Lecture overview

- Background: Studying the responses of neurons in the visual system -- why should we care?
- What kinds of stimuli should we use to study a sensory system?
- Getting ready for quantitative physiology -- an introduction to recording from visual neurons in the fly

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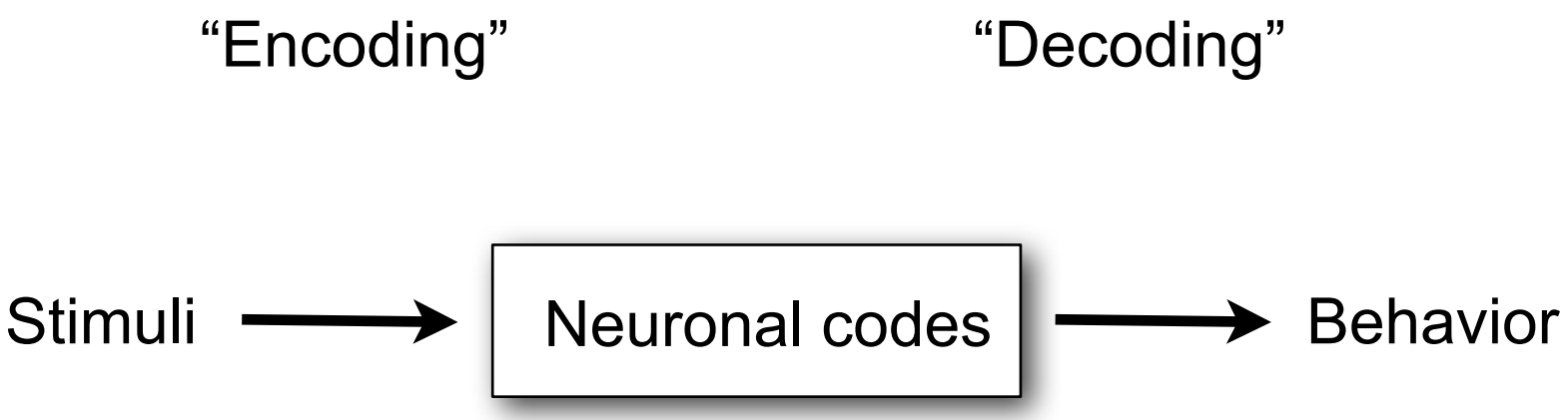
Sensory systems neurophysiology in a nutshell



What are the “atoms” of these codes?
action potentials (spikes)

What are the limitations of this approach?
- multiple neuronal structures
- many potential “codes” in each structure
- potentially non-stationary (i.e. changing) (e.g. learning)
- correlation vs. causation

Stimuli → Neuronal codes → Behavior

Image: Kimberly Brown-Azzarello. Flickr. CC BY-NC.

Stimuli → Neuronal codes → Behavior

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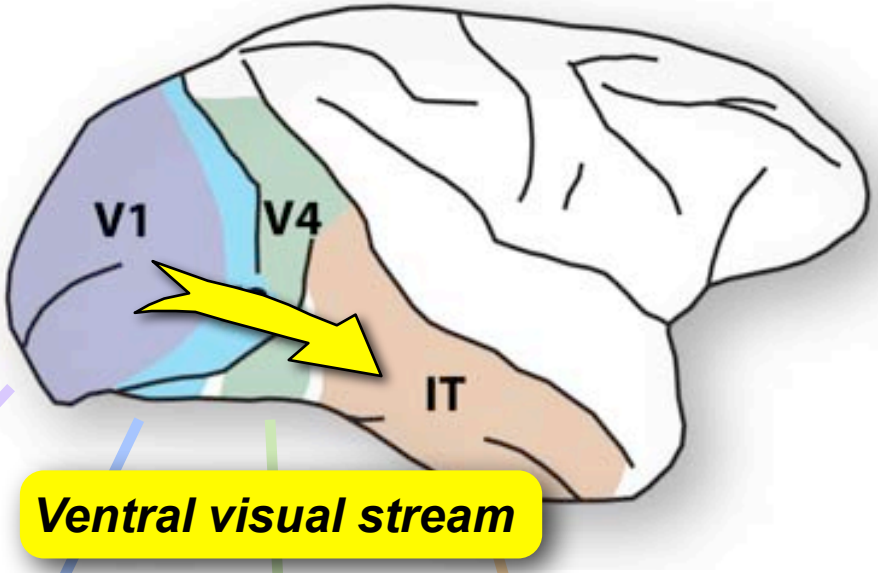
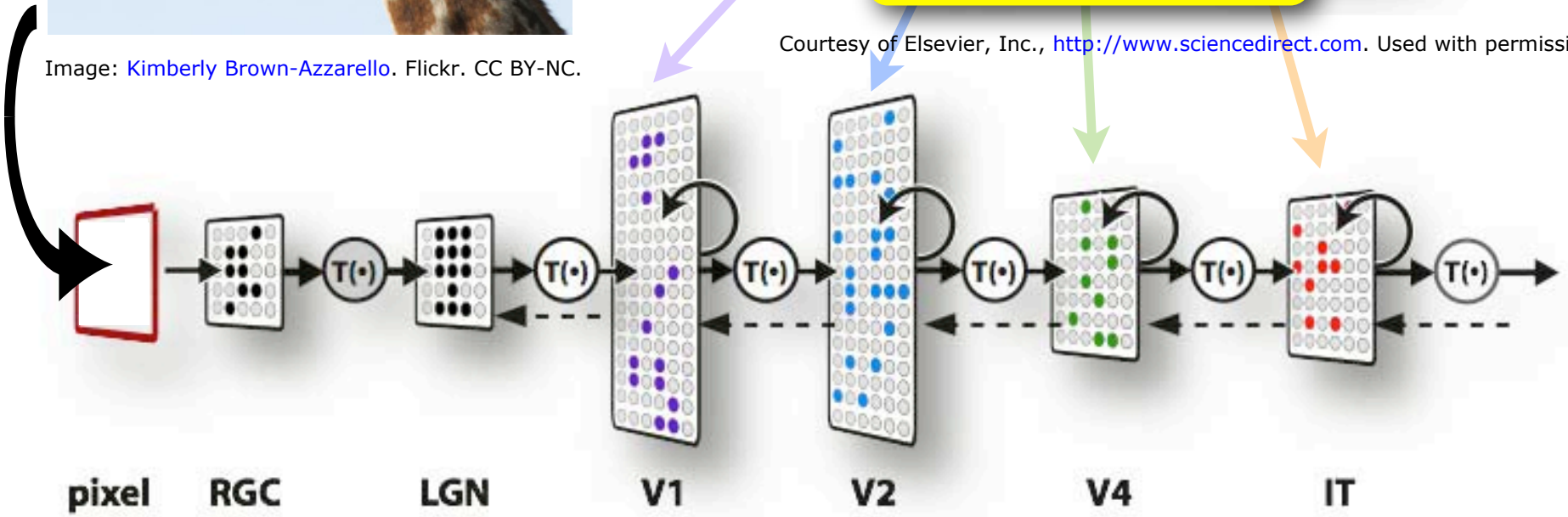


Courtesy of Elsevier, Inc., http://www.sciencedirect.com. Used with permission.



