



Brain and Behaviour

PSYC 304 922

T/TH 6 – 8:50 pm

FRDM Floor 1 Room 153

Acknowledgements

UBC's Point Grey Campus is located on the traditional, ancestral, and unceded territory of the xwməθkwəy̓əm (Musqueam) people. The land it is situated on has always been a place of learning for the Musqueam people, who for millennia have passed on in their culture, history, and traditions from one generation to the next on this site.



Introductions

Dr. Todd Kamensek

PhD, Neuroscience

- Visual Perception, face perception/recognition, Autism Spectrum Disorder, Prosopagnosia

Clinical Neurophysiology fellow, VCH

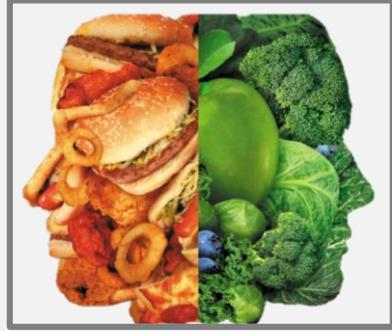
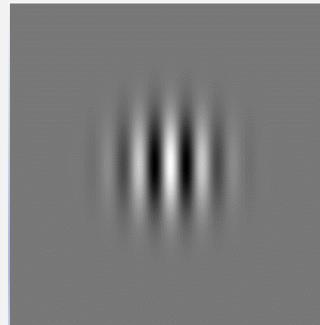
- *Intraoperative Neuromonitoring*

BSc, MSc. University of British Columbia

- General science (health sciences and math, minor psychology); Neuroscience

Hobbies

- Golf, volleyball, hockey, camping, surfing
- TV and film
- Learning about the brain



TA Details



Email response time:

24 – 72 hours



What the TA is here for!

Check and grade tweet machine assignments, midterms

Answer questions about grading

Help with comprehension of course material

Identify and implement effective study techniques



Contact:

raymond.macneil@psych.ubc.ca

ggu02@mail.ubc.ca

Raymond MacNeil

PhD Candidate working with Jim Enns in the UBC Vision Lab

Research looks to understand the brain and cognitive processes involved in visually-guided action, like reaching and grasping

In my free time, I like trail running, mountaineering, and caving.

Office hours: Weekly, Wednesday, 4:00 PM - 5:00 PM, Kenny Building, Room 3606, accessed via 3602 (Vision Lab).



About Me!

Hi my name is Gloria!

I just finished my first year Master's in Psychology in the Attentional Neuroscience Lab with Dr. Todd Handy

My research interests

My research looks at the effects of **weather** on **cognition** and **mood**. We examine how changes in day-to-day weather patterns change our ability to pay attention or remember things, as well as how we feel. Please reach out if you have any questions about the course, my research, or graduate school in general!



Introductions

Please take 5-10 minutes to speak with the students around you.

- Is this the first time meeting them in person?
- Anything exciting happen in the summer?
- How are we feeling about PSYC304?
- What are you hoping to get out of this class?



Highlights

Goals



Guidelines

(Will be added to the syllabus)

Respect!!

Syllabus

Learning Goals

By the end of term, you will...

1. Describe basic biopsychological processes.
2. Navigate behavioural neuroscience literature.
3. Relate the current literature and understanding of the brain and behaviour to your daily life.
4. Engage in discussions regarding current and contemporary topics in behavioural neuroscience.
5. Describe classical and state-of-the art techniques for studying neurons and brain function.
6. Have a contemporary view of the theories and research that has shaped our understanding of how the brain integrates information from our senses to create representations that can be stored as memories.
7. Understand and discuss the neurobiological underpinnings of stress, emotion, sleep, addiction, motor control, consciousness, and attention.

Syllabus

Learning Appraisals (Full course grade breakdown)

Grade breakdown		
Tests	4 non-cumulative tests	82%
Tweet Machine	8 tweets over two semesters (basically free marks!)	4%
Reading club	Read real empirical research!	12%
Bonus HSP	Research experience component	3%
Syllabus Quiz		2%
	Total	103%

Syllabus

Exams

- This course is split into 4 sections, each followed by a non-cumulative exam
- Each exam is roughly 60 minutes and is composed of multiple choice and short answer questions
- The 2nd and 4th exams will take place during the final exam periods. Do not make travel plans until you know the date of your final exams. You cannot take the final at a different time.
- Exam will be closed book and Zoom invigilated – Webcams are essential for ensuring a fair synchronous Zoom exam. The exam will be recorded.
- Canvas tracks how often you leave the page and your key strokes on short answers.

Syllabus

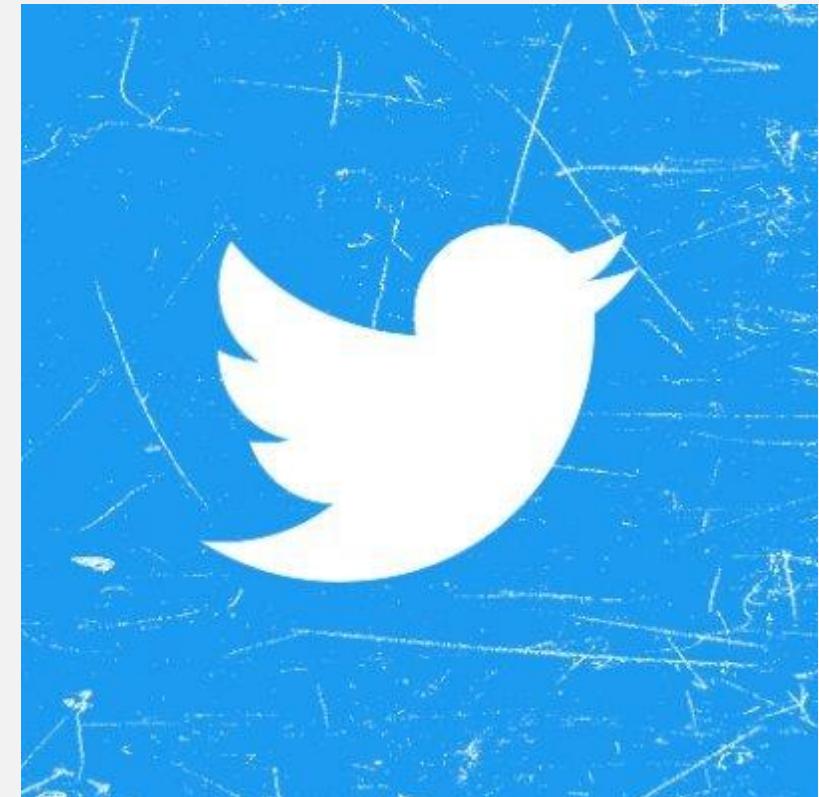
Exams

- You may be asked to show your student card/share you screen during the exam
- Arriving late: A student will not be allowed to write an exam if: they are more than 30 minutes late – OR – a student has already completed the exam
 - Students in this situation will receive a 0
- There will be in-class exam reviews following each exam (time-permitting)
- Any grade change requests must be made in writing to Todd

Syllabus

Tweet Machine

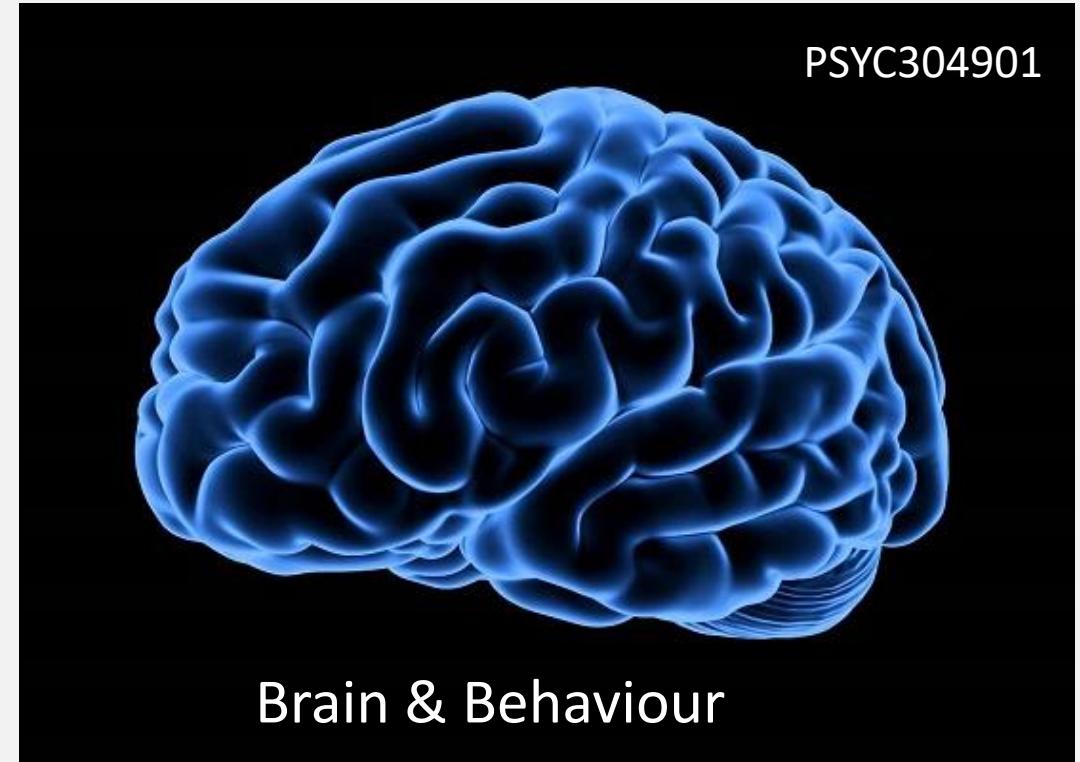
- Starting following week 1, 4% of your final grade (*2% each semester*) will be earned by uploading a screenshot of a 280-character Tweet, or tweet draft (in Word) for each eligible week of the course.
- The tweets are meant to promote weekly engagement with the course material while highlighting and expanding on topics introduced in the course.
- Relating newly learned material to your own experience is called semantic learning and is a powerful tool for memory consolidation. Creativity is recommended! Select tweets will be featured in Canvas each week.
- Simply stating that the topics covered that week were interesting, or reiterating course material verbatim will not be counted. ***Please no generative AI!***
- ***You must complete 4 of 5 tweets each semester for full marks***



Syllabus

PSYC 370 Research Club (2 PPTs x 6% each)

- Students will create a 9-10 slide recorded PPT lay-summary of a select empirical article.
- Each article will be provided by the instructor and students will sign up prior to the article becoming available.
- Detailed instructions and grading rubric will be provided on Canvas.
 - 9-10 slides, 7-8 minutes long
 - “Lay-summary” – a non field expert could understand the presentation – have fun and be creative!
 - You may have to choose specific information from the article to share, that is up to you!



Course Policies

Lectures and Readings

- Course content will be presented in a variety of formats including traditional lectures, student presentations, and in-class discussions/activities. Regular attendance is highly recommended.
- Lecture slides will be uploaded to Canvas just before class. Lecture slides will be numbered to facilitate note taking.
- Lectures will be recorded – but start of class reviews, and in-class discussion will not be captured. Attendance recommended.
- **Study tip:** try to take notes on your own, then combine with the provided slides afterwards!
- The provided, **optional** readings are meant to supplement your understanding of the content covered in lecture. For exams, you are responsible for all material covered in-class (lecture and assigned literature review readings). Material found in the selected textbook readings not covered in class will not be tested.

Course Policies

Emails

- In most cases, emails will be answered within 2 business days.
- Please include “PSYC 304” in the subject line.
- For specific questions about assignments, grading, and exam viewings please contact your TA.
- For specific questions about material covered in class, or any other comments, questions, or concerns please contact Todd.

Course Content Questions

- We will be using **Piazza** for asynchronous class discussion. See syllabus online for class sign up

Course Policies

Exams

- If you miss an exam for a valid reason, without notice, (see [UBC Vancouver Senate's Academic Concession Policy V-135](#)) you must contact Todd within 72 hours of the exam date and you may need to submit a request for academic concession. For a missed exam, the weight will be equally transferred to the other 3 exams.

Accommodations

- Please let Todd know as soon as possible if you will be seeking accommodation through the Centre for Accessibility or if you have religious obligations that will conflict with this course in any way.
- Students who plan to be absent for varsity athletics, family obligations or similar commitments cannot assume they will be accommodated and should discuss their commitments with Todd before the withdrawal date (May 27th).



Lecture 1 ‘Seeing’ Neurons

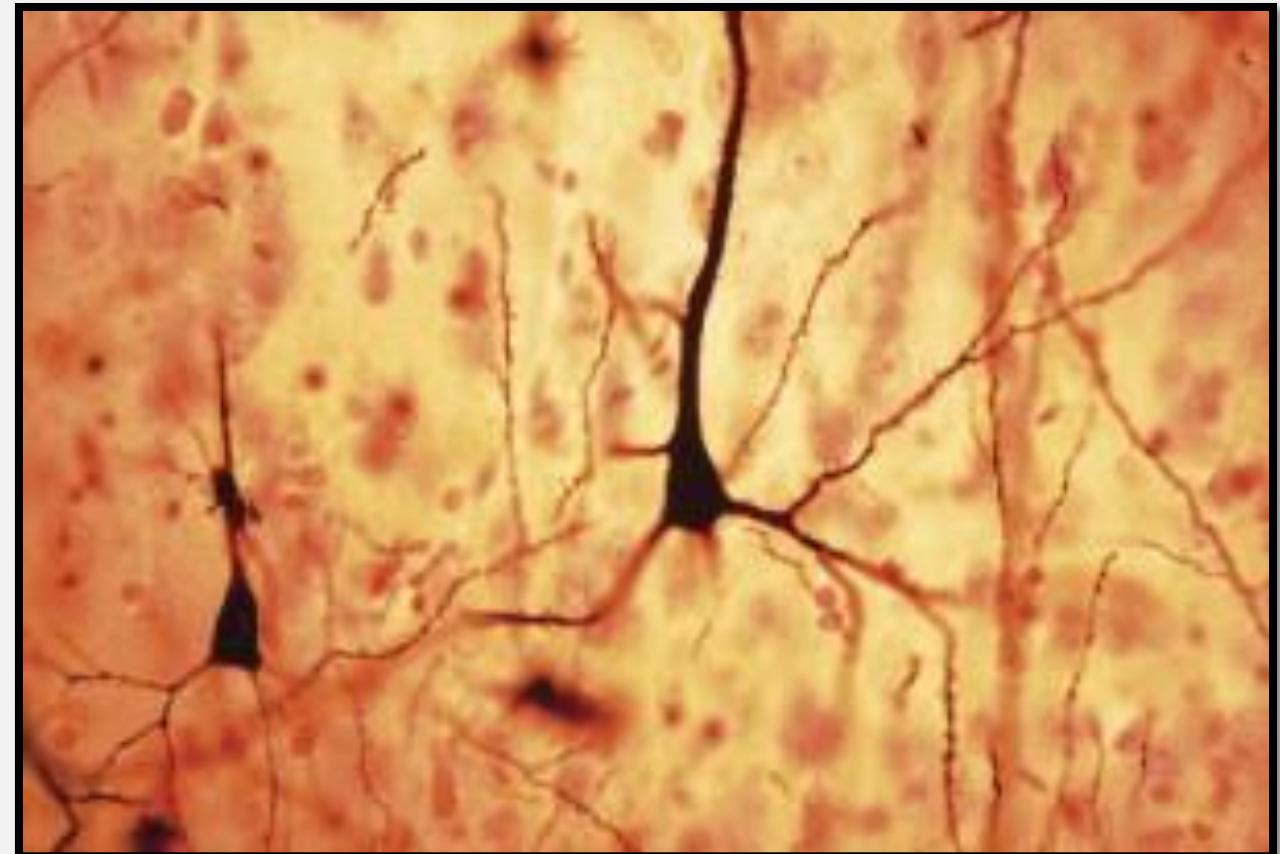
PSYC 304-922

May 13, 2025

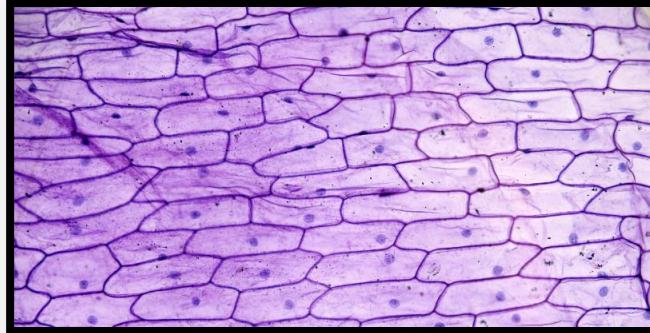
Neurons & Circuits: Learning outcomes

By the end of lecture, you will...

