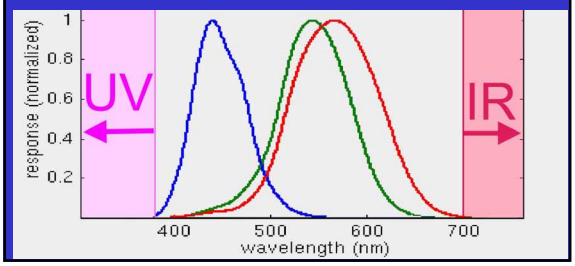
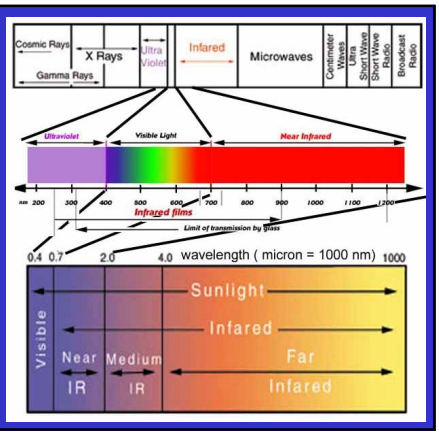
Perception of infrared radiation

- Properties of infrared radiation
- 'seeing' short wavelength IR light
- thermo-reception
- 'sensing' longer IR wavelengths :
  - prey detection
  - detection of fires

Like ultraviolet, infrared is 'light' beyond the human's spectral sensitivity range



INFRARED



Like other radiation, objects can reflect or emit infrared waves.

It can be associated with 'light' or with 'heat'

Infrared photograph:

reflected 'light' (ca. 800-1200 nm)

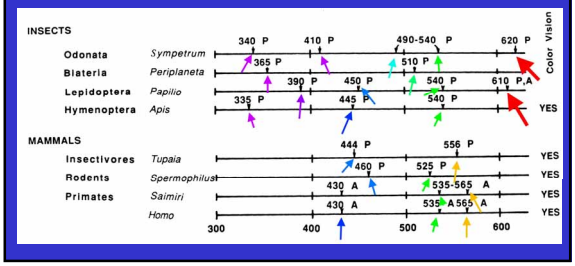
Thermograph:

'heat'

(ca. 3000 - 14000 nm)

Infrared perceived as ‘light’, using photoreceptors

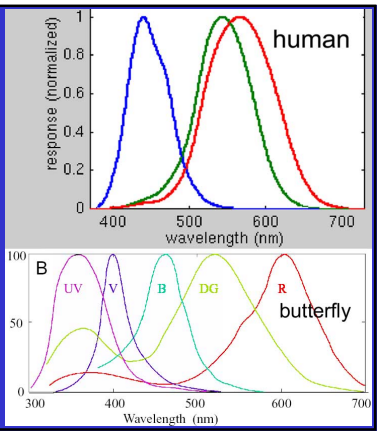
Most animals have wider visual spectra than mammals



Some butterflies can see the short-wave IR as **‘light’**.

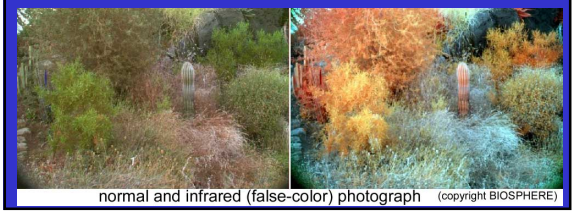
They cannot ‘see’ an object’s **‘heat’**- evoked IR

The butterflies’ ‘red’ receptor also absorbs in the (very) near infrared



Butterflies may use their IR sensitivity to detect wing patterns or green plants.

(The mesophyll of leaves scatters IR, hence healthy leaves can be detected by their high IR reflection.)



normal and infrared (false-color) photograph (copyright BIOSPHERE)

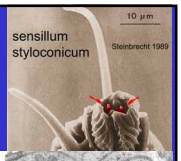
- Wavelengths longer than about 1.2µm are not energy-rich enough to bring about chemical changes (e.g. cis-retinal to all-trans retinal).
- Regular photoreceptors are not able to detect those IR wavelengths.
- When IR radiation is absorbed, tissue will get warmer

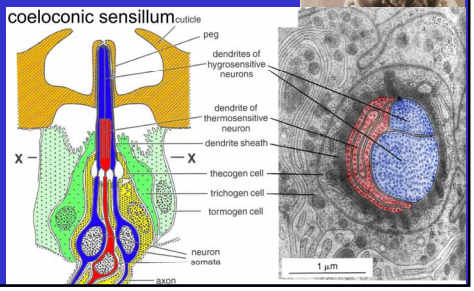
Thermo-receptors

- Different thermoreceptors in vertebrates and invertebrates (e.g. warm, hot and cold)
- Temperature - sensitive K+ channels (voltage-gated) in vertebrates, *C. elegans, Drosophila*
- Some thermo-receptors also respond to agonists: cold- and menthol-sensitive receptor (CMR1; K^+, Ca^{++} conductance)
  Mammalian capsaicin receptor: heat-activated ion channel in nociceptors

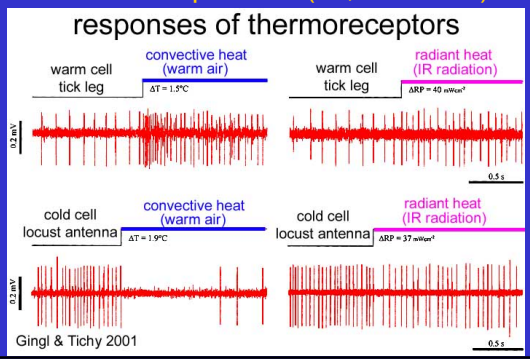
- Insects feature thermo-sensitive neurons (cold and warm cells);
- most often found on antennae (butterflies, bees, moths, locust, cockroach) or tarsi (ticks);
- respond to small temperature changes;
- not suited for perception of IR radiation (at biologically meaningful amplitudes).

Thermoreceptors are often associated with hygro-receptors in sensilla embedded within the cuticle

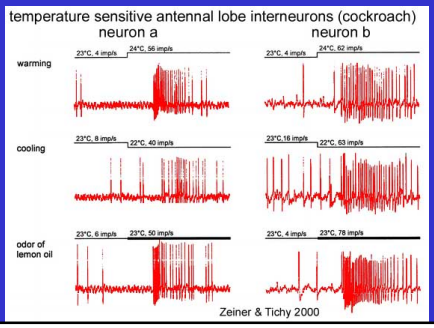




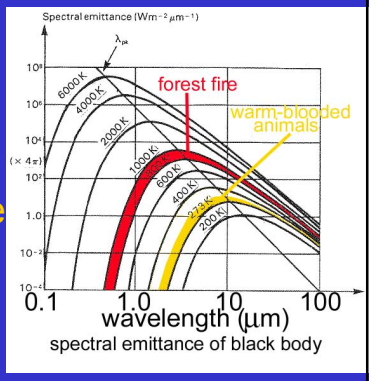
Thermoreceptors respond to changes in ambient temperature (air, substrate)



Interneurons may respond to warming **and** cooling and integrate temperature with odor or mechanosensory information

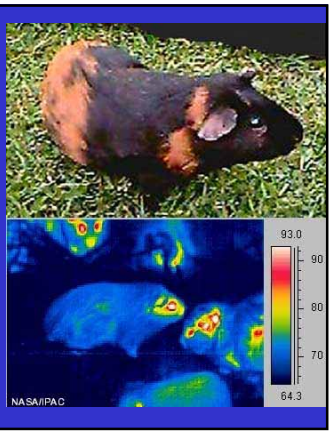


Emission of radiation is temperature dependent

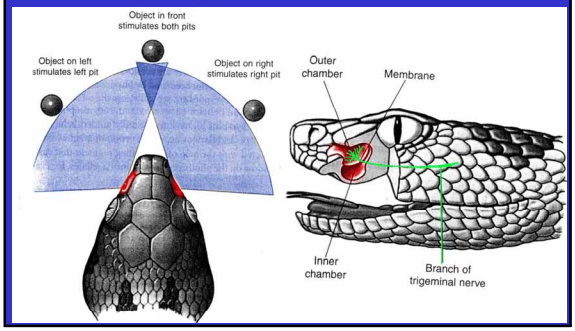


Warm-blooded animals emit infrared radiation

('heat')



Boas, **pythons**, and pit vipers (e.g. **rattlesnakes**) use IR to detect prey. Python max. IR sensitivity: **8-12 µm**; emission maximum of mammalian/bird **prey : 10µm**



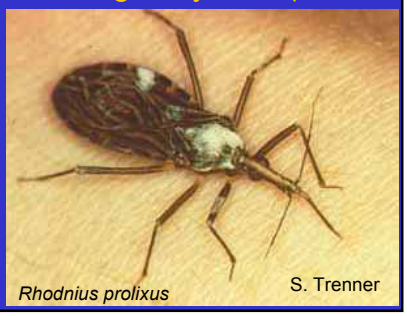
'Normal' thermoreceptors rely on contact or **convective heat**. They can sit deeper within the skin or body (vertebrates).

Receptors for **radiant heat** have a small (thermal) mass, sit close to the surface, are isolated or cooled (snake pit organs)

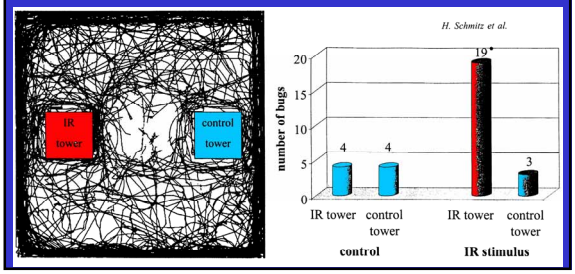
Snakes use thermoreceptors to detect IR radiation as heat (increased temperature of IR organ).

The same is true for some beetles, bloodsucking bugs and probably other insects (mosquitoes?).

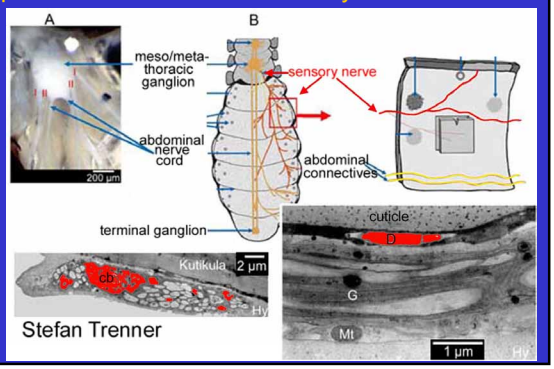
Blood-sucking bugs *Rhodnius* and *Triatoma* (vectors for Chagas disease) find their hosts using body heat (IR radiation)



Rhodnius bugs visit an IR emitting window (37°C) more frequently than one without IR. They perceive the radiation, not just the ambient (air) temperature.

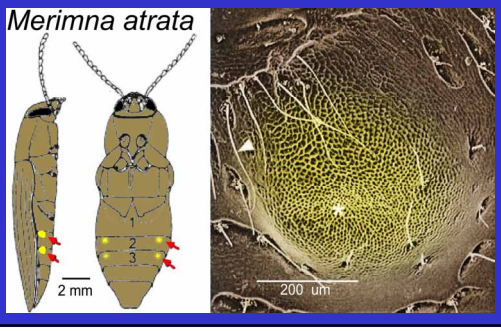


Warm stimuli are probably perceived by non-specialized dendrites in the body-wall of *Rhodnius*

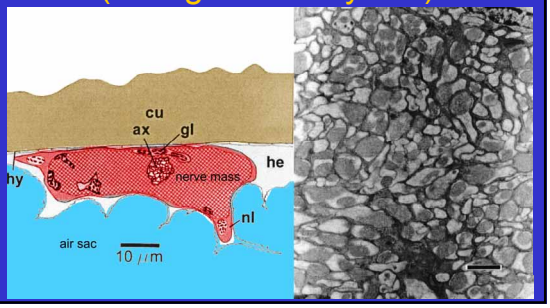


Some beetles can detect forest fires

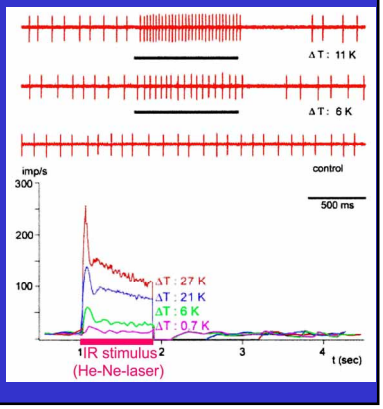
The Australian 'fire beetle' has an abdominal infrared organ



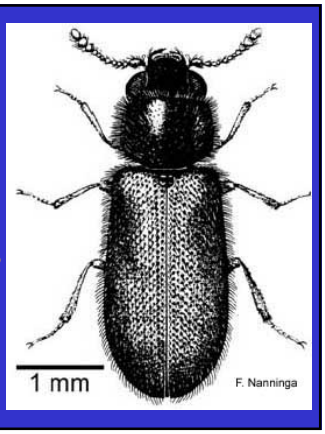
Like in boid snakes, the IR organ contains a 'dendritic mass' (a single sensory cell)



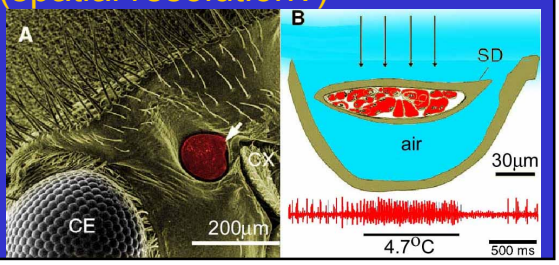
The IR organ of the Australian fire beetle responds to temperature changes (phasic-tonic responses; spontaneous activity)



Acanthocnemius nigricans uses a simliar mechanisms to detect forest fires

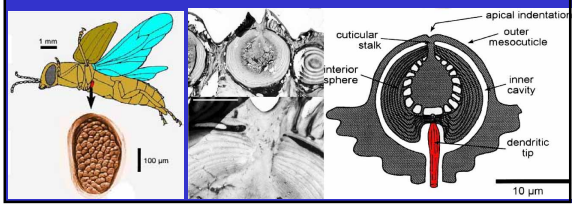


Acanthocnemus' IR organ is air-isolated (higher sensitivity?) and comprises 30 warm receptors (spatial resolution?)

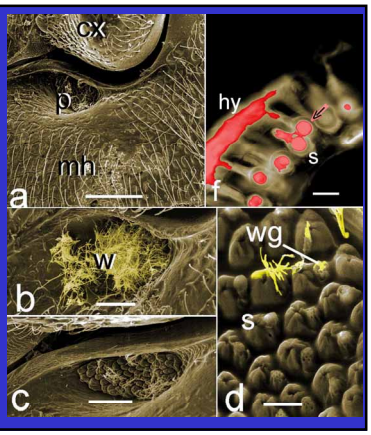


Buprestid *Melanophila* beetles:

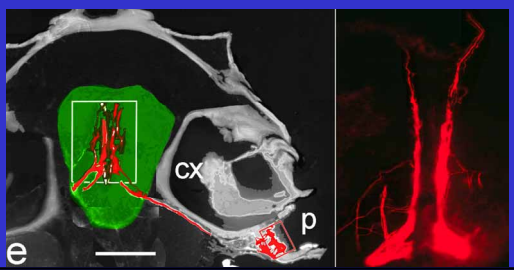
- IR sensitive pit organs behind middle legs
- detect and approach forest fires from up to 80 km.
- IR sensilla: 'photomechanic' mechanism (heat-induced strain)

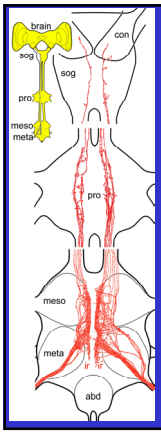


The IR organ (pit organ) contains ca. 60 domed IR sensilla. The organ is covered with wax filaments (not IR opaque)

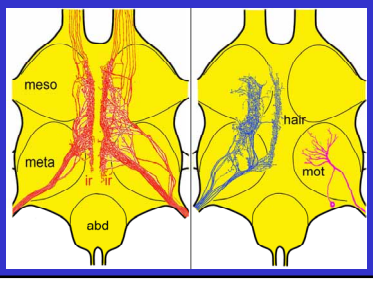


From the IR sensilla, axons project to the beetle's ventral nerve cord

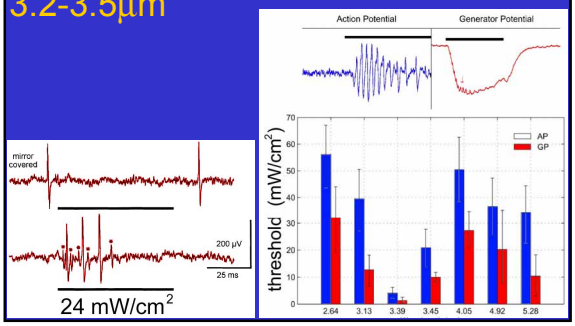




IR-sensitive axons extend to the brain. They are probably derived from hair afferents



The maximum sensitivity of *Melanophila* IR receptors is 3.2-3.5µm



Melanophila IR sensitivity exactly matches forest fire emission