Using insect sensory systems as biological inspiration for complex sensing problems

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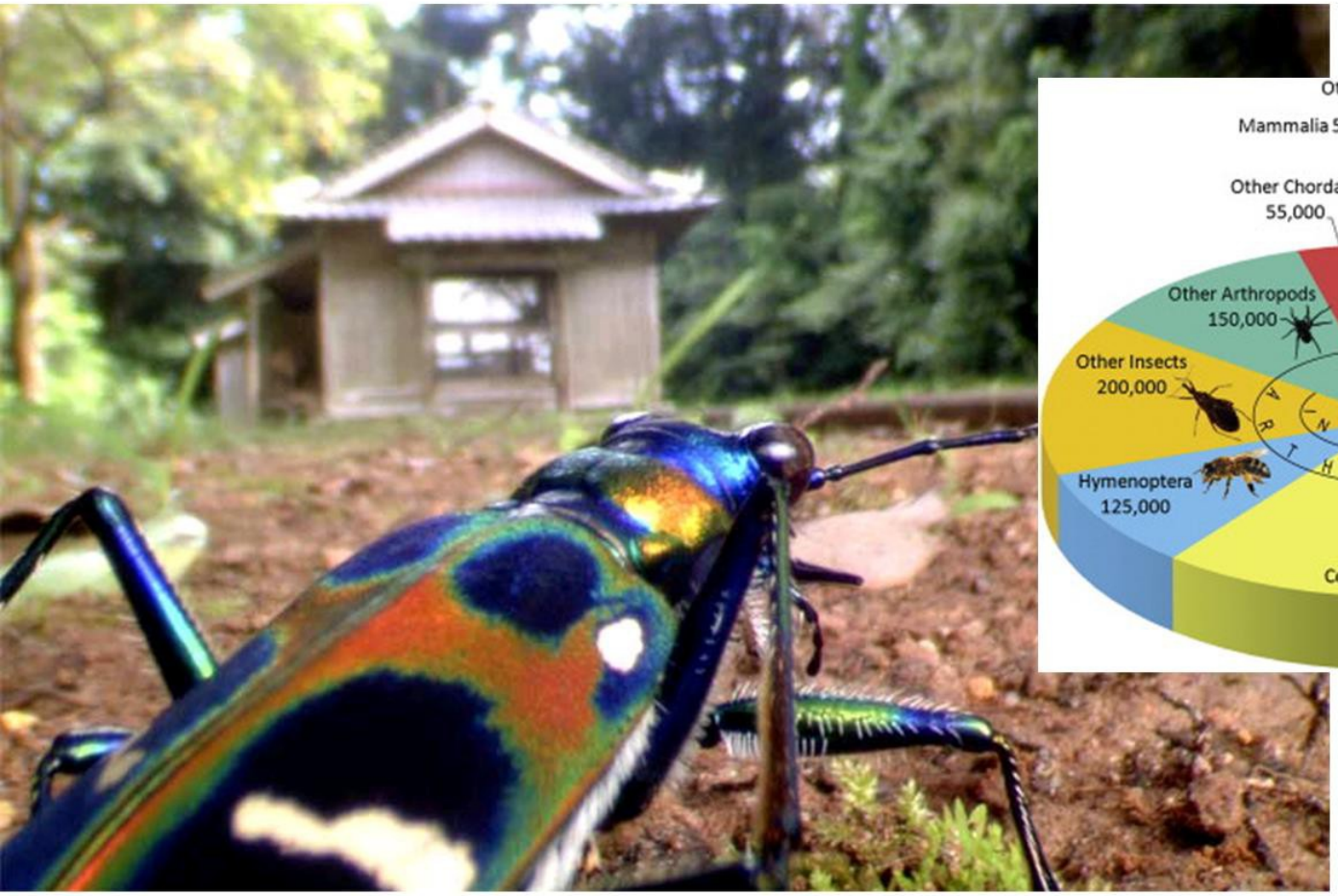
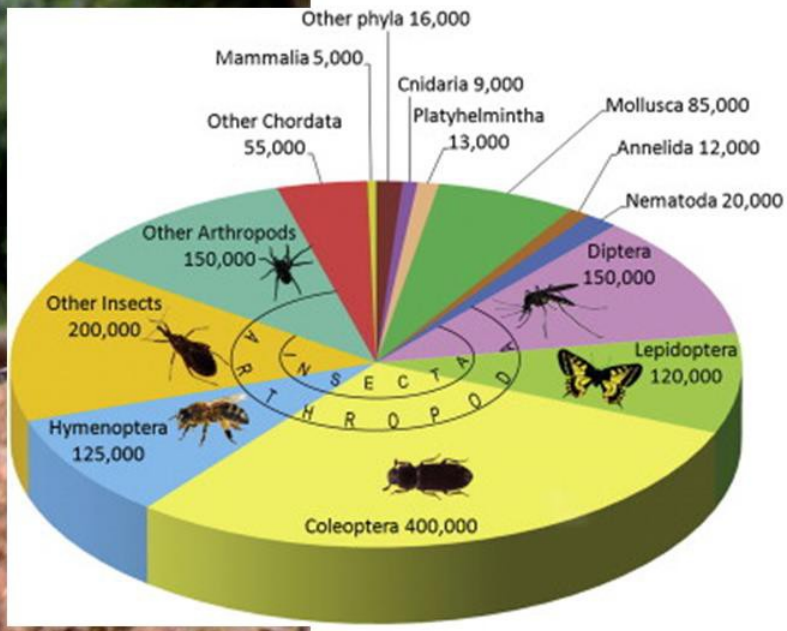
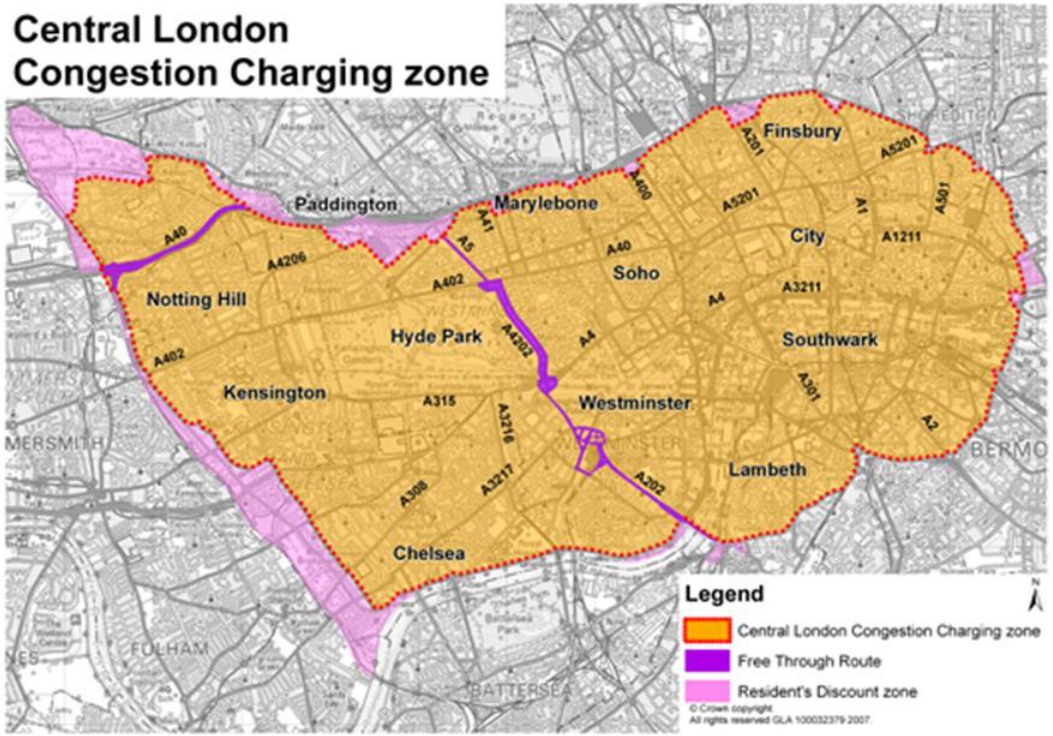
Insects rule the world