1. Appreciate that neurons and circuits are the foundational units of brain function.
2. Be able to label and differentiate between different types of neurons.
3. Be able to evaluate methods for identifying neurons as anatomical building blocks, including Golgi, dye injection, genetically-encoded fluorescent proteins, immunohistochemistry, electron microscopy and brain clearing
4. Understand research applications for different visualization techniques.



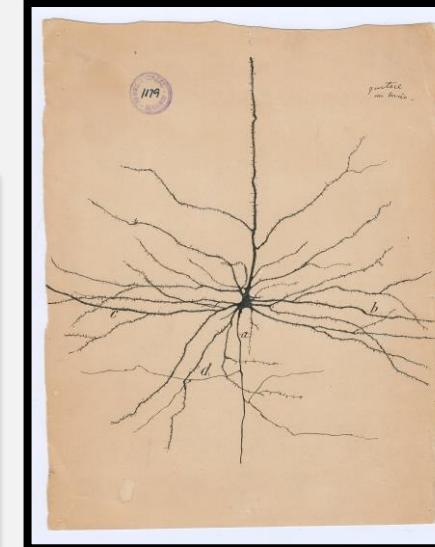
Neuron Doctrine



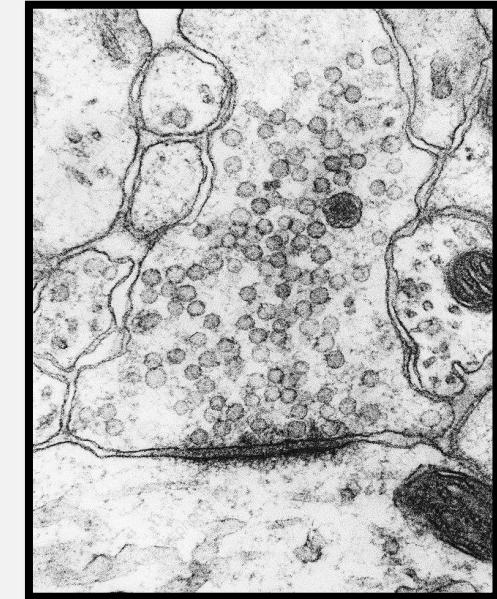
- Cell theory – 1830s
 - Theodor Schwann, Matthias Jakob Schleiden



- Reticular Theory
 - Camillo Golgi (1873) – Silver stain

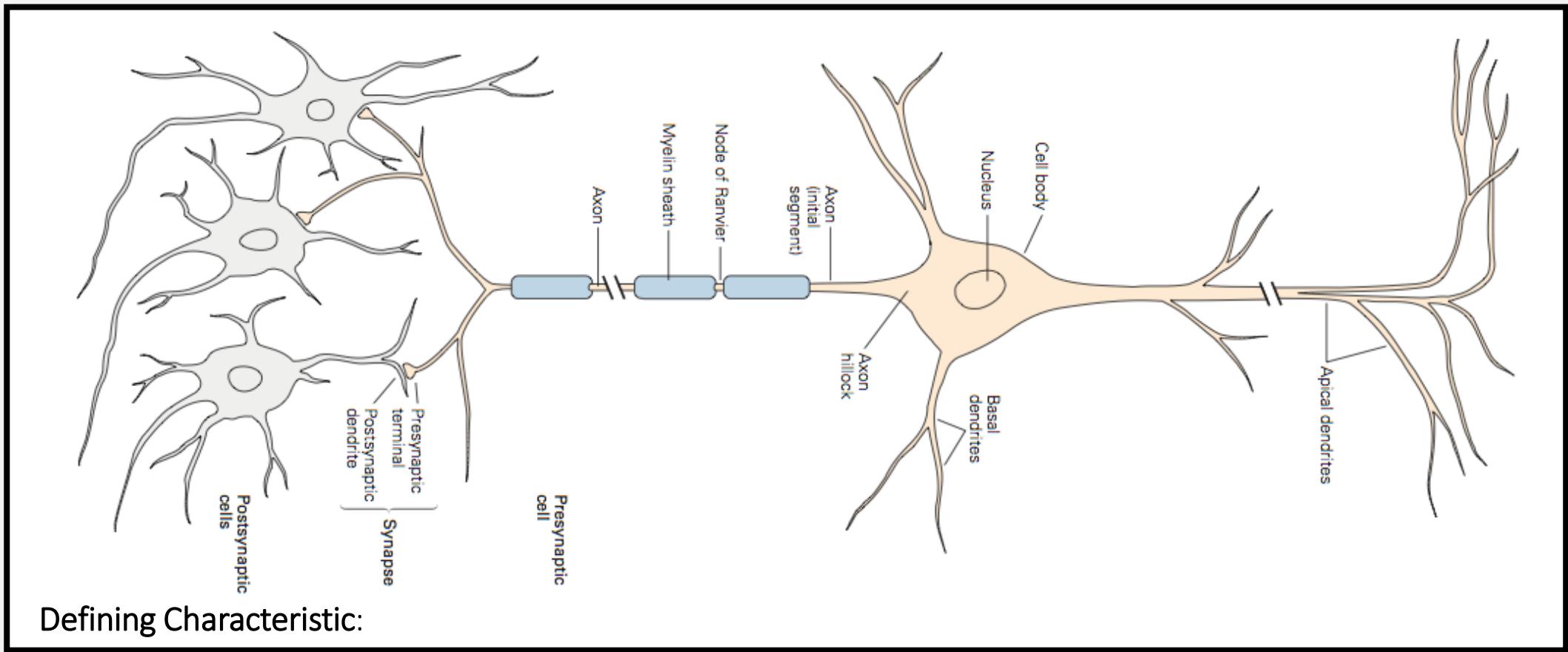


- Ramon Y Cajal (1889)



- Electron Microscopy (1950s)

A prototypical vertebrate neuron

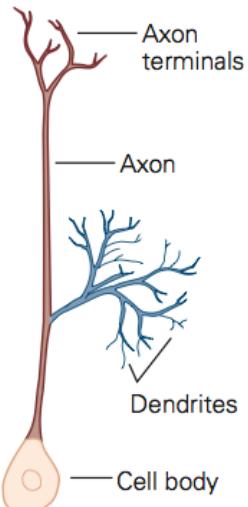


Kandel Fig 2-1

Many different types of neurons...

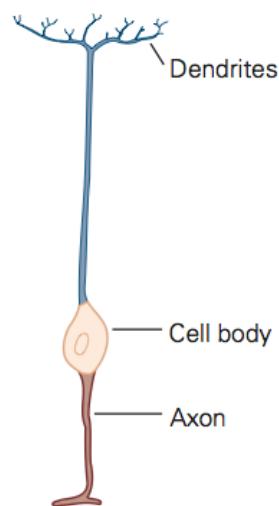
(what makes them different?)