Stimuli → Neuronal codes → Behavior

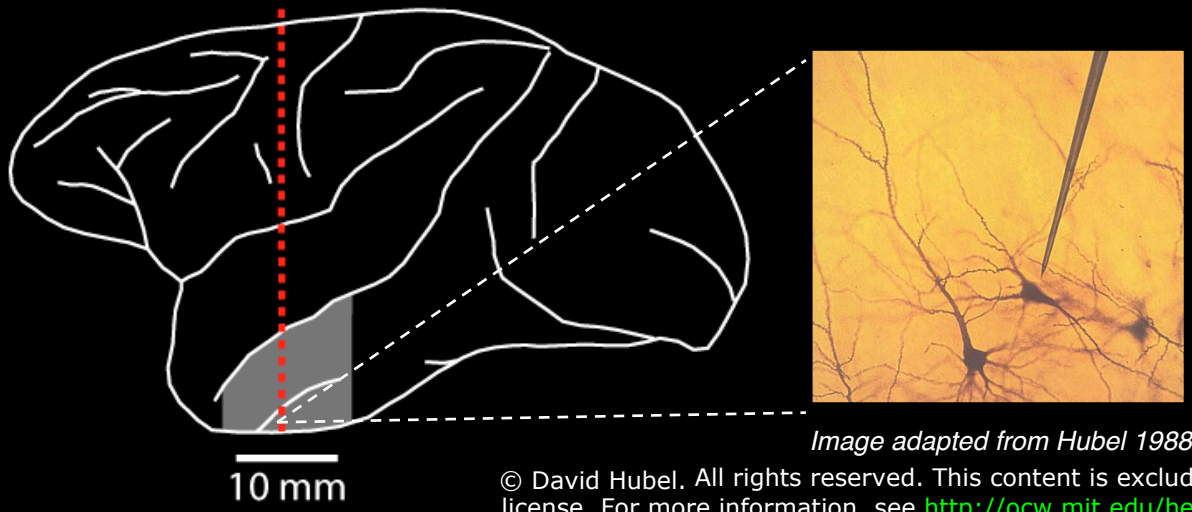
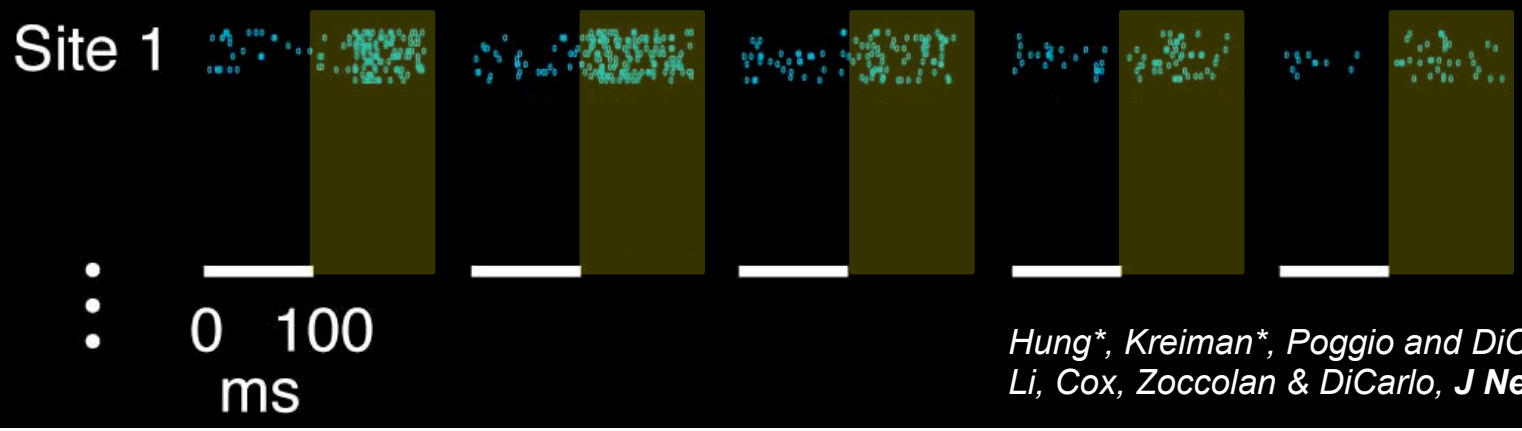


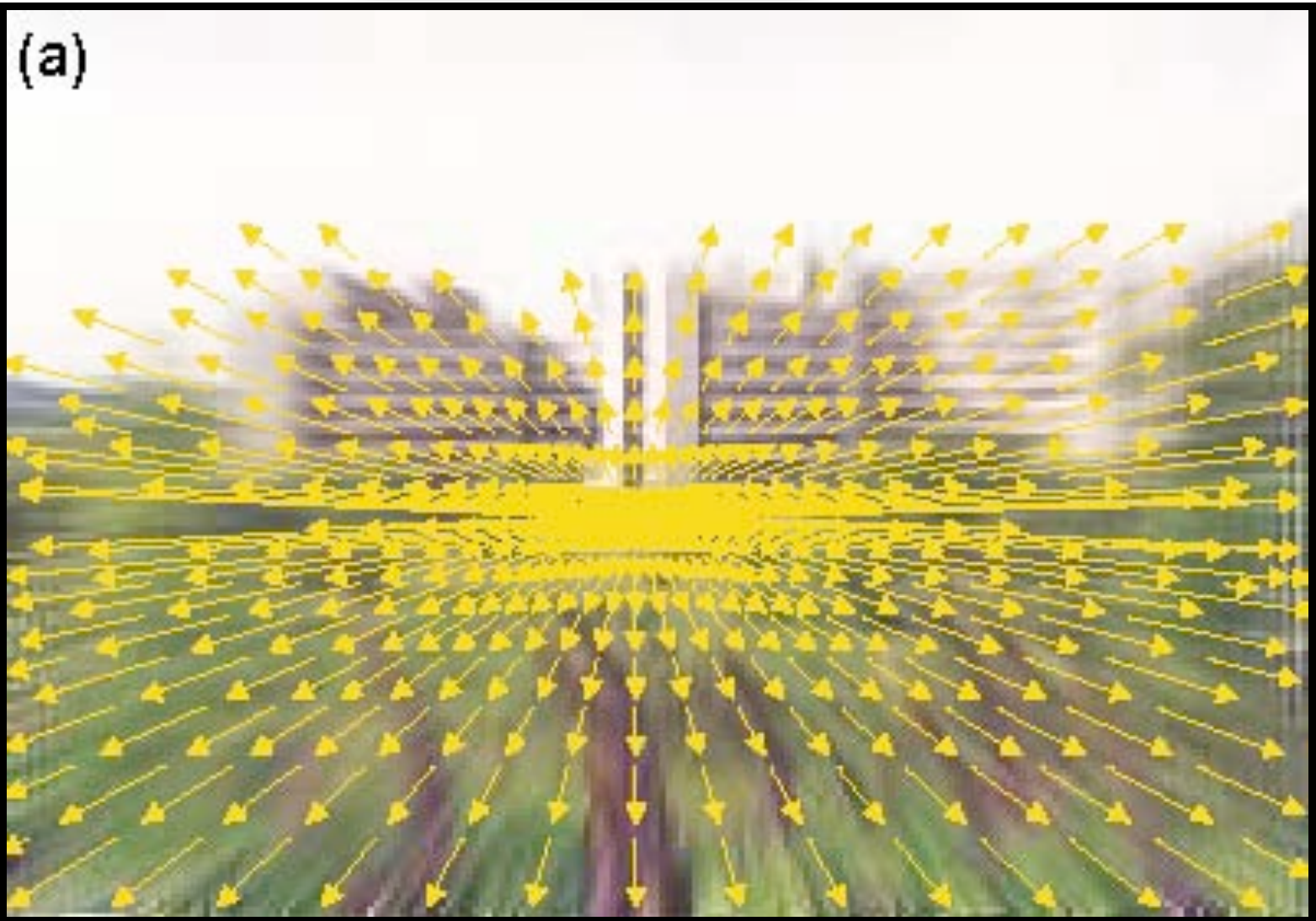
Image adapted from Hubel 1988



Behaviorally relevant analysis window

Hung, Kreiman*, Poggio and DiCarlo, **Science** (2005); Li, Cox, Zoccolan & DiCarlo, **J Neurophys** (2009)*

Stimuli → Neuronal codes → Behavior



Egelhaff et al. (2002)