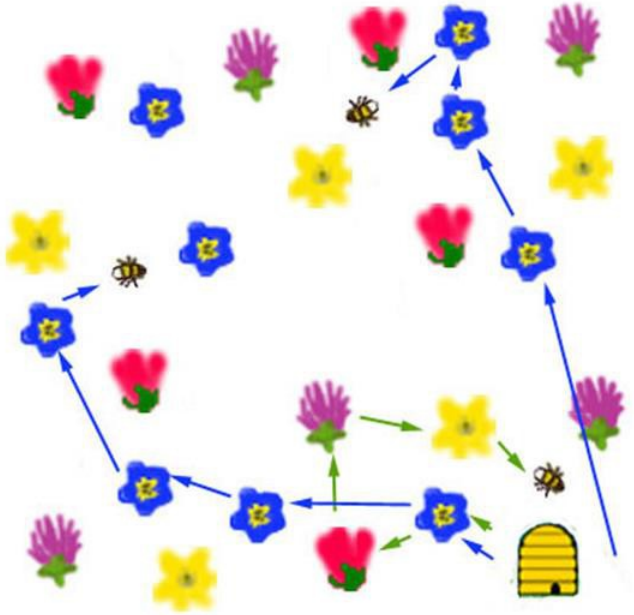




Japanese tiger beetle Photo: Satoshi Kuribayashi

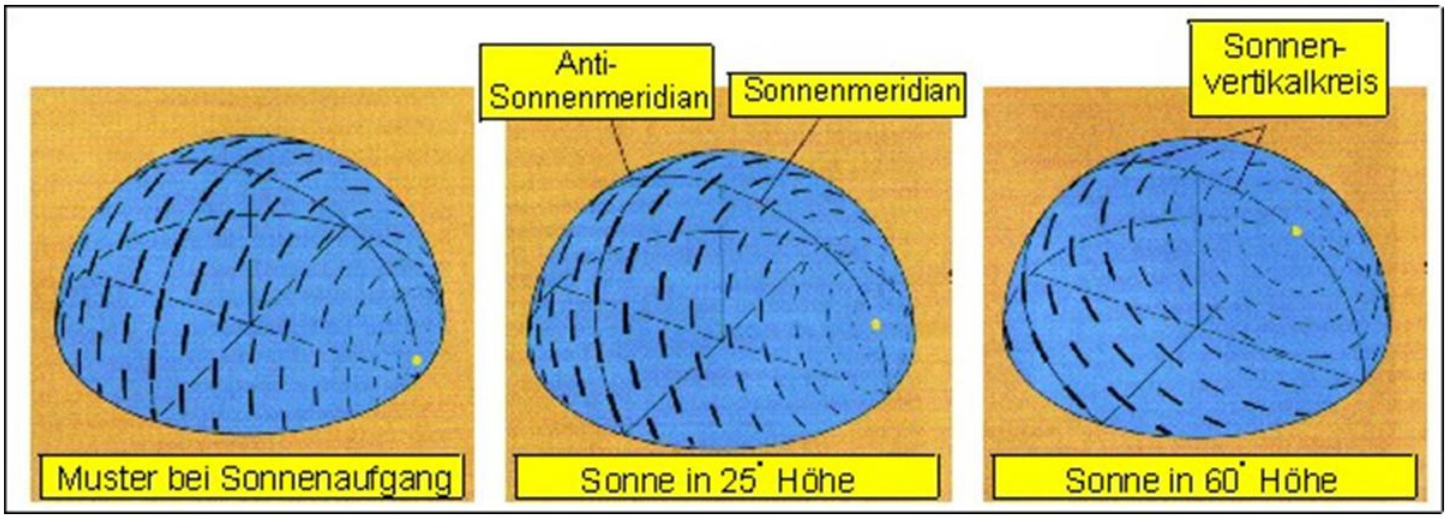
Foraging in the flower supermarket



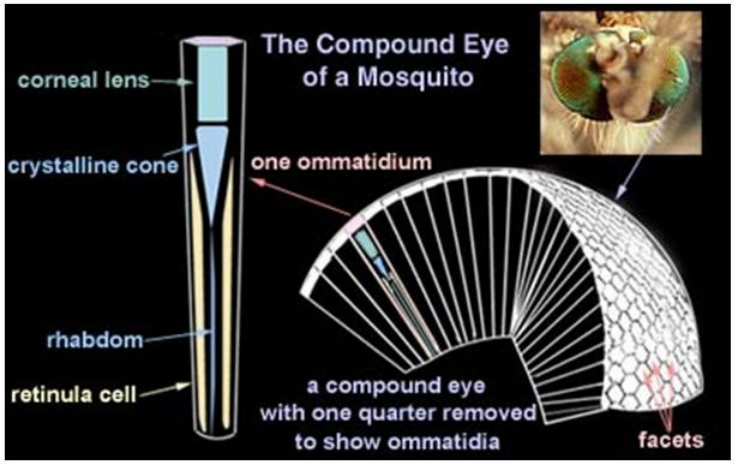


Bees must remember flower colours, scents, shapes, handling techniques and locations/routes

Polarisation vision in insects

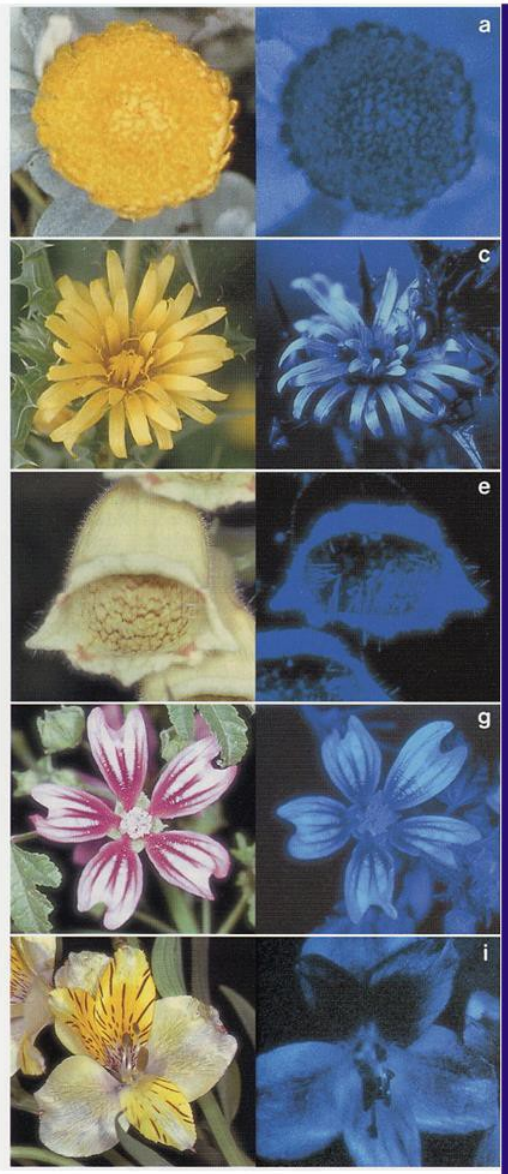


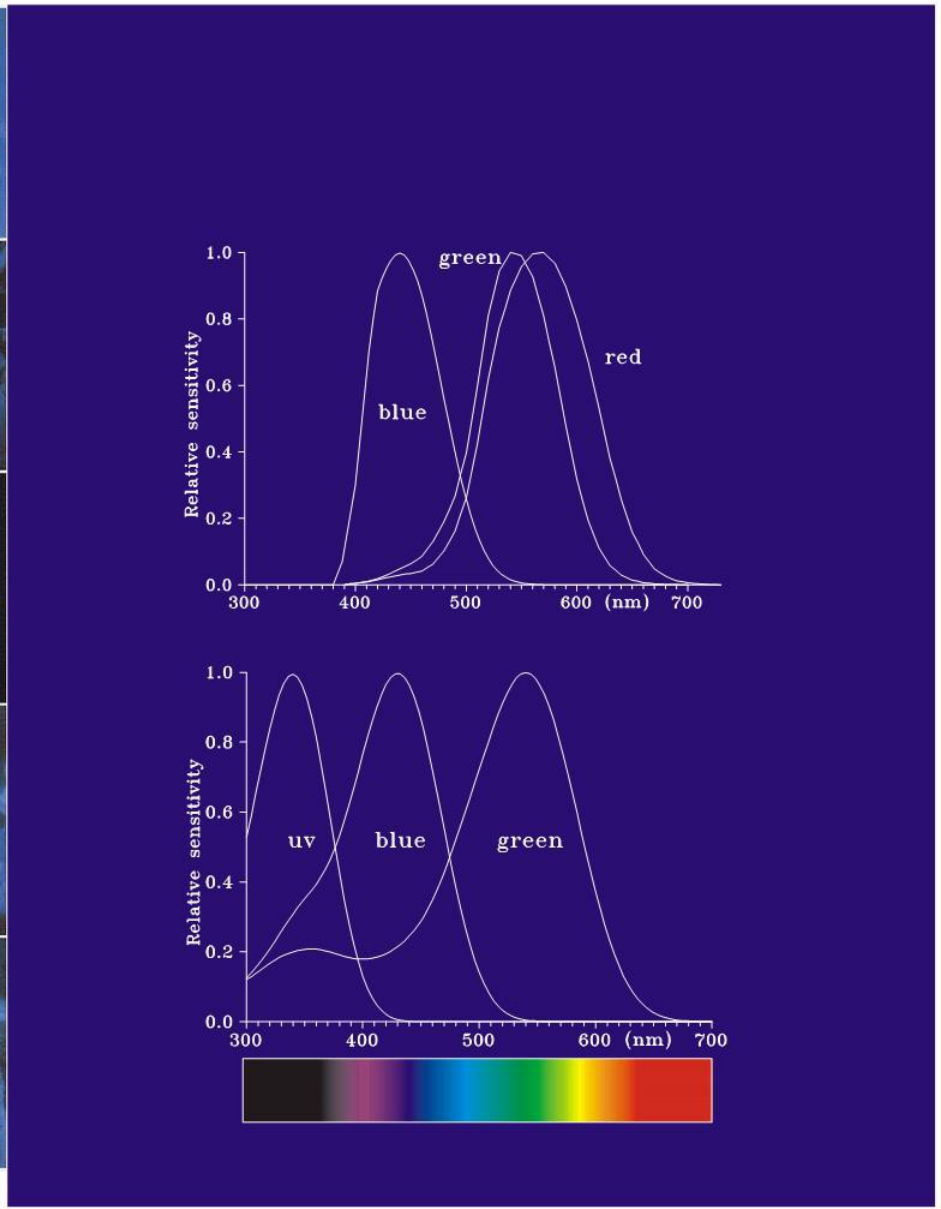
“Toothbrush” photoreceptor cell



microvilli containing opsin (photopigment)