A Unipolar cell



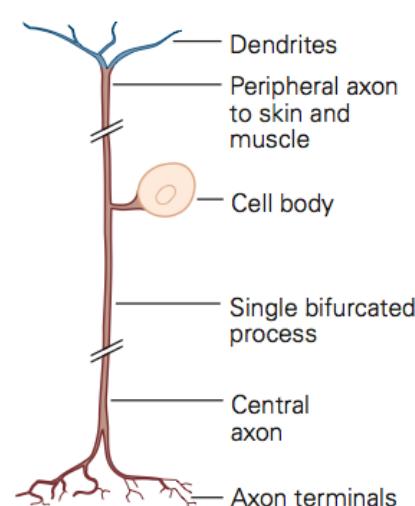
Invertebrate neuron

B Bipolar cell



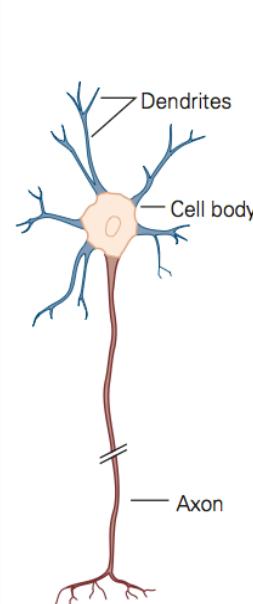
Bipolar cell of retina

C Pseudo-unipolar cell

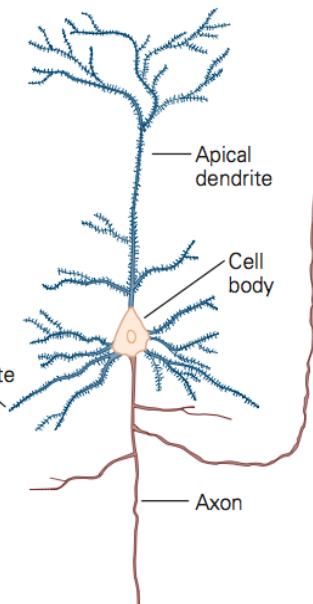


Ganglion cell of dorsal root

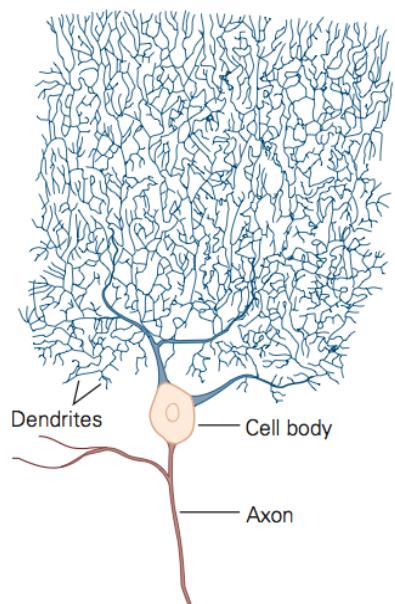
D Three types of multipolar cells



Motor neuron of spinal cord

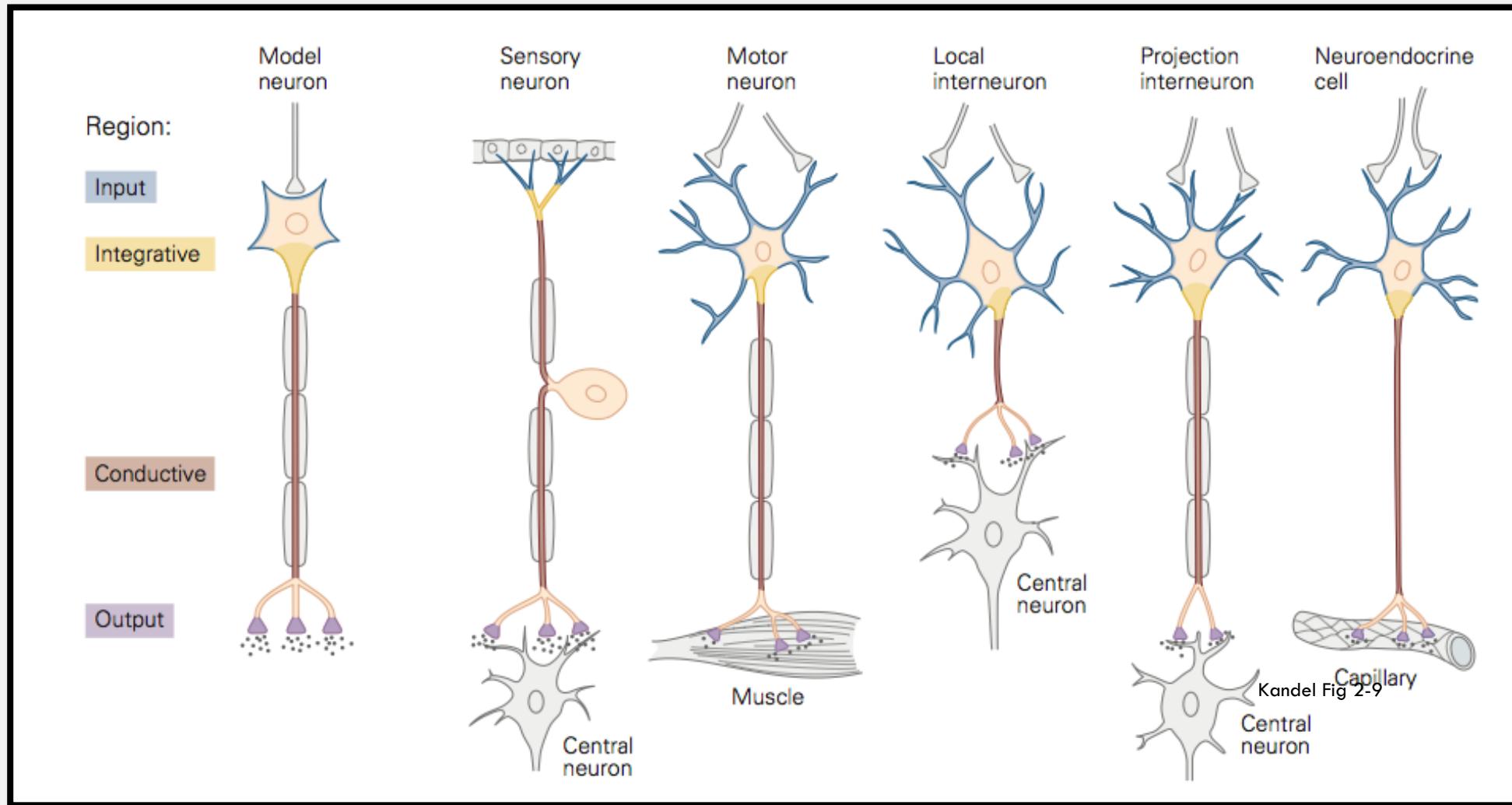


Pyramidal cell of hippocampus



Purkinje cell of cerebellum

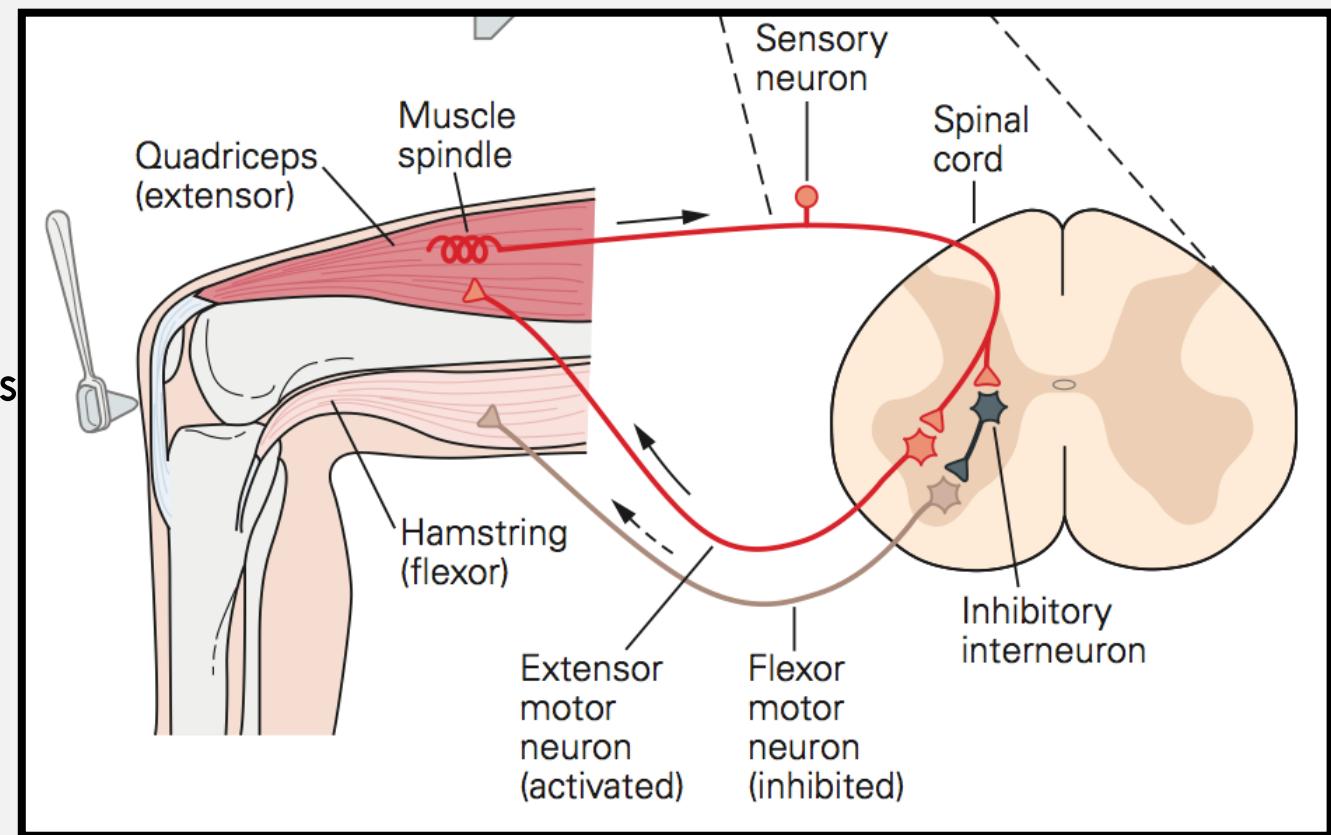
Similar functions



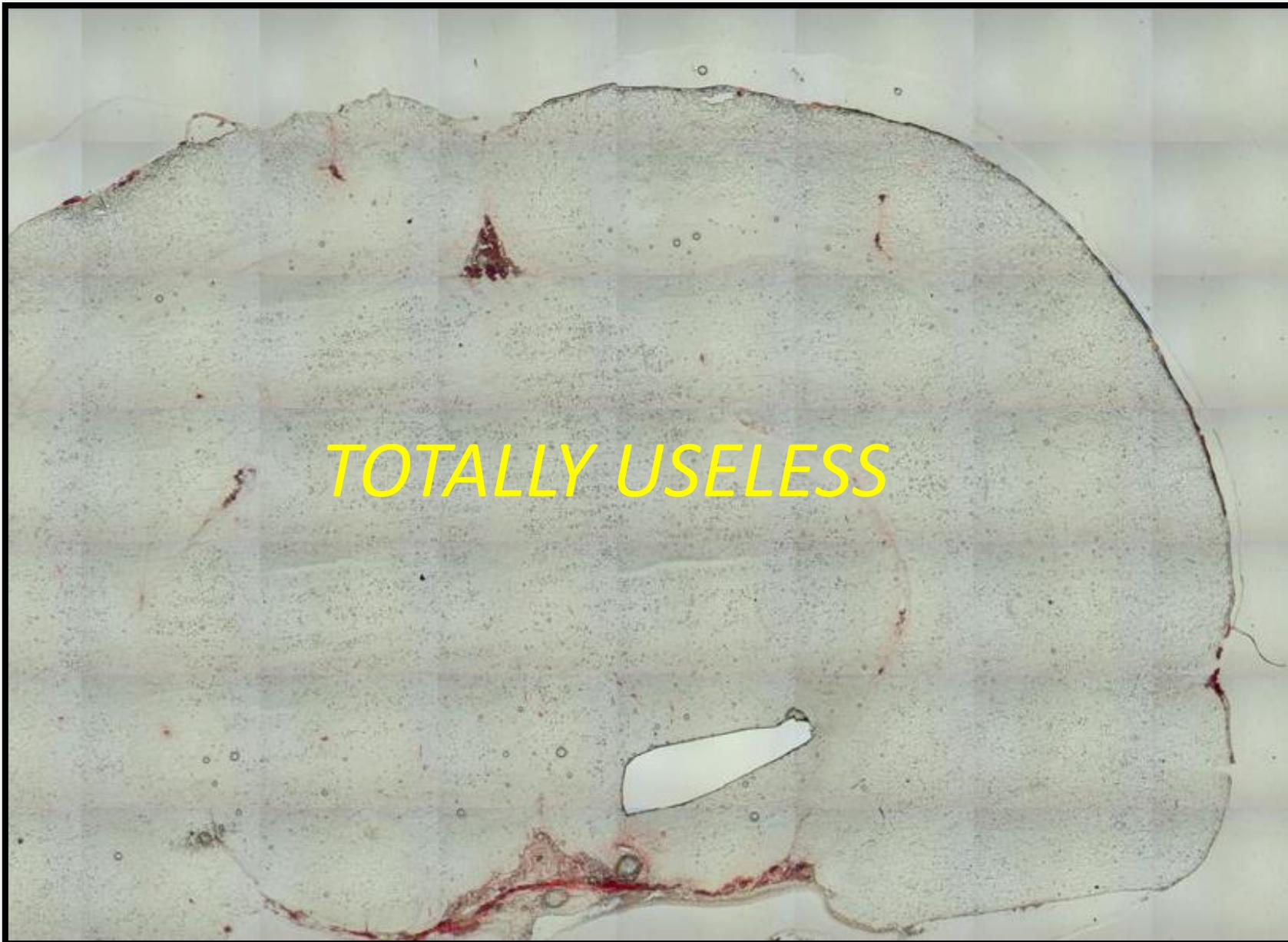
A surprisingly challenging problem:

Visualizing a neurons anatomy and connectivity in a circuit

- **Connectome** = the wiring/synaptic connectivity of all neurons
- Know connectome for a circuit - infer its function
- *What else can you do if you know the connectome?*



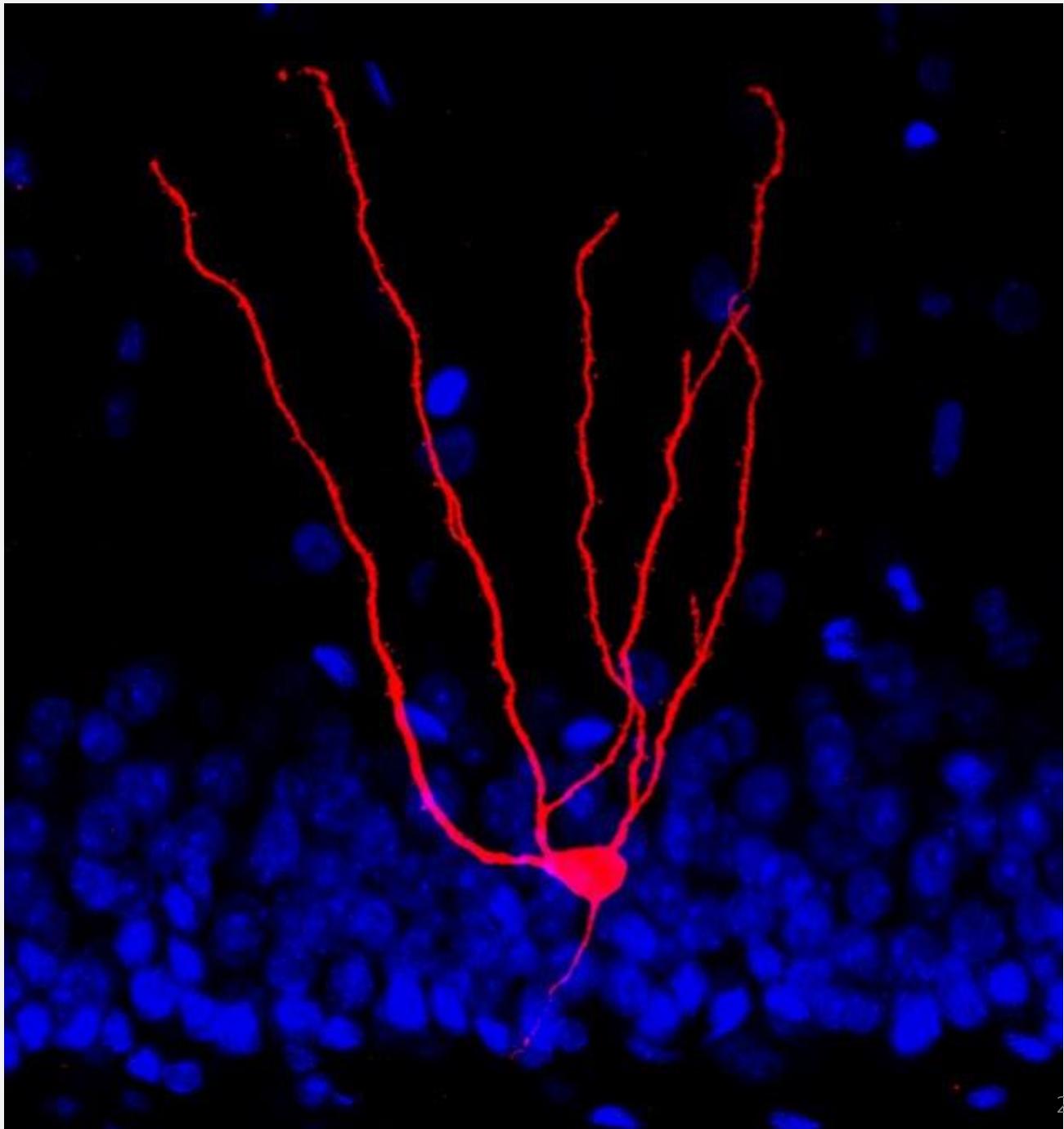
Mouse brain slice, unprocessed



TOTALLY USELESS

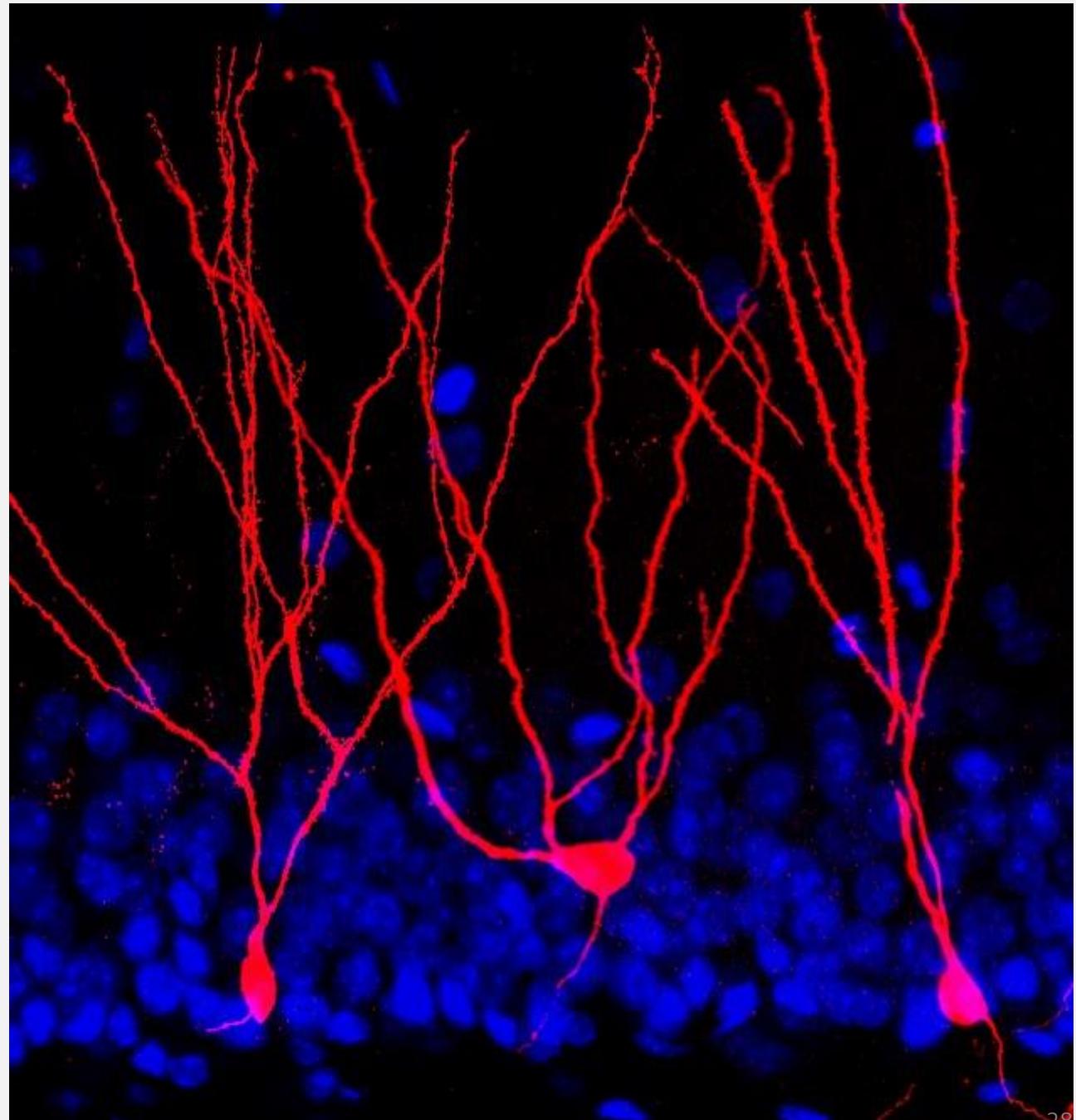
Visualizing Neurons

- Seeing only one neuron makes it easy...



