WALKING, SWIMMING, JUMPING, GRASPING, AND DIGGING AS AN INSECT

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Angelique Paulk

Objectives

- What is the basic design of the insect leg?
- How do insects walk?
- How do insects swim?
- How do insects jump?
- How do insects grasp?
- How do insects dig?

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The insect leg comes in many different designs

1. Long dance fly (*Empis livida*)
2. Long Nosed Weevil (*Rhinotia hemistictus*)
3. Assassin bug in the family Reduviidae sub-family **Harpactocorinae**
4. Mole Cricket (*Gryllotalpa brachyptera*)
5. Emperor gum moth (*Opodiphthera eucalypti*)
6. European Wasp (*Vespula germanica*)

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The insect leg comes in many different designs

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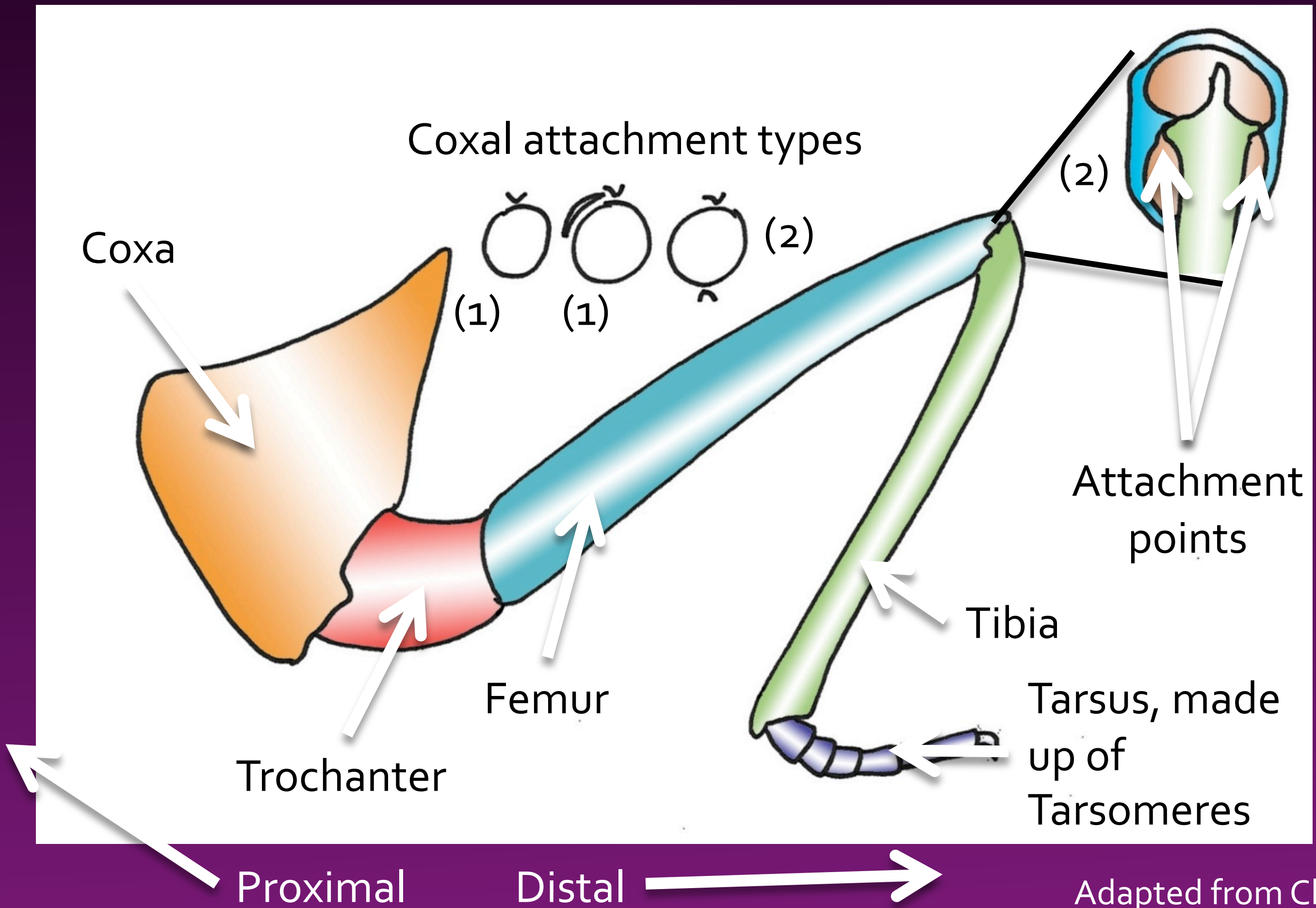
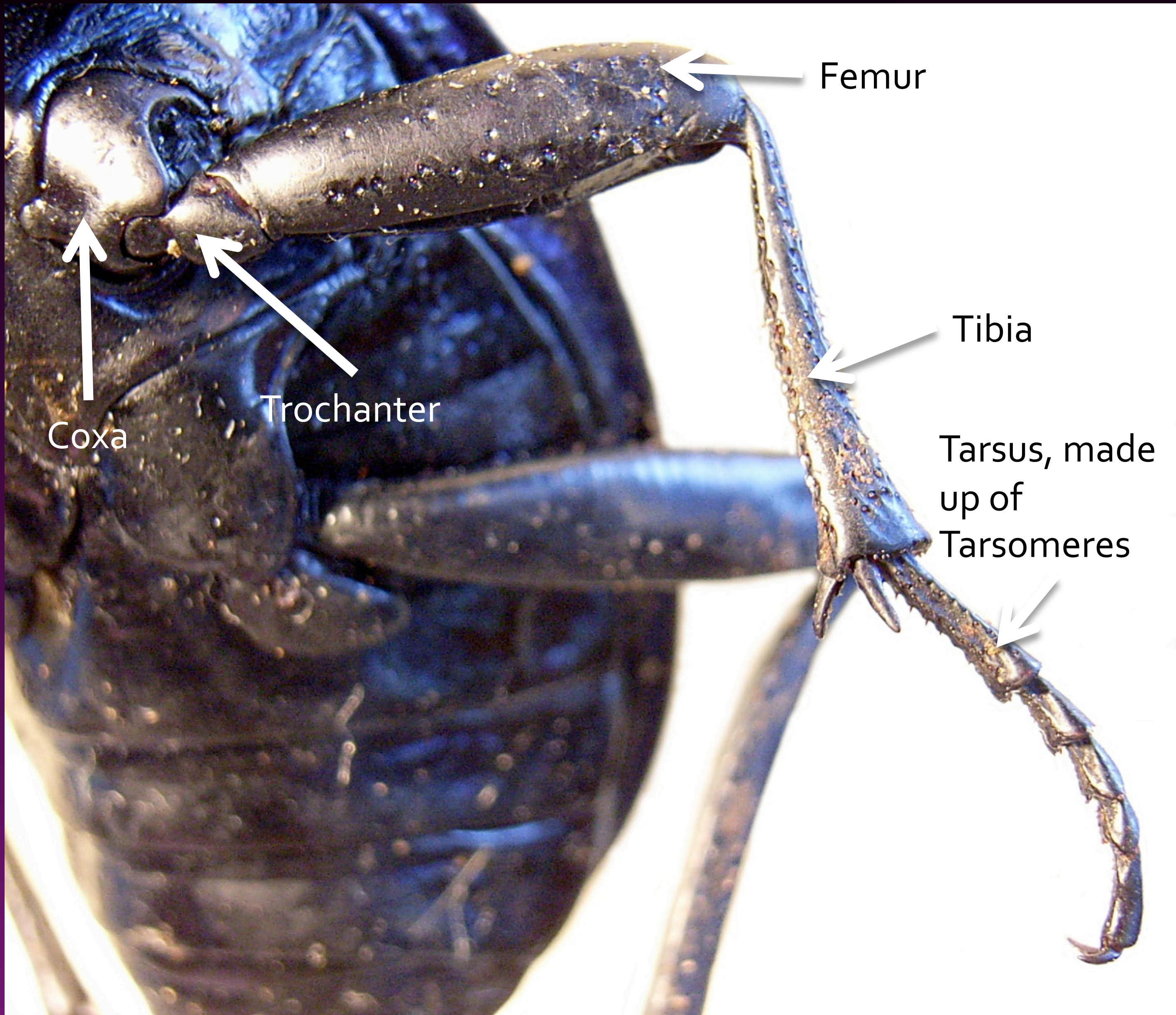
The insect leg

- The insect leg has one general ground plan, with the base of the leg called the coxa, followed by the trochanter, the femur, the tibia, and ending in the tarsi
- The attachments of the joints can vary considerably, from single pivoting points (1), such as between the coxa and the thorax, to two attachment points (2), such as between a coxa and the thorax or between the tibia and the femur.