UV Vision in bees





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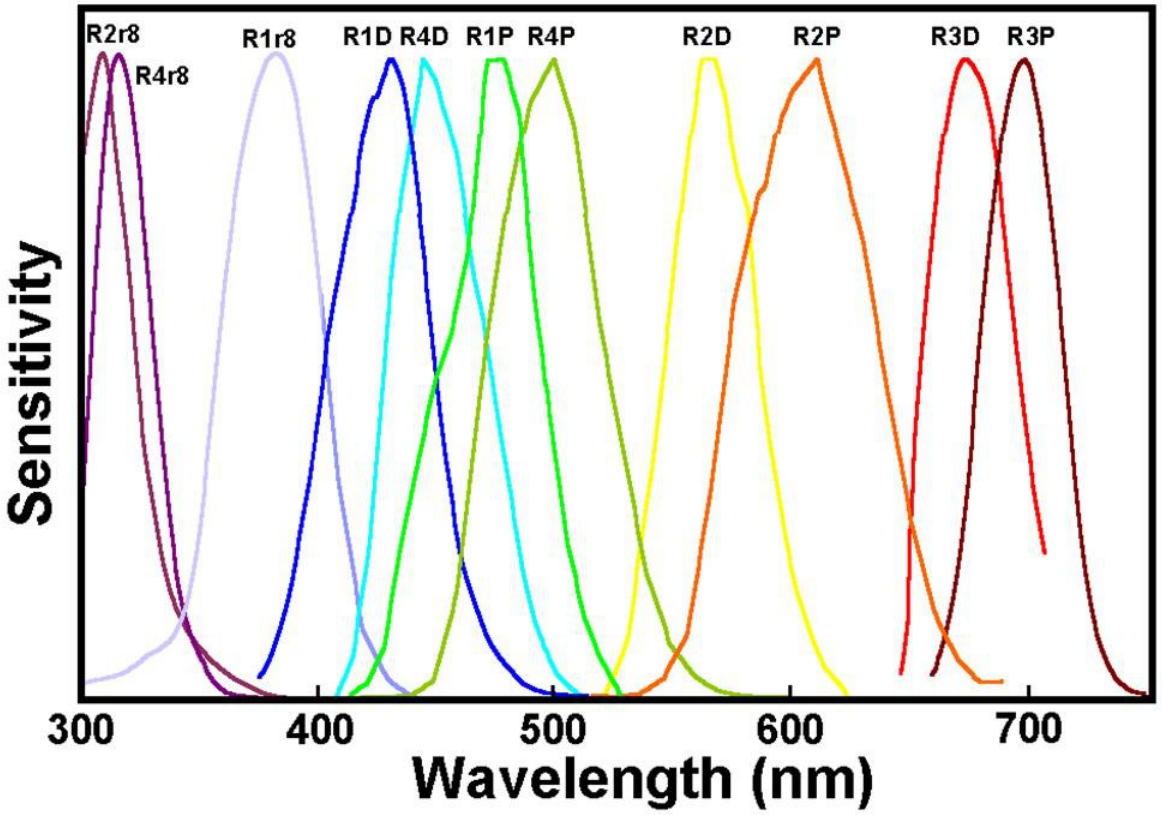
Colour vision in Stomatopod Crustaceans

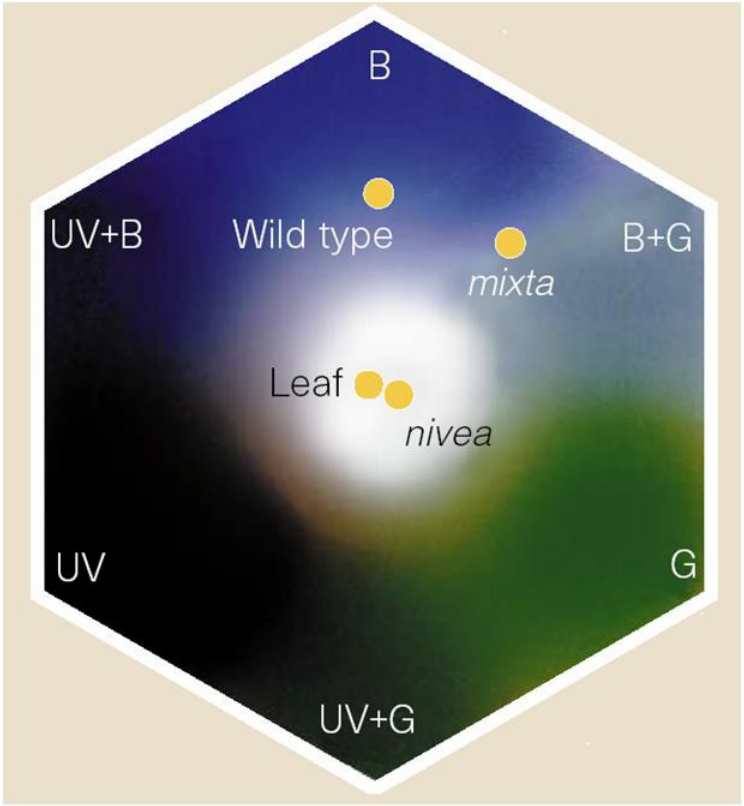


Figures courtesy of T. Cronin

Is bee colour vision adapted to code flower colour?

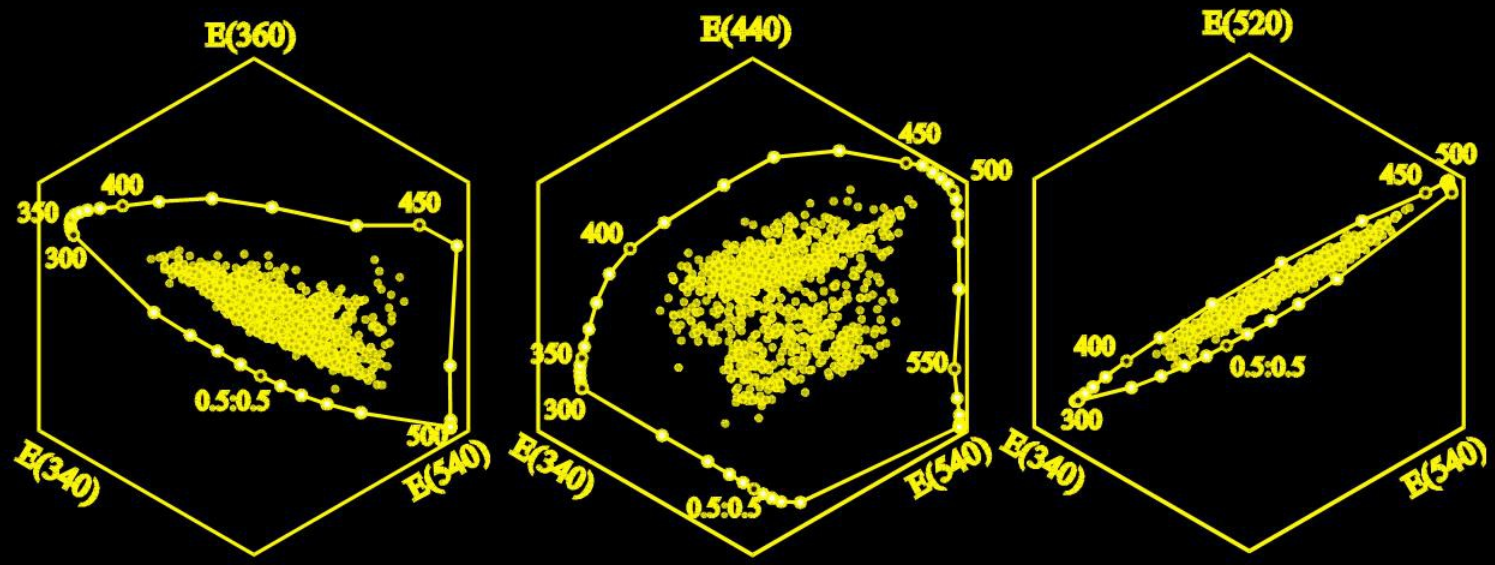
Photos by K. Lunau (cf Lunau, Wacht, Chittka 1996, JCP)

The bee colour space



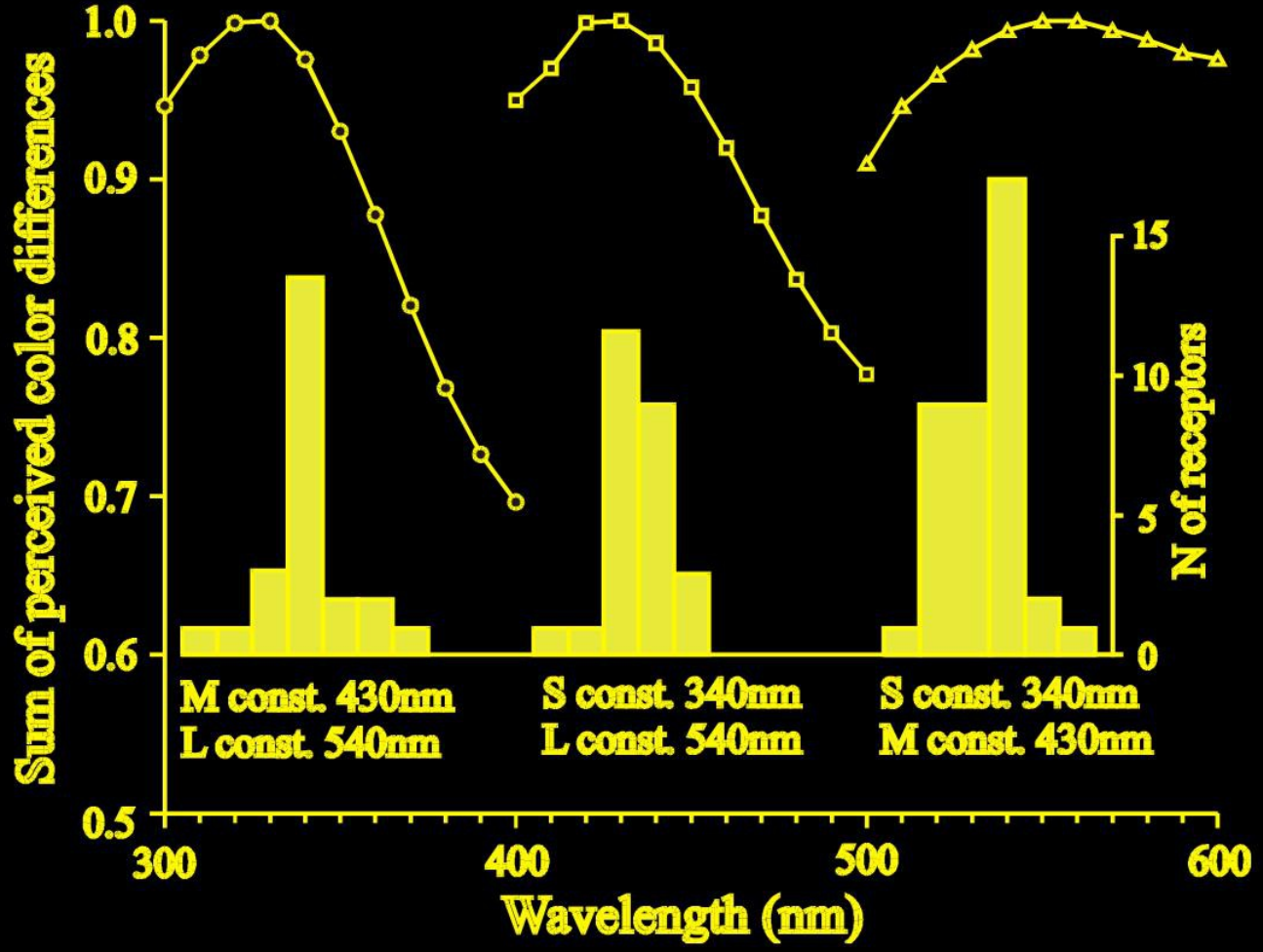
Waser NM & Chittka L
(1998) Nature 394: 835-836

Finding optimal sets of colour receptors



Chittka 1996 J Theor Biol

Similarity of actual and optimal receptors



Underwater vision

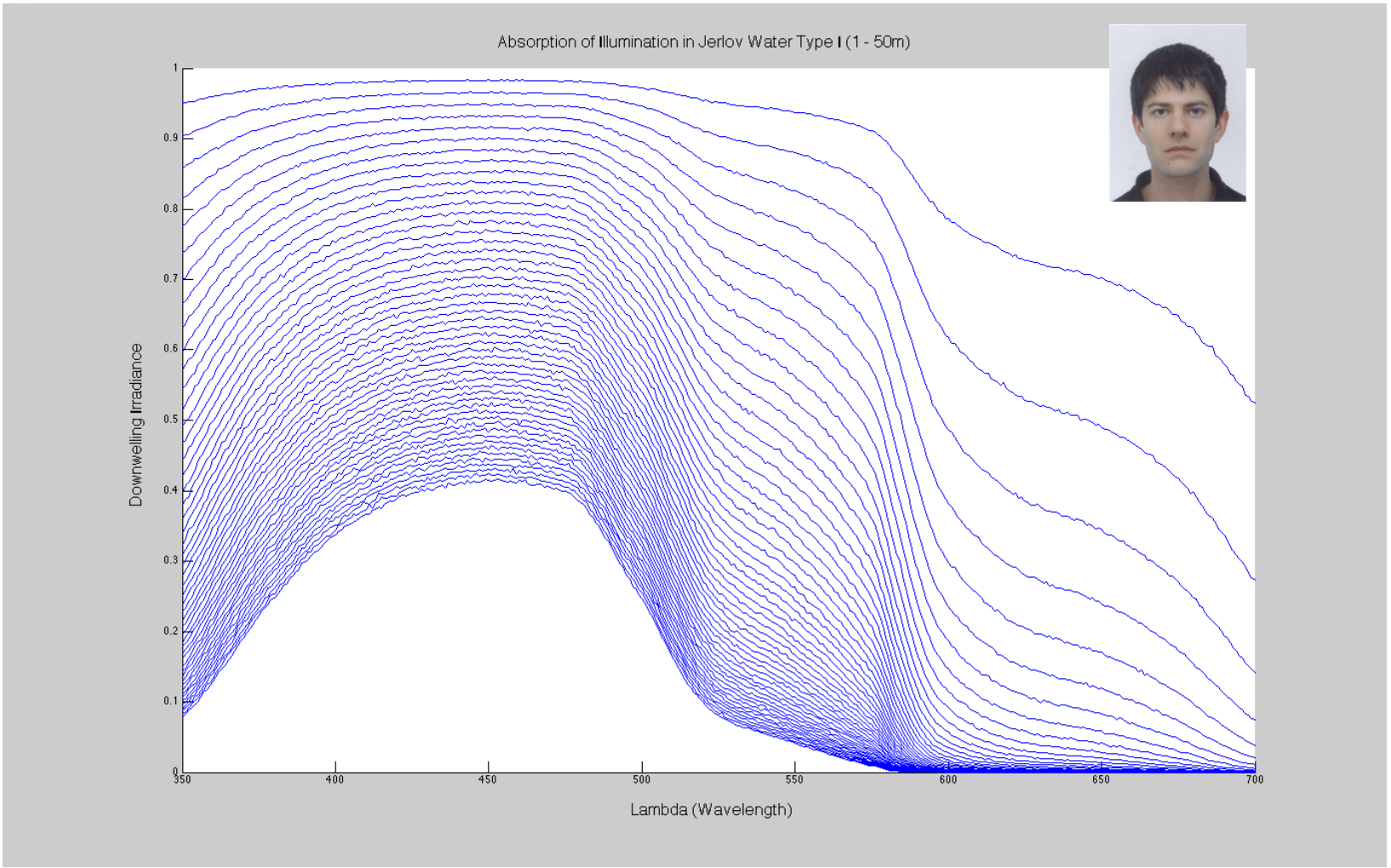


Image by Simon Emberton

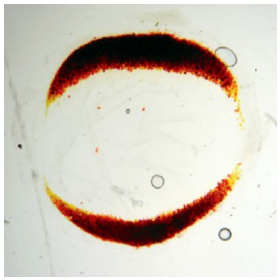
Underwater vision

Simon Emberton, supervised by Andrea Cavallaro (EECS) and Lars Chittka (SBCS)

Underwater vision

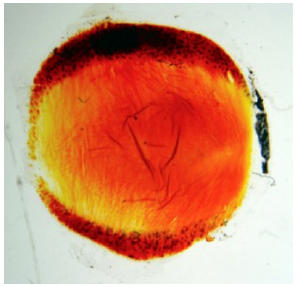
Underwater light is spectrally impoverished – can we develop computational methods or devices to retrieve lost spectral information

Underwater vision



Dark adapted

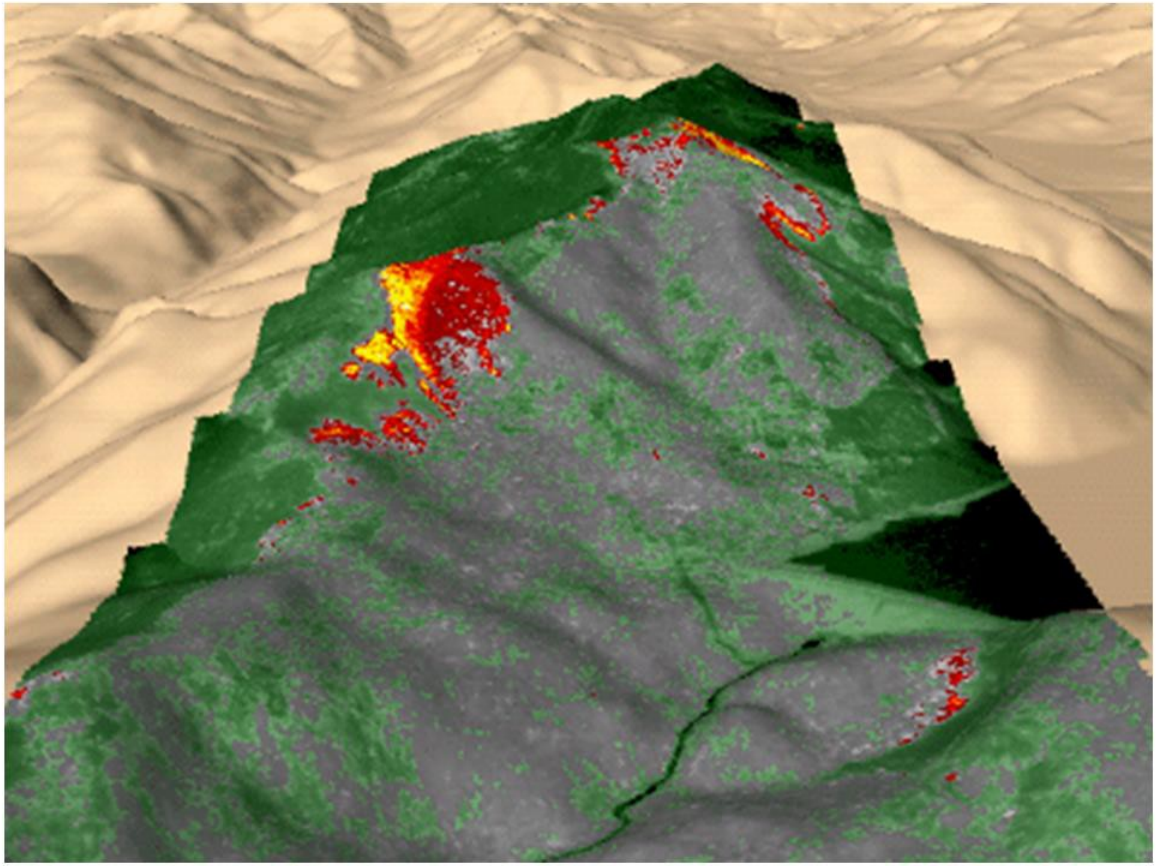
Twilight



Light adapted

The masked greenling – a fish with colour-changing lenses (depending on ambient light quality)

Infrared satellite imaging to detect forest fires



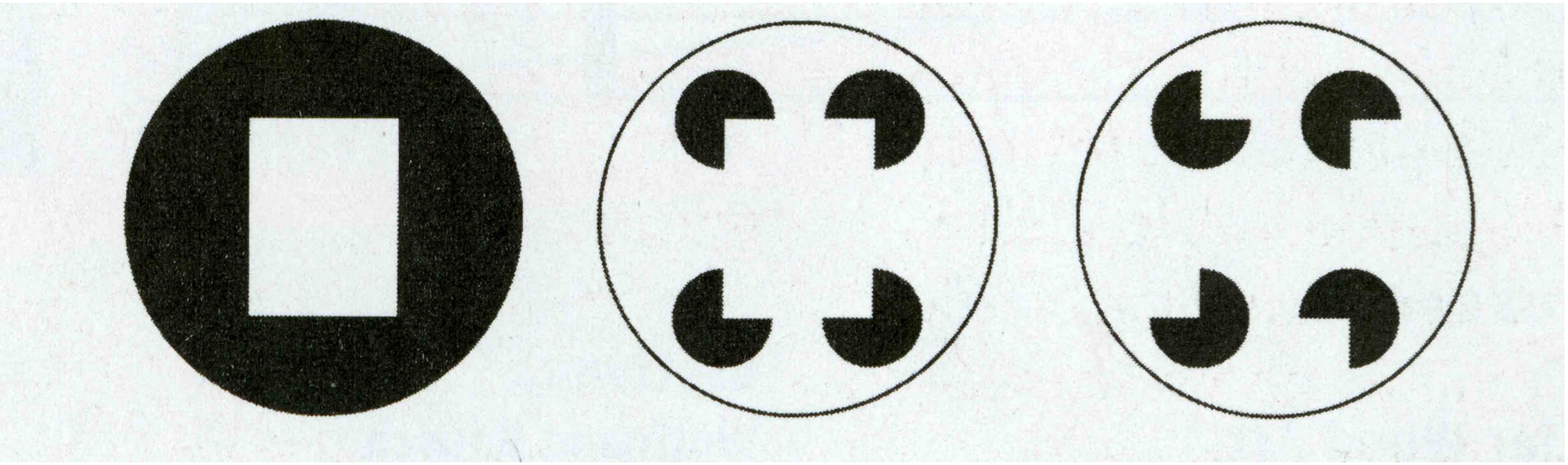
Infrared ‘vision’ in the behind of fire beetles

H. Schmitz, Bonn

- Fire beetles mate and lay eggs on freshly burnt wood.
- Using infrared receptors, they can detect fires from 32km away
- Receptors are particularly sensitive to radiation at 3 micrometres – just the wavelength emitted by forest fires

Pattern learning abilities of bees

- Bees can categorise visual patterns according to symmetry and angular orientation of stripes, and even see visual illusions as humans do.



M Srinivasan et al

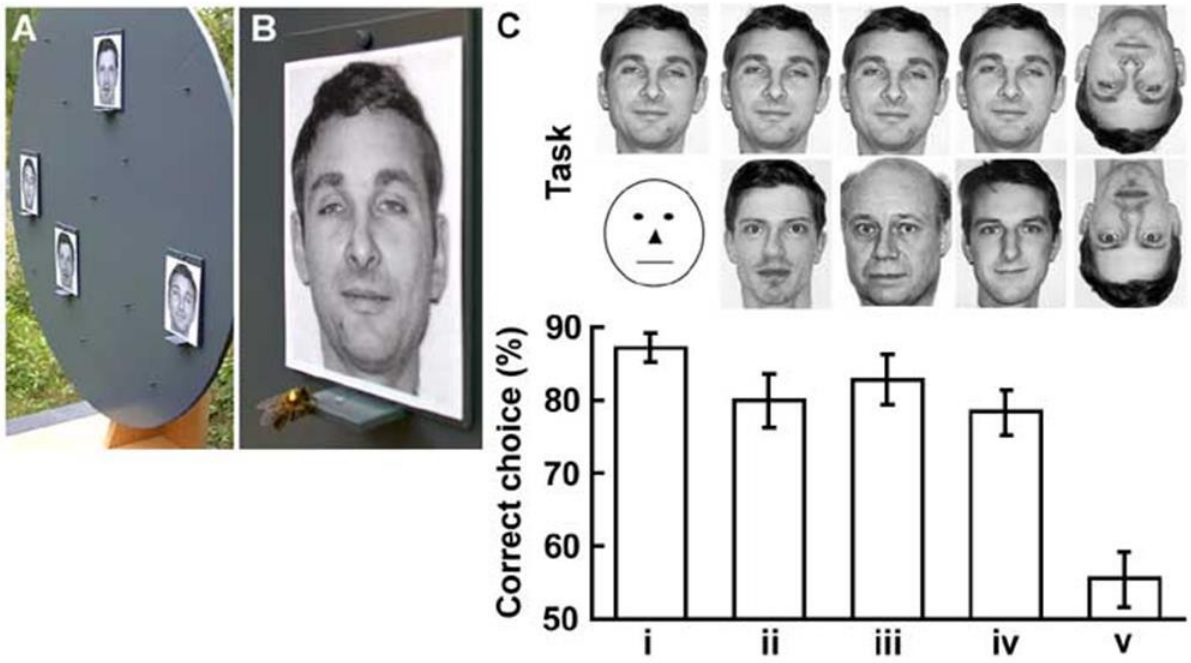
Can bees recognise human faces?

" ... the ability to recognise faces ... is the glue which holds societies together and which has enabled humanity to develop a complex culture unique in the animal kingdom. "
The Economist
(Dec 2004)

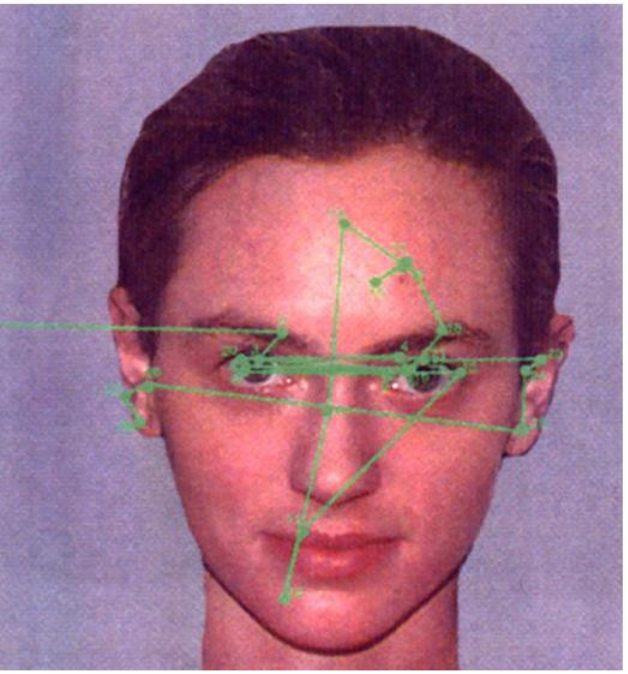
"The Beekeeper" by Jessica Perry

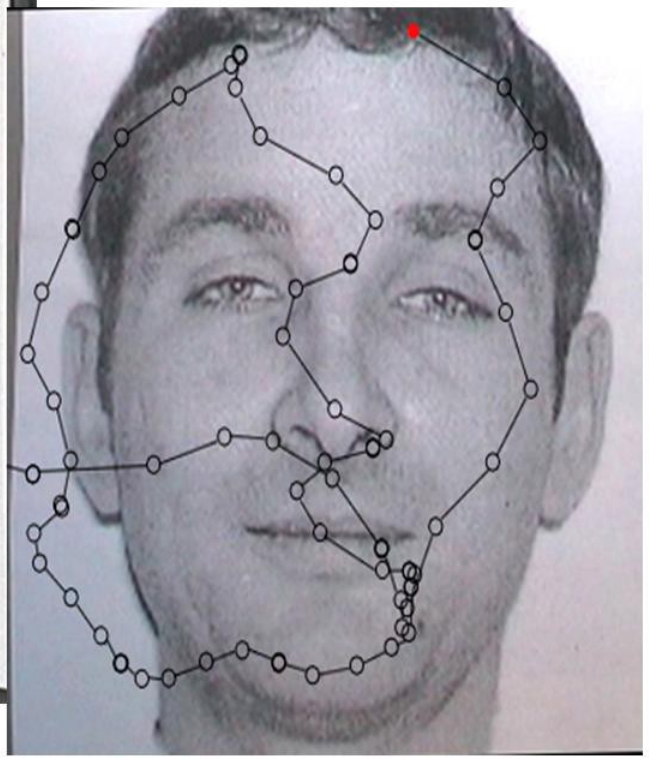
Bees recognise images of human faces

Dyer, Chittka, Neumeyer 2005 JEB



Bees scan outline and facial landmarks
(but largely ignore eyes)





A minimal neural network for face recognition?

- 32 x 32 ‘pixels’
- two hidden layers
- 2 output neurons, presence or absence
- Total 1024 : 453 : 118 : 2
- 95% accuracy
- Aitkenhead MJ, McDonald AJS: ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE 16: 167-176

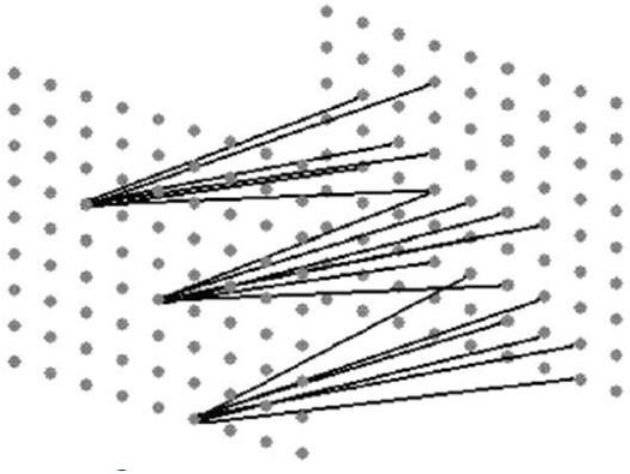


Image: S. Laughlin

Frontal view of honeybee brain (total: ca. 850,000 neurons)

Optic lobes: ~216,000 cells each, in:

La- lamina

Me - medulla

Lo - lobula

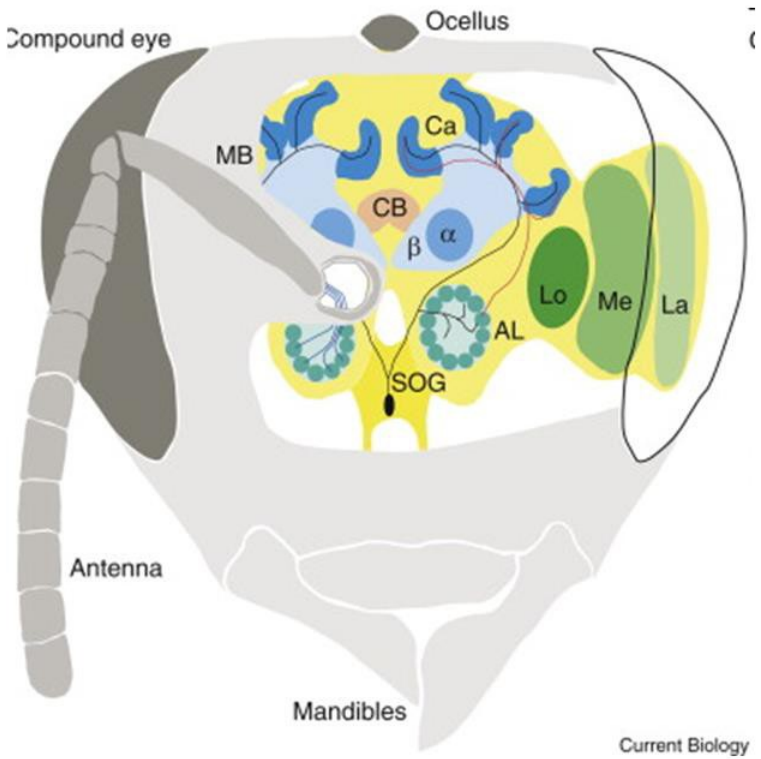
MB - mushroom bodies (~170,000 cells each)

Ca - calices α and β lobes: output region.

CB - central body (CB),

AL - antennal lobes, ~160 glomeruli.

SOG - suboesophagal ganglion



after (Chittka & Niven 2009 Curr Biol)

Brains are not optimally designed circuit boards!

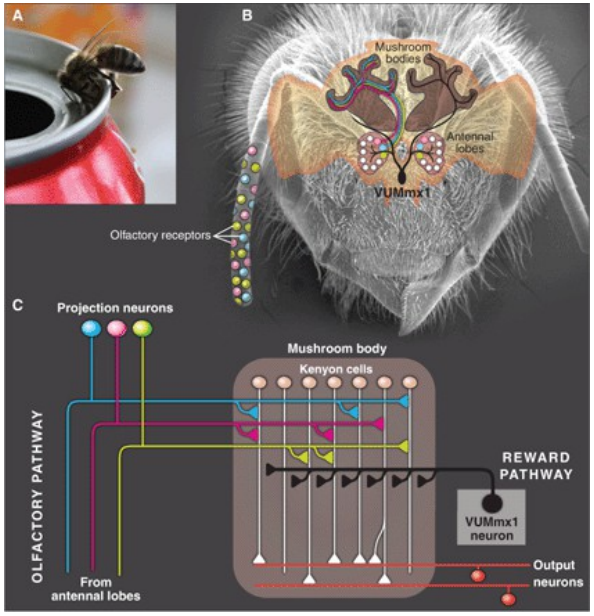


Fig. from Chittka & Peng (2013) Science

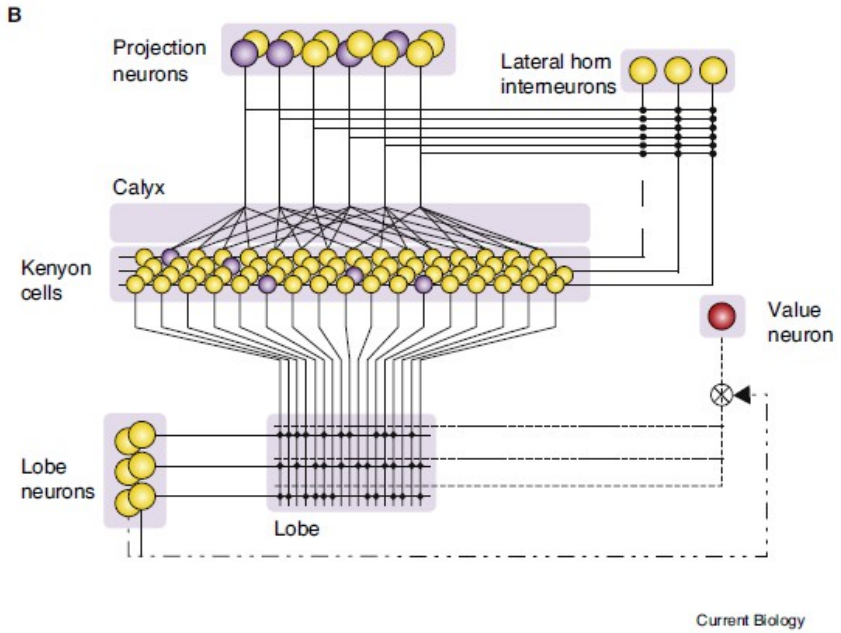
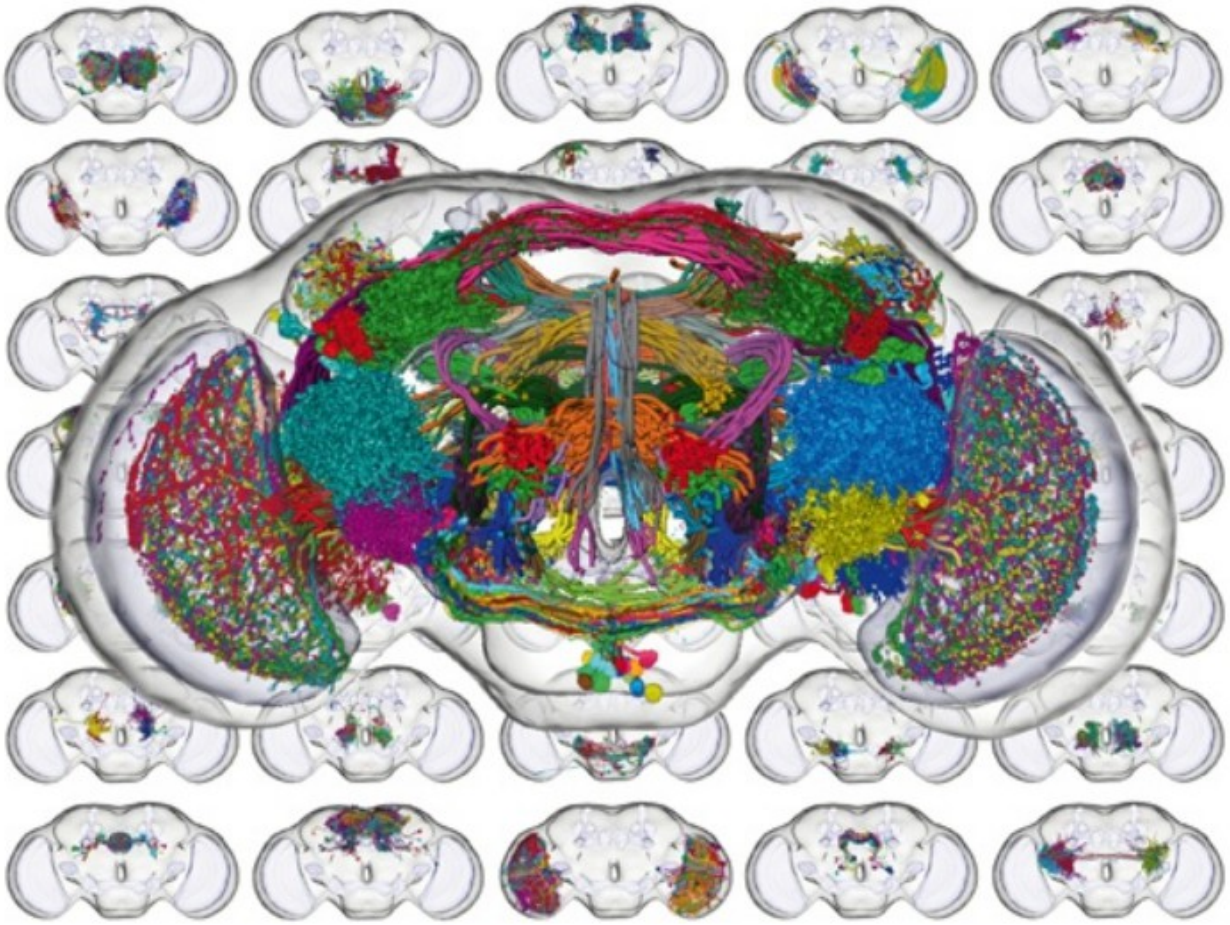


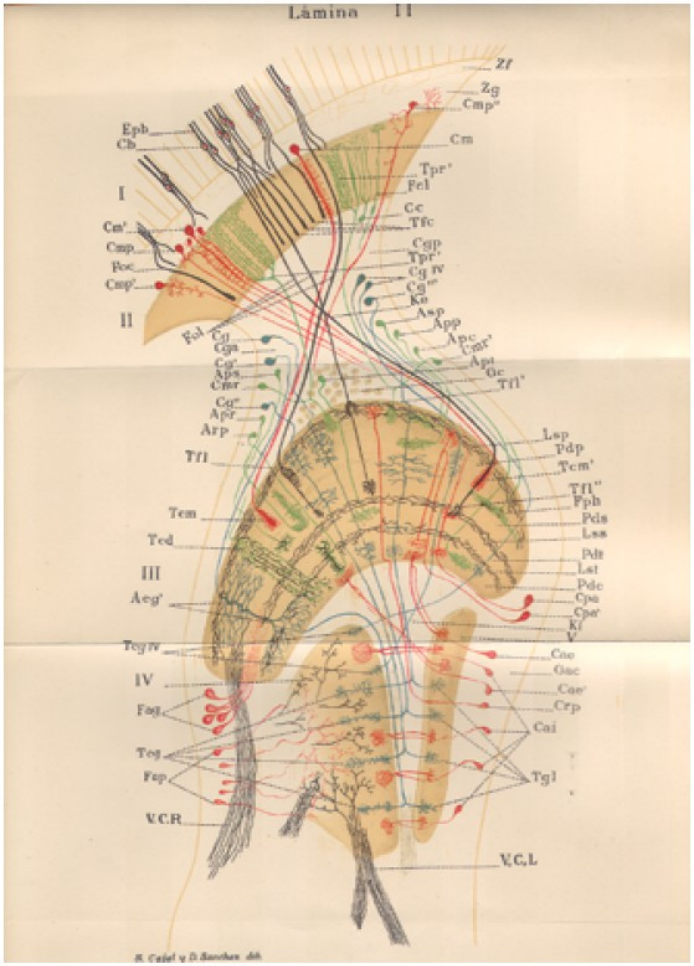
Fig. from Chittka & Niven 2009 after Smith, D., Wessnitzer, J., and Webb, B. (2008)

16% of ~100,000 Drosophila neurons manned



Ann-Shyn Chiang et al 2011 Curr Biol

How do miniature brains solve cognitive problems?



Fei Peng

Mark Roper

(supervised by
Chrisantha Fernando,
Peter McOwan (EECS)
and Lars Chittka (SBCS)

Image from Cajal & Sanchez 1914

How do bees move between flowers?

radar

3

4

2

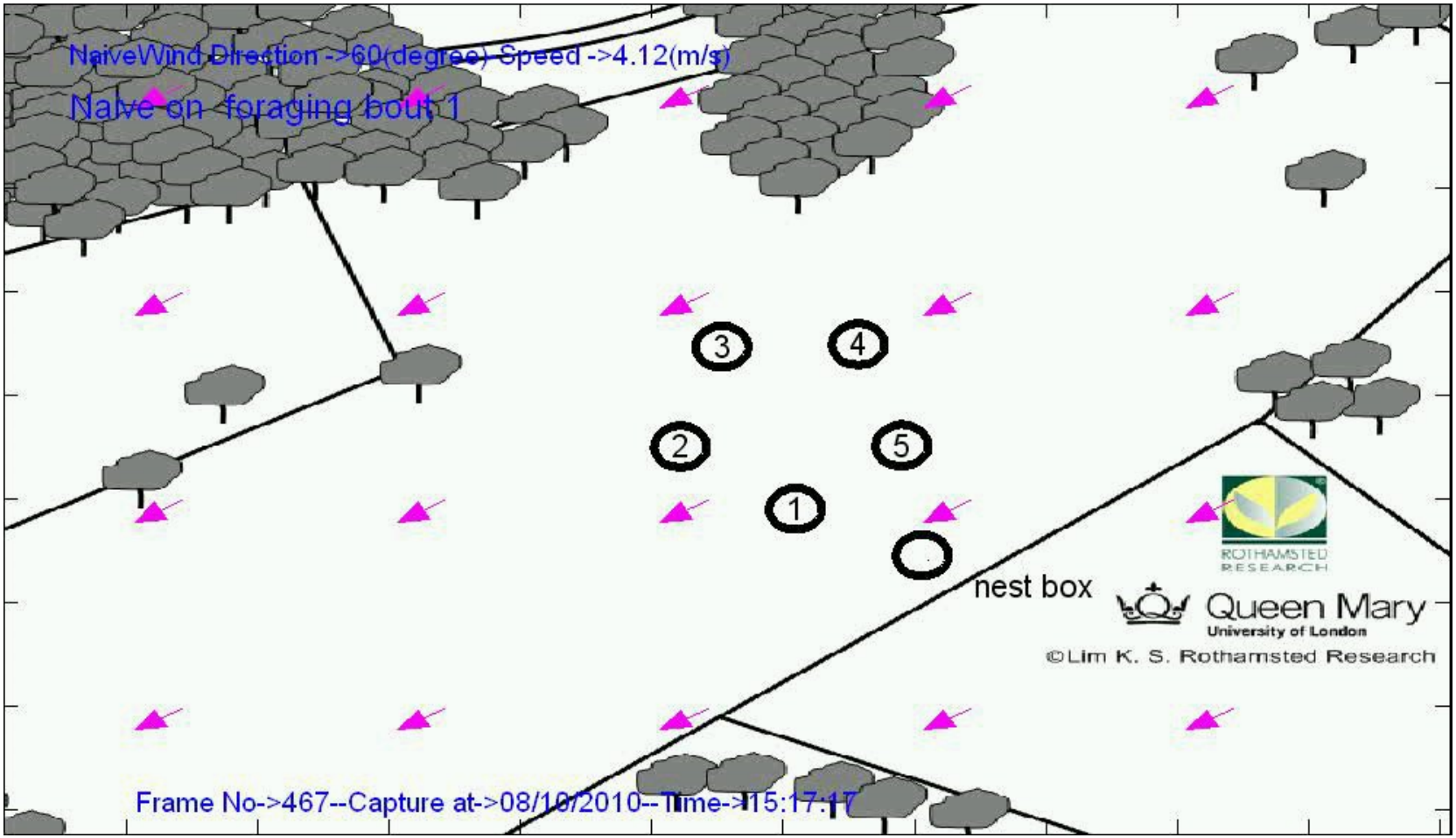
5

1

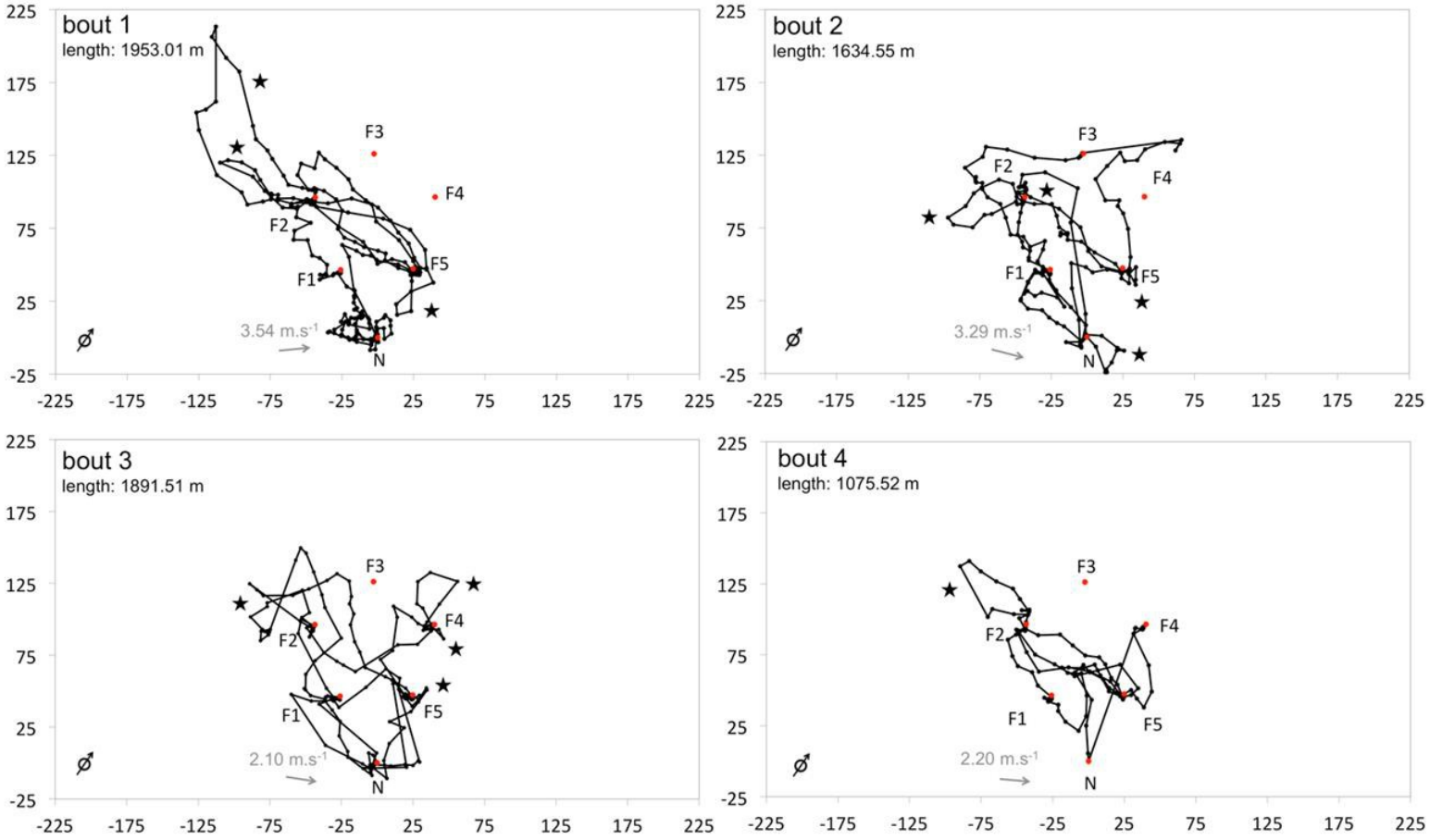
N

50 m

Radar track of naïve bee



Radar tracks of naïve bees



Track of experienced bee

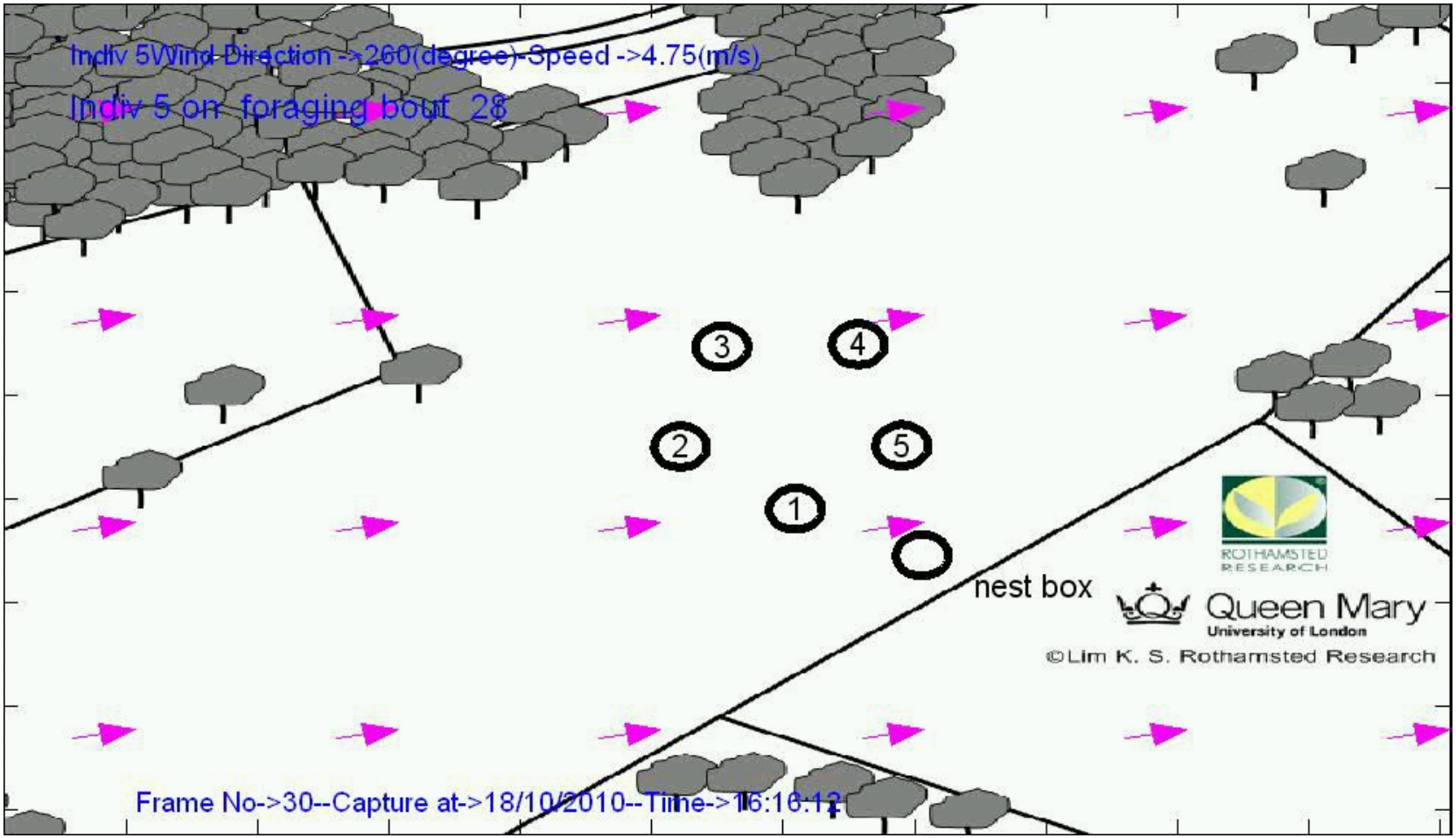
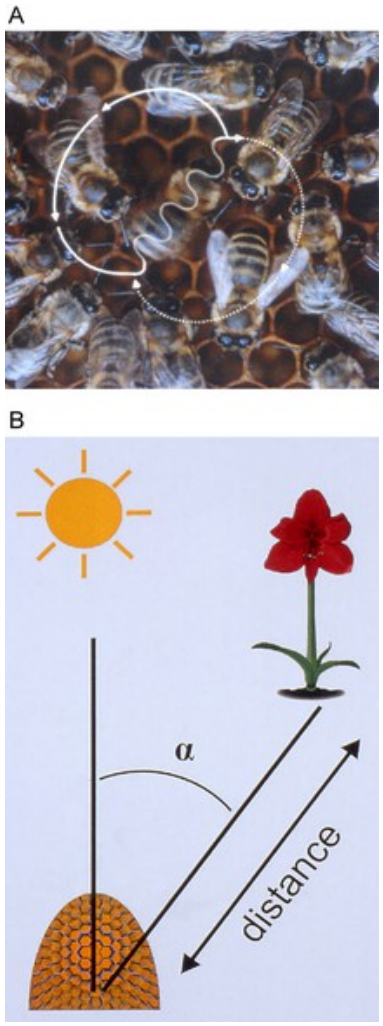


Figure 1. Figure-Eight-Shaped Waggle Dance of the Honeybee (Apis mellifera)



Chittka L (2004) Dances as Windows into Insect Perception. PLoS Biol 2(7): e216. doi:10.1371/journal.pbio.0020216
http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0020216

Decoding the honeybee dance as a basis for ethomics

- Identify dancers from crowds of bees by automated tools (motion capture etc)
- Decode dance information online
- Develop a syntax and grammar of limb movements (multiple routines nested within one another

Prof Andrea Cavallaro

Fabio Poiesi

Eliana Frigerio

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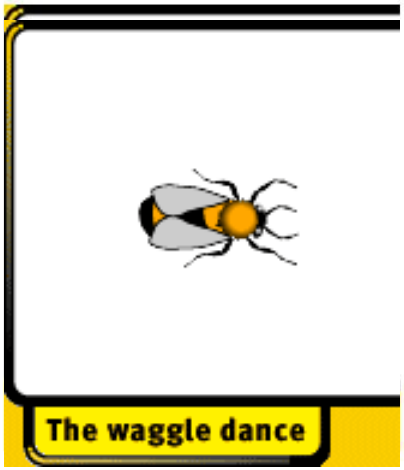
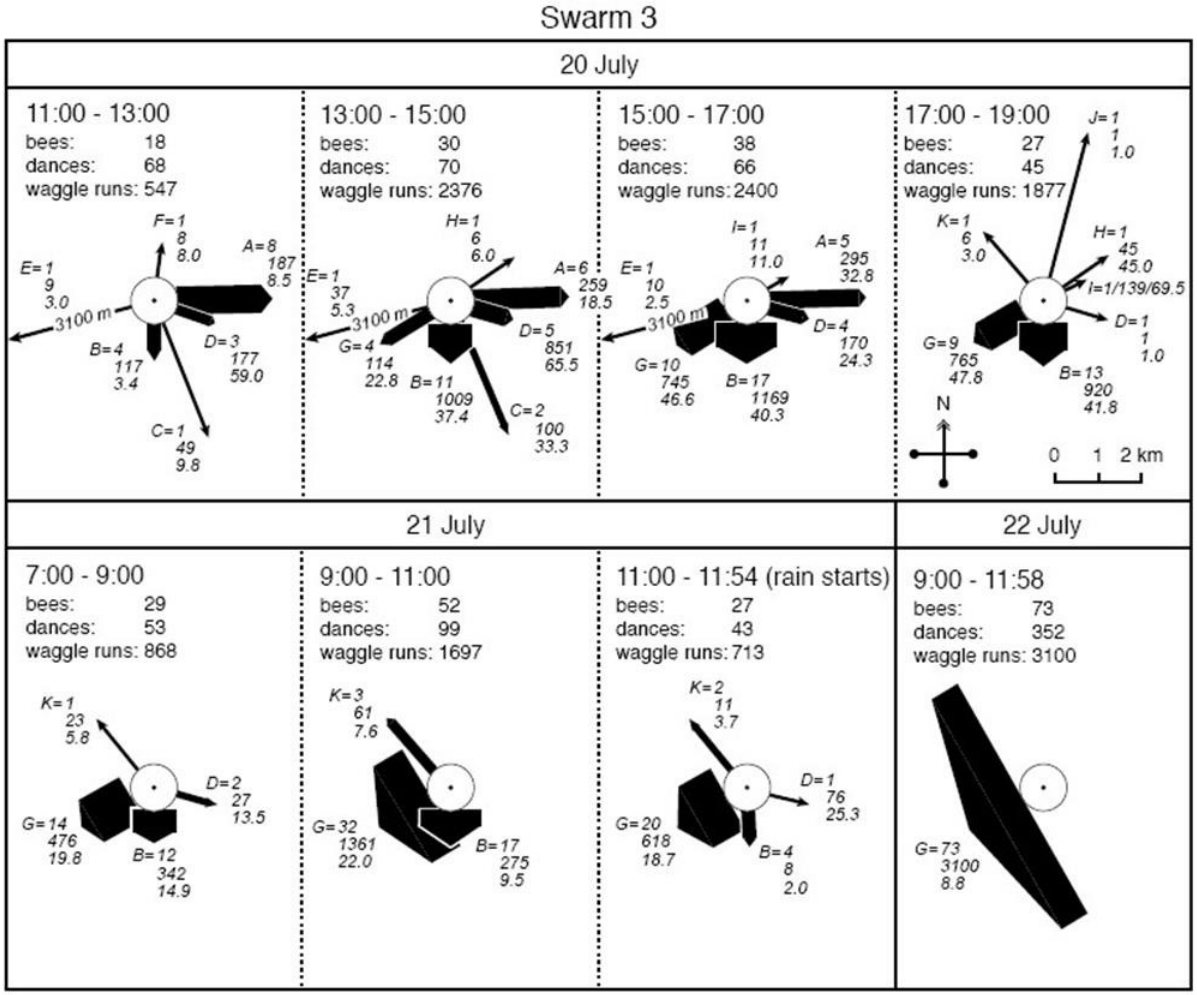
Consensus building in honeybee swarms



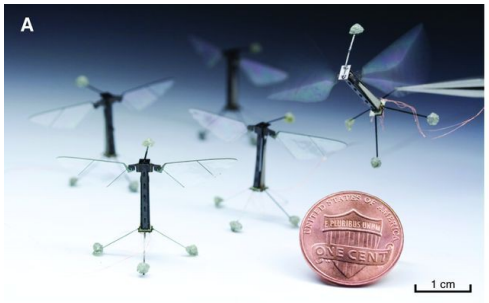
Leadbeater & Chittka
2007 Curr Biol

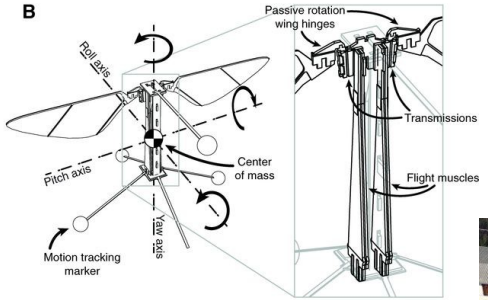
Consensus building in honeybee swarms

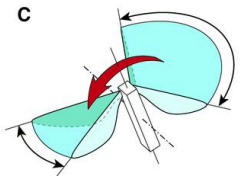


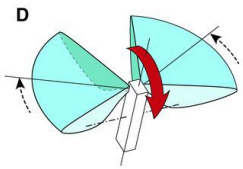
- Leadbeater & Chittka 2007 Curr Biol, after Lindauer

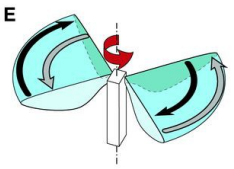
Applications – e.g. swarms of small robots surveying disaster areas for survivors?

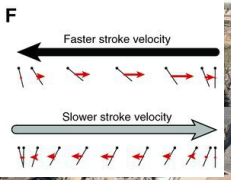












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John Lubbock 19th century banker, politician, naturalist: *Intelligent sensing in the wild*

"…We find in animals complex organs of sense, richly supplied with nerves, but the function of which we are as yet powerless to explain. There may be fifty other senses as different from ours as sound is from sight; and even within the boundaries of our own senses there may be endless sounds which we cannot hear, and colors, as different as red from green, of which we have no conception. … The familiar world which surrounds us may be a totally different place to other animals."