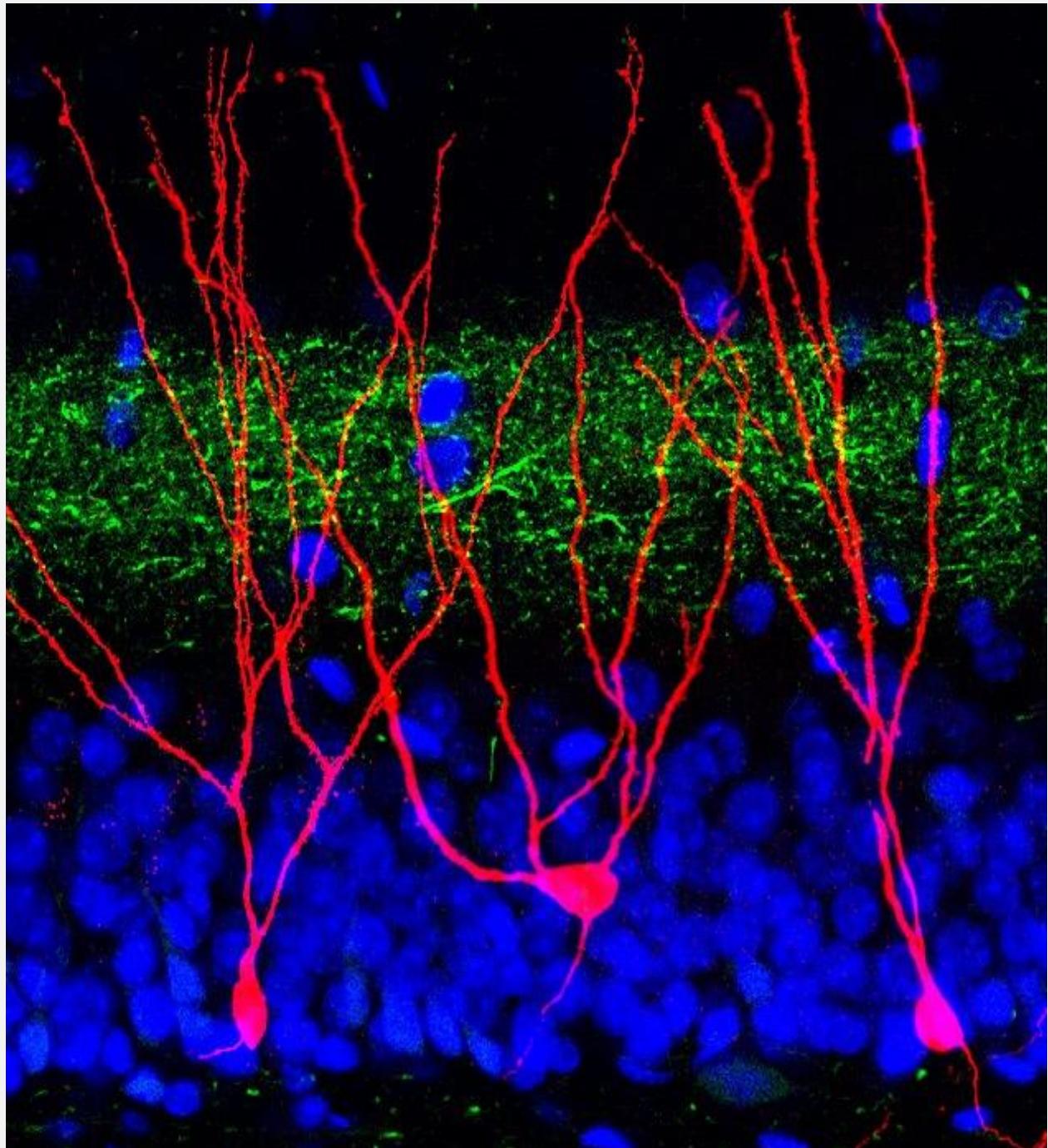
Visualizing neurons

- Seeing only one neuron makes it easy...
- But we want to picture circuits, so we stain a few more



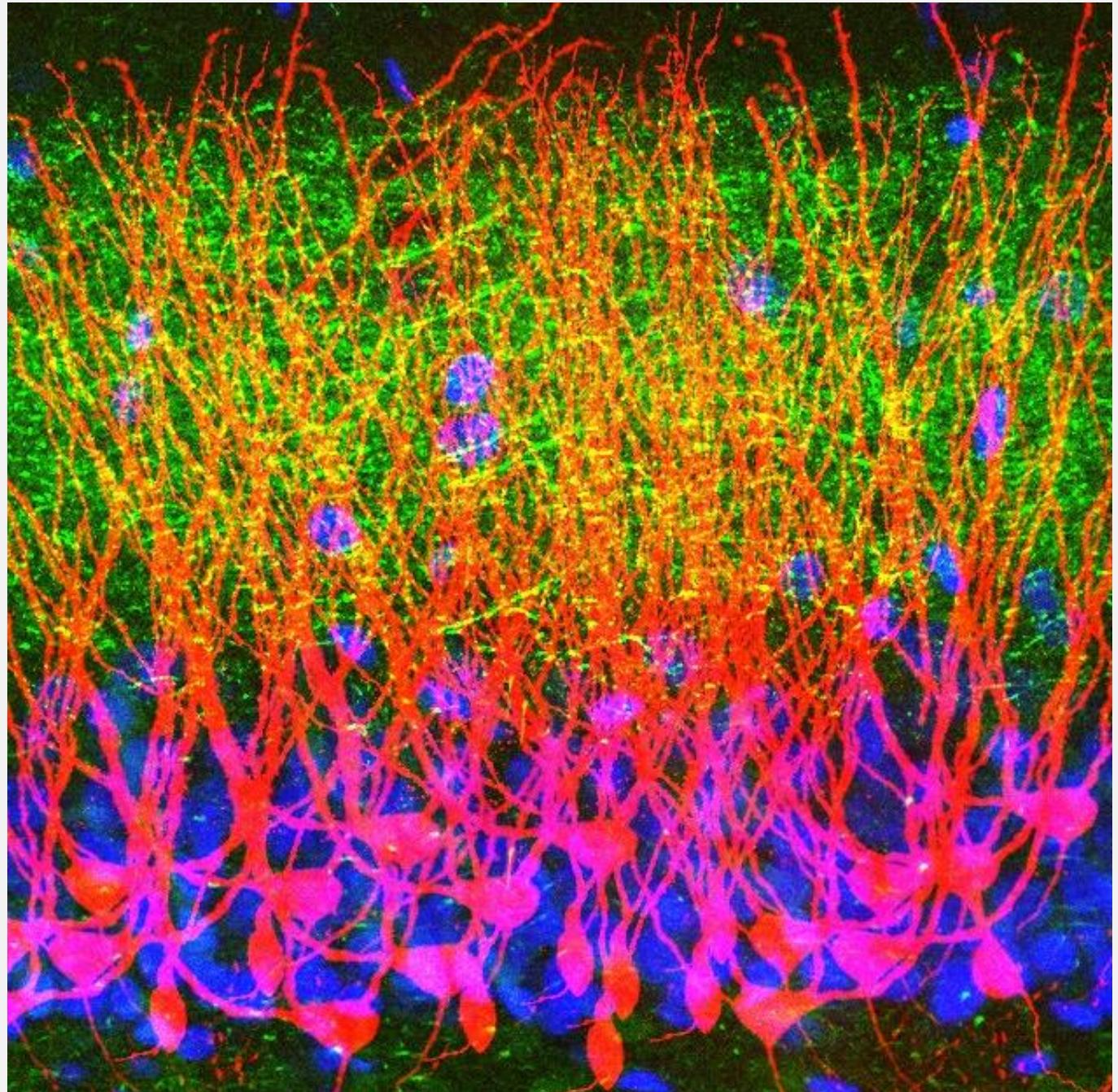
Visualizing neurons

- Seeing only one neuron makes it easy...
- But we want to picture circuits
- Stain a few more
- Stain a few other cell types



Visualizing neurons

- Seeing only one neuron makes it easy...
- But we want to picture the circuits
- Stain a few more
- Stain a few other cell types
- But now too many cells are labelled!



How do we visualize neurons?

Complementary approaches

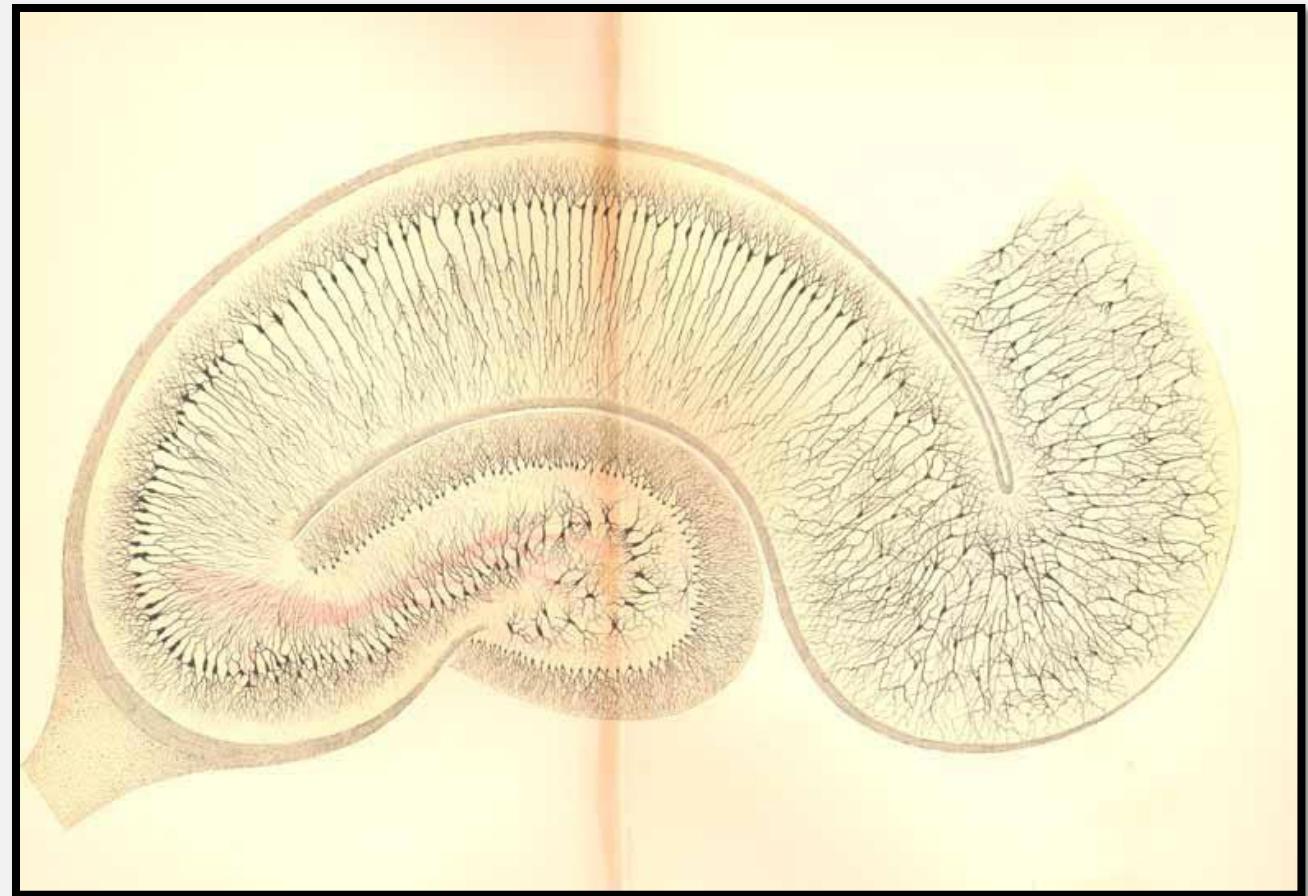
- dead tissue
- live tissue
- based on specific cell type or presence of specific molecules
- cheap vs expensive
- low vs high resolution
- easy vs hard
- fast vs slow

***Each has advantages and disadvantages (but whether an advantage or disadvantage depends on the experiment)

Methods for visualizing neurons

Method 1: The Golgi stain

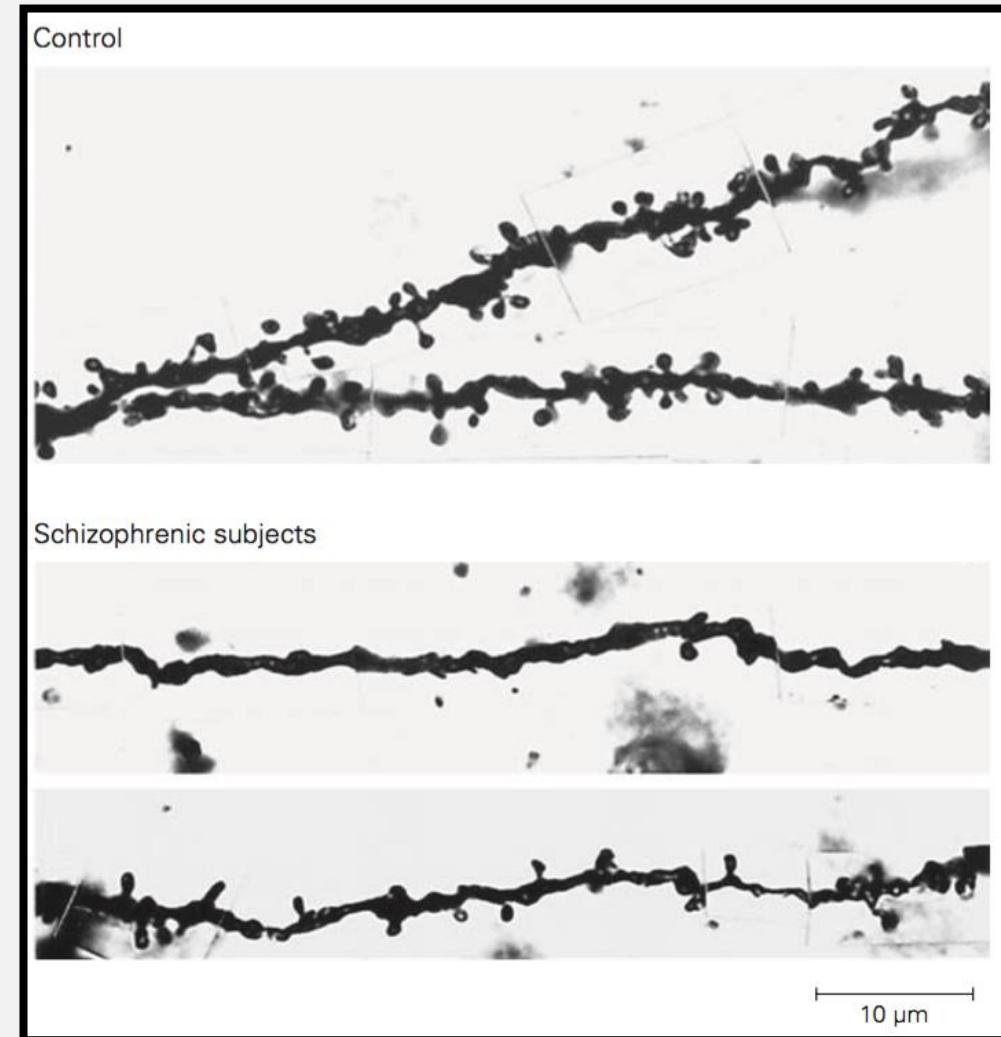
- chemical process that causes silver impregnation in neurons
- small % of neurons labelled
- unknown why some are labelled and not others
- can be used on dead tissue, including humans
- tried and true technique; relatively easy