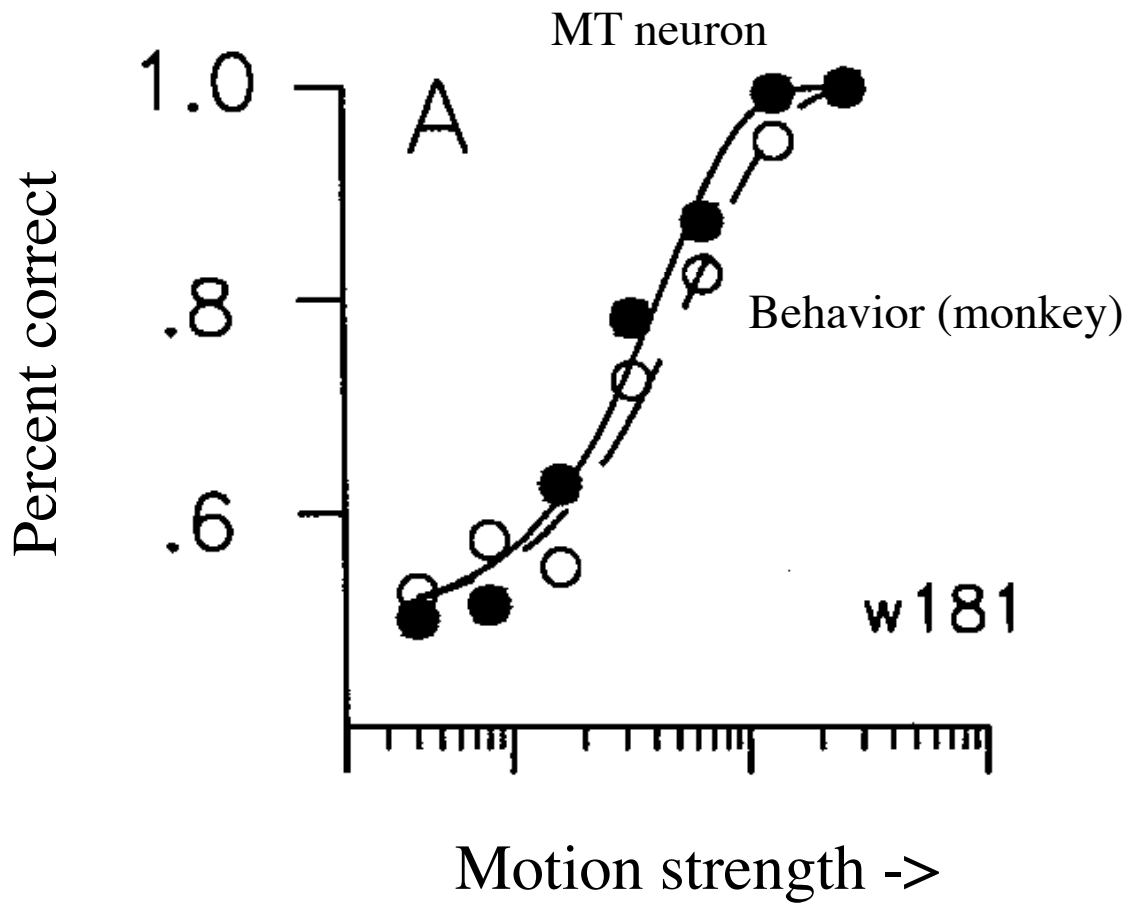
Stimuli → Neuronal codes

Motion detectors in primate brain (MT)

Fig. 1 and 5. removed due to copyright restrictions. See Maunsell, J. H., and D. C. Van Essen. "Functional Properties of Neurons in Middle Temporal Visual Area of the Macaque Monkey. I. Selectivity for Stimulus Direction, Speed, and Orientation." *Journal of Neurophysiology* 49, no. 5 (1983): 1127-47.

Stimuli → Neuronal codes → Behavior

Your motion detectors (MT) are as good as you are !



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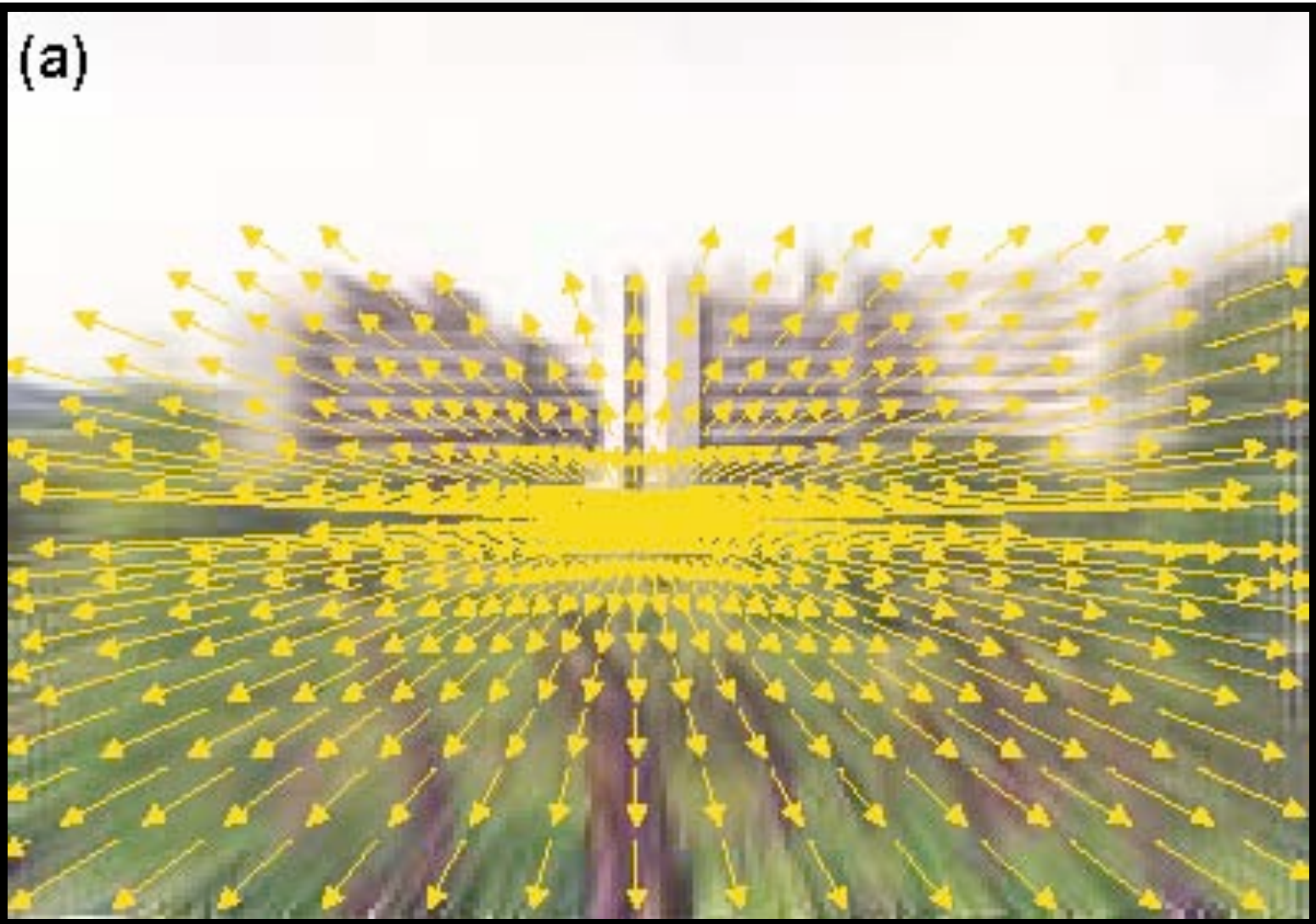
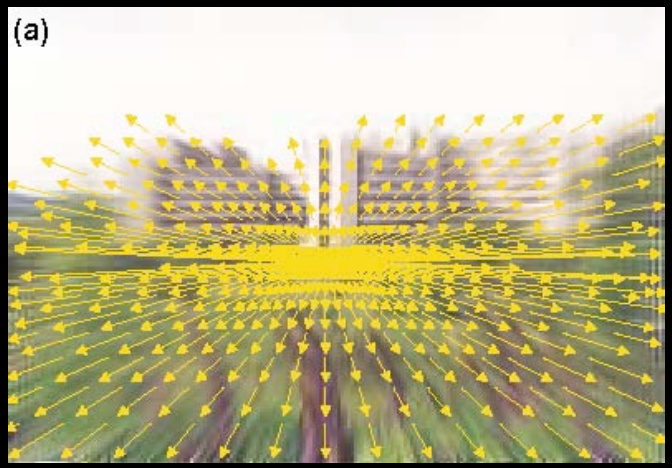
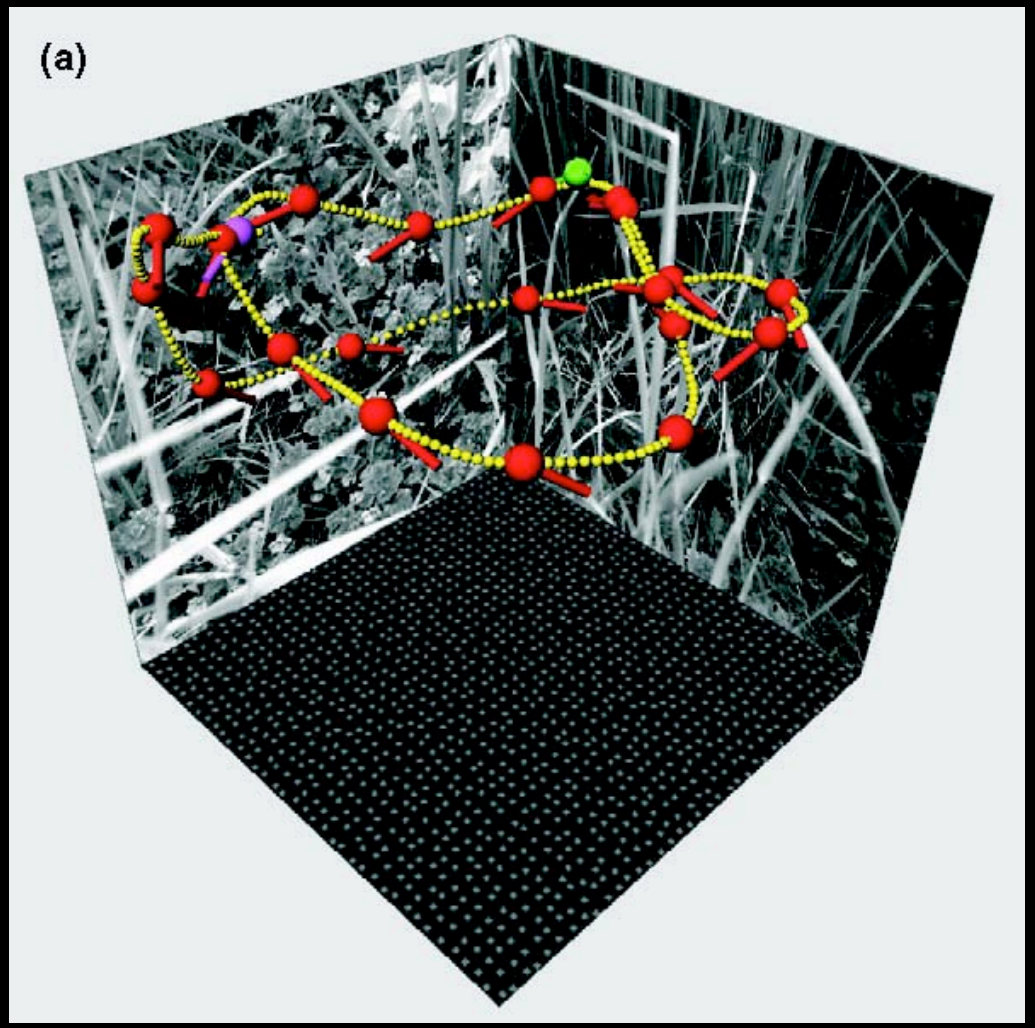
Stimuli → Neuronal codes → Behavior