Adapted from Chapman (1998)

The insect leg



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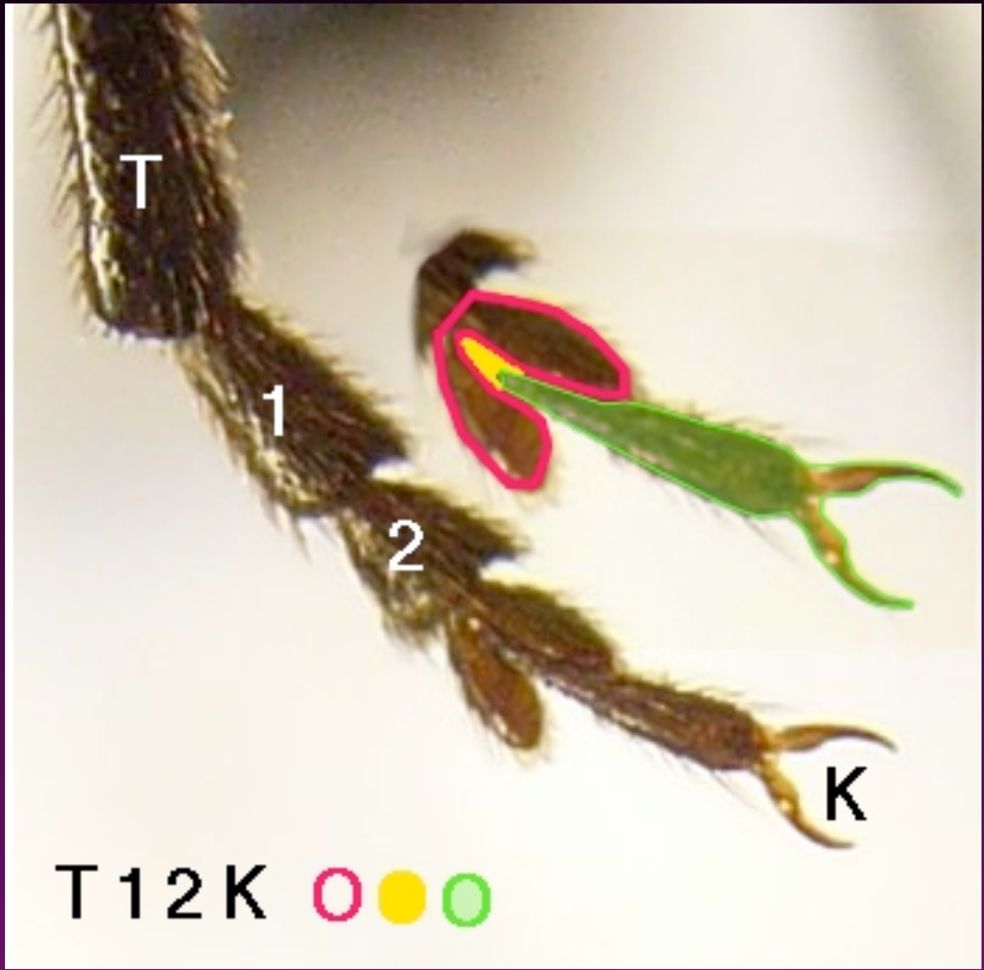
The insect tarsus



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The insect tarsus is made of different components labelled here.

Different insects can have differing numbers of tarsal segments, with some insects having just a few tarsi or a single claw and others with expansions beyond and around the tarsi

Callidium violaceum
T : Tibia
1 : Tarsus 1
2 : Tarsus 2
K: Claws
red circeled area: Tarsus 3
solid yellow area: Tarsus 4
weak green circled green area: Tarsus 5

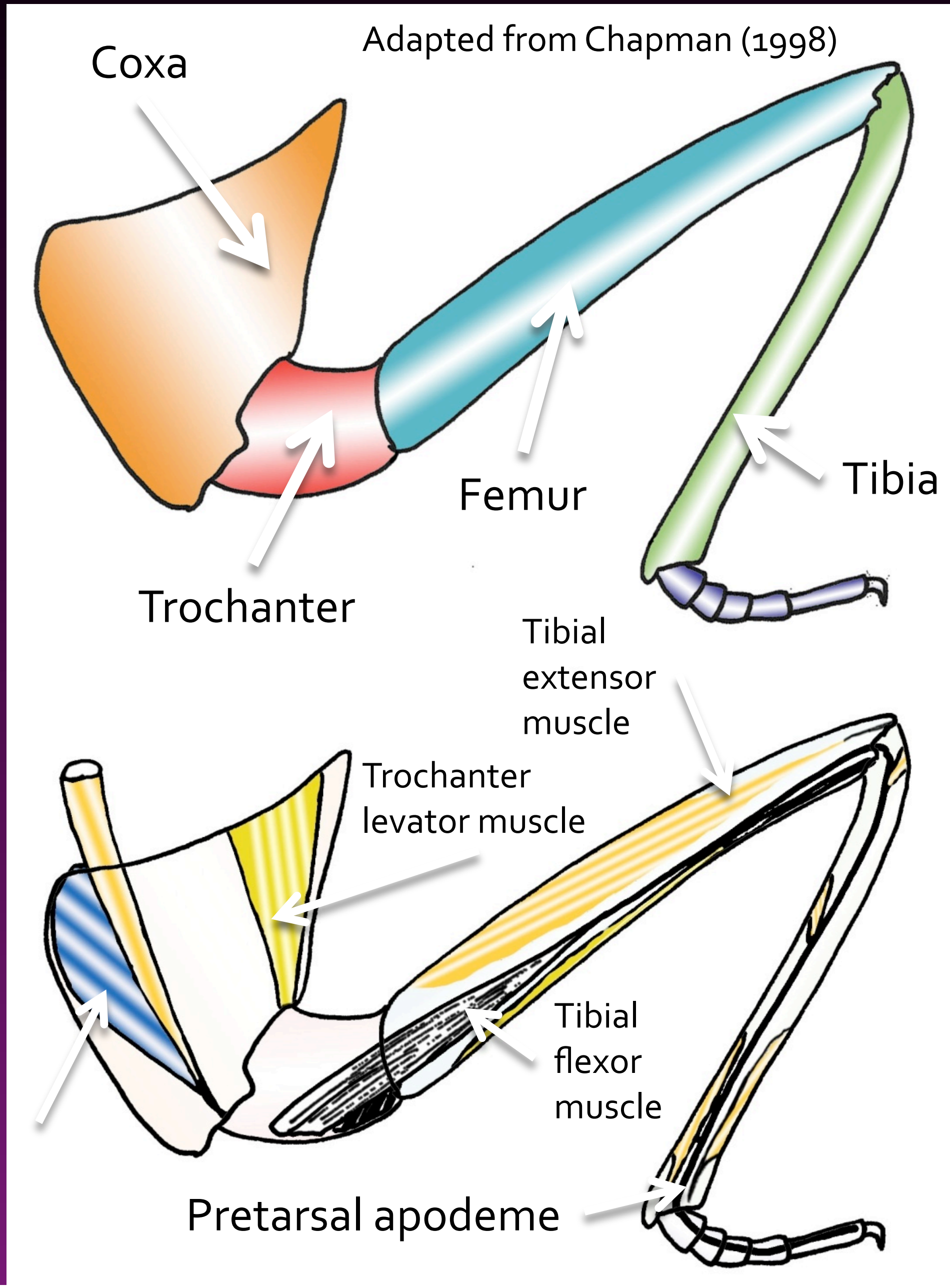
The insect leg musculature

The leg musculature can be divided into two types:

1) Intrinsic muscles, which are the muscles with all the attachment points within the leg
2) Extrinsic muscles, which have attachment points outside of the leg, such a within the thorax

The nomenclature of the musculature normally describes the muscle function:

Adductor: pulls limbs away from the body
Abductor: pulls limbs toward the body
Rotator: rotates the limb around a joint
Levator: flexes the parts of the joint upward
Depressor: extends the parts of the joint downward
Extensor: extends the joint
Flexor: extends the joint



Insects walking: sensory input

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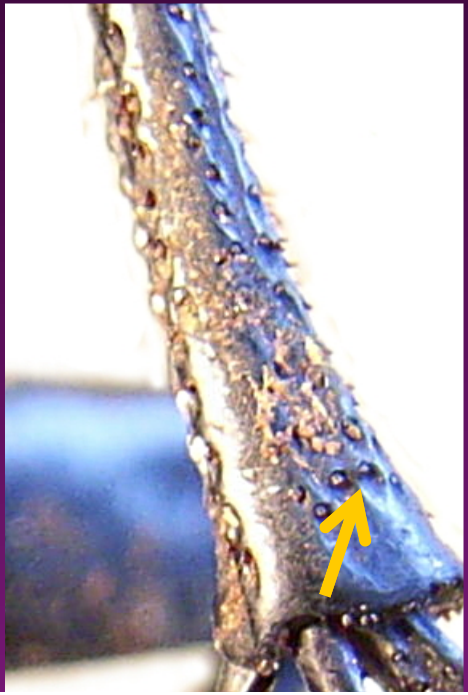

Various sensory input comes in from all over the leg.

- Small peg-like sensilla, sensory hairs, campaniform sensilla, and various mechanosensory inputs all over the leg allow the insect to detect strain, pressure, and leg position.
- Within the leg, there are chordotonal organs, which are tendon-like sensory organs which detect cuticular strain.
- The femoral chortodotal organ, for example, detects strain along the femoral-tibial joint

Insects walking: the tripod gait

Photograph taken by Dirk van der Made
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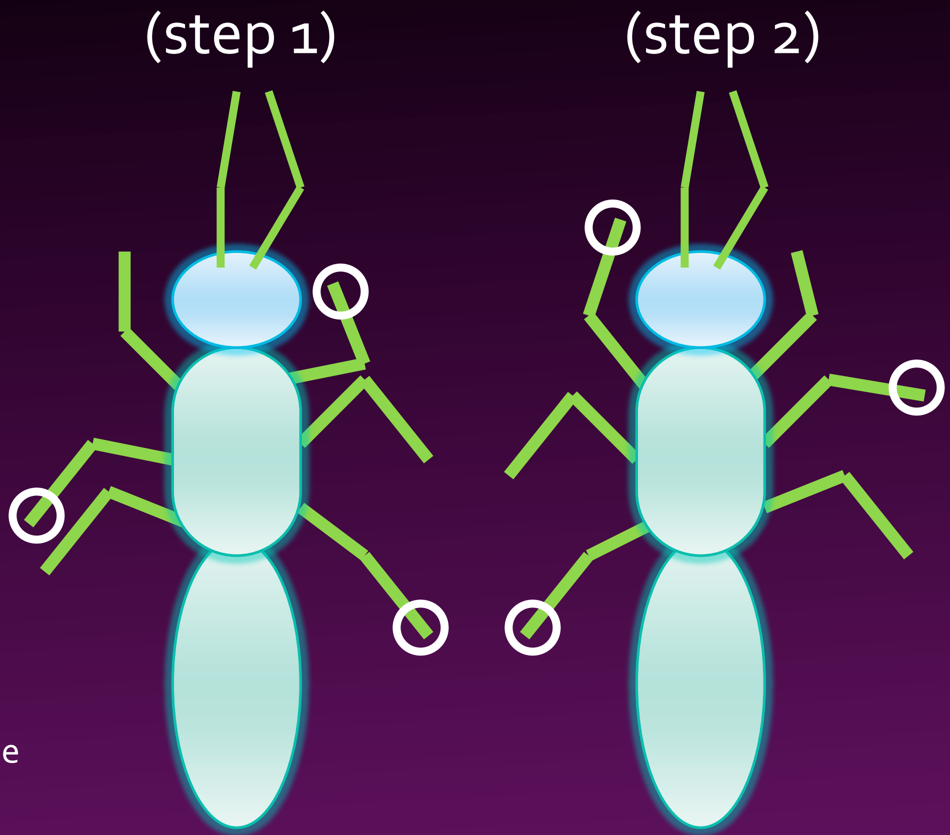


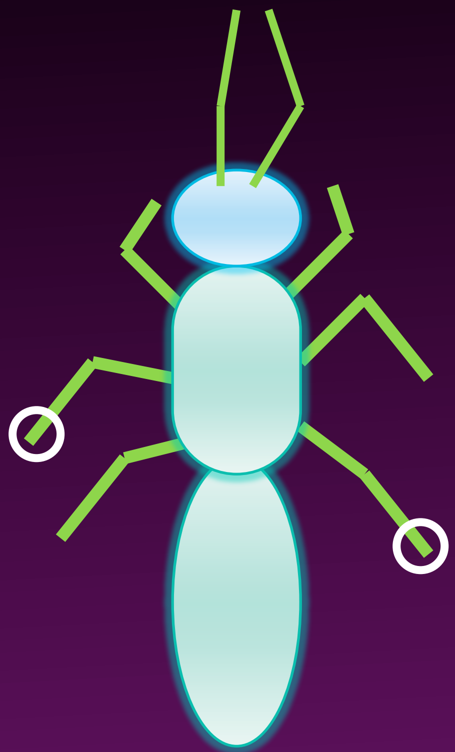
- The tripod gait involves alternating between a set of three legs in contact with the ground. In this case, the white circles are the legs in contact with the ground.
- The alternating pattern of walking allows the insect to be stable moving across different types of terrain

Insects walking: the tripod gait

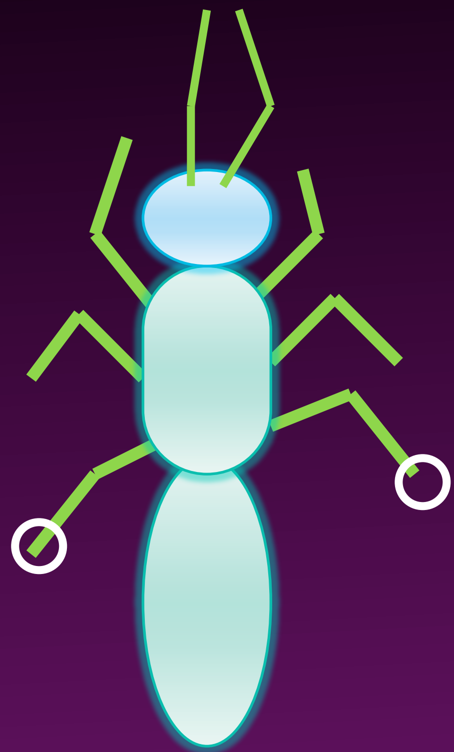
- As you can see in this movie, the legs alternate between a stance phase, where the legs push backward, and a swing phase, where the legs move forward
- This alternating tripod gait allows the insect to be stable at all times while still moving forward

Author Chris Thomas of www.miltoncontact.com I prepared this file as an animation exercise and would now like to make it freely available as a demonstration of insect locomotion.
Original uploader was Miltoncontact at en.wikipedia, Wikimedia Commons

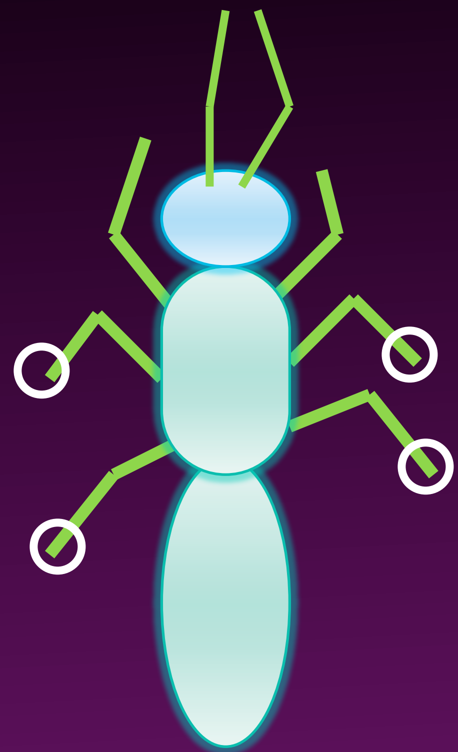
Insects walking: Other gaits and searching



Some insects which walk only on their back four legs (such as mantids)



High speed running in cockroaches involves the insect rearing up on their back two legs and running forward



The front legs can also act as antennae, searching for a foothold.

An example of limb searching is in the following video: Stick insect

Insects walking: Understanding walking in a walking stick

- Stick insects have been studied extensively to understand how insect can walk.
- Many of the circuits controlling walking is in the thoracic ganglion

(see Module 16)

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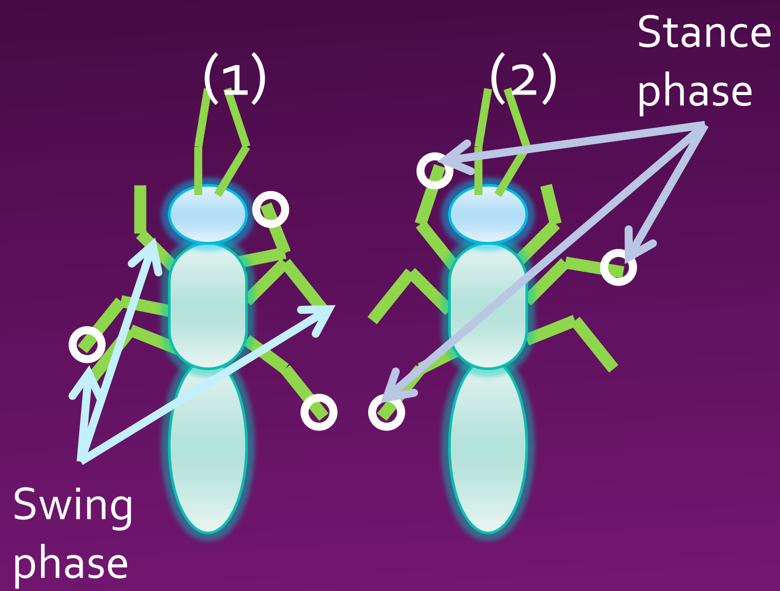
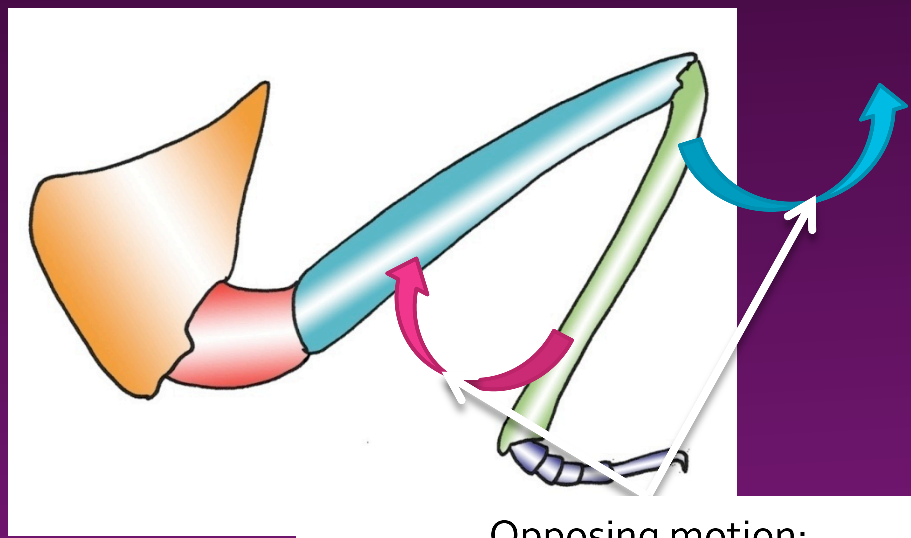
Insects: wiring how to walk

- Walking involves alternating between flexion and relaxation of different muscles
- Each muscle generally has its counterpart, in that muscles bending a leg one way can be opposed by muscles bending the leg the other way.
- To be able to walk, one set of muscles have to be inhibited, or quieted, while the other set have to be excited in alternation
- The motor system in insects allows this because most muscles have inhibitory and excitatory innervation

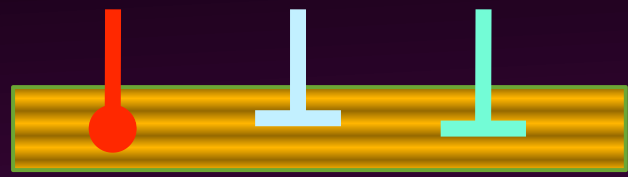




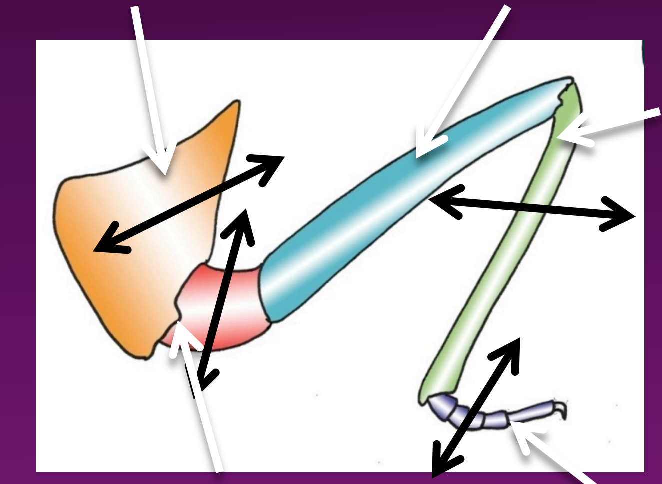
Opposing motion:
different sets of muscles called an antagonistic muscle pair

Insects: wiring how to walk

- In the motor circuit, the interneurons in the thoracic ganglion alternate their activity
- To create these patterns of walking, the network *oscillates* between stance and swing which involves contraction and relaxation of different types of muscles
- The rhythmic activity of a single thoracic ganglion in the locust results in alternating contractions between the different motor neurons

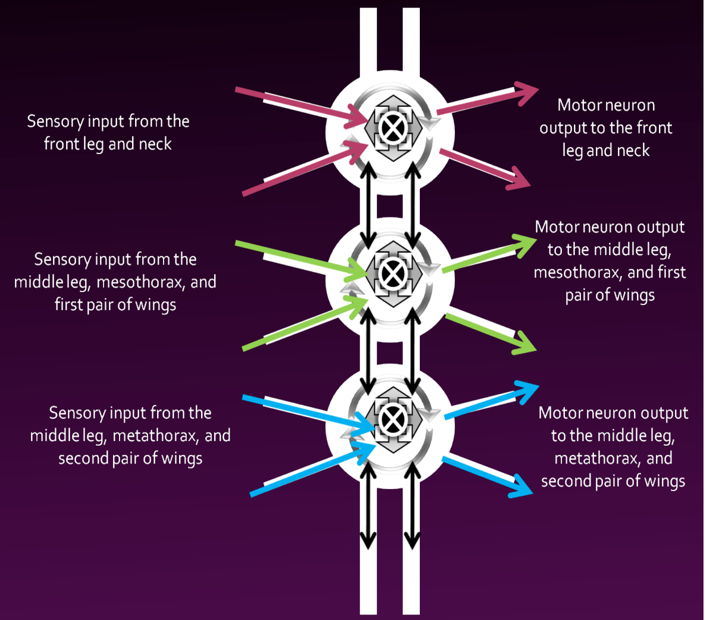


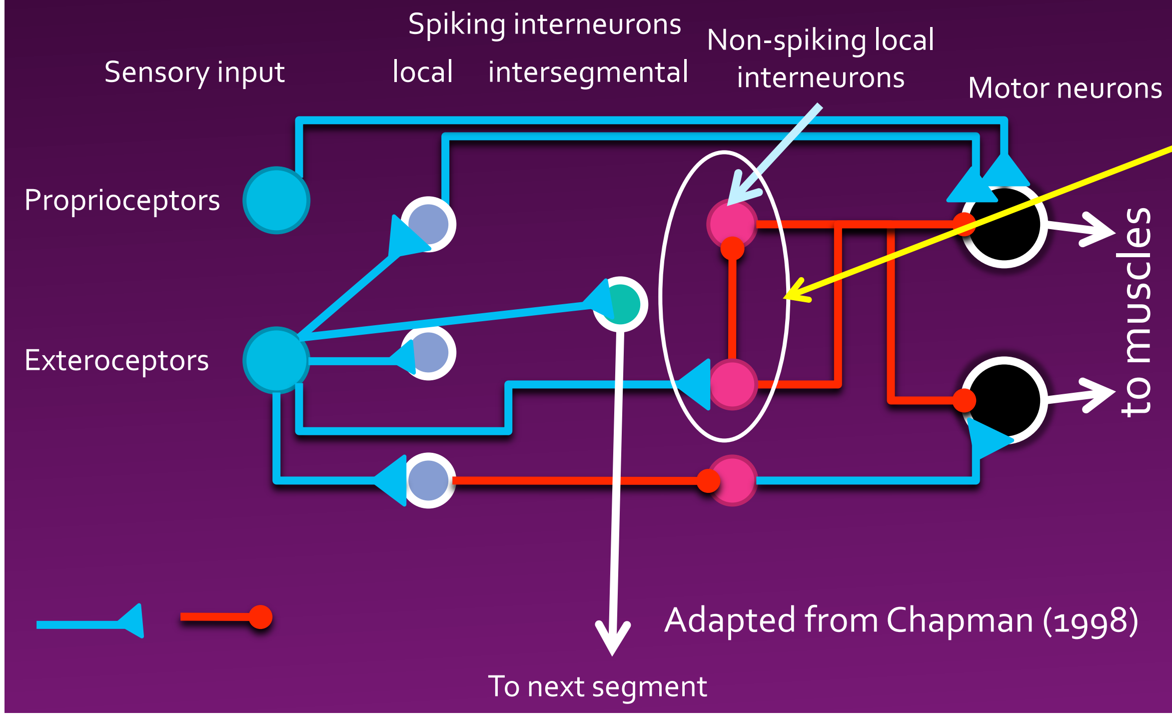
After Chapman (1998)



Insects: wiring how to walk

- In the motor circuit, the interneurons in the thoracic ganglion alternate their activity
- Proprioceptors sense the position of the limbs and body parts relative to the body, such as coxal hair plates or the femoral chordotonal organ at the connection between the tibia and the femur
- Exteroceptors detect other information, such as touch or wind or strain on the leg, often coming from outside the body
- Interneurons which then form the circuit for walking can be spiking (produce an action potential) or non-spiking (not produce an action potential) (see Module 16)
- Local interneurons are interneurons within the one segment.
- Intersegmental interneurons project between segments.



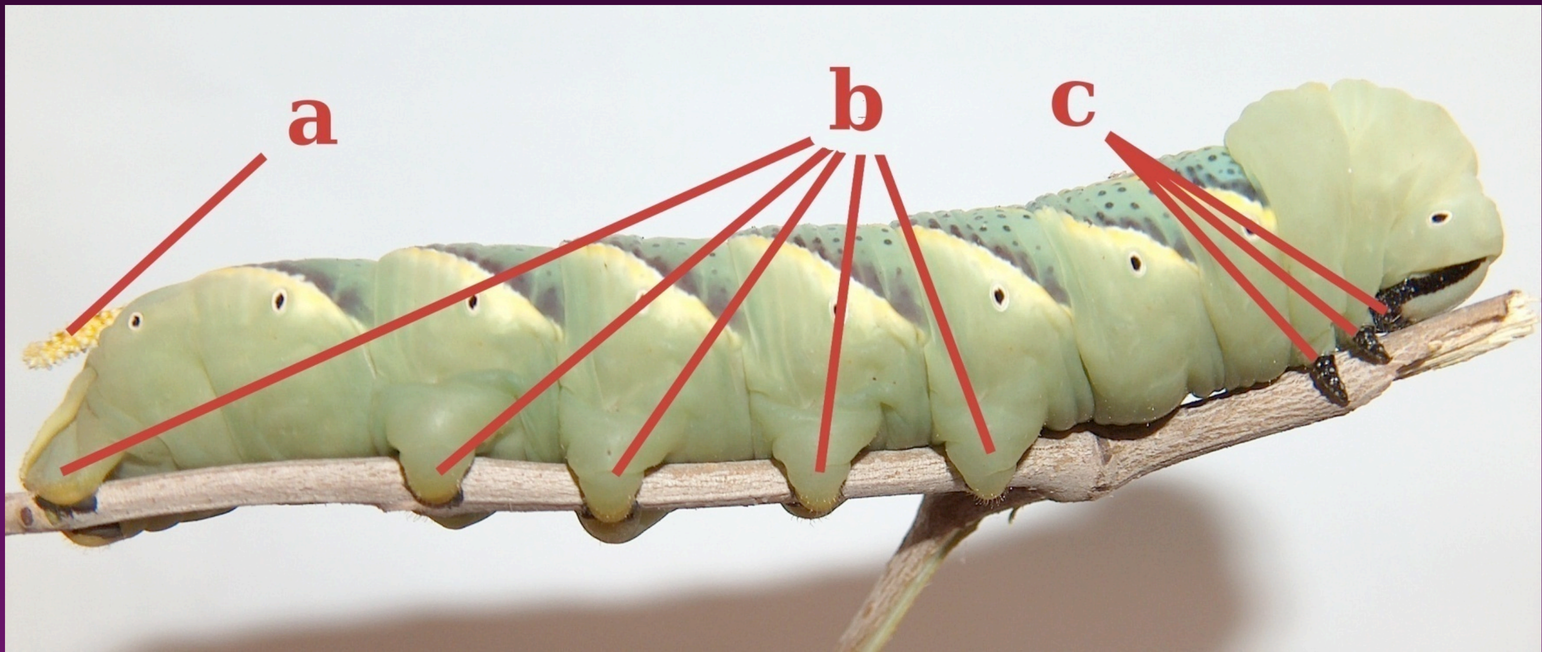


Adapted from Chapman (1998)

To be able to walk, many of the neural circuits have cells that inhibit their partner, such as in an antagonistic muscle pair.
First, one interneuron is excited, which then inhibits the other interneuron and other muscle group on the other side.
Then, as the excitatory input to the first interneuron decreases (from decreased exteroceptor input), it decreases inhibition on the other interneuron, which then allows the other muscle to experience decreased inhibition, producing an oscillating loop

Insects: larval movements

- A series of contractions, leading from the posterior to the anterior sections of the body wall lead to larval movement in many holometabolous insects
- The series of contractions allow the larvae to move forward through constant contraction and extension of the body parts.
- Some insects also have prolegs (b) along the abdomen as well as the thoracic legs (c). Watch the movie below to see how they can move around



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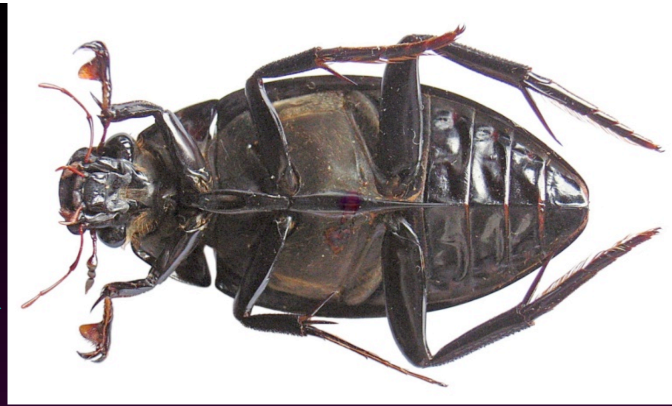
http://commons.wikimedia.org/wiki/File:Aglais_urticae_larvae.ogv

Insects swimming

- Various insects, particularly adults, have specializations in their legs, such as the tarsi, to increase surface area and enable swimming through the water, like this hydrophilid beetle
- Gyrinid beetles (whirlygigs) also have these specializations, but they also swim on the surface of the water, where part of their eye faces upward and another part faces downward, under the water.



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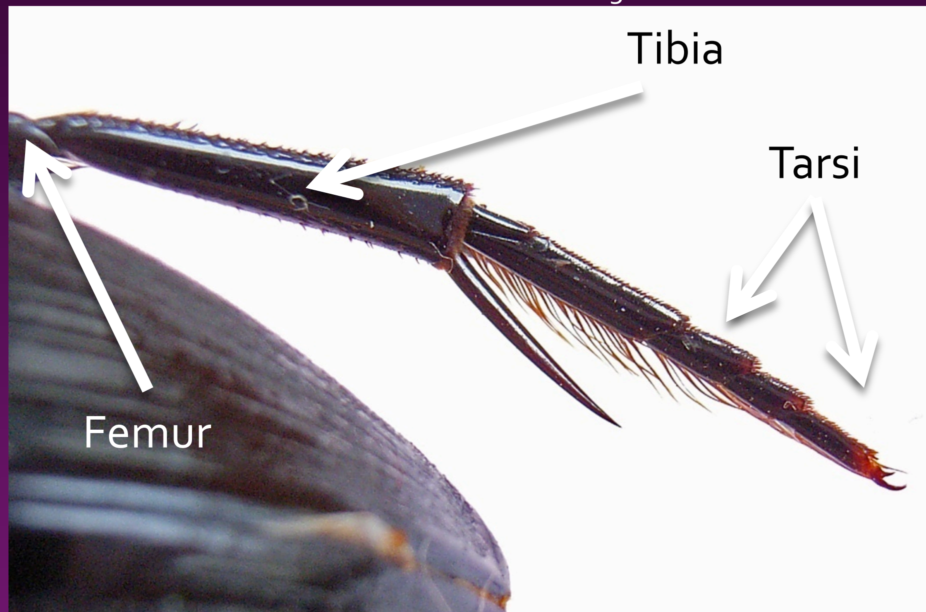
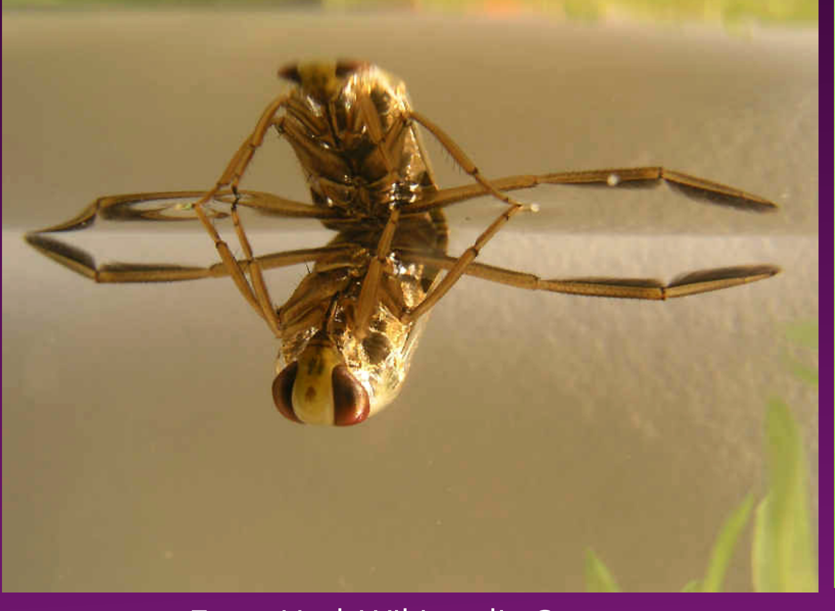


Insects swimming

- Backswimmers (Notonectidae) and water boatmen (Corixidae) also have expansions of the metathoracic leg to allow them to swim in the water

Backswimmer swimming:
http://arkive.org/water-boatman/notonecta-glauca/video-oo.html



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Corixa punctata from the Netherlands (species uncertain) Piet Spaans, Wikimedia Commons

Insects swimming

- Insect larvae can move in various ways through the water.
- For example, dragonflies can use their anal gills to project thorugh the water.
- Ephemeropteran larvae can move their gills on the sides of their abdomens to move forward.
- Other larvae, including mosquito larvae, swim by jerking their bodies back and forth (see video).

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James Gathany, CDC, Wikimedia Commons

Film of a mosquito larva feeding and moving: http://commons.wikimedia.org/wiki/File:Anopheles_head_turning6314.ogg

Insects surface walking

Markus Gayda Wikimedia Commons

- Numerous insects, such as these water striders (Gerridae), have specializations in their legs and tarsi which allows them to remain on the surface of the water using surface tension, and they shift their legs backward to move forward

- Check out the website below, where you can see how the water striders move across the water:

http://www.arkive.org/common-pond-skater/gerris-lacustris/videos.html

Insects jumping

- The jumping mechanism in grasshoppers involve the pull between the extensor tibiae muscles and the tibial flexor muscles.
- The two sets of muscles contract at the same time.
- They have the same articulation point at the joint between the tibia and the femur, placing pressure on an area of the apodeme along an area called a semilunar process, which means the joint doesn't move, after Chapman (1998)
- When the insect jumps, the tibial flexor muscle is relaxed, allowing the extensor tibiae muscles to contract and cause the fast extension of the tibia, such as shown in the video below:

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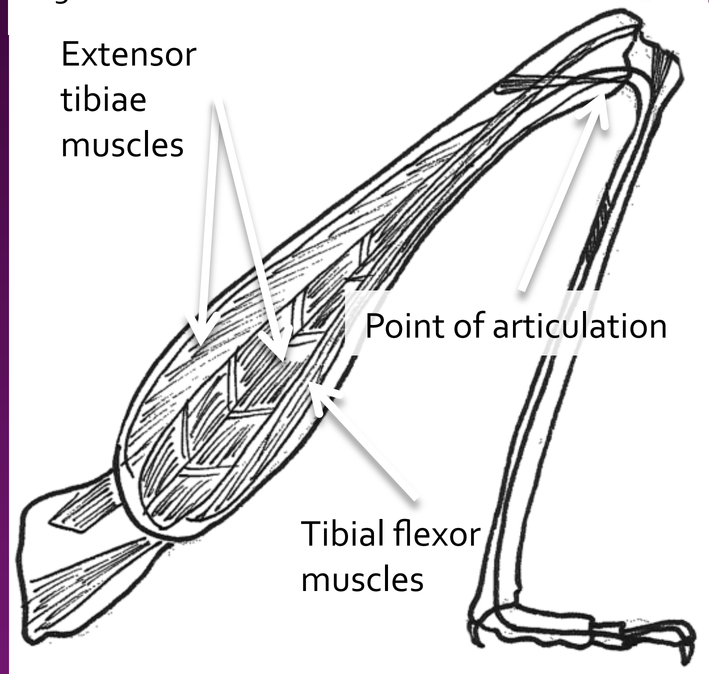


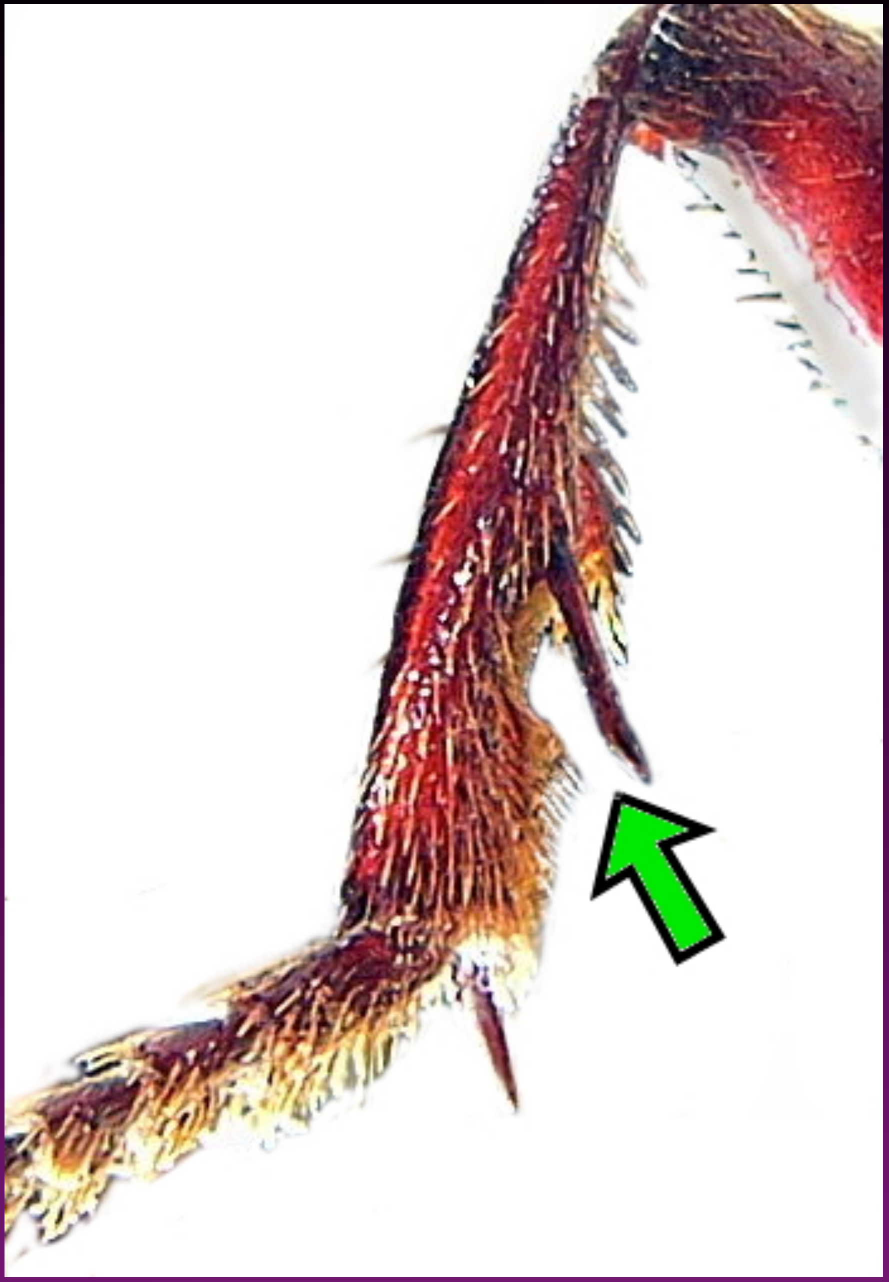
Adapted from Chapman (1998)

http://www.arkive.org/common-field-grasshopper/chorthippus-brunneus/video-oo.html

Insects grooming

- Other uses for the limbs is for grooming
- Since the surface of the insect is covered in sensory organs, including mechanosensory hairs, insects need to clean their cuticle regularly.
- Insects have specialization, such as a small notch in the front leg, to allow the antenna to be guided along the groove.

- Check out the movie below on cercal mechanosensory hairs, where you can see how cockroaches clean their antennae:
- Cockroach movie



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The corbiculum: the pollen basket

- The corbiculate bees have specializations on their tibia and tarsi to allow the storage of pollen called a corbiculum

- Pollen is gathered at the tooth area at the end of the tibia (*), and is then moved into the series of combs in the first tarsal segment (#)

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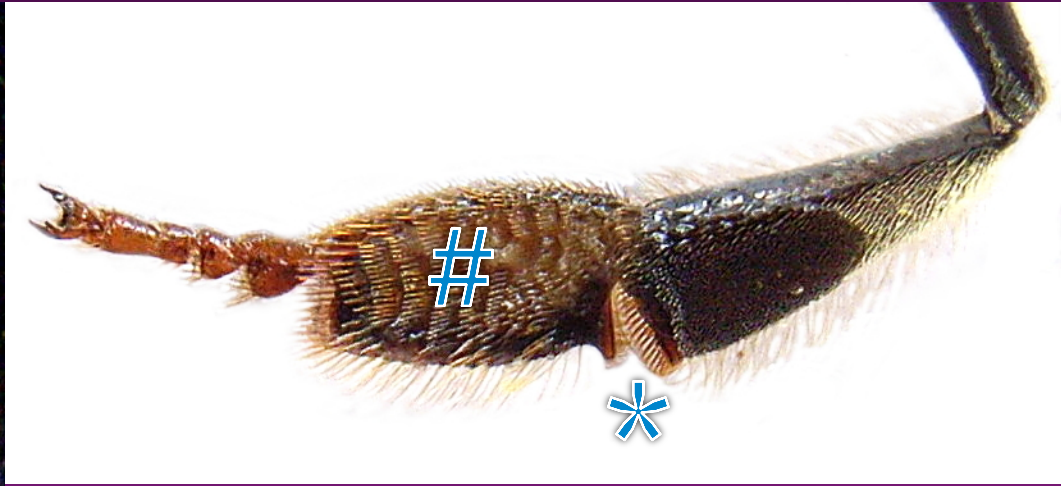

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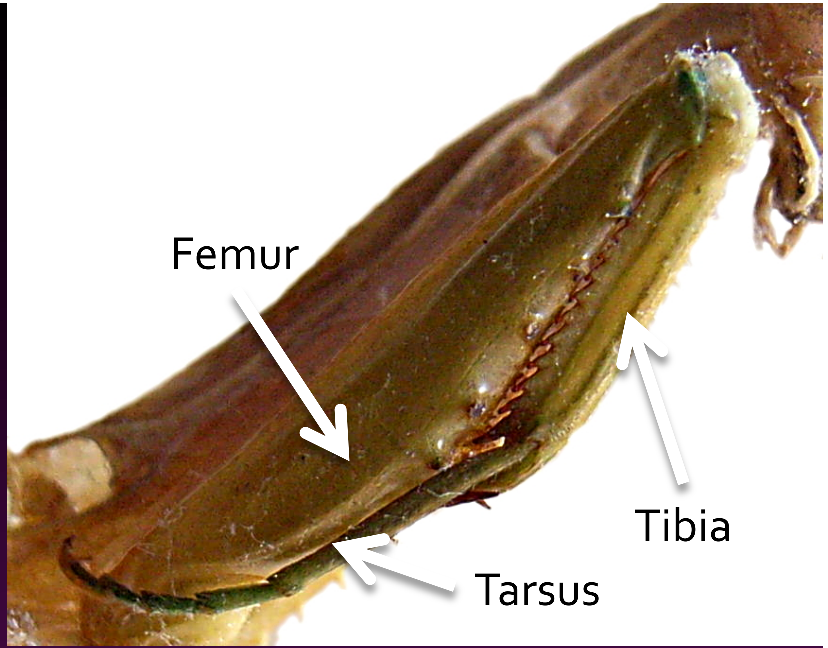
Insects grasping

- In many predatory insects, the front legs are modified to allow the insect to grasp prey
- In mantids, belostomatids, and various other insects expand the femur and tibia such that they fit into each other



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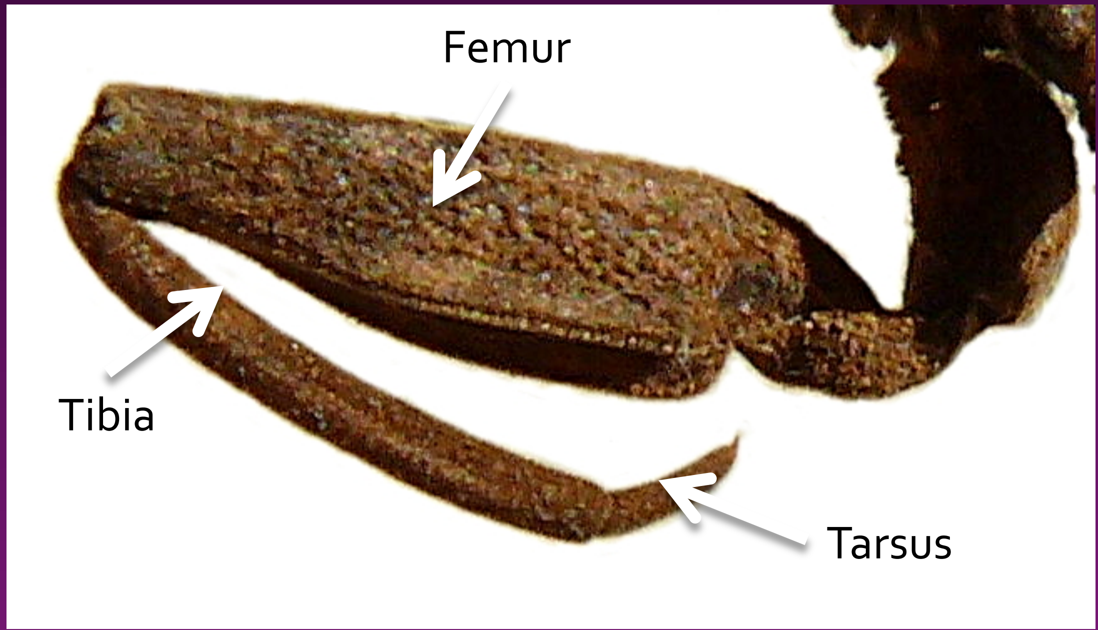

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Belostomatidae

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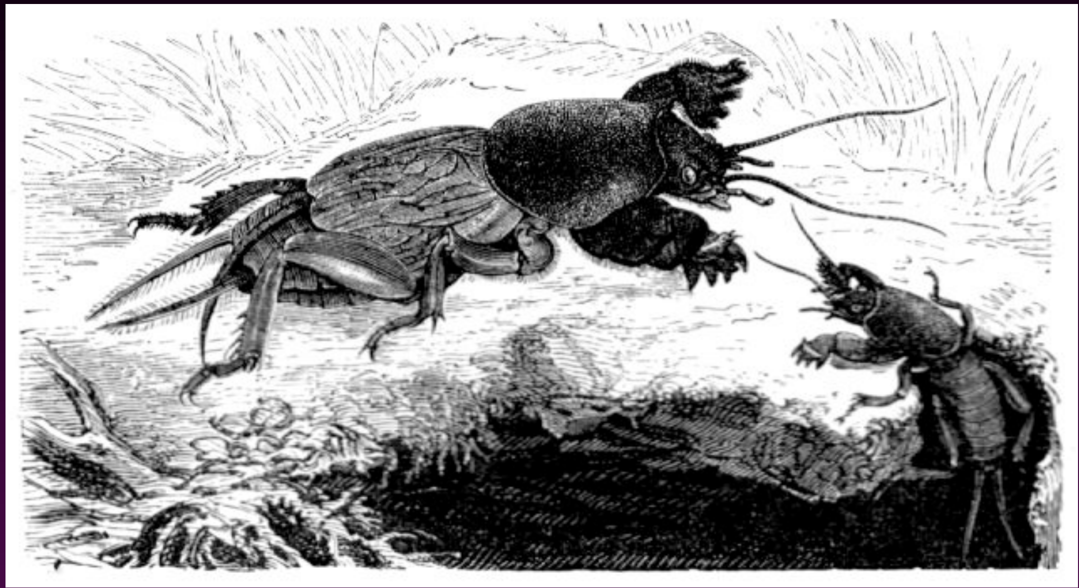
Insects digging



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- Many digging insects have specializations in their first legs.
- These mole crickets have expansions and thickening of the front set of tarsi, tibia, and femur
- This is also seen in various scarab beetles.

Siga Wikimedia Commons Gryllotalpa sp.

Insects doing other types of movements

- Paper wasps in particular use their mandibles and mouthparts to regurgitate bits of wood in saliva to make their paper nests:

Common wasps and nests

http://www.arkive.org/common-wasp/vespula-vulgaris/videos.html

Paper wasp video

- As a curiosity, some insects appear to oscillate and move as if in a breeze. Stick insects do it to imitate a branch in the wind. However, these whiteflies are doing it in synchrony all along the branch. Why would they be doing something like this? Check out the video below:

http://commons.wikimedia.org/wiki/File:Oscillating_whiteflies.ogg