Method 1: Golgi Stain

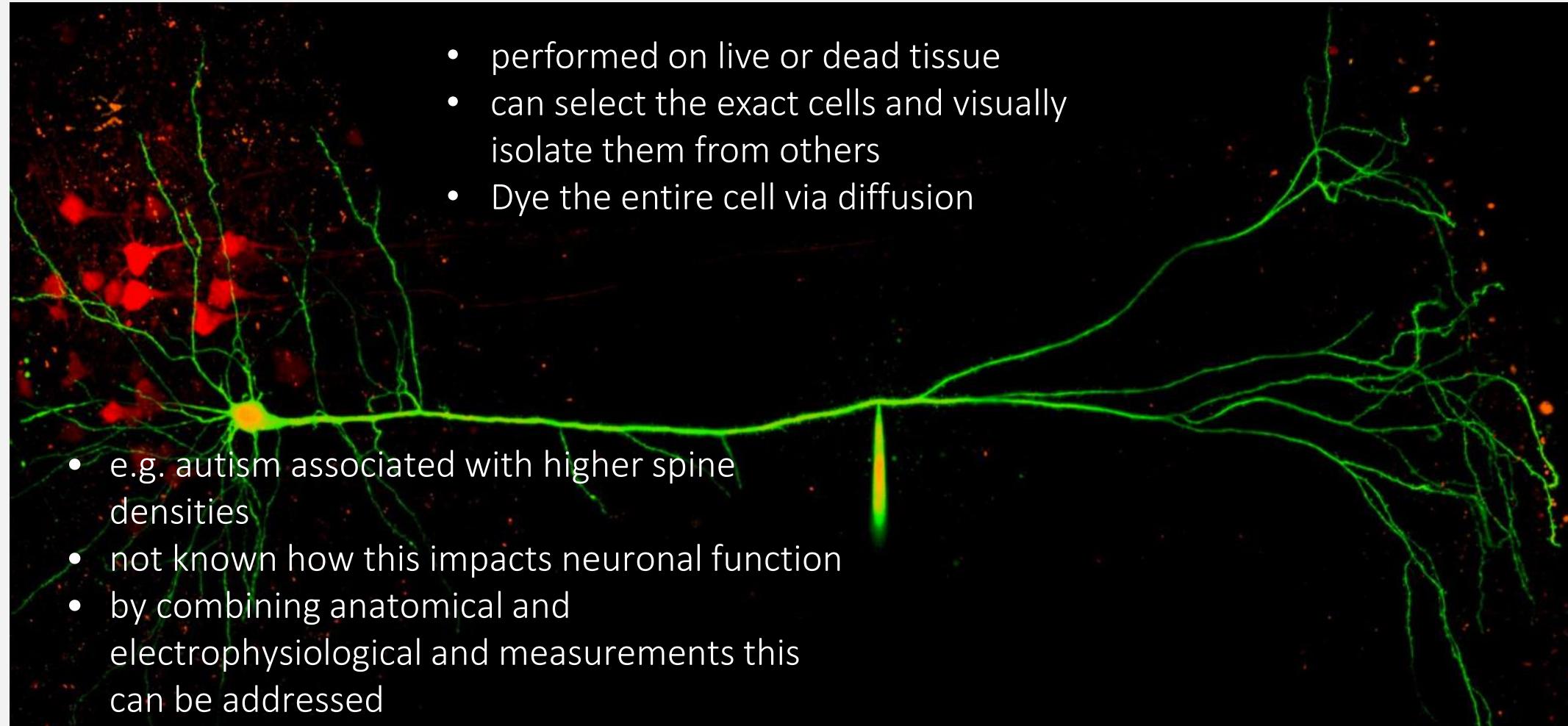
Golgi Stain in action

- The prefrontal cortex develops over the first decades of life
- synapses are pruned
- schizophrenia is a developmental disorder
- patients have fewer spines in prefrontal cortex



Kandel
Fig 62-4

Method 2: Dye filling neurons



- performed on live or dead tissue
 - can select the exact cells and visually isolate them from others
 - Dye the entire cell via diffusion
-
- e.g. autism associated with higher spine densities
 - not known how this impacts neuronal function
 - by combining anatomical and electrophysiological measurements this can be addressed

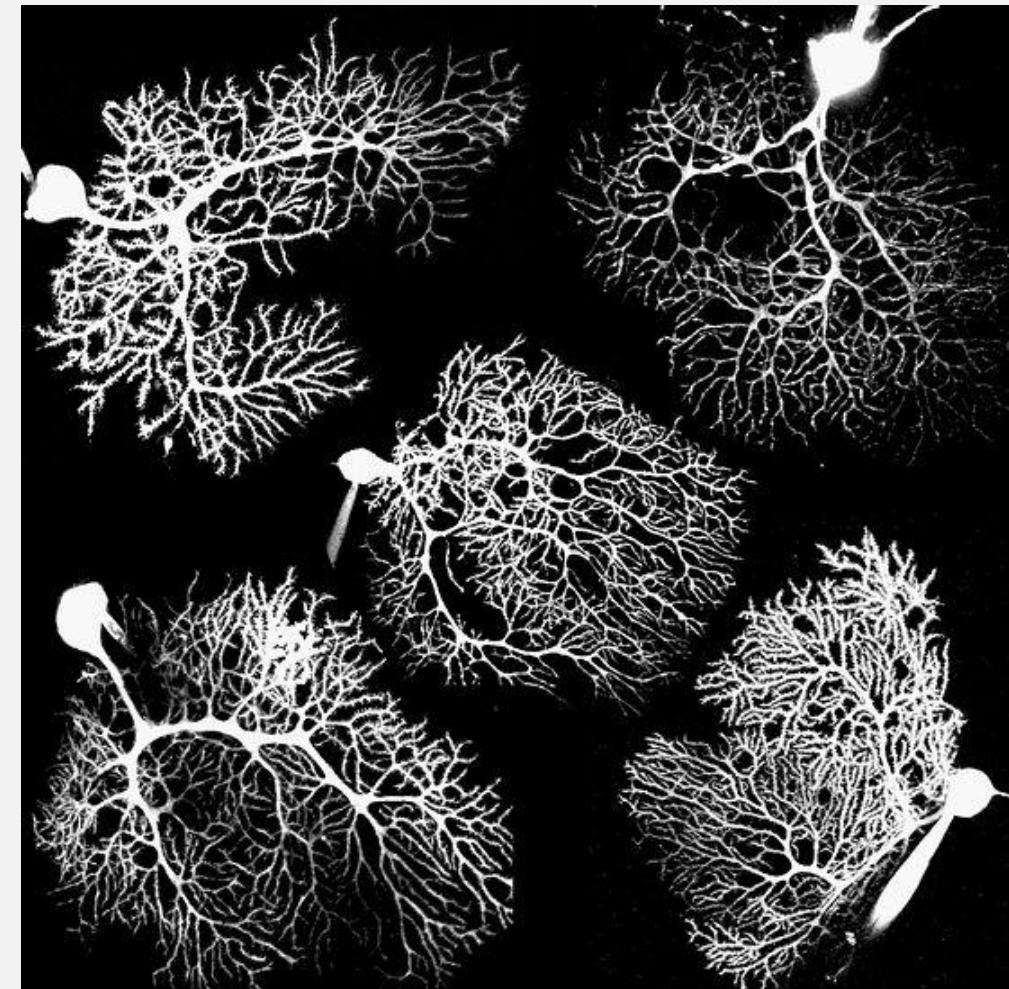


Interstellate

Method 2 – dye filling

Cerebellar Purkinje neurons

- What can we tell from the anatomy revealed?
- Can you spot the glass pipettes?

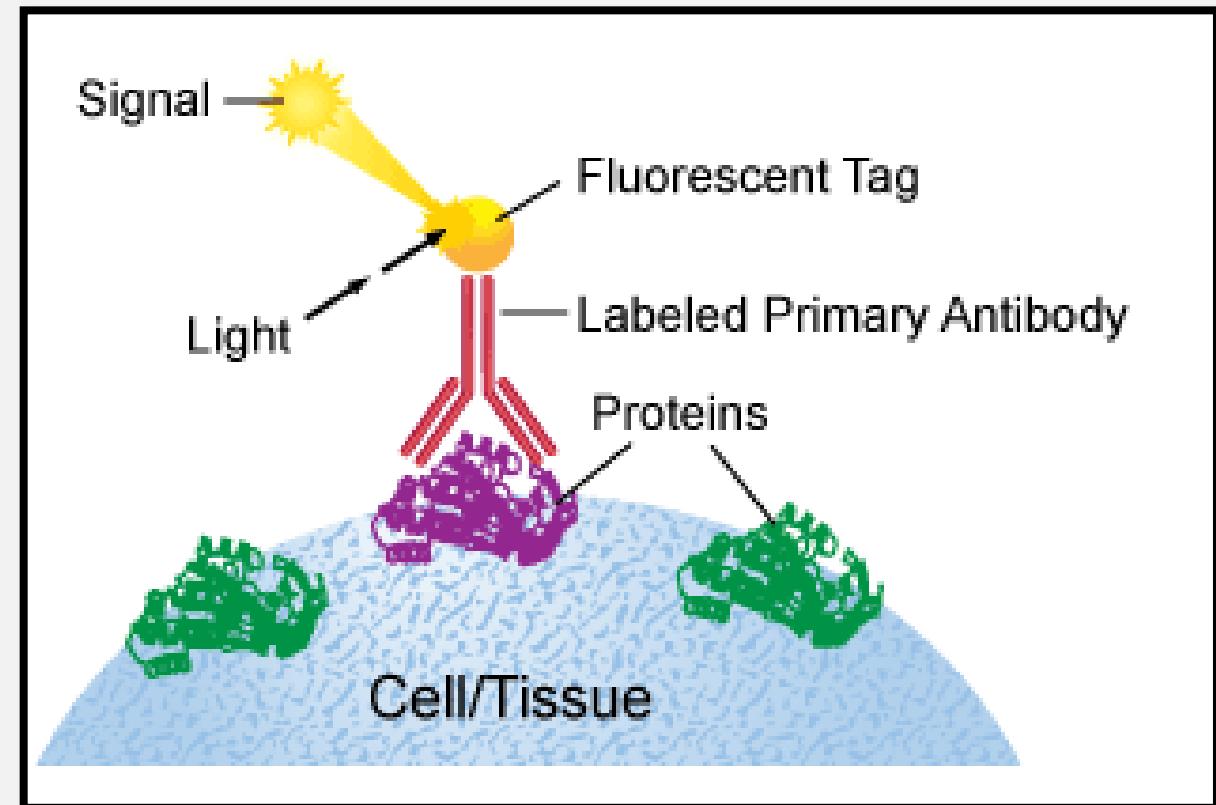




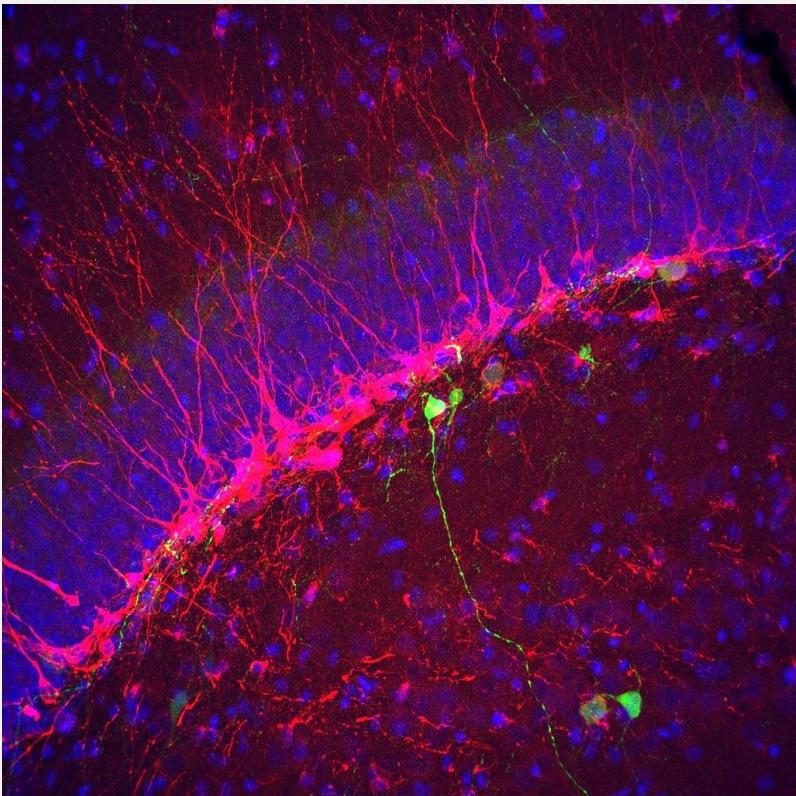
End of lecture 1

Method 3: Immunohistochemistry

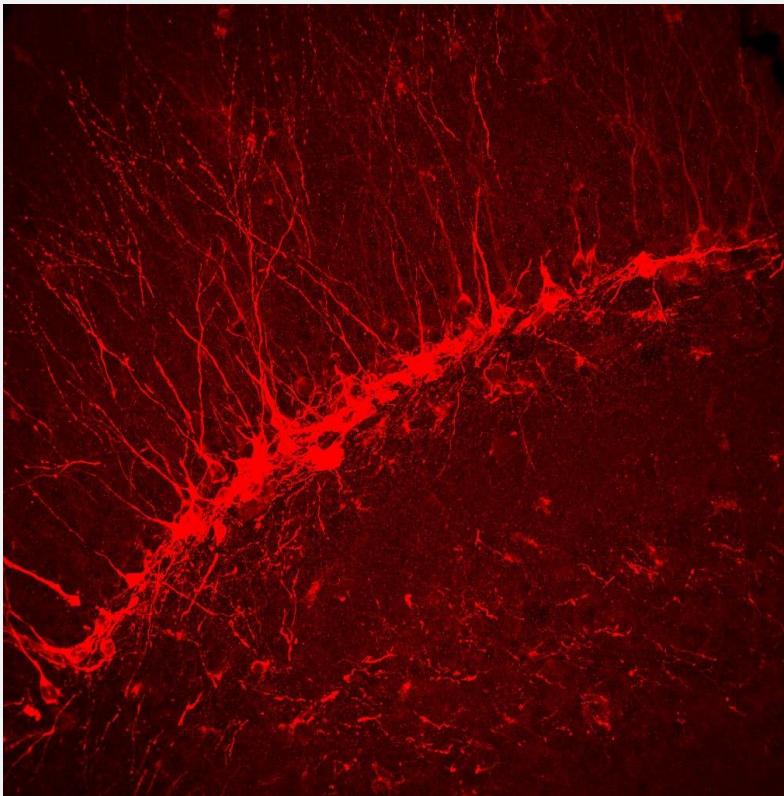
- Targets/identifies any specific protein (antigen) – biomarker localization
- can combine multiple antibodies to examine multiple cell types in same tissue, localization of different molecules within the same cell, etc.
- dead tissue, can be used on human tissue
- relatively cheap and feasible with standard technology
- has been used to show that one of the first pathological signs of Alzheimer's is a loss of synaptic proteins