Egelhaff et al. (2002)





Egelhaff et al. (2002)

What the fly ‘sees’ while flying (played at 1/5 speed)

Figure removed due to copyright restrictions.

Courtesy of Dr. Martin Egelhaff

Concept: **population code.**

The information about the variable(s) of interest is distributed among a set of neurons ("population" of neurons).

H1 neuron
(the fly has two)

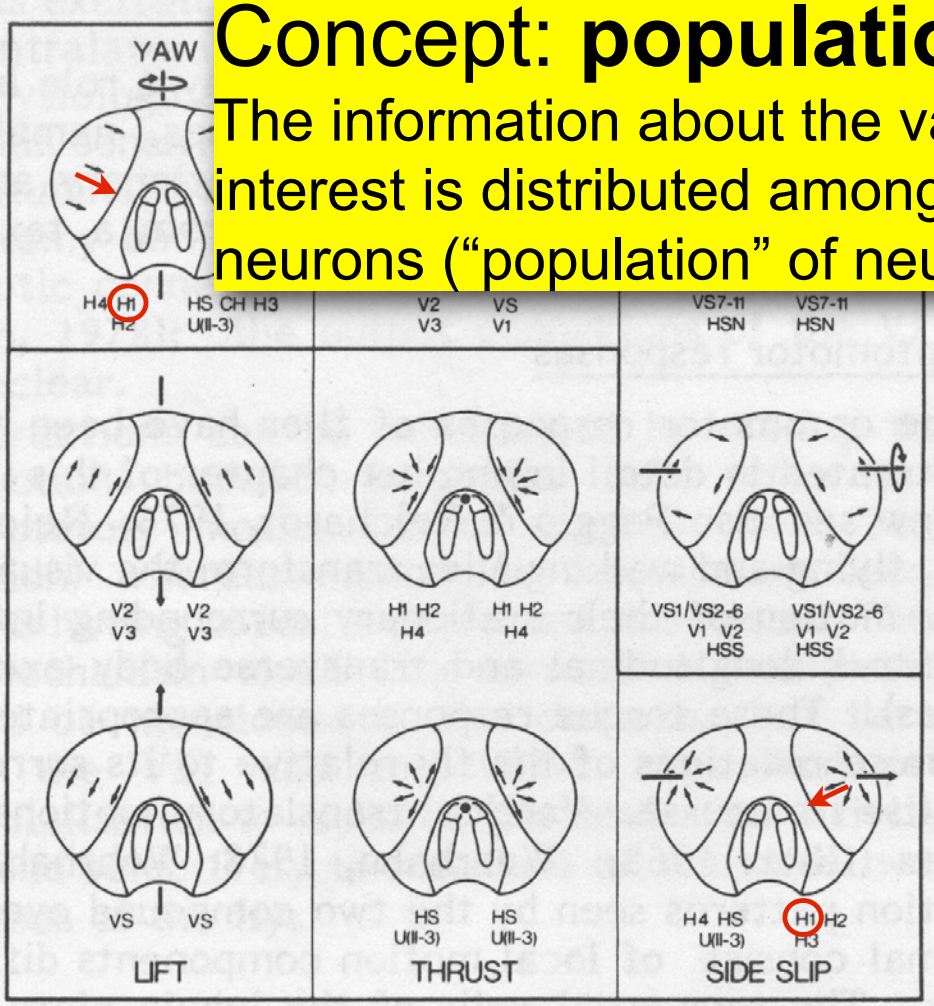


Fig. 12. Diagram of retinal motions induced by translations (lift, thrust, side slip) and rotations (yaw, roll, pitch) of the head of a fly in a stable visual surrounding. For each situation, the tangential cells of the lobula plate excited selectively by the sketched retinal motion pattern are listed.

Placing an electrode to record from neurons in the fly visual system

Figure removed due to copyright restrictions.

