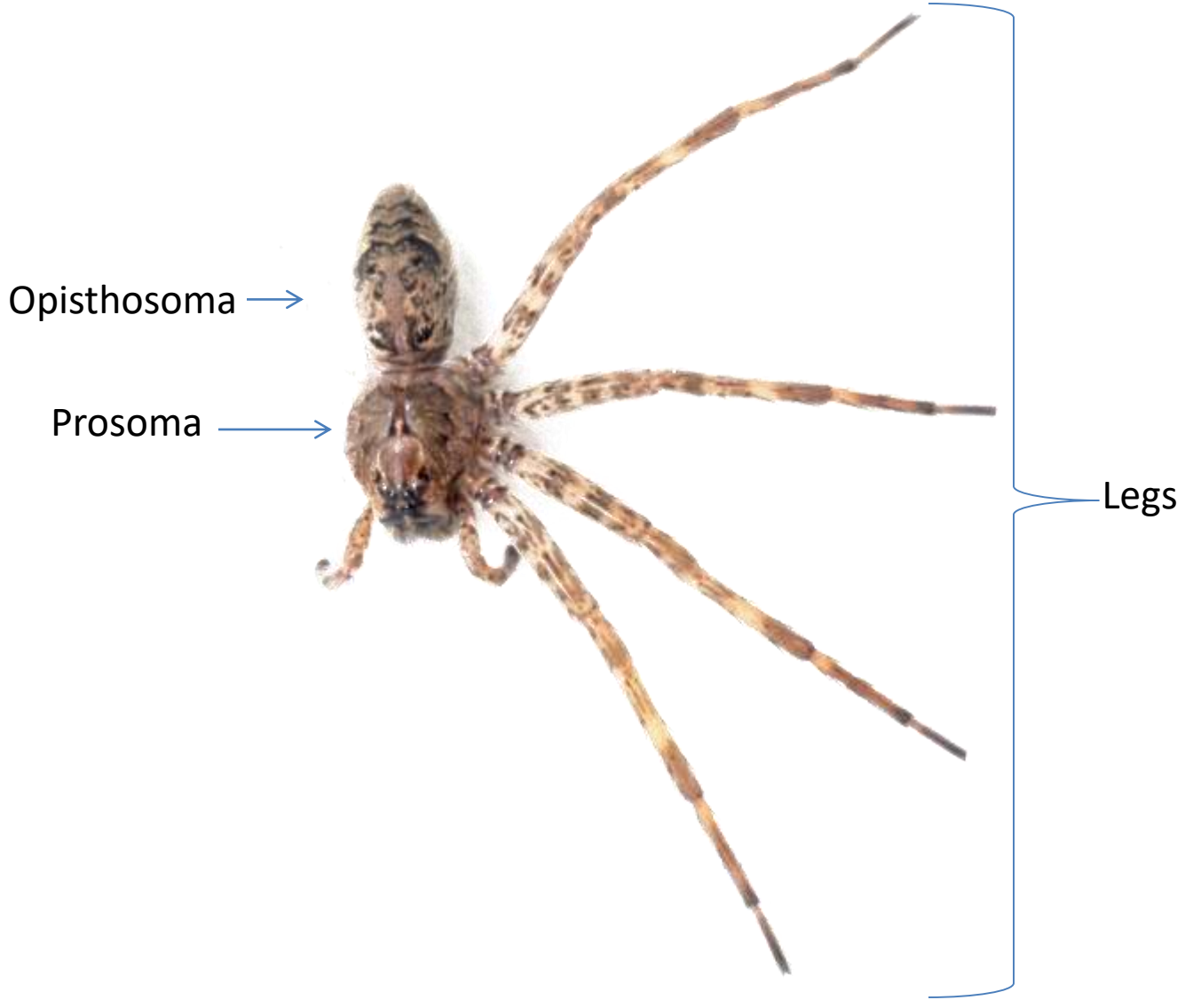
Agelenidae (funnel web weavers)

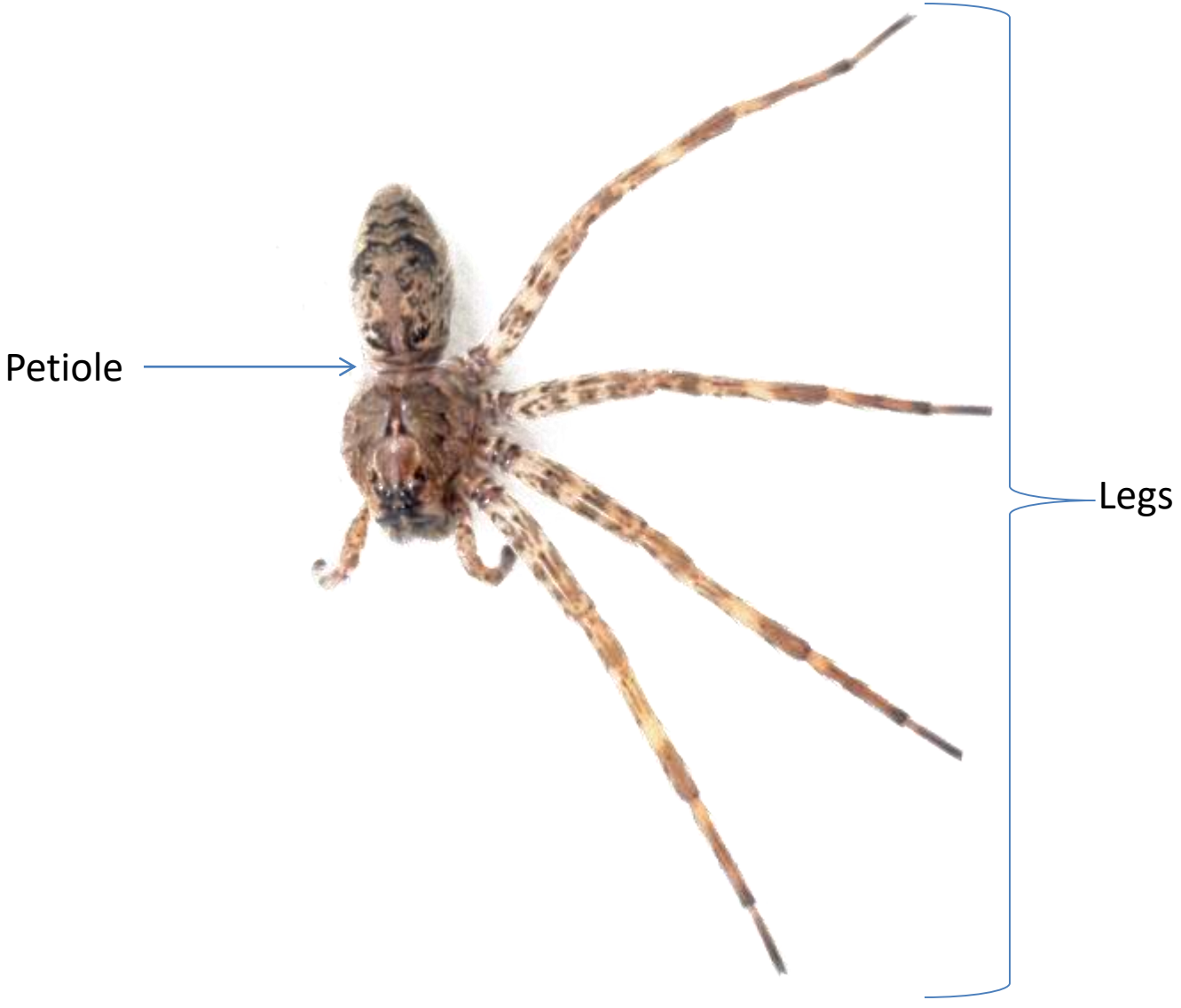
Agelenopsis sp. (Agelenidae)

Morphology

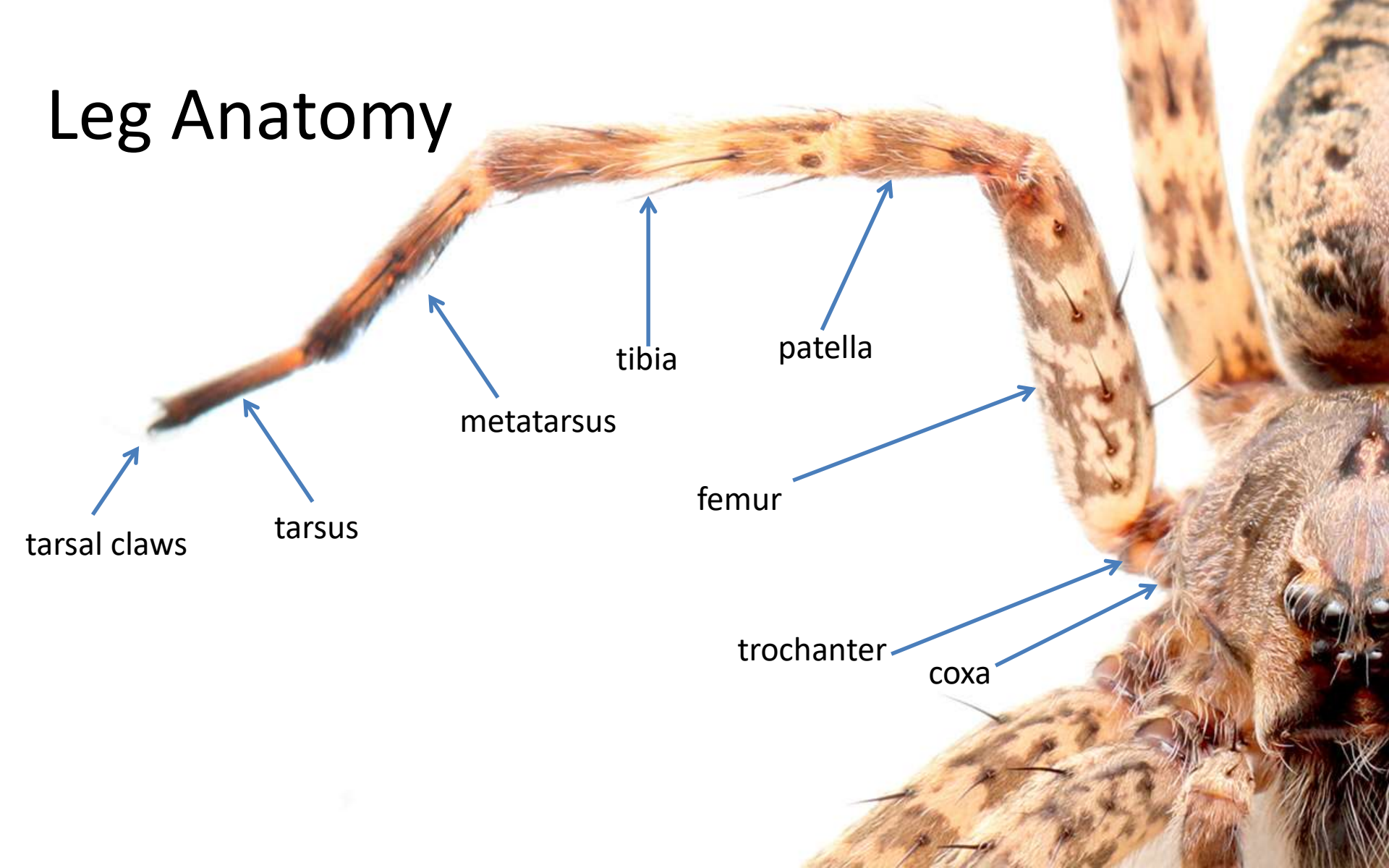
Dysdera crocata
(Dysderidae)


Abdomen
Cephalothorax
Legs


Opisthosoma
Prosoma
Legs

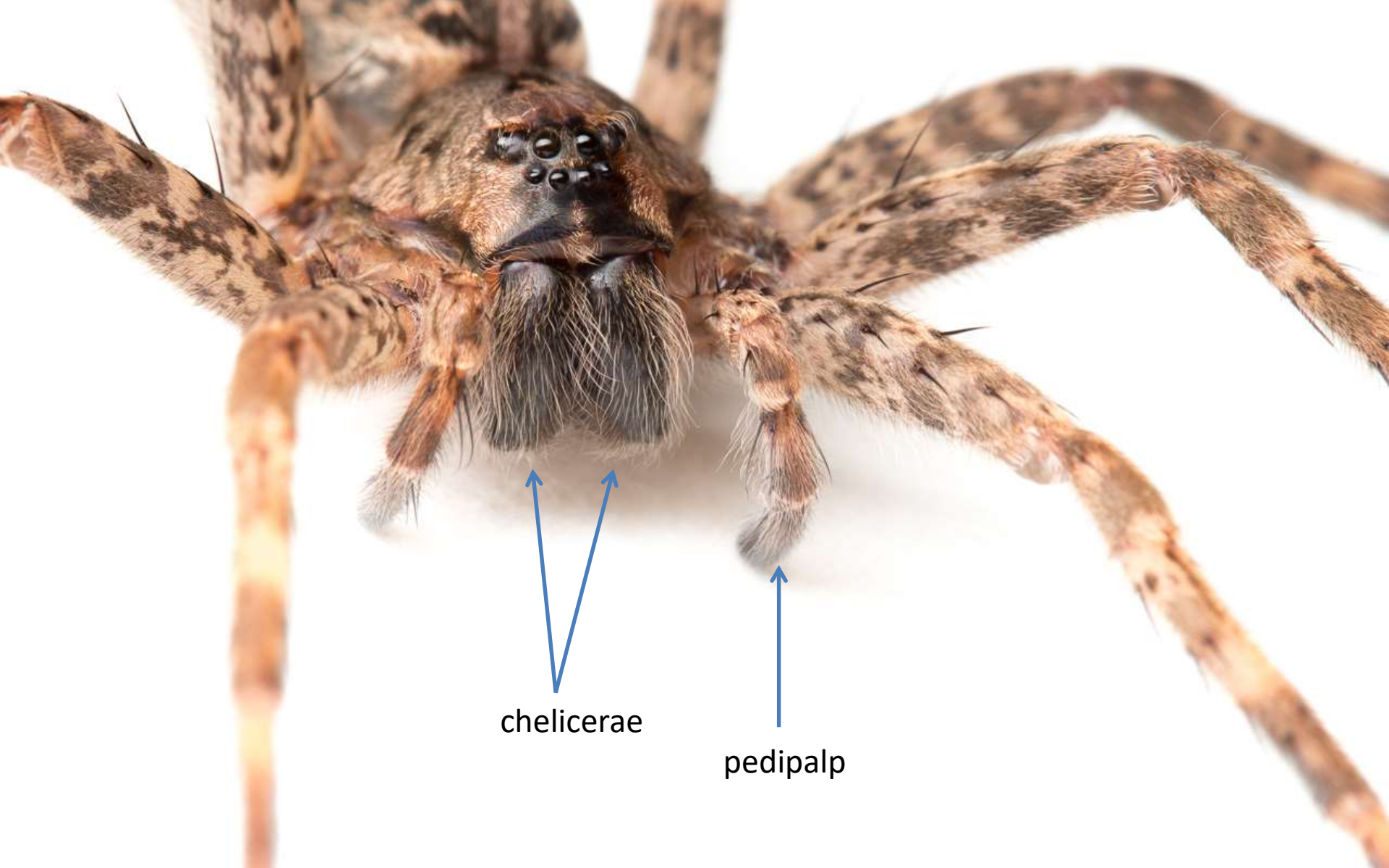

Petiole
Legs

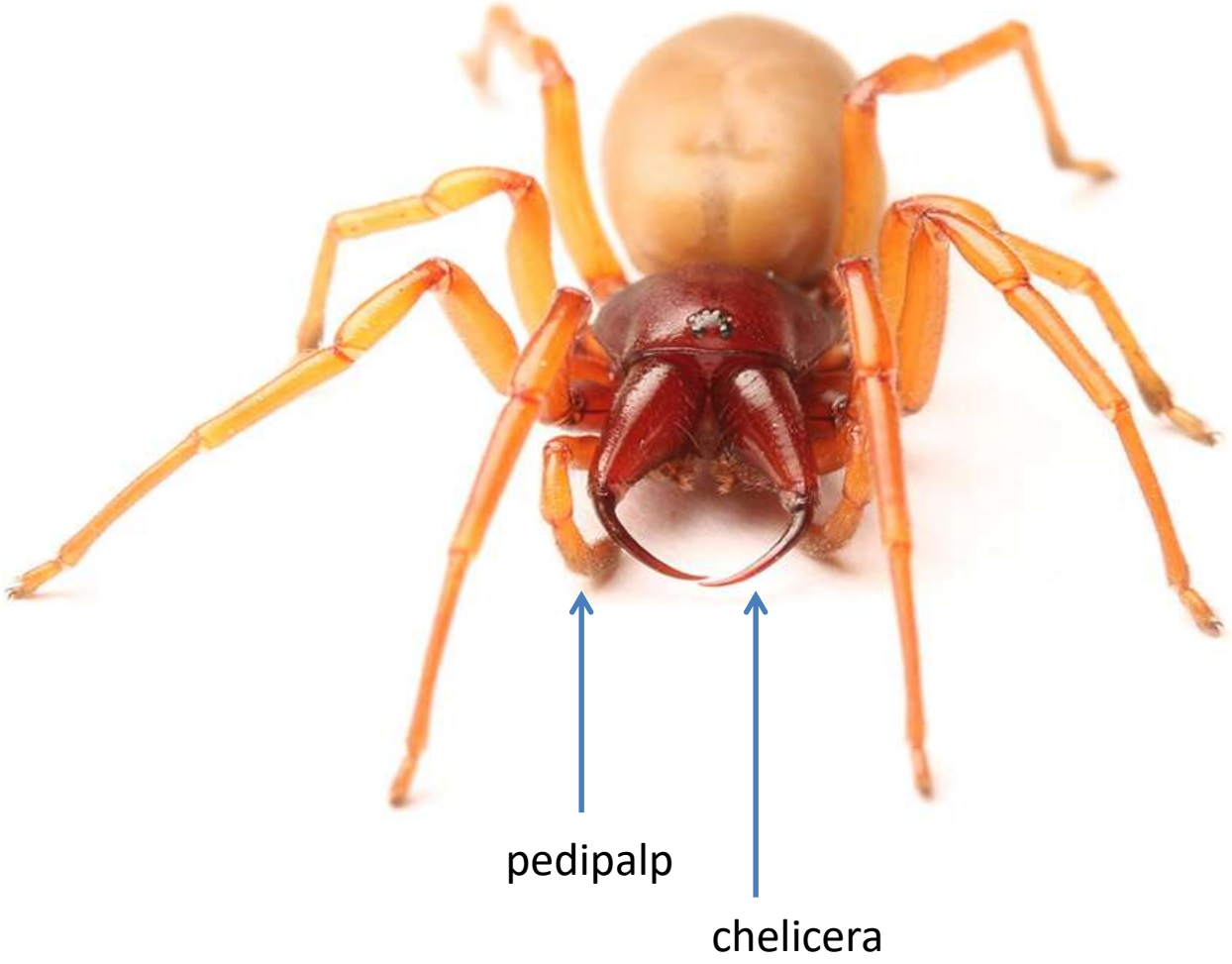
Leg Anatomy


tarsal claws
tarsus
metatarsus
tibia
patella
femur
trochanter
coxa

A note on legs

- Generally speaking, the longer the legs, the faster the spider
- Many spiders have “scopula hairs” on the underside of their tarsus that allow adhesion to smooth surfaces


chelicerae
pedipalp


pedipalp
chelicera

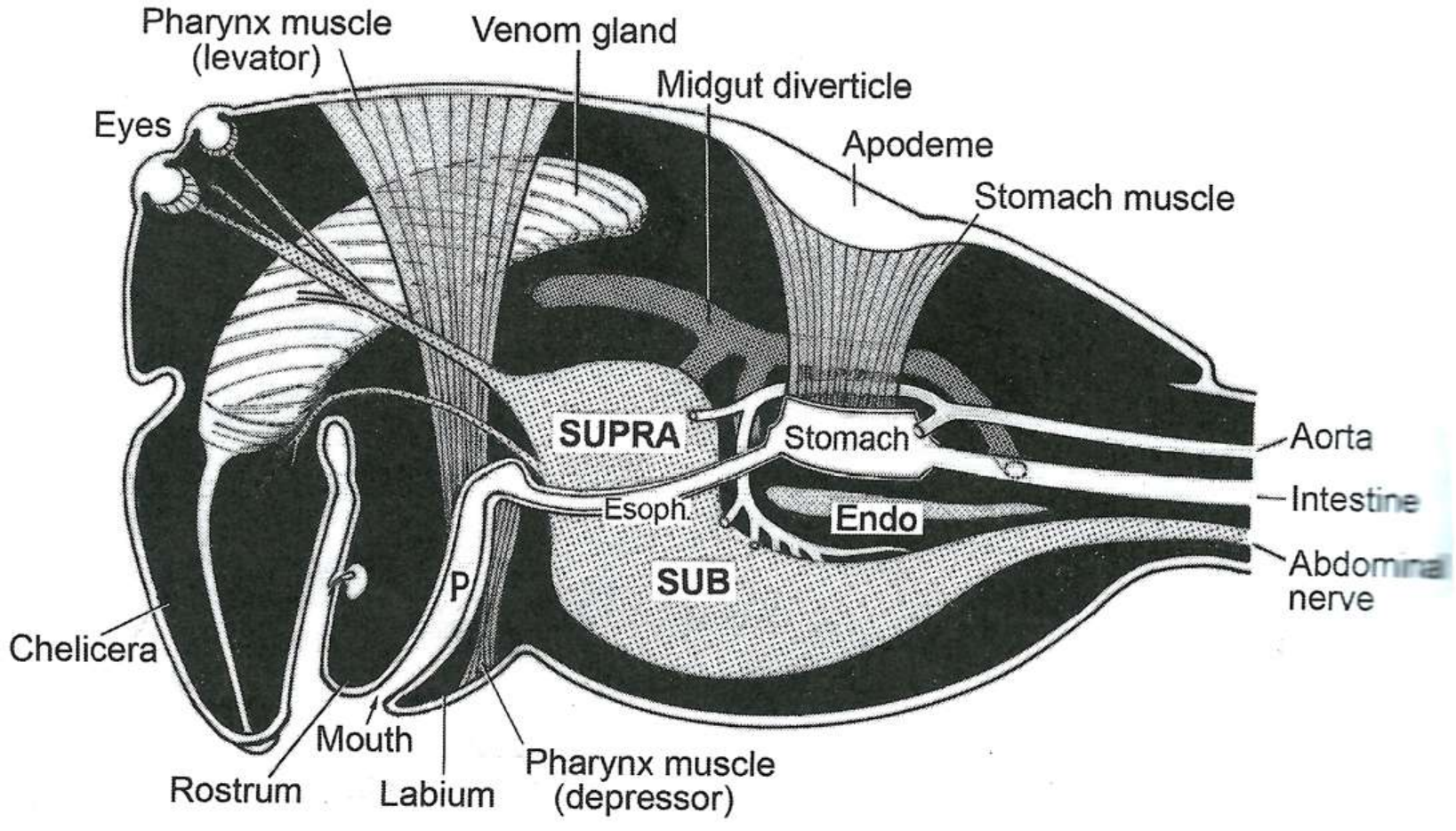
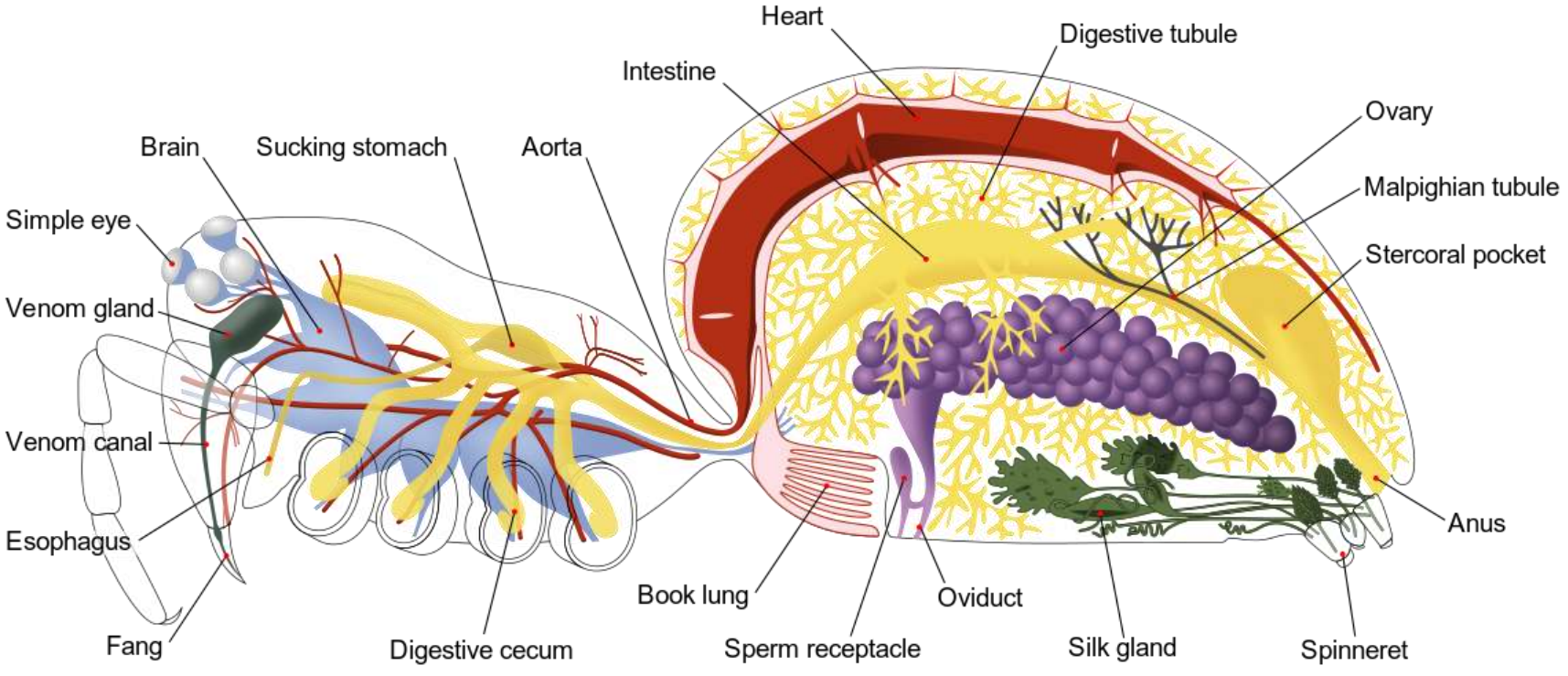


Figure 2.23

Longitudinal section of the prosoma. Endo = endosternite, Esoph = esophagus, P = pharynx, SUPRA = supraesophageal ganglion, SUB = subesophageal ganglion.

Circulatory and respiratory systems



Hemolymph

- Spider hemolymph contains nutrients, immune cells, and a freely-dissolved respiratory pigment called hemocyanin
- Hormones are also carried in hemolymph
- Cellular respiration depends on glucose, and this is the free sugar that is dissolved in the blood

Circulatory organs

- A single dorsal heart in the form of a muscular tube, pumping blood from posterior to anterior
- Aorta splits anterior to petiole, supplying thoracic muscles and brain
- Return of blood to abdomen mediated by pressure differential maintained by heart
- Virtually all blood returning to heart passes through book lungs

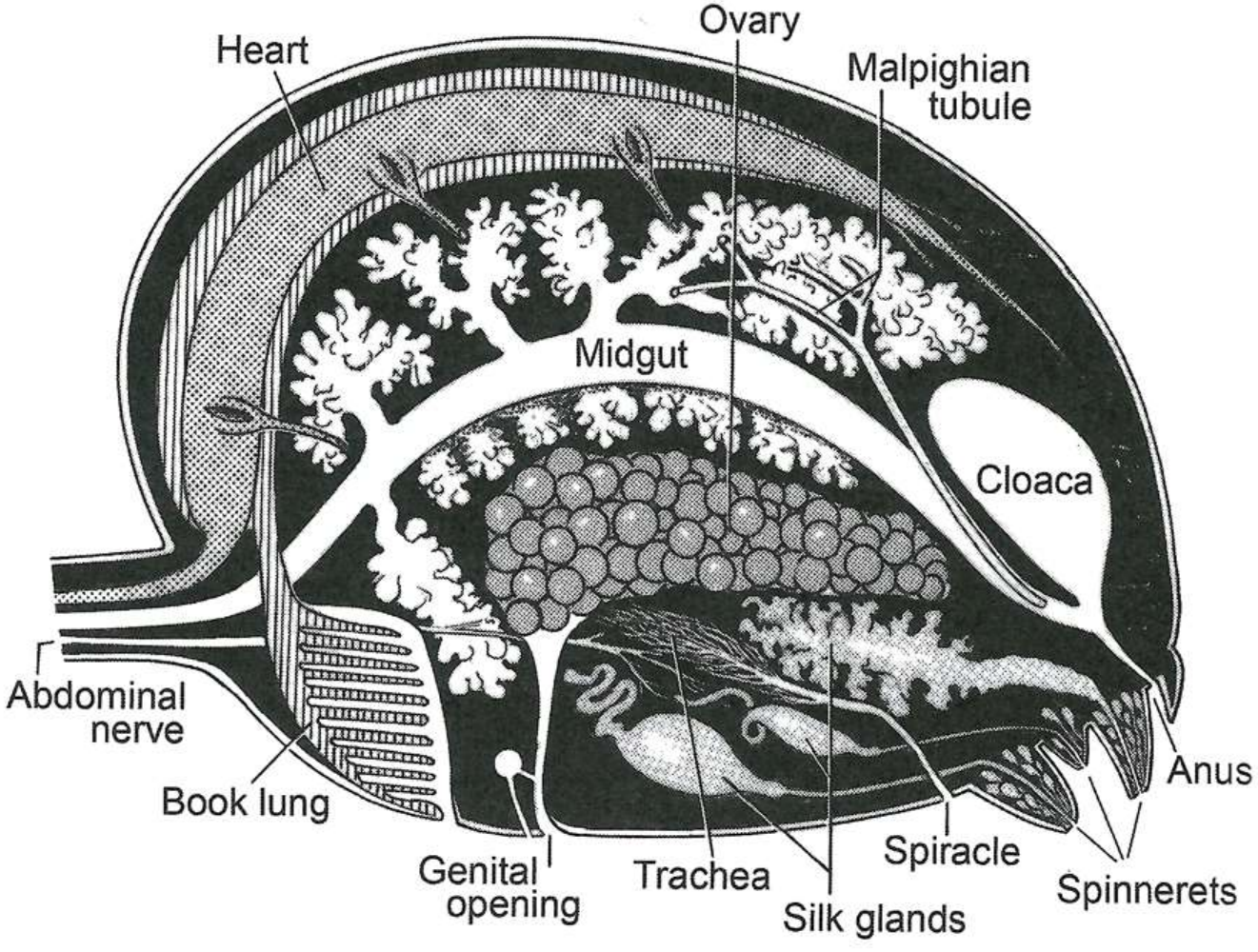
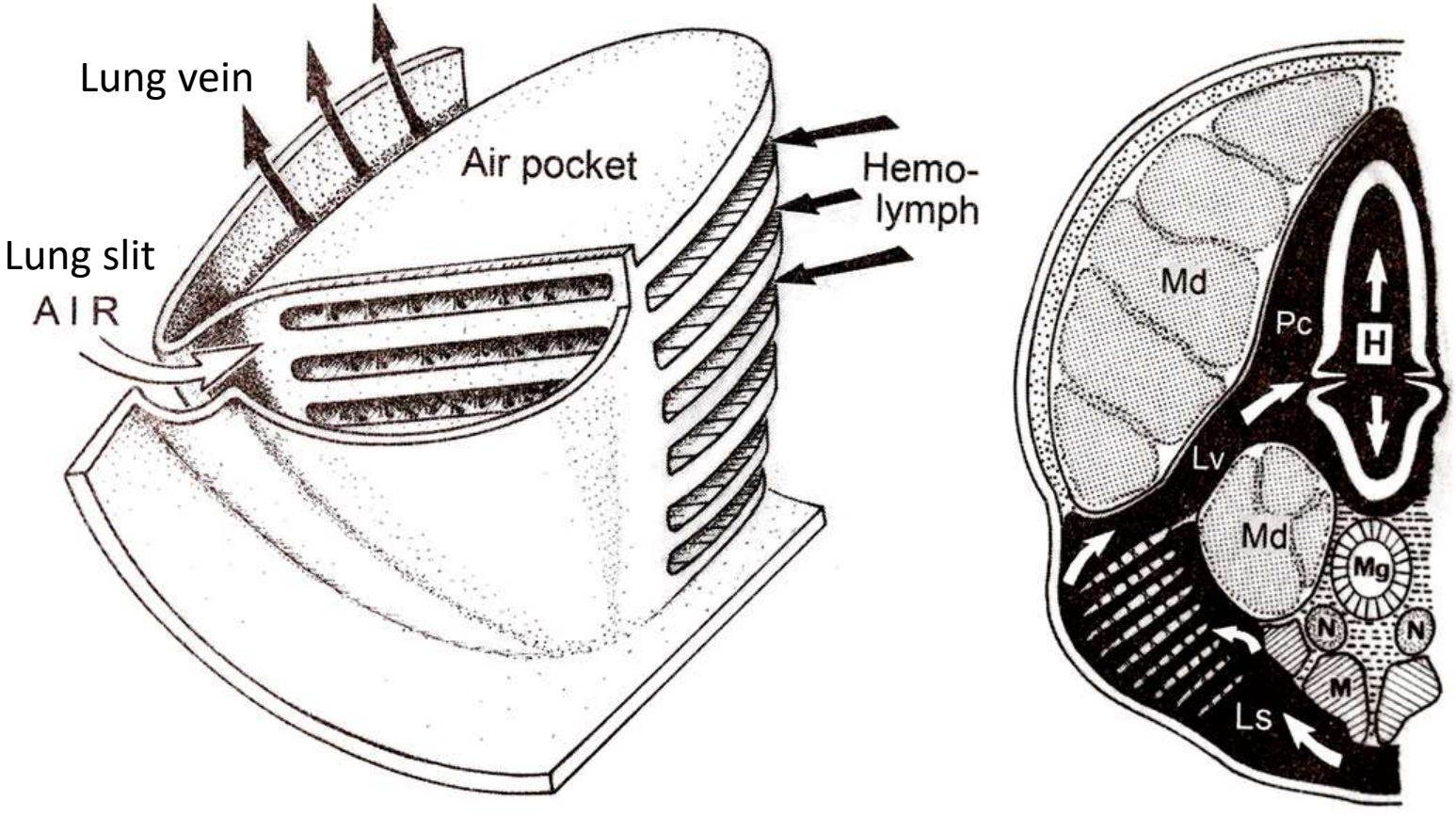


Figure 2.24
Longitudinal section of the opisthosoma of a female spider.

From: Foelix, Rainer. *Biology of spiders*. OUP USA, 2011

Book lungs

- In more basal lineages (Mesothelae, mygalomorphs) there are two pairs
- In more derived forms (araneomorphs) posterior pair have evolved into tracheae



Book lungs thought to be ventilated by wavelike oscillations due to hemolymph pressure

Fig 3.23: Foelix, Rainer. *Biology of spiders*. OUP USA, 2011

Tubular tracheae

- The posterior book lungs of araneomorph spiders have evolved into a tracheal system analogous to that of insects
- Rather than ramifying to contact cells directly, spider tracheae open into hemolymph
- This is several orders of magnitude less efficient than the tracheal system of insects

Tracheae

- Nonetheless, spiders with large tracheal systems capable of more extensive aerobic respiration
- The tracheal system of jumping spiders, wolf spiders, and other fast-moving taxa is the most highly-developed

Spider respiration and cardiac constraints

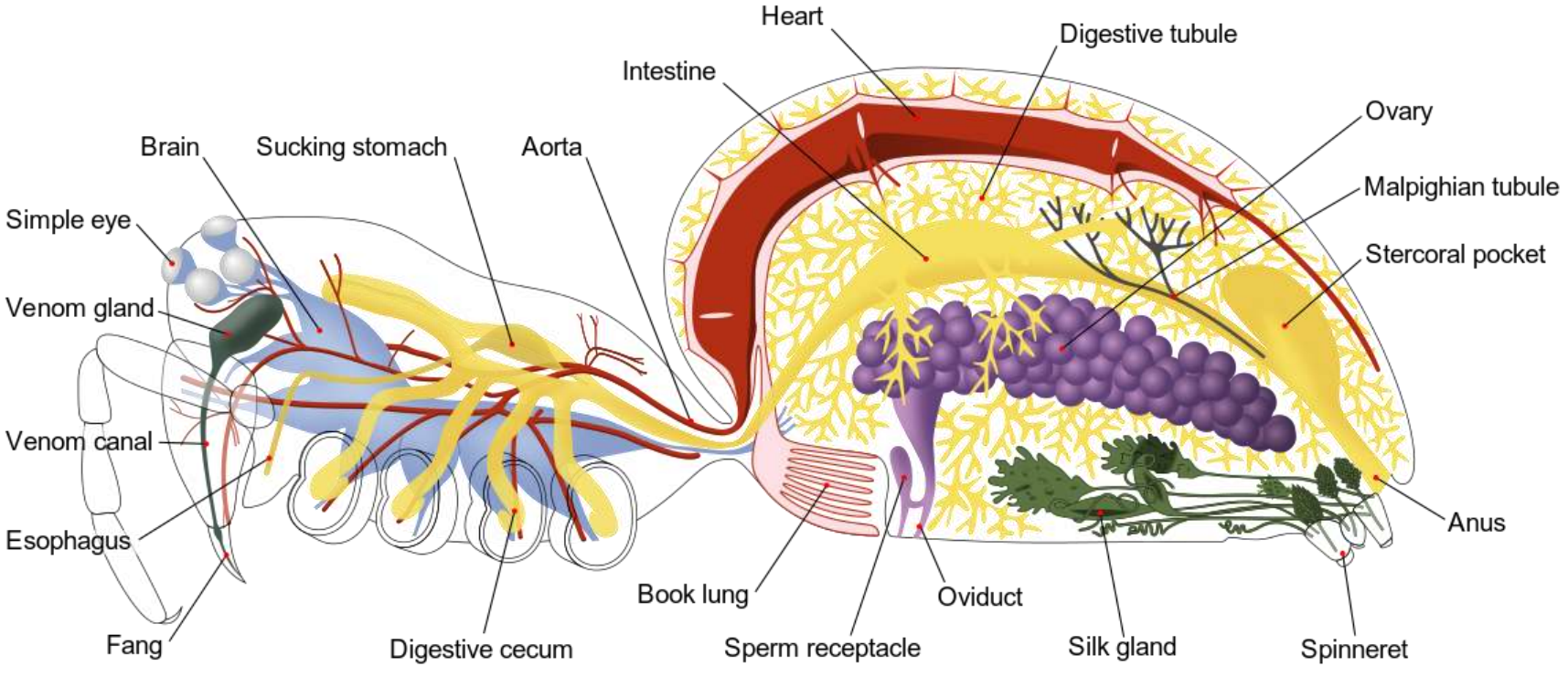
- The majority of spiders cannot sustain prolonged athletic activity without incurring significant oxygen debt
- Behaviourally, this means that a great many spiders are sit and wait predators (ambush hunters)

Also, even fat spiders are not “fat”

- Spiders do not store fat, they store predigested food in elaborations of the midgut
- These are termed midgut diverticula and ramify throughout the thorax, legs and most of the abdomen

A “Phat Phiddy” (female *Phidippus apacheanus*, likely gravid)

Silk glands: Exocrine glands to end all exocrine glands



Silk

- Silk originally evolved (it is thought) to function in protecting eggs (primarily preventing water loss) and lining burrows
- Secondarily, it has diversified into one of the most versatile tools employed in the animal kingdom

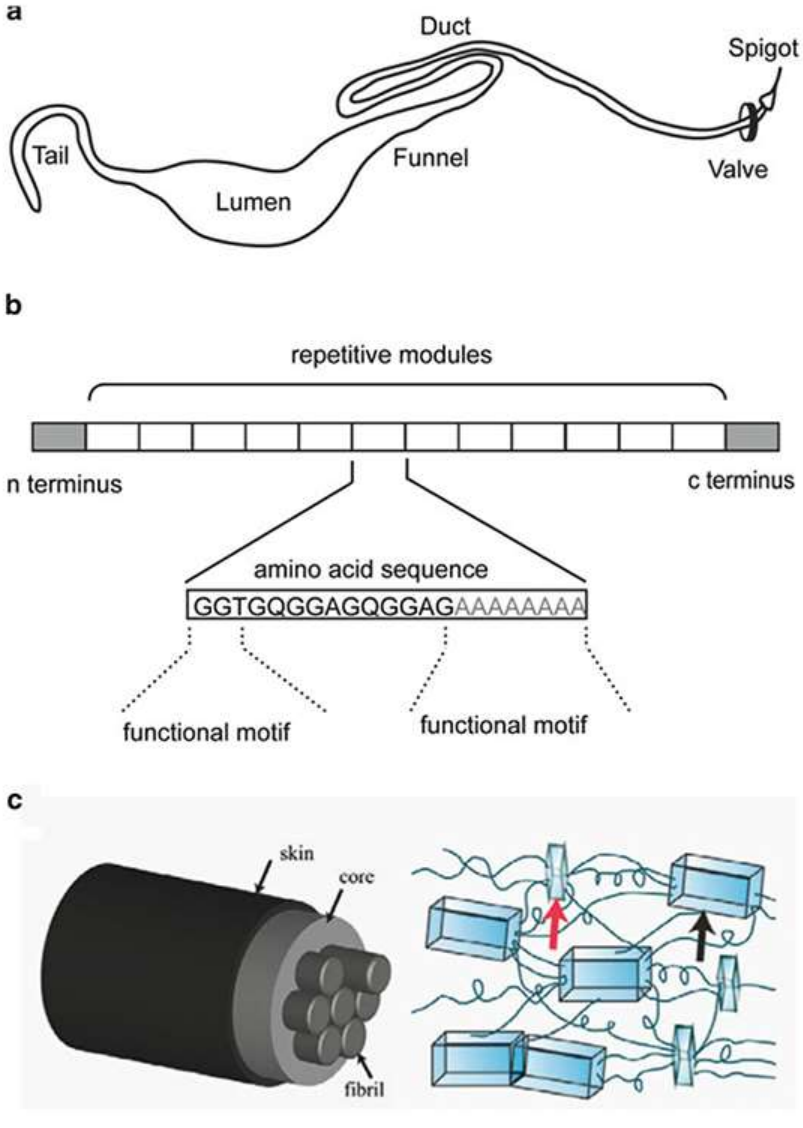


Fig. 20.1 Silk production and structure. (**a**) Spidroins are synthesized in the tail of the silk gland and are stored in the lumen as a liquid dope. As the dope passes through the spinning duct, a combination of shear forces, water uptake, and ion exchange produces a phase shift that causes nanocrystals to form and interlock the spidroins, thereby solidifying the fiber. The still wet silk fiber passes through a muscled valve that acts as a friction brake and controls the alignment of the spidroins along the fiber axis. (**b**) Spidroins consist of repeated modules of amino acids. Each module is composed largely of a few common functional motifs that form specific secondary structures. The N- and C-terminal regions are more heterogeneous, and their amino acid sequences are conserved among divergent silk types. (**c**) Hypothesized structure of major ampullate silk in an orb spider. A skin of lipids and glycoproteins surround a core of spidroins. The core likely consists of multiple fibrils. Individual spidroins are organized into highly crystalline domains embedded and an amorphous matrix. Two levels of crystalline domains are shown here. Adapted from Blackledge (2012) with panel C from Eisoldt et al. (2011)


Spider Silk Reeling
© Oxford Silk Group 2013

Egg sac weaving is a stereotyped behaviour

- Results in very uniform and characteristic sacs

Phoneutria sp.
(Ctenidae)

Pholcidae

Scytodes sp.
Scytodidae

Herpyllus ecclesiasticus
(Gnaphosidae)

Webs!

Tetragnatha sp.
(Tetragnathidae)

Scytodes sp.
(spitting spider, Scytodidae)

Bolas spiders (*Mastophora* sp., Araneidae)
have a very special use for silk
Video credit: Tapinopa
https://youtu.be/zvtZIRlLmWU

Venom!

Spider Venom

- Functions to immobilize and kill prey
- Will also begin the digestion process, breaking down internal structures of the (usually insect) prey
- Is present in all spiders except for a couple taxa
- Toxic components are mainly proteins, with various properties
- Venom research is increasingly common in pharmacology and other industrial chemistry

Sense Organs

Proprioception, touch and vibration sensing

- Spiders are very adept at sensing vibrations
- Sense organs include trichobothria, slit sense organs, lyriform organs and assorted hairs of the body
- Sensitivity to substrate borne vibration aids in prey capture, courtship

Trichobothria

- Extremely fine (5 µm diameter) hairs, found mainly on the legs, respond to high amplitude, low frequency airborne vibrations (nearfield sound)
- *Cupiennius* (a tropical wolf spider) can accurately locate a buzzing fly 30 cm away, even when blinded.

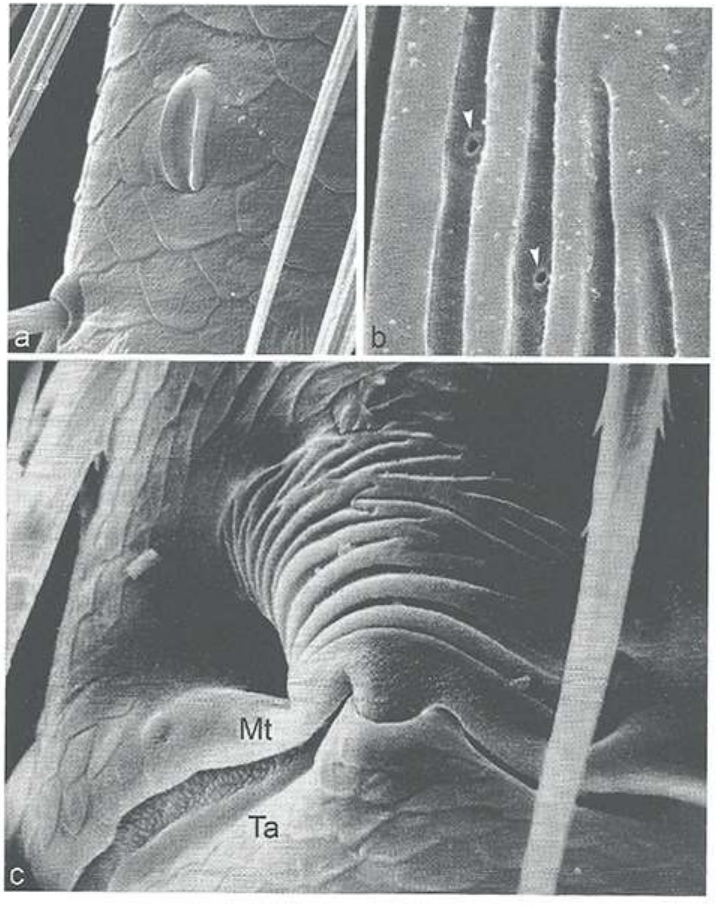
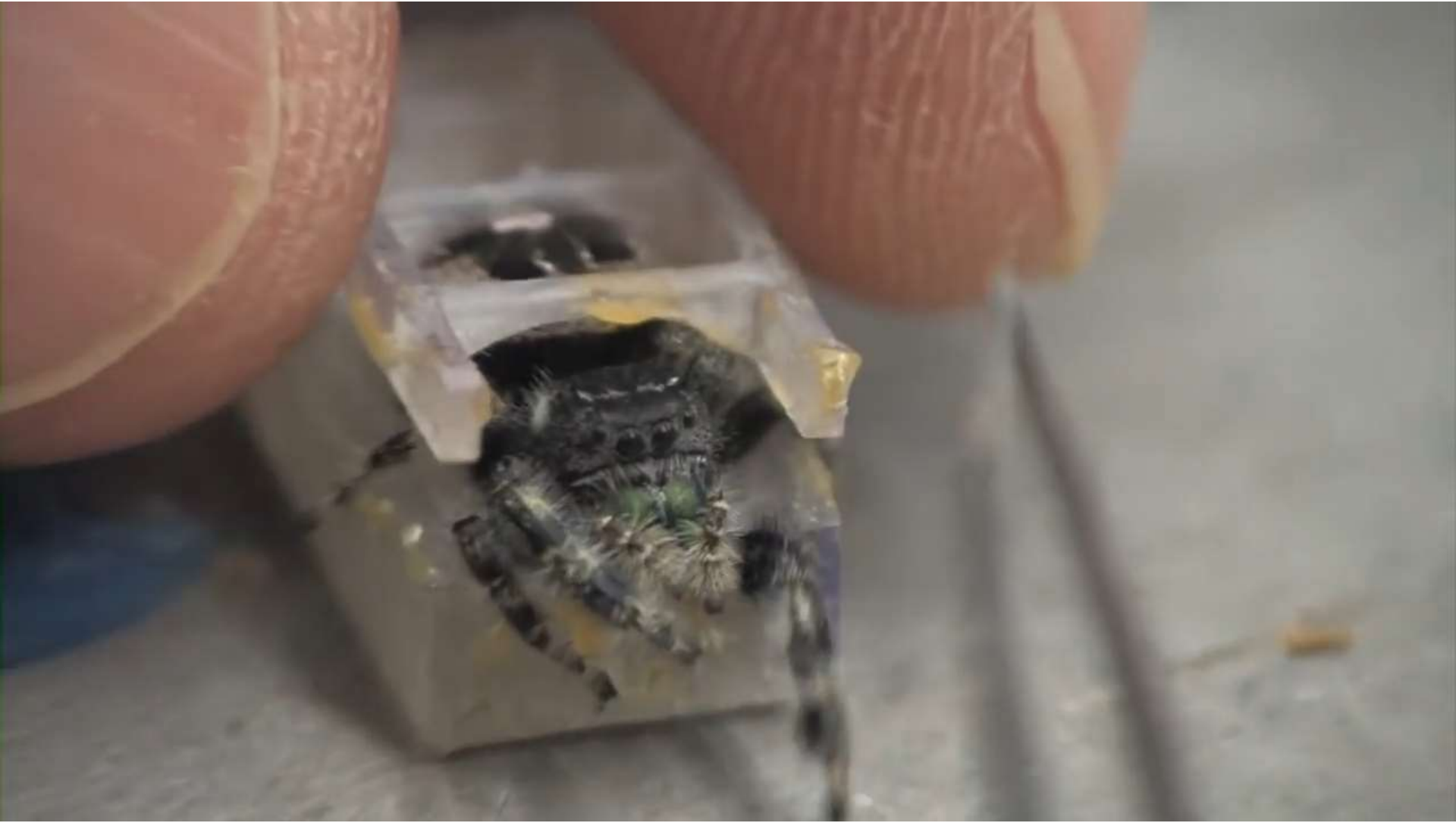
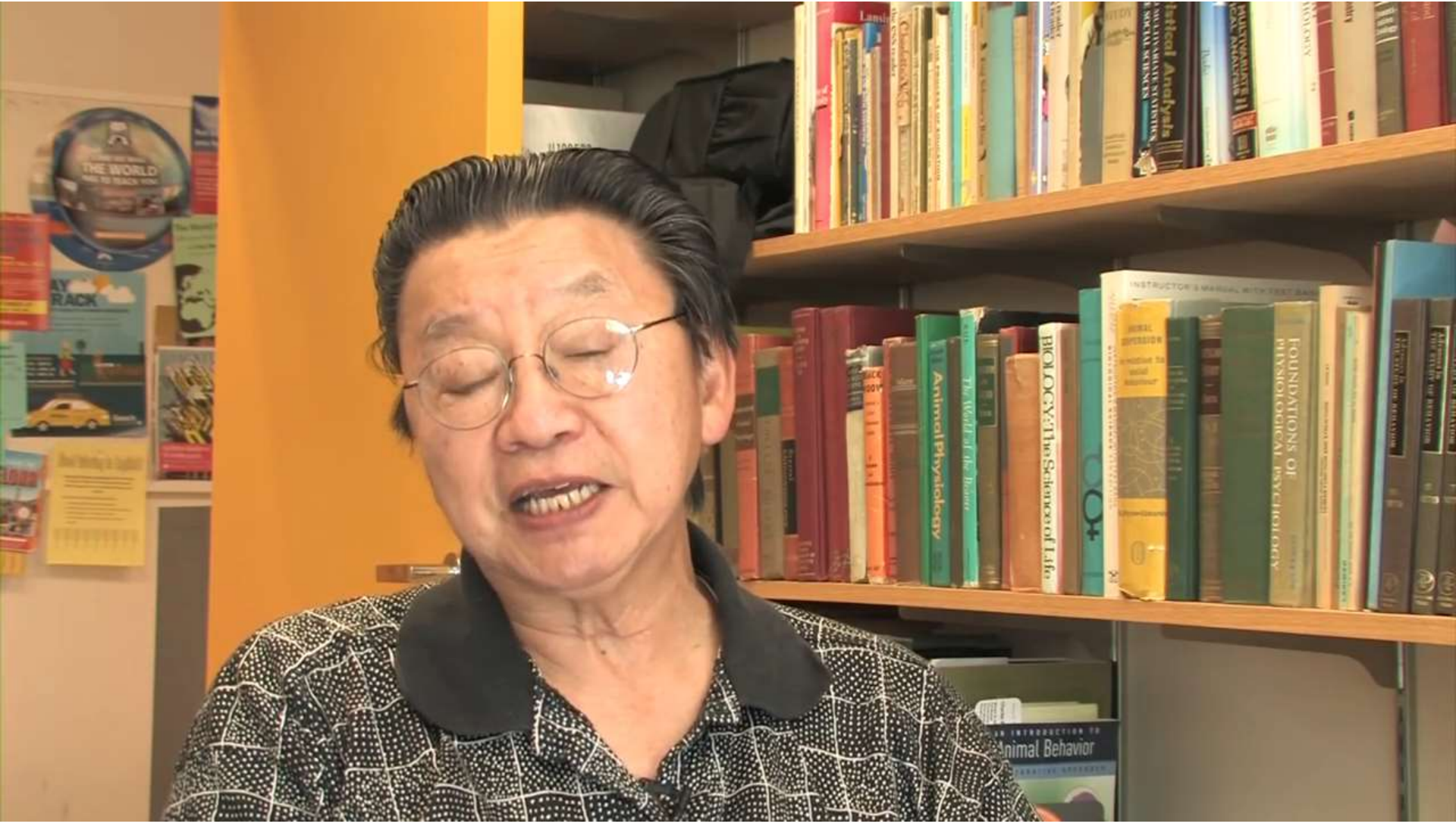


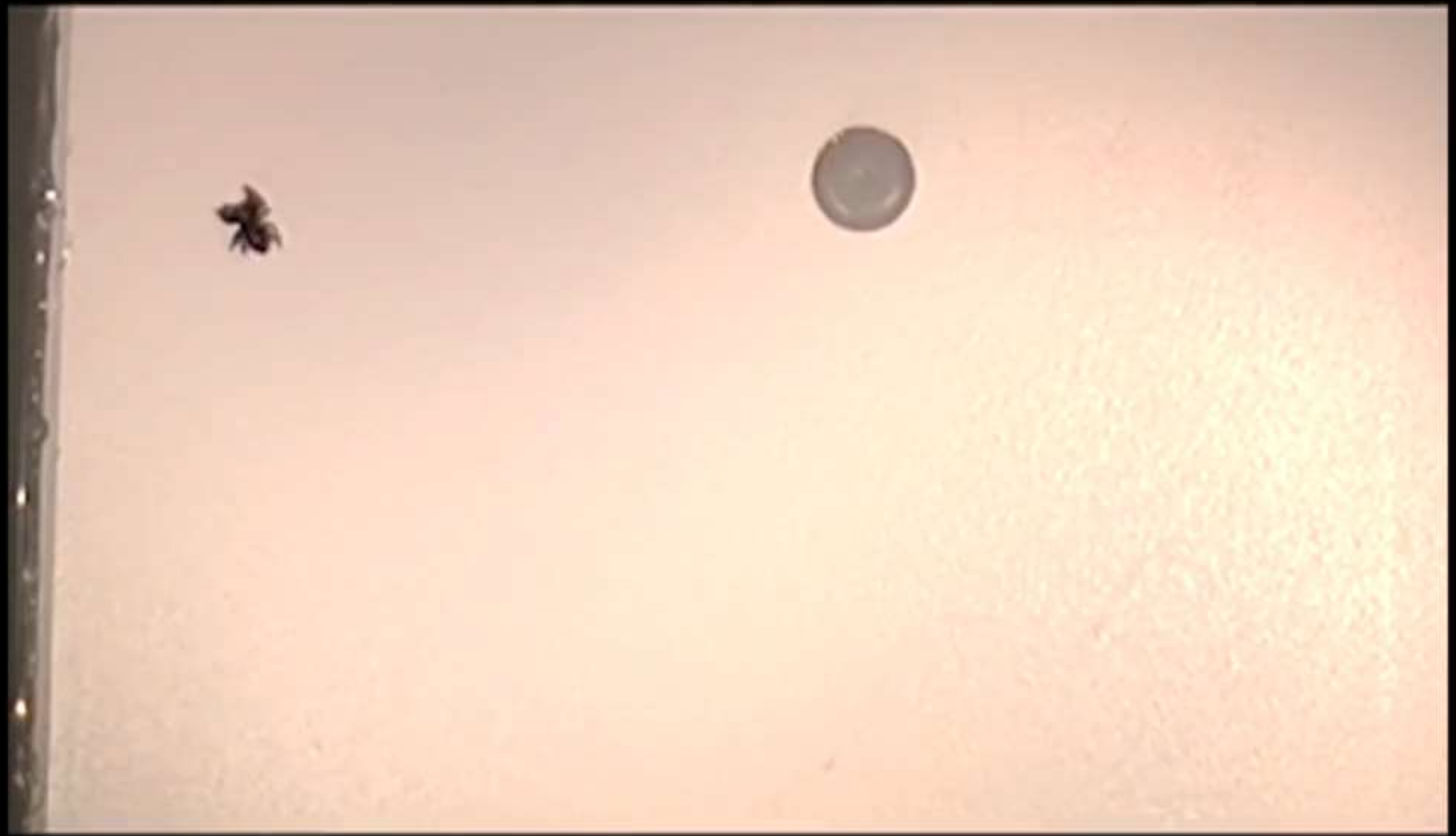
Figure 4.9
(*a*) A single slit sensillum from the leg of a theridiid spider in the typical lengthwise orientation within the leg cuticle. 1,200 x. (*b*) A high magnification of the slits in the crab spider *Diaea* reveals the attachment sites of the dendrites as tiny cuticular rings (arrows). 1,900 x. (*c*) Metatarsal lyriform organ in *Araneus diadematus*. The slits are here arranged perpendicular to the leg axis and lie at the border of the metatarsus (Mt) and the tarsus (Ta). 1,000 x. (From Foelix, 1970a.)

Hearing may be more than just nearfield sound:

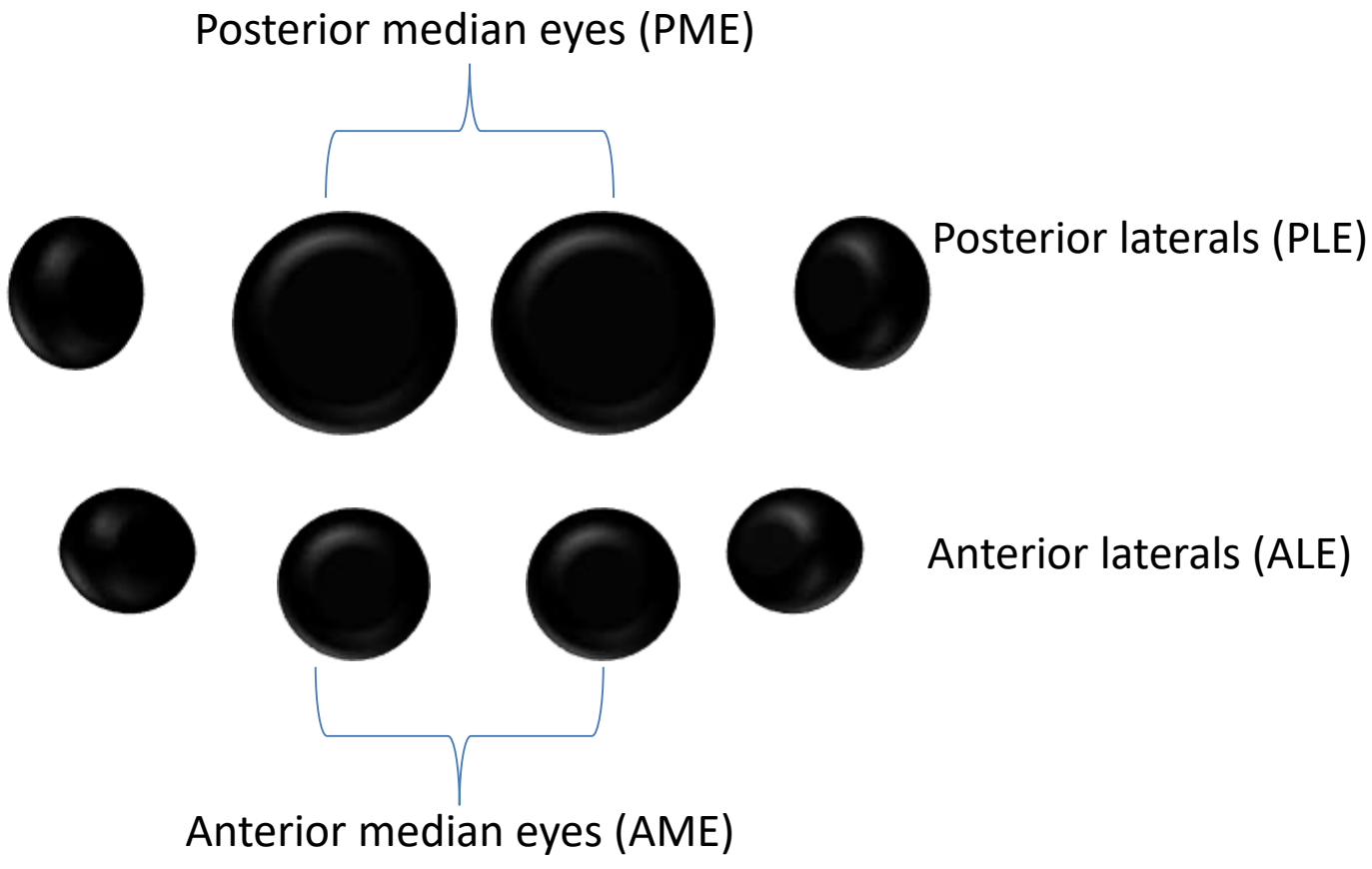
Shamble, Paul S., Gil Menda, James R. Golden, Eyal I. Nitzany, Katherine Walden, Tsevi Beatus, Damian O. Elias, Itai Cohen, Ronald N. Miles, and Ronald R. Hoy. 2016. "Airborne Acoustic Perception by a Jumping Spider." *Current Biology* 26 (21): 2913–20. doi:10.1016/j.cub.2016.08.041.

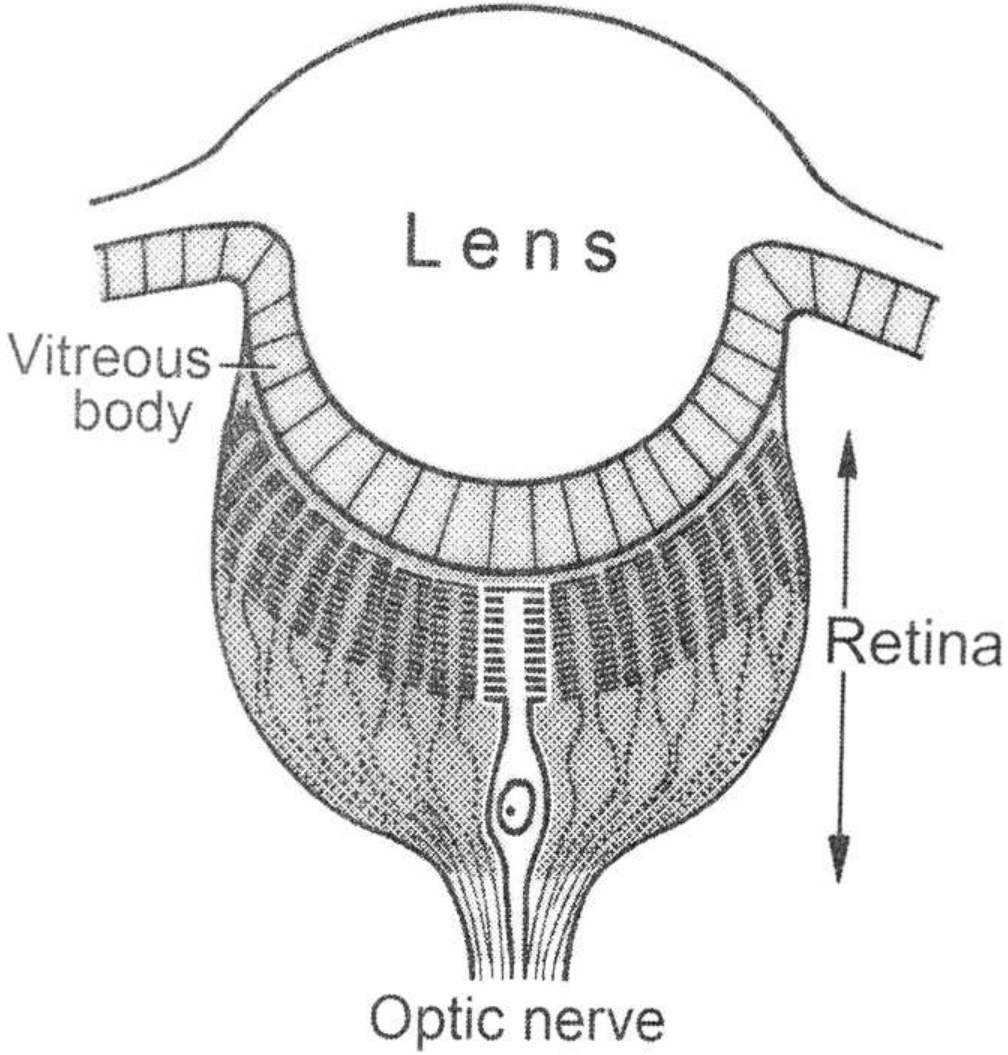



THE WORLD
Animal Physiology
BIOLOGY: The Science of Life
FOUNDATIONS OF PHYSIOLOGICAL PSYCHOLOGY
Animal Behavior



Eyes+Vision

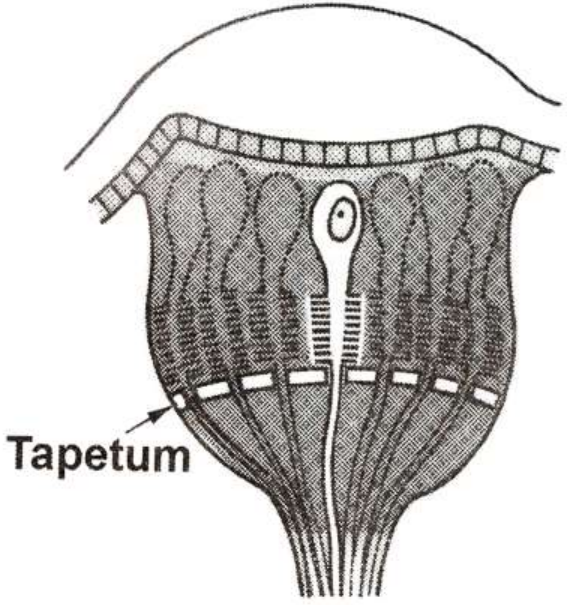

Posterior median eyes (PME)
Posterior laterals (PLE)
Anterior laterals (ALE)
Anterior median eyes (AME)



Main Eye

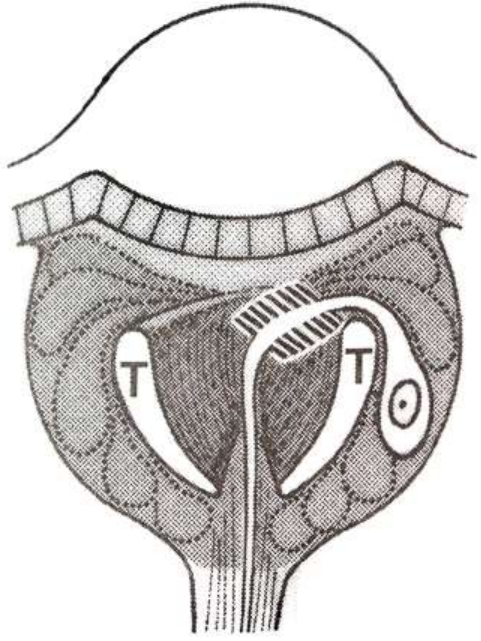
Fig 4.18: Foelix, Rainer. *Biology of spiders*. OUP USA, 2011

Secondary eyes



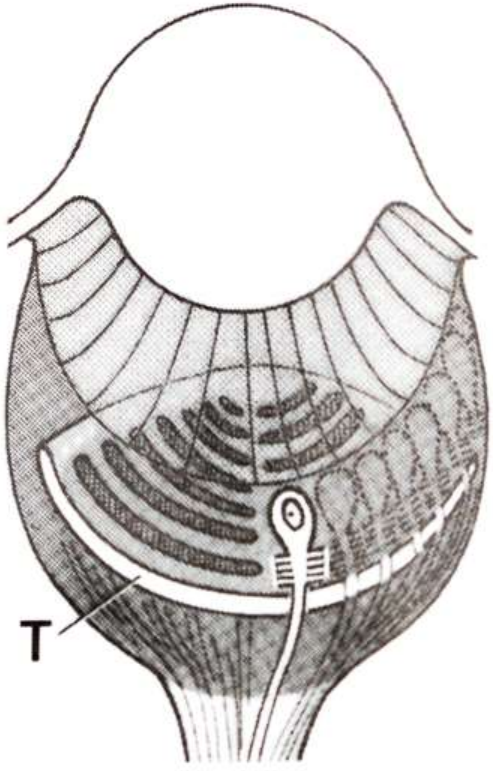
Primitive type

(typical of myglalomorphs and haplogynes)



Canoe-shaped type

(typical of Theridiidae, Agelenidae)



Grate type

(Lycosoidea)

Fig 4.19: Foelix, Rainer. *Biology of spiders*. OUP USA, 2011

Some things to remember about vision

- The number and type of photoreceptors in the retina determine what sorts of images can be perceived
- Visual pigments determine the sensitivity to various wavelengths and thus the degree of colour discrimination

The very ridiculously awesome eyes of Salticidae

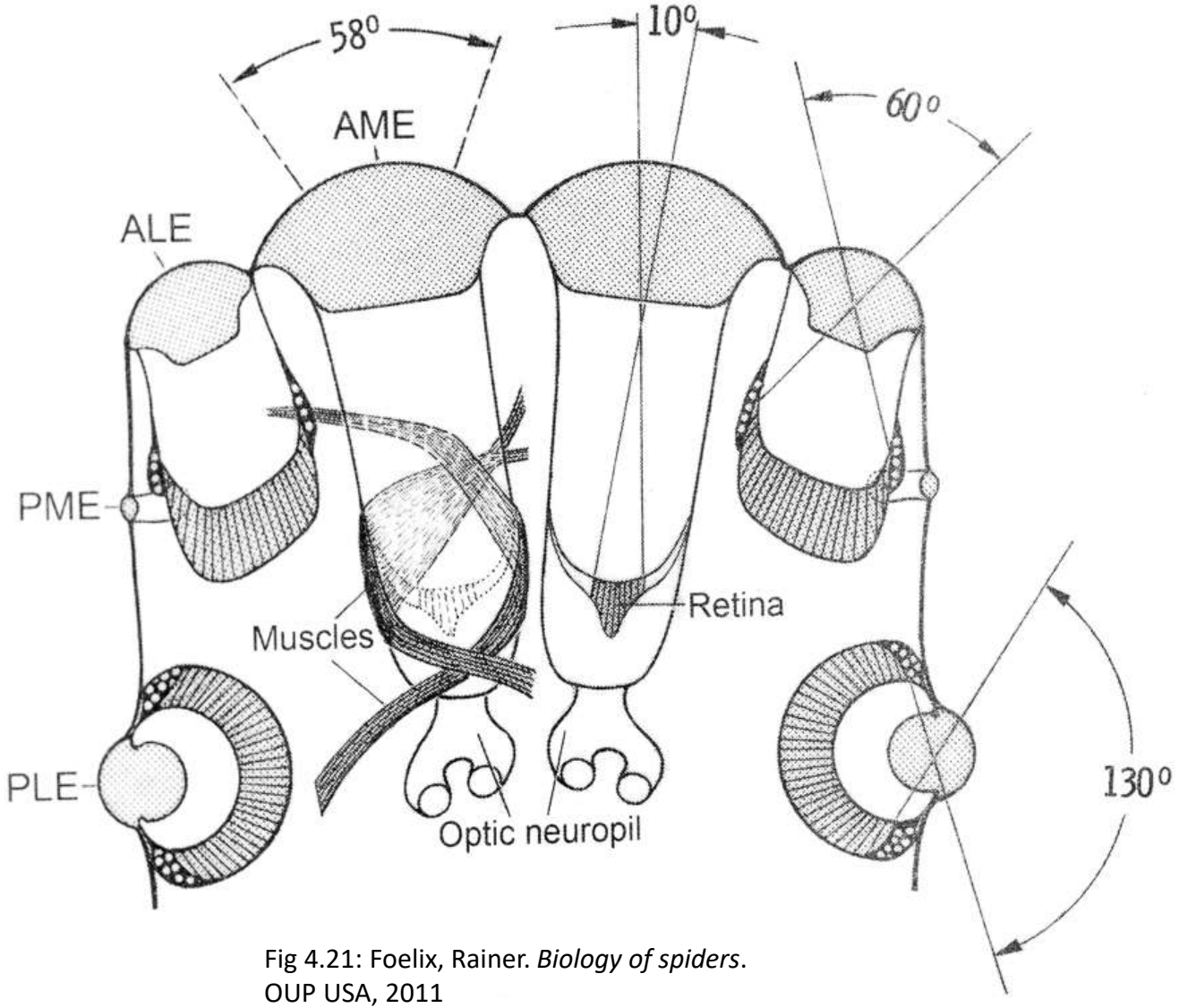


Fig 4.21: Foelix, Rainer. *Biology of spiders*.
OUP USA, 2011

Lyssomanes eye movement video can be found here:

https://youtu.be/AW7SuEZJ8qk

Eyetracker movie: courtesy of Elizabeth Jakob (Cornell University)
Available here:
https://youtu.be/669OTufccIo

Some spiders can also see polarized light

Sunny day, strong polarization in the sky

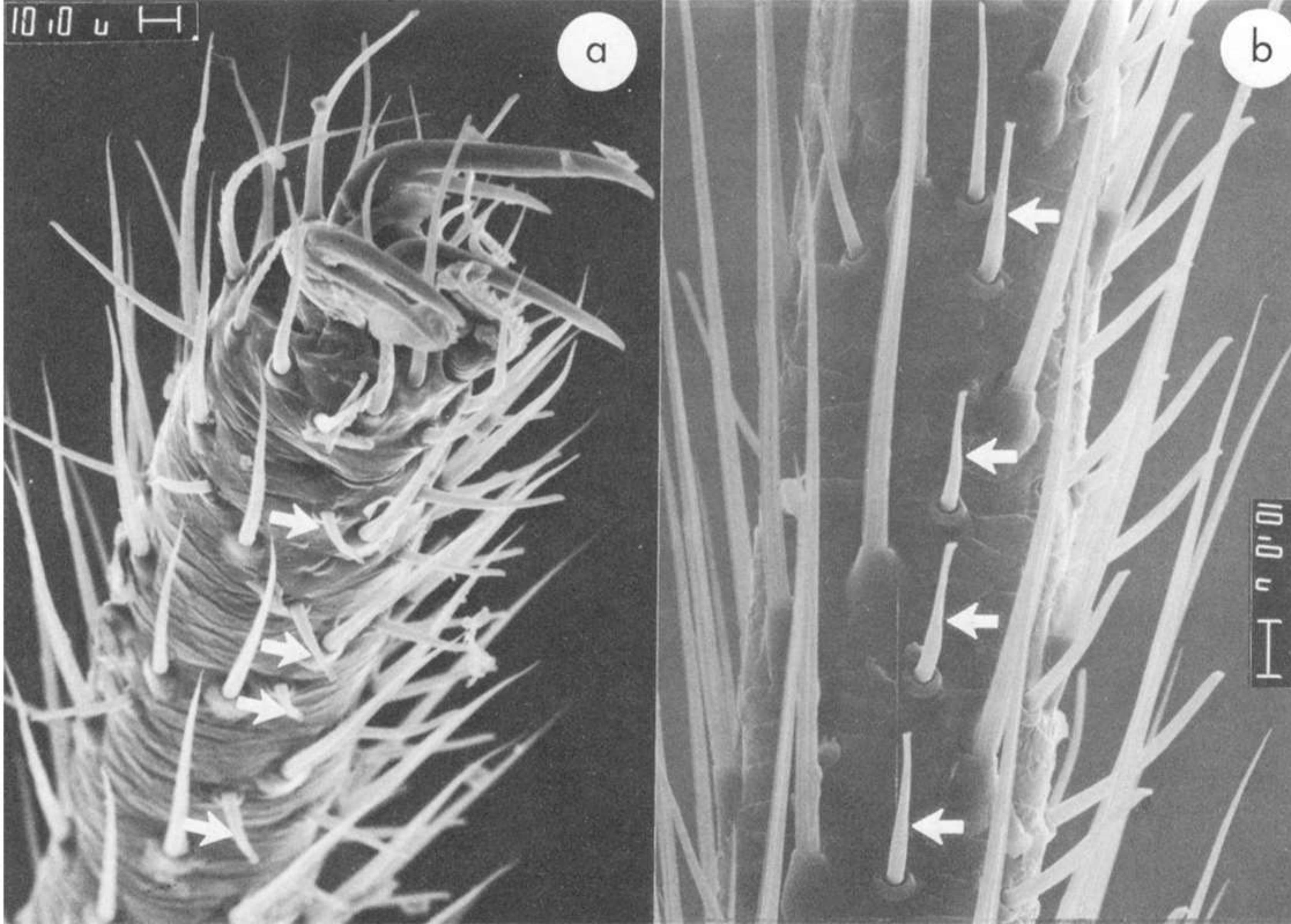
Sunny day, strong polarization in the sky

Sunny day, strong polarization in the sky

Cloudy day, no strong polarization evident

Chemical senses

- Chemosensitive hairs have been identified on tarsi and mouthparts, many of these are contact chemoreceptors
- It is currently unknown whether these or other structures are responsible for spider olfaction
- Nonetheless, there is much behavioural evidence for very sensitive olfaction in spiders, at least as far as sex pheromone localization


10.0 u
a
b
10.0 u

Sex Pheromones

- Sex pheromones have been identified in a few species, but this work is very difficult due to the lack of electrophysiological techniques
- Orientation to sex pheromones indicates that their chemosensory abilities are finely honed
- Catherine will talk more of sex pheromones, and we will put up a review paper

Gaskett, A.C., 2007. Spider sex pheromones: emission, reception, structures, and functions. *Biological Reviews*, *82*(1), pp.27-48.


High five!!!

Why behavioural research on spiders?

- Spiders are diverse, ancient arthropods, many are easy to find and rear
- Sensory capabilities enable rapid behavioural adjustment to conditions
- Several dominant sensory modalities within the group, can study a wide variety of behaviour
- Their behaviours are often very obvious, easy to record and informative