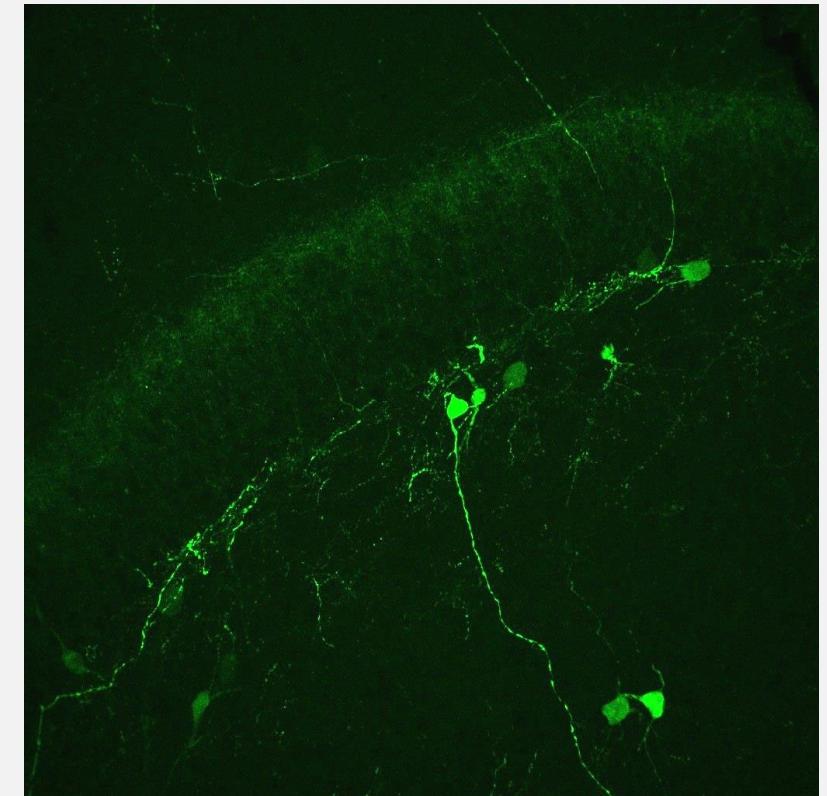
Immunohistochemistry example



DAPI (all cells)



Doublecortin (immature neurons)



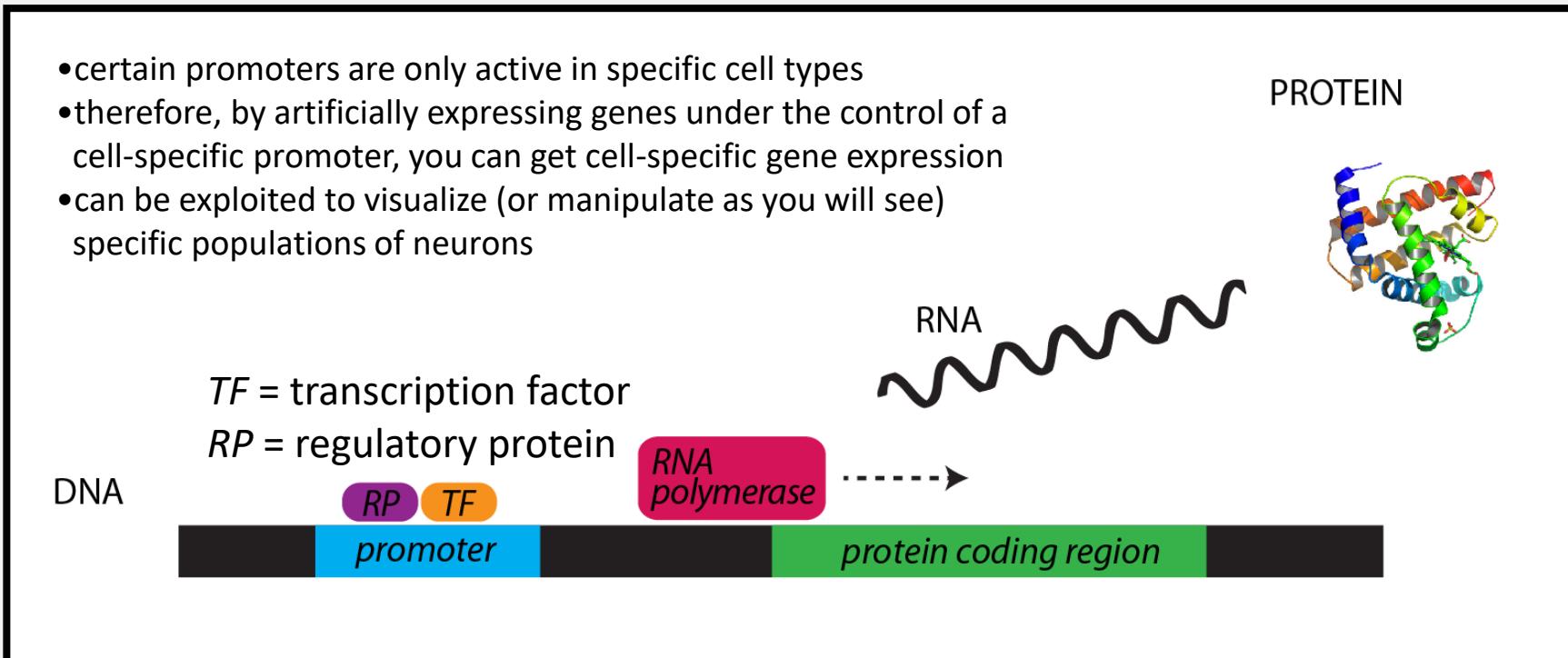
Calretinin (subtype of inhibitory interneuron)

Method 4: Genetically-encoded fluorescent proteins



Regulation of gene expression 101

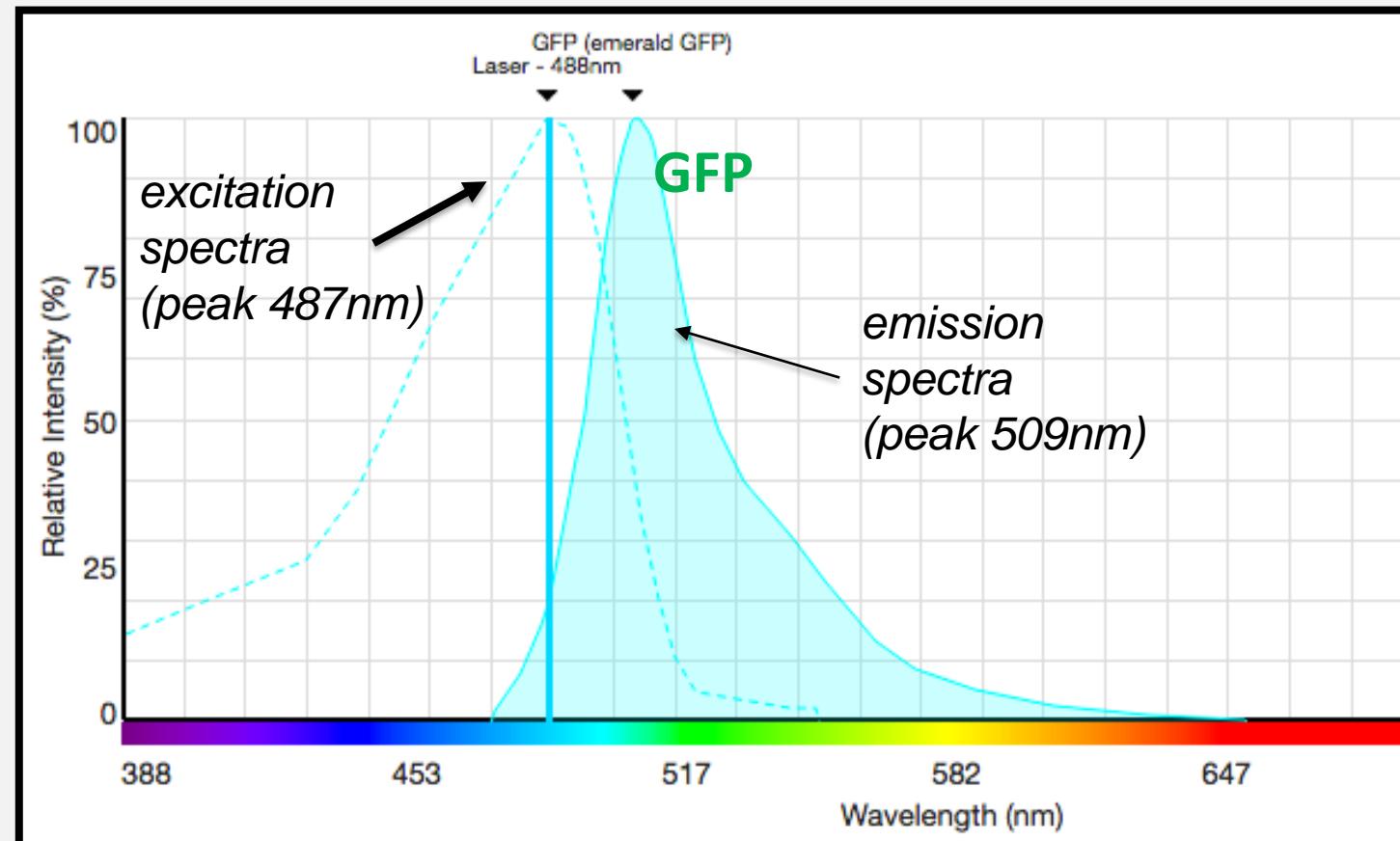
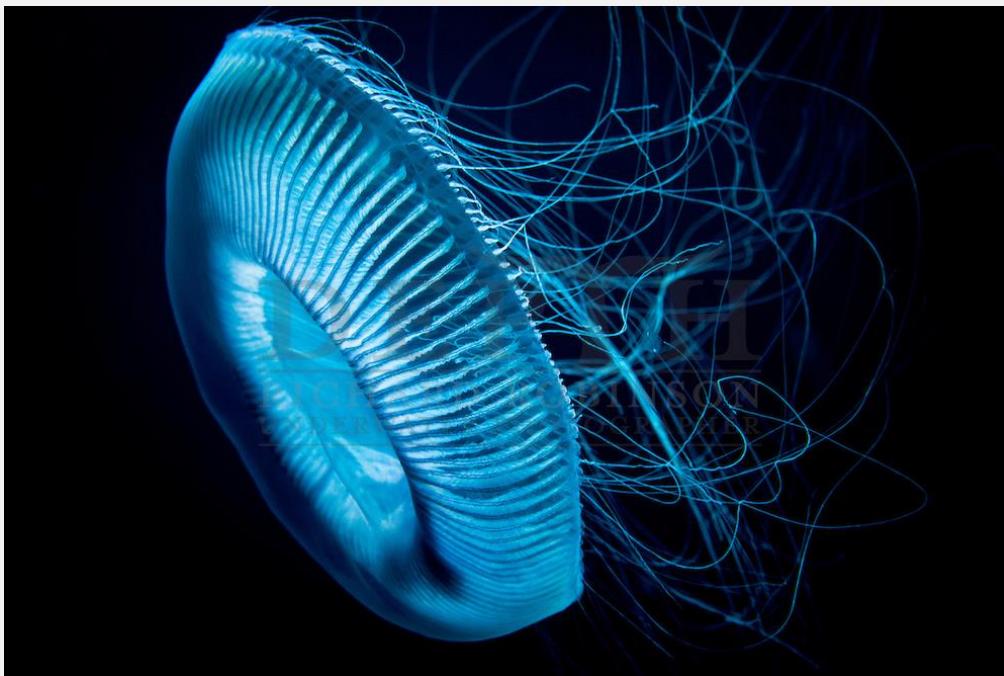
- All cells share the same DNA, but differential transcription causes different genes to be expressed in different cells → distinct neuron types, tissues, regions, etc.



Genetically-encoded fluorescent proteins

Green Fluorescent Protein (GFP)

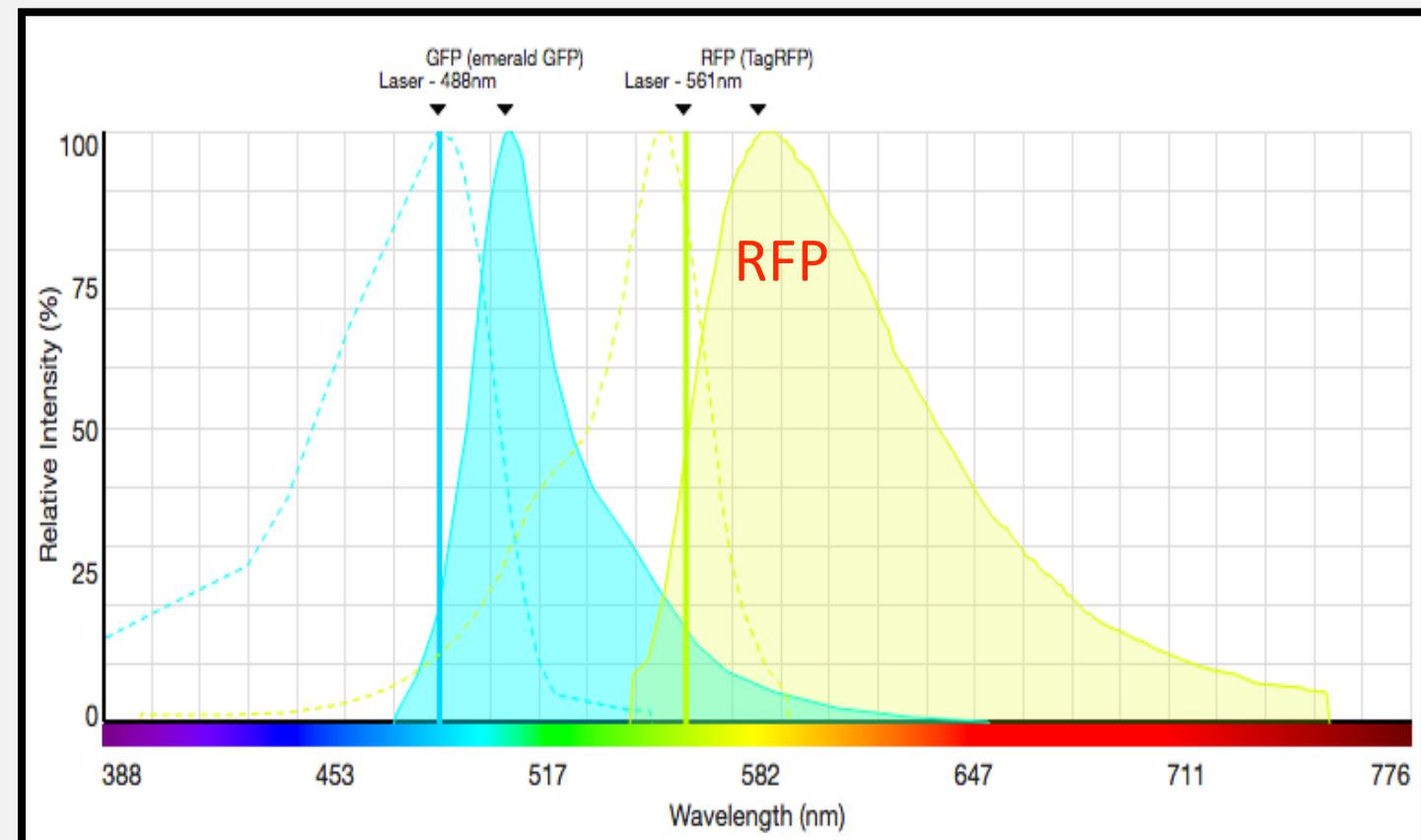
- Isolated from jellyfish



Genetically-encoded fluorescent proteins

Green Fluorescent Protein (GFP)

- Isolated from jellyfish
- Mutate GFP and FPs from other species to have all colours of the rainbow



Genetically-encoded fluorescent proteins

Details

- Critical choice – what promotor to use
- Create genetic construct – transgenic animal lines, viral transduction
- Costly set up, cheap and efficient once you have the transgenic animal or virus
- Can label genetically-identified cells, or label modified cells (did your DNA insertion work?)
- Challenges – variable gene expression



Choosing the right promotor

Example

- The CAG promoter is active (and therefore expresses GFP) in all cells
- Useful: did GFP+ cells from a donor animal survive when transplanted into a disease model?
- Can genotype these mice

Drawback?