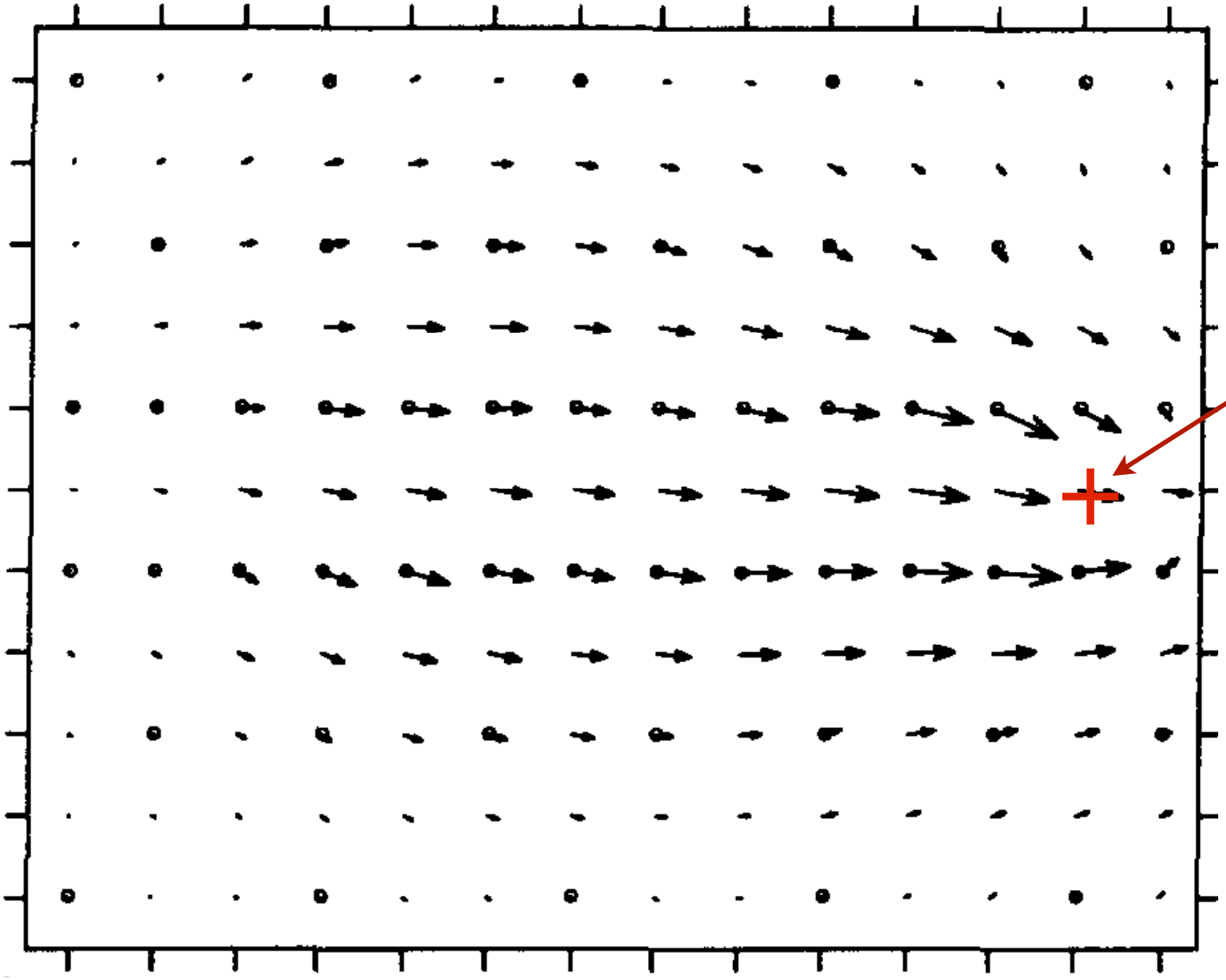
Courtesy of Dr. Martin Egelhaff

Neural activity of ‘H1’ neuron during walking simulation

Figure removed due to copyright restrictions.

Courtesy of Dr. Martin Egelhaff

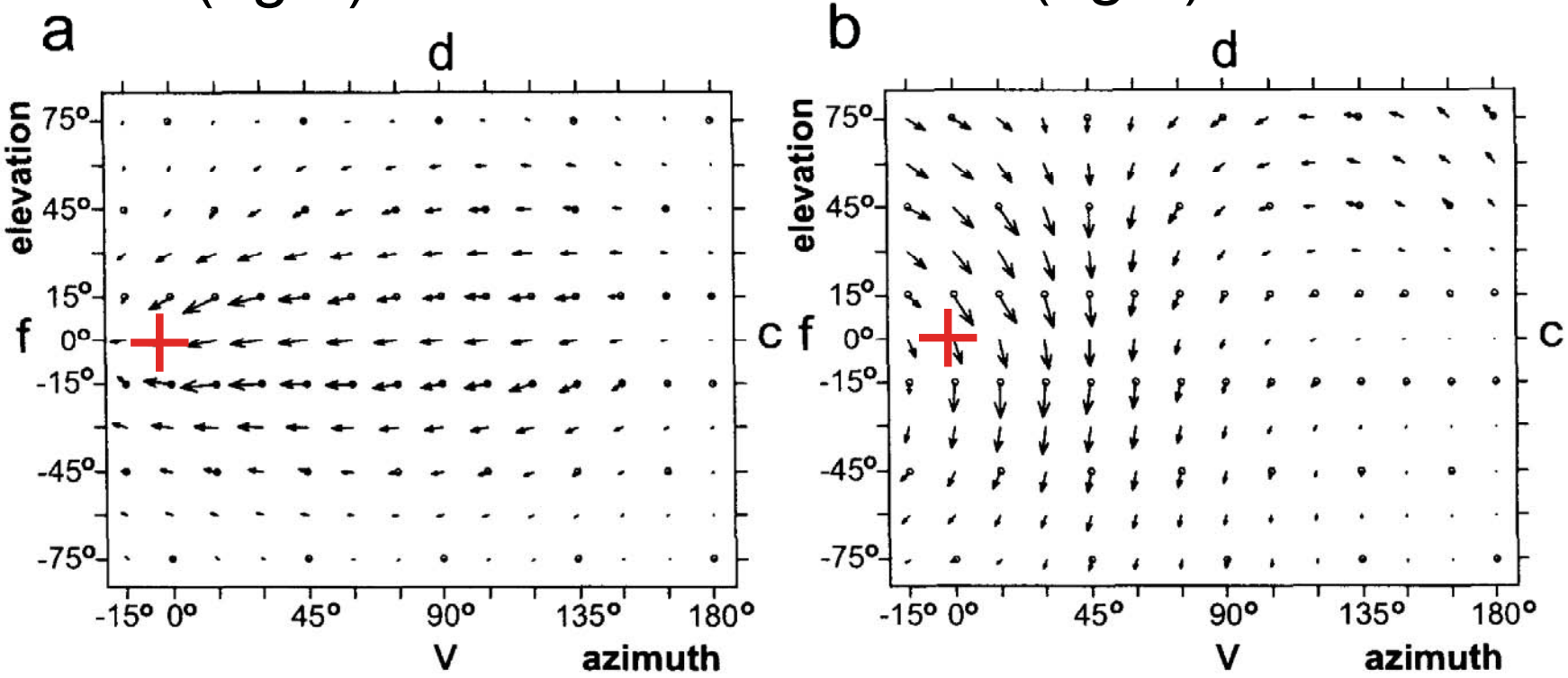
The (left) H1 neuron's receptive field



Krapp and Hengstenberg, Vision Res. (1997)

The (right) H1 neuron

The (right) V1 neuron



&RXUWHV\ RI (0VHYLHU ,QF KWWS ZZZ VFLHQFHGLUHFW FRP 8VHG ZLWK SHUPLVVLRQ

FIGURE 8. Response fields of the neurons H1 (a) and V1 (b) are shown in a Mercator projection (see text) of the right visual hemisphere (f, frontal; c, caudal; d, dorsal, v, ventral). The fly's straight ahead direction would be an azimuth of 0 deg and an elevation of 0 deg. Local motion tuning (obtained with standard stimulus parameters) is represented by arrows. Their direction indicates the local preferred direction (LPD) and their length the normalized local motion sensitivity (LMS). Locations of measurements are marked with little circles; unmarked arrows are interpolated from neighbouring measured responses. The response fields of both neurons extend into the left visual hemisphere (azimuth = −15 deg). The H1 neuron (a) is highly sensitive to horizontal back-to-front motion along the equatorial regions of the visual field. Its motion sensitivity decreases towards the poles of the visual hemisphere. In contrast, the V1 neuron (b) is most sensitive to vertical downward motion in the frontolateral part of the visual field. In the dorsal part of the lateral to caudolateral response field V1 is sensitive to horizontal back-to-front motion and in the dorsocaudal region the neuron responds to slightly tilted upwards motion. The global structure of extended parts of both response fields shows striking similarities with specific rotatory optic flow fields. For the H1 neuron the axis of rotation corresponds to the vertical body axis of the fly. The axis of rotation for the V1 neuron lies approximately in the equatorial plane at an azimuth of about 120 deg. Note the gradual change of LPD and LMS over both response fields.

Krapp and Hengstenberg, Vision Res. (1997)

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Overall goal of the fly labs: the basics of carrying out a complete, quantitative neurophysiology experiment.

• Design visual stimuli to test a hypothesis	MATLAB proj 2 FLY design lab
• Setup a prep to record from relevant neurons	FLY WET LAB 1
• Present your visual stimuli in a controlled, repeatable manner	FLY WET LAB 2
• Collect digital data during that presentation	FLY WET LAB 2
• Isolate individual spikes in that data	MATLAB proj 1 Fly analysis lab 1
• Analyze the relationship between the stimuli and the neuronal spikes	MATLAB proj 3 Fly analysis lab 2
• Document your findings	Lab Report 2

Life cycle of a fly

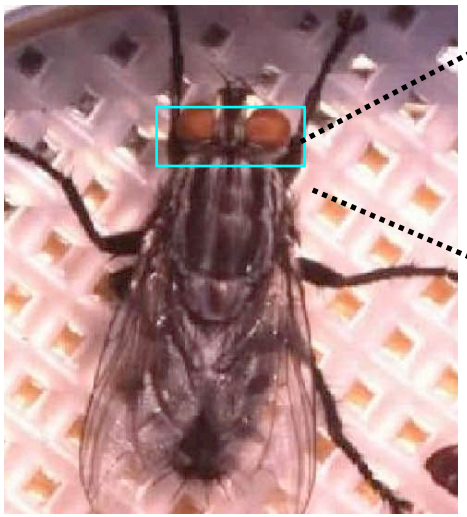
Eggs

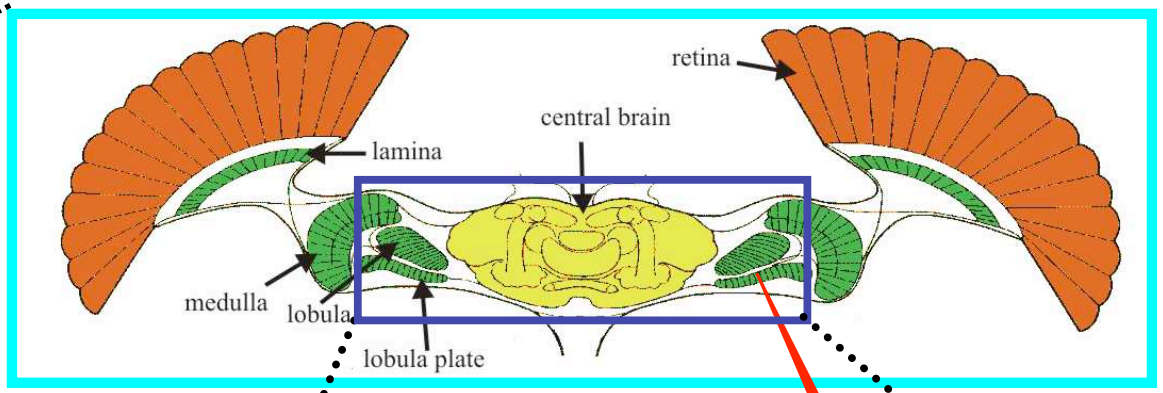
Larva (maggot)

Pupa (mummy)

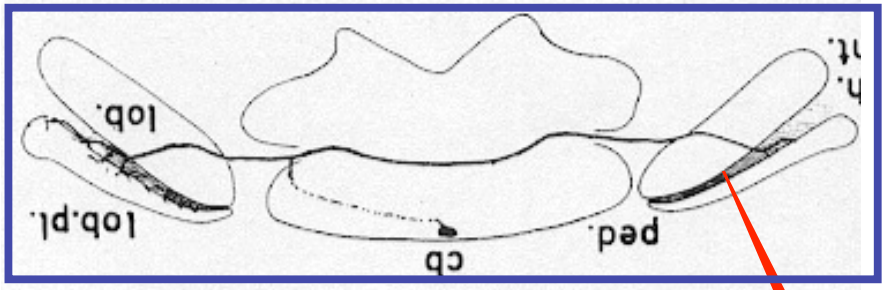
Hatchling --> adult

Fly visual system

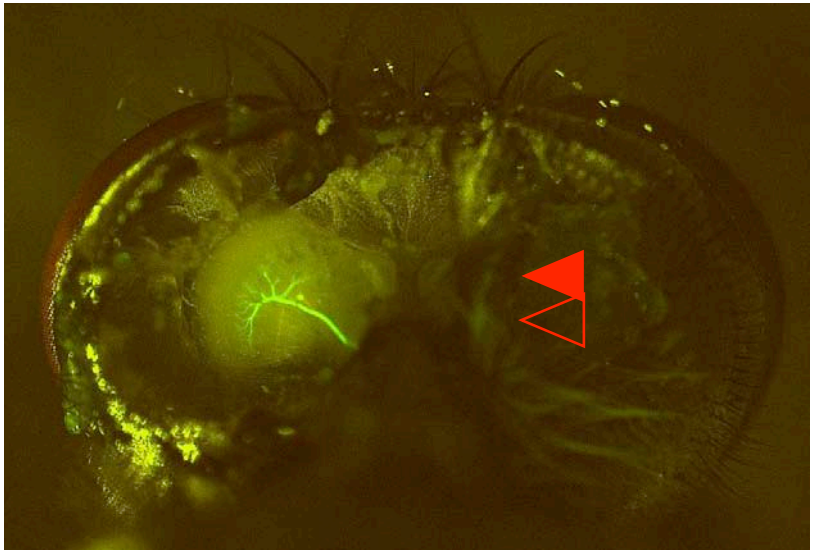




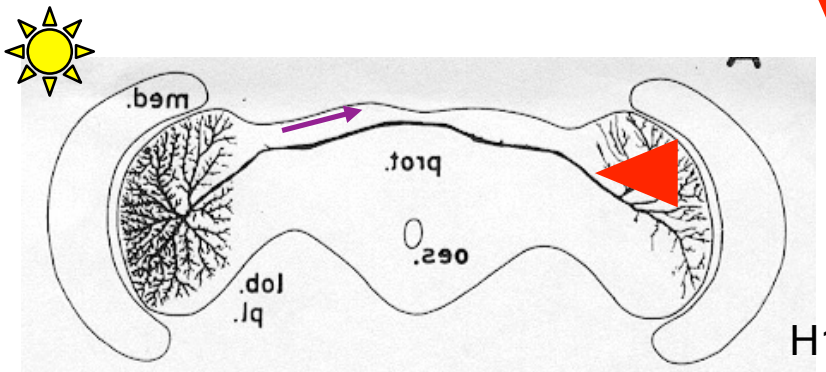
Lobula plate tangential cells
(~60 tans, 10 are spiking)



H1 cell

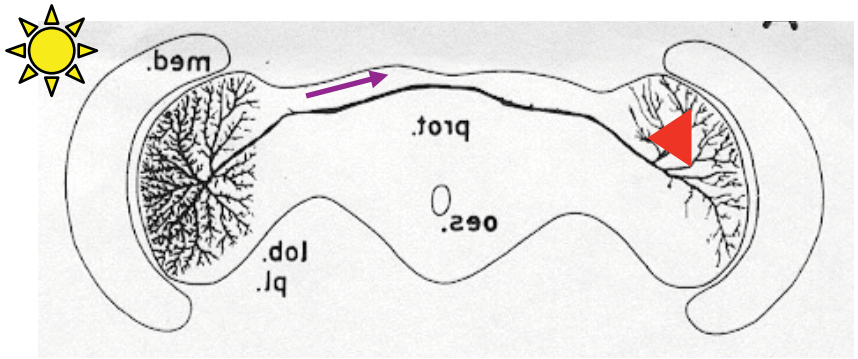


VS1 cell, Jurgen Haag



H1 cell

H1 cell



Viewed from behind the head

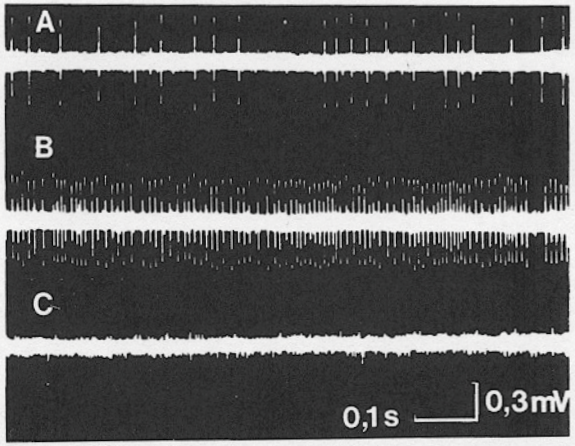
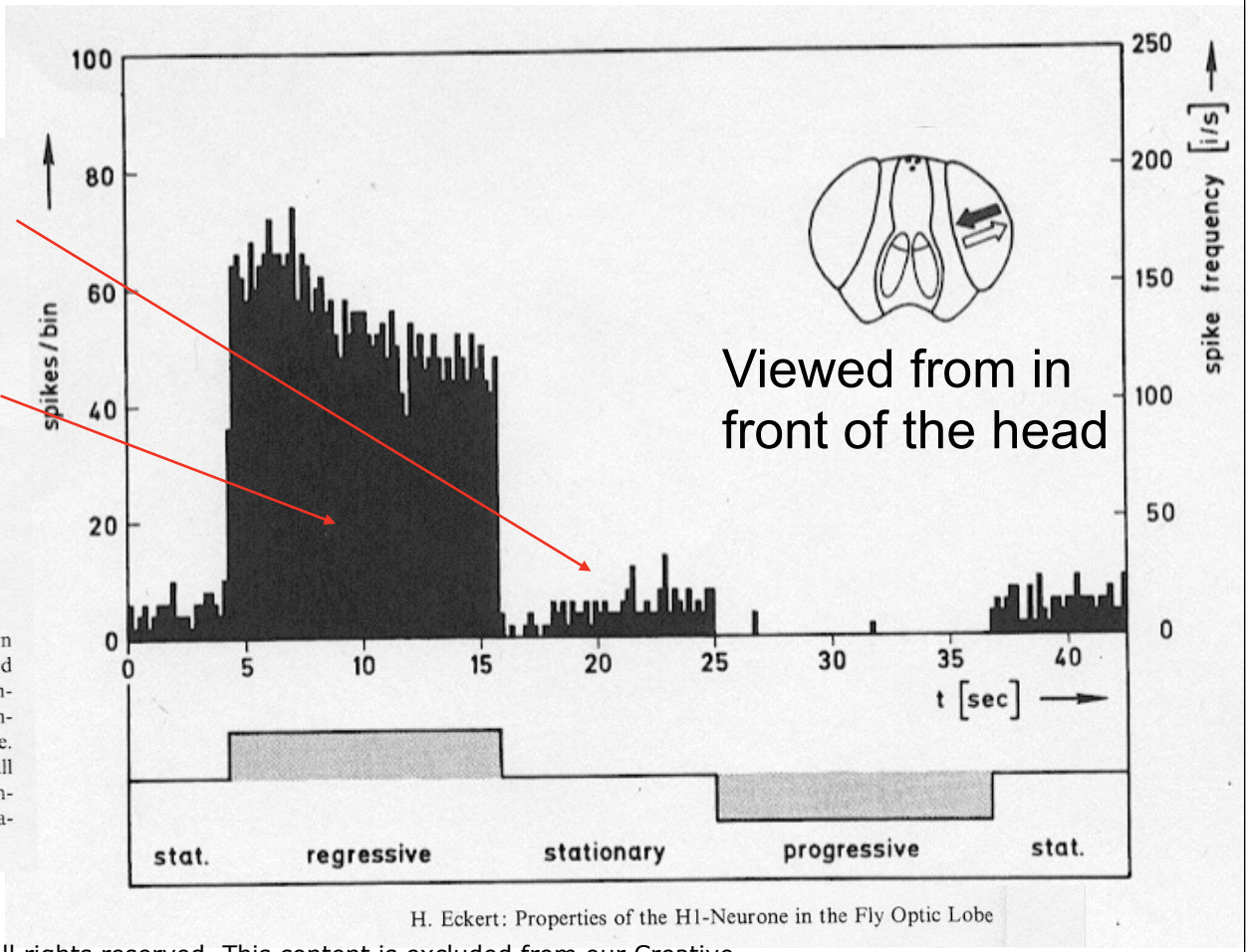


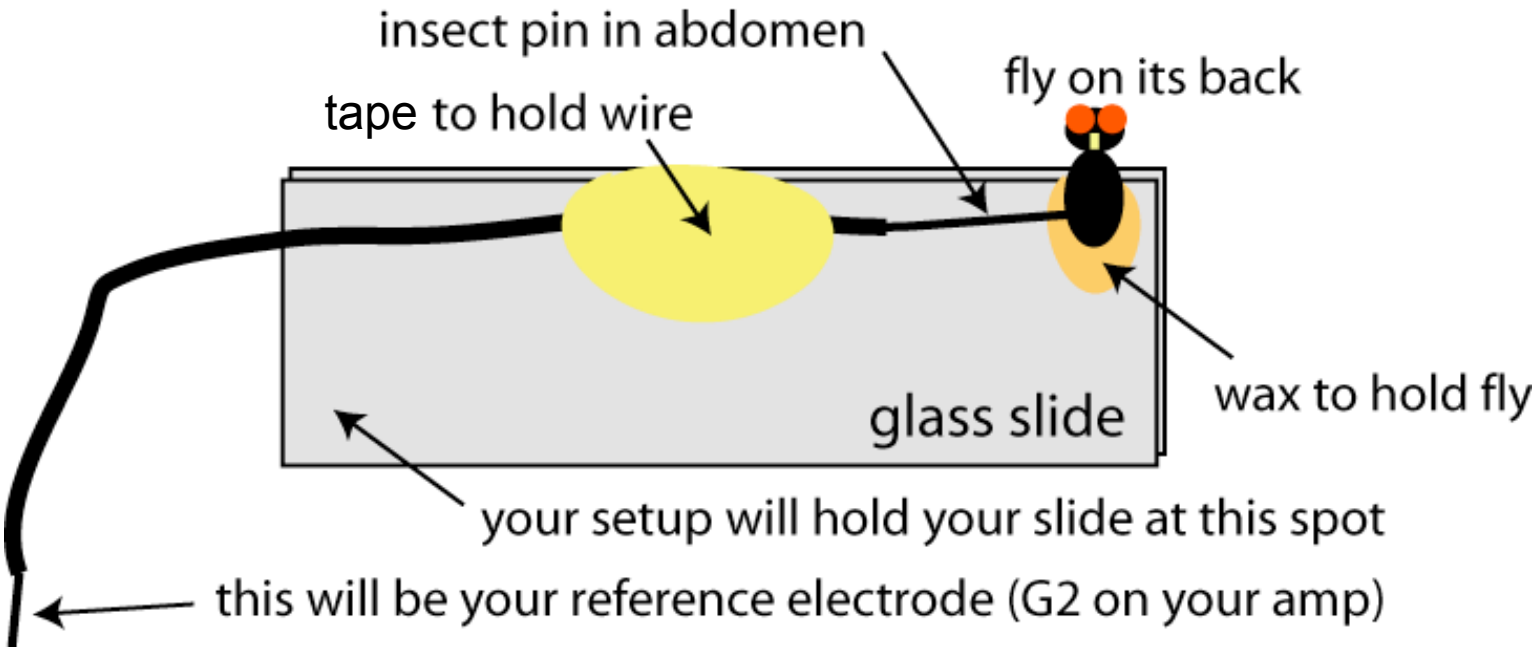
Fig. 3A–C. Response of the H1-neurone to a moving grated pattern 3 s after the onset of the stimulus. The more intensely reproduced part of the spike corresponds to a second peak of the action potential. The stimulus was presented to the contralateral eye. **A** Stationary pattern. **B** Pattern movement in the preferred direction, i.e. regressive. **C** Pattern movement in the anti-preferred direction (null direction), i.e. progressive. Pattern wavelength $\lambda = 21.5$ deg; contrast $m = 0.68$; angular velocity $w = 11$ deg/s; average pattern irradiance 0.08 mW/cm^2. *Phaenicia* ♀