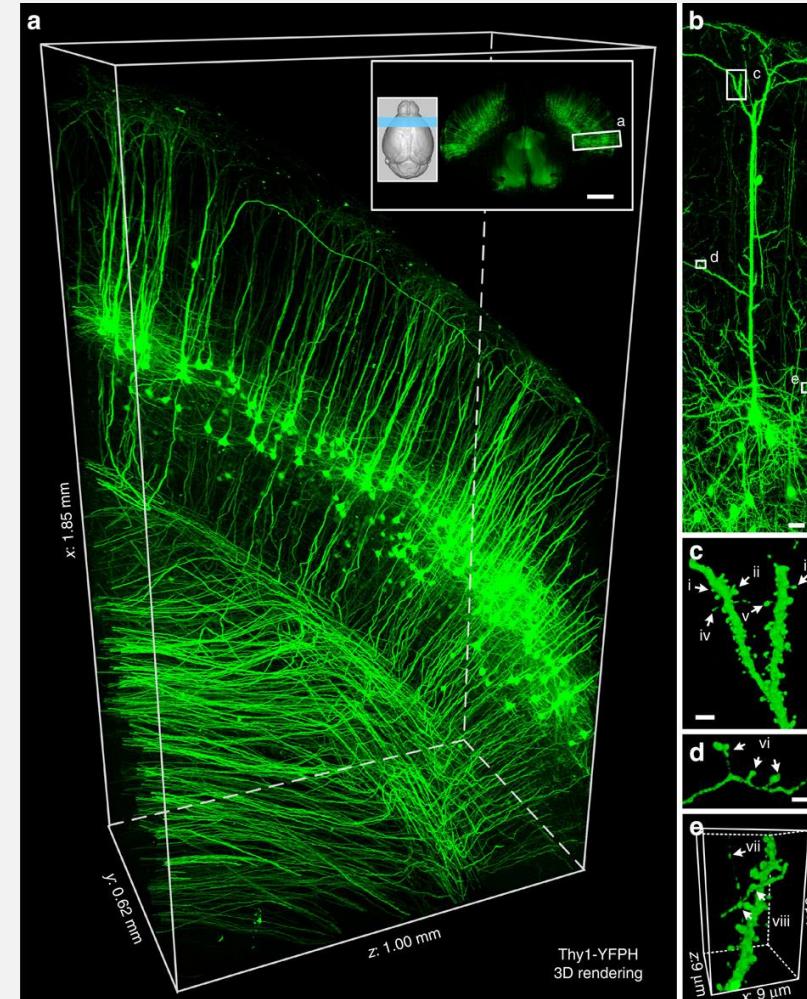


***CAG** = synthetic promoter composed of **Cytomegalovirus** enhancer + chicken **Actin** promoter region + splice acceptor of rabbit beta **Globulin** gene

Choosing the right promotor

Thy 1 promotor

- Active in a fraction of all types of neurons
- Fancy Fluorescent Golgi
- Can do in-vivo imaging
 - Image over time
- No tissue treatment, chemicals

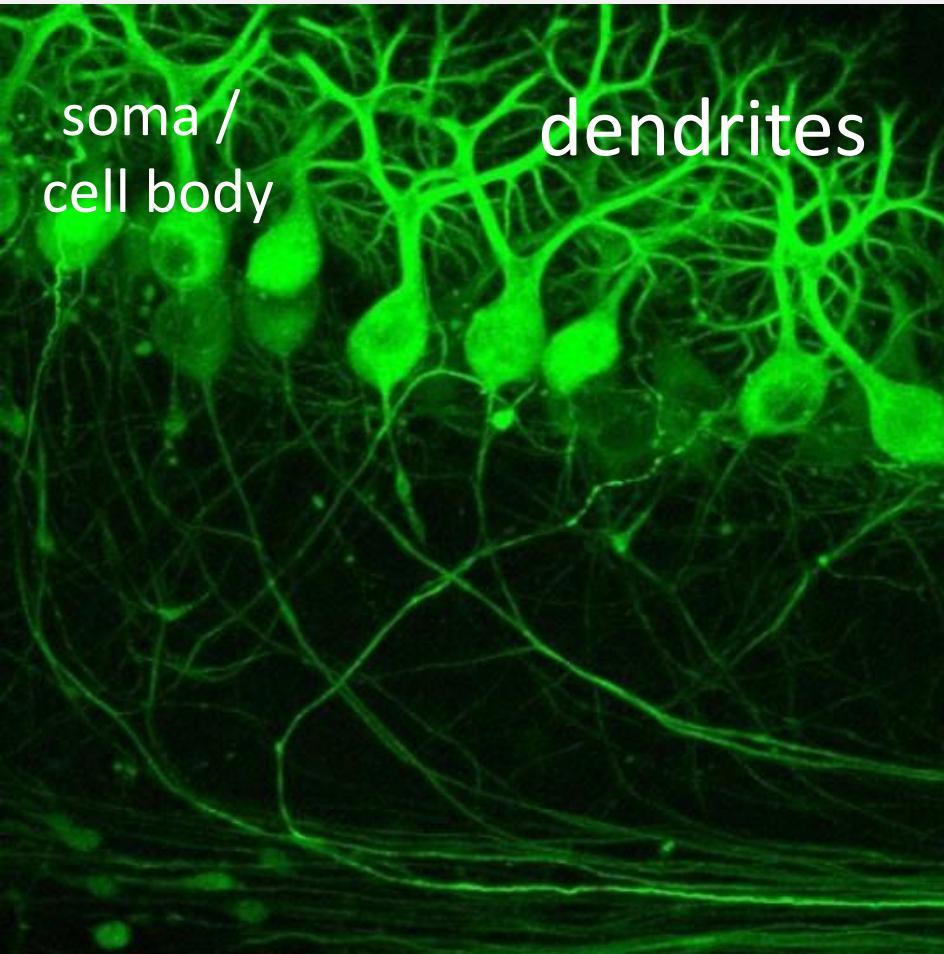


Promotor Choice

L7 promotor

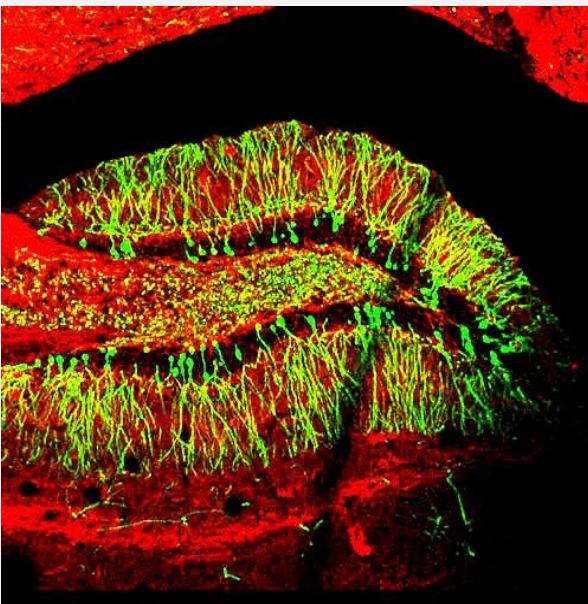
- Active (therefore produces GFP) only in cerebellar Purkinje neurons

axons

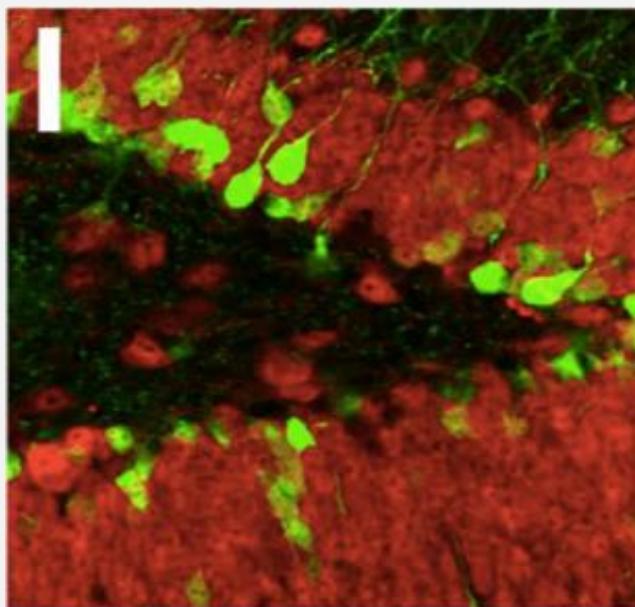


Promotor choice

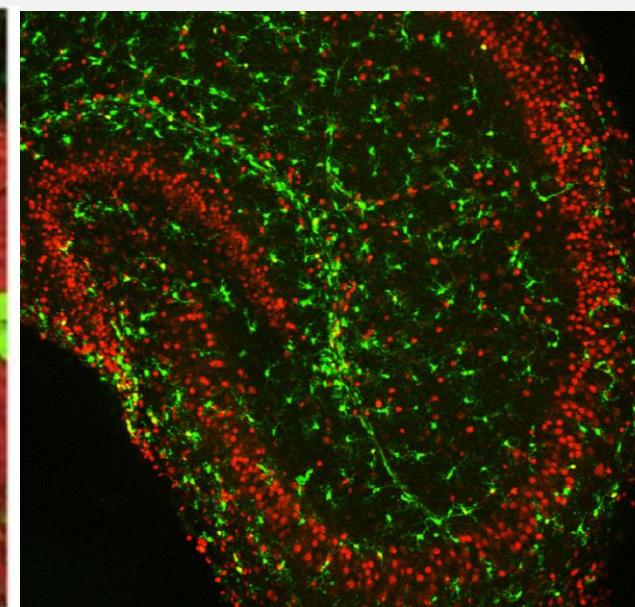
Different cells in the same brain region



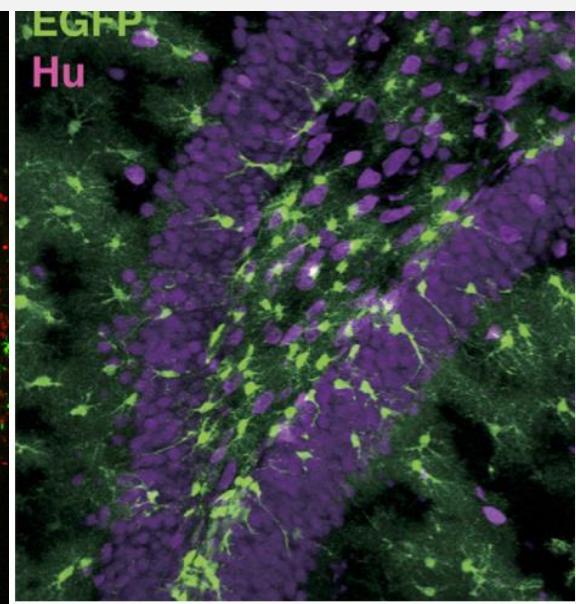
Thy1 promoter
• neurons



Doublecortin promoter
• immature neurons



Iba1 promoter
• microglia

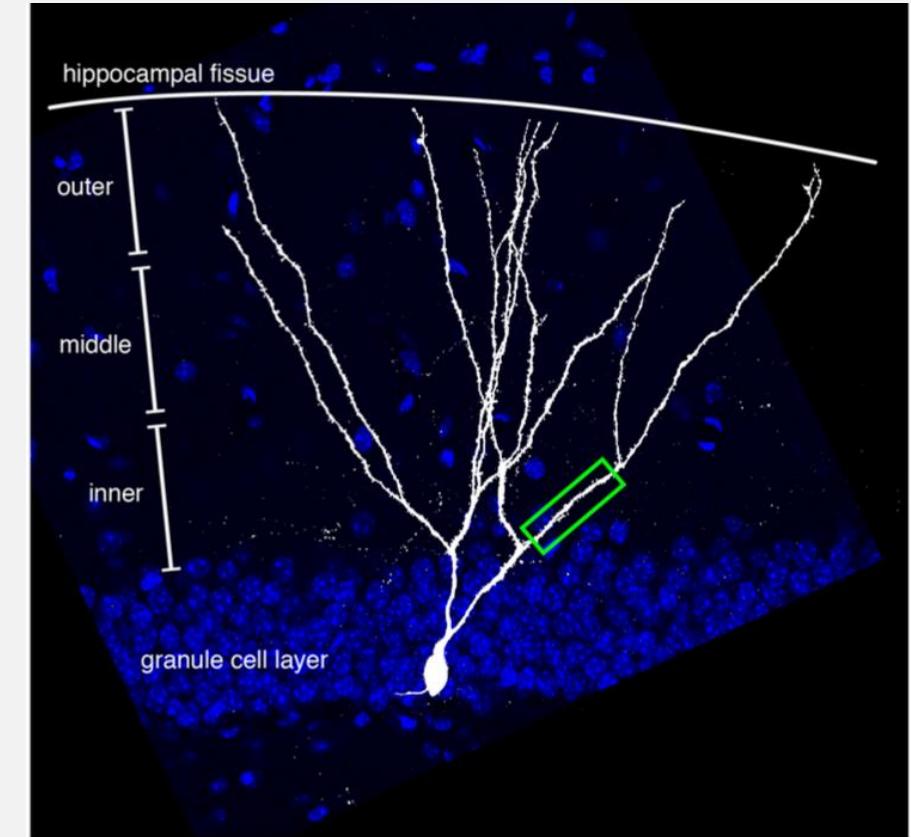


GFAP promoter
• astrocytes

Expressing FPs with viruses

- Inject engineered viral vectors into a specific brain region
- Does not require transgenic animals to obtain genetically modified cells
- Can target different cell types with different virus types
 - Neurons vs. glia
 - Dividing vs non-dividing
- Example: Retrovirus
- Requires surgery – can be invasive!