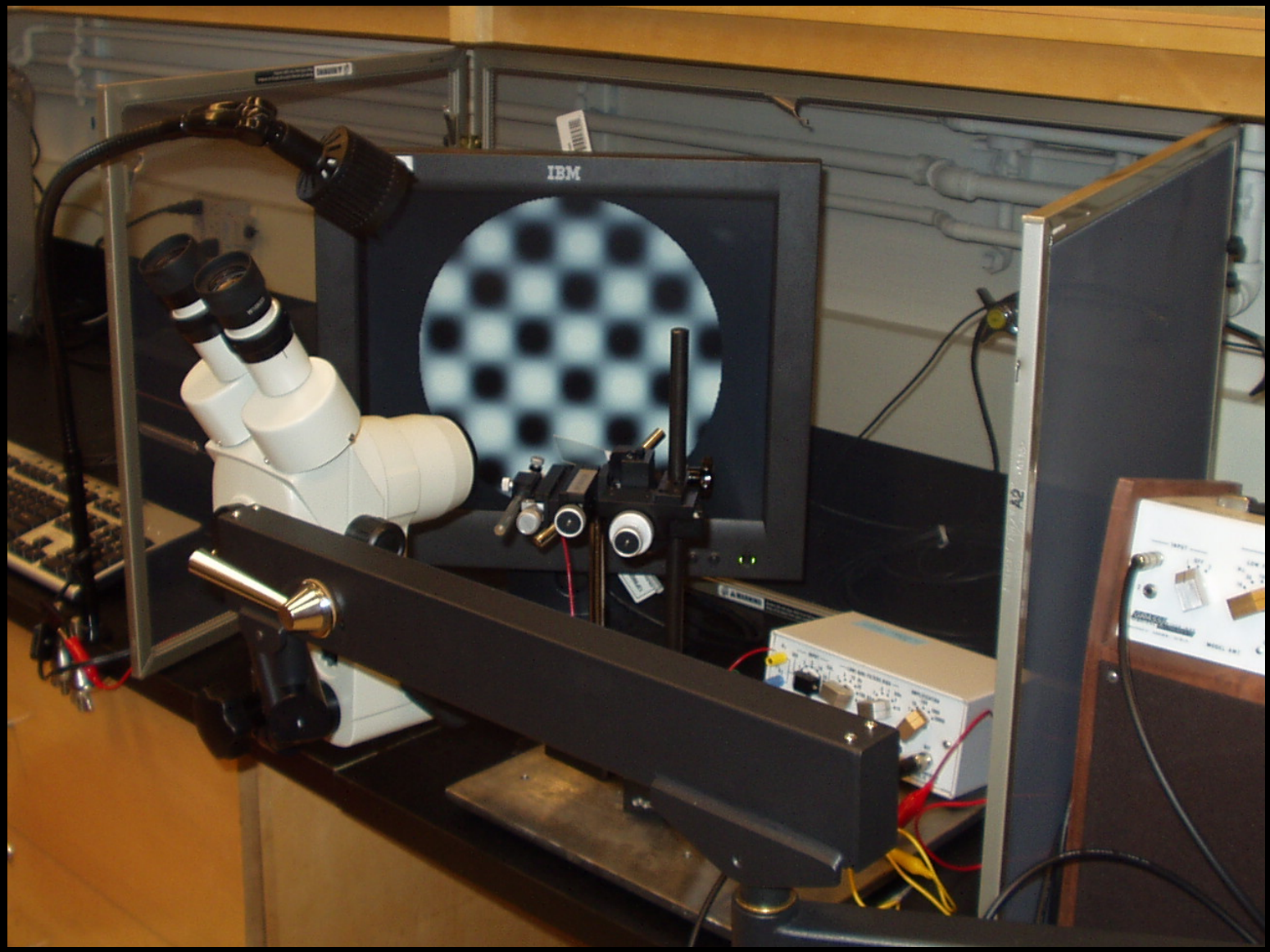
Preparation of the fly for dissection

Dissection of the fly for neuronal recording

Fly setup


insect pin in abdomen
fly on its back
tape to hold wire
glass slide
wax to hold fly
your setup will hold your slide at this spot
this will be your reference electrode (G2 on your amp)

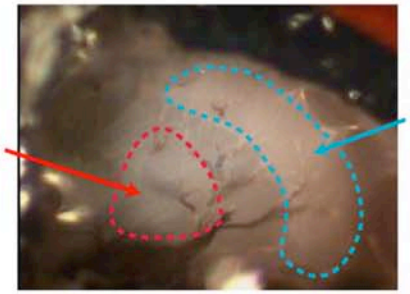
Fly setup

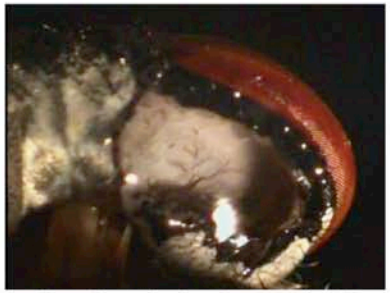


Dissection of the fly for neuronal recording

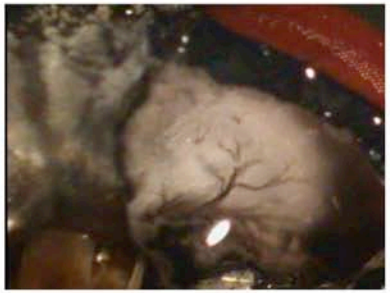
Step 5: Setup the fly in your recording rig, visualize neural structures, and place a recording electrode.

*** before proceding to your rig, you should place a reference electrode in the abdomen and secure it to the glass slide (see lab handout)**

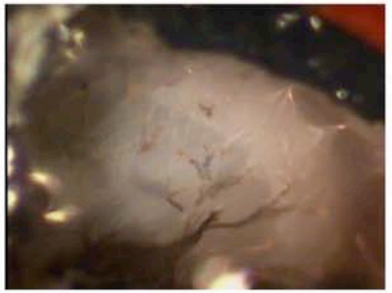




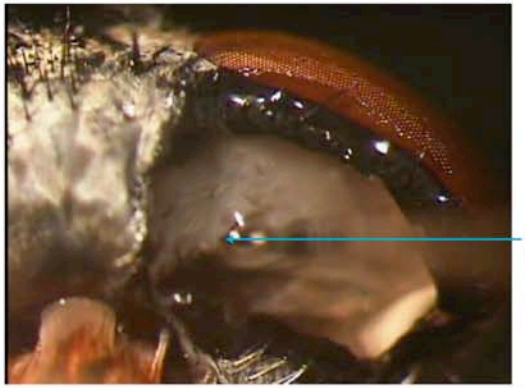
5.1 Note that saline has been applied. You should add saline from time to time to prevent the tissue from drying out.



5.2 Closer view.



5.3 Still closer. Structures are outlined above. If you have trouble visualizing neural structures, try adjusting your light. If you do not see everything perfectly, you can still try to record.



5.4 One electrode placement. The arrow is aligned aling the electrode entering from the right. The electrode tip is in the saline and just about to contact the tissue. It is at this point that you should turn on your amplifier, etc.

5.5 Another electrode placement. There is no magic spot, but you should aim your electrode near or medial to the lobular plate (even more medial than shown here), listen closely for neural activity, and not advance the electrode much beyond first contact with the tissue. (please see your lab handount for more details)

Your primary goals for FLY LAB 1

- Practice the fly preparation and dissection
- Practice recording from neurons
- Qualitative 'mapping' of visual responses from those neurons

Homework before Wed lab

- LAB NOTEBOOK for wed lab: how to record from fly
- QUIZ: today's lecture, how to record from fly, recitation paper
- QUIZ next week: Any of the above + Matlab code

9.17 Systems Neuroscience Lab

Spring 2013