axon
(efferent)

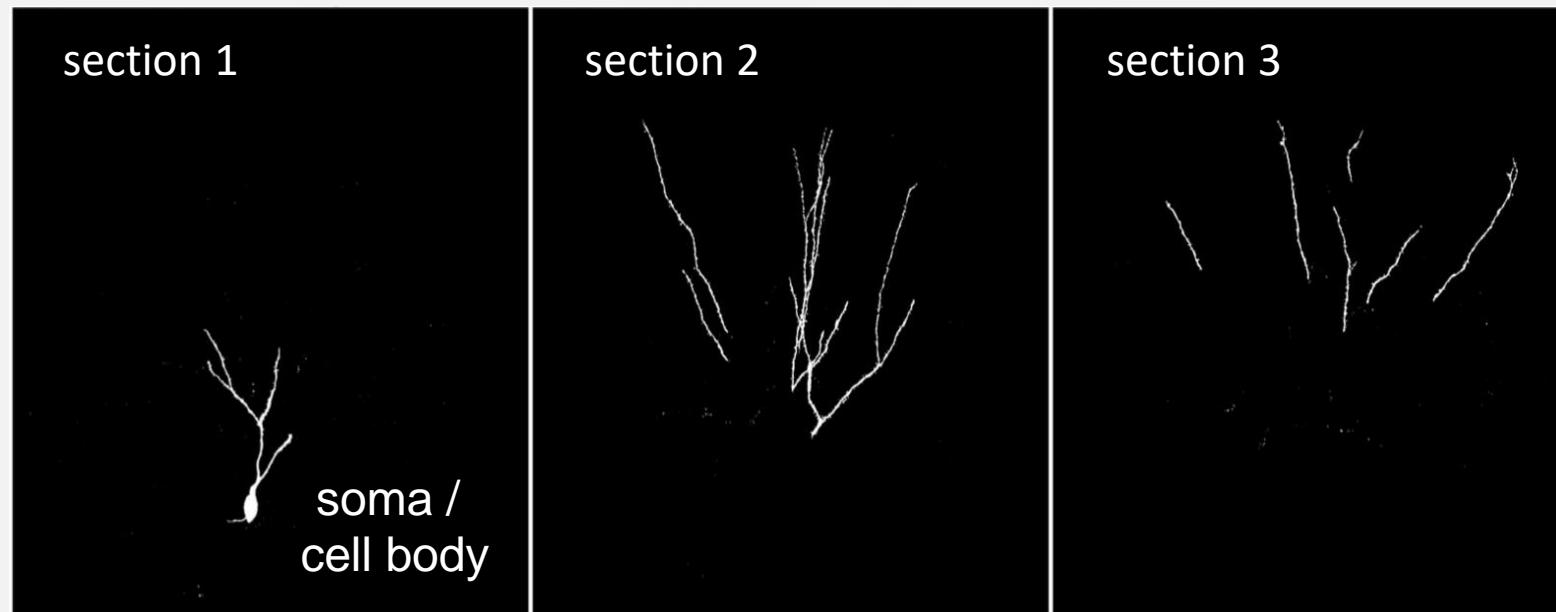


Adult-born neuron in the hippocampus,
labelled with a GFP-expressing retrovirus
(which only infects dividing cells)

Traditional visualization techniques

Disadvantages

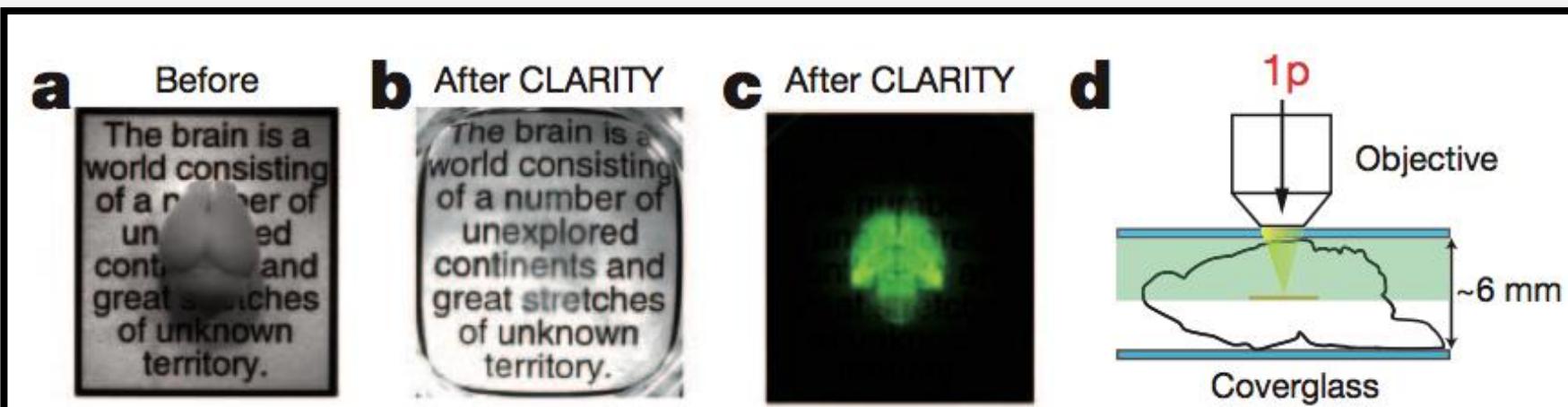
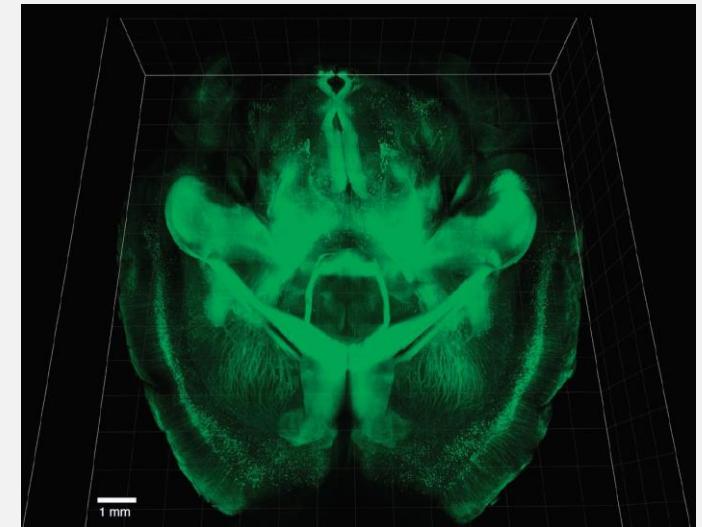
- Brain tissue must be cut to visualize neurons
- Anything that is translucent scatters light – thick brain tissue challenging



Clarity technique

Brain clearing

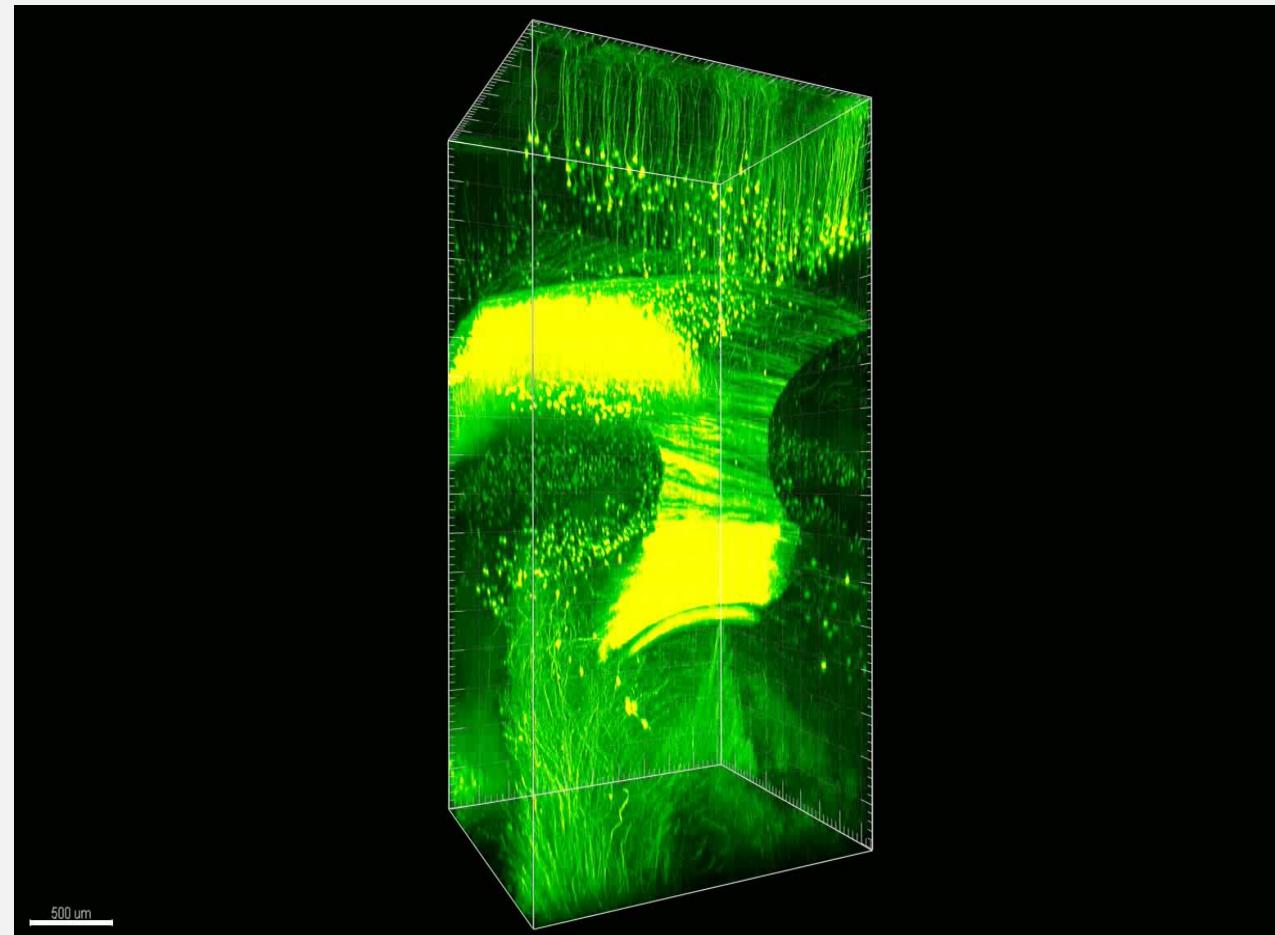
- clear membranes/lipids/fats which scatter light
- Light can penetrate deeper, emitted light will be captured without scattering
 - Also allows the antibodies to penetrate
- Allows imaging of FPs in larger blocks of tissue
 - Can track axons over longer distances, identify networks, characterize coarse neuroanatomy



Chung, 2013, Nature ("CLARITY")

Clarity

*Mouse Neocortex +
Hippocampus +
Thalamus*



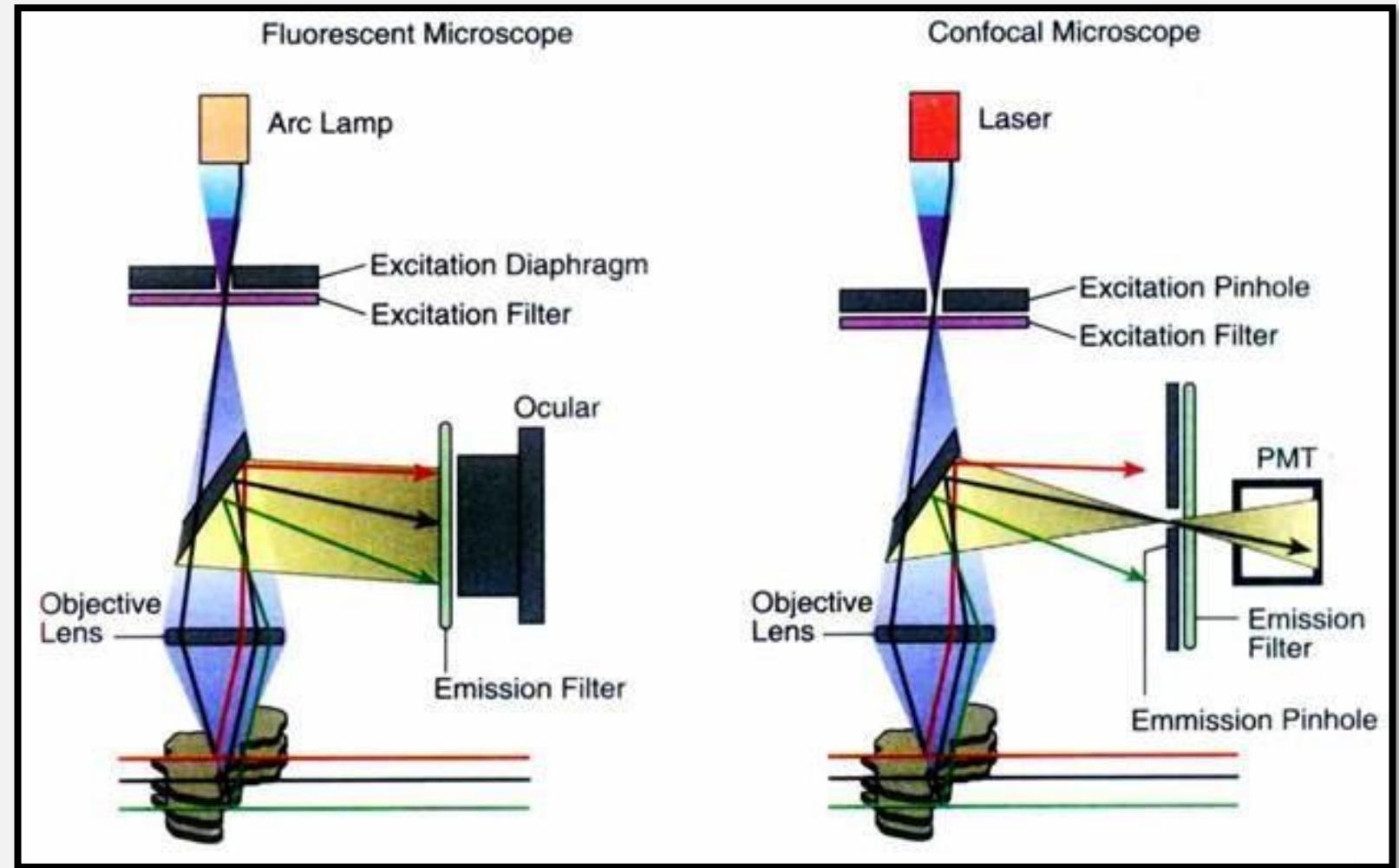
Visualizing FPs with Confocal Microscopy

Fluorescent microscope

- All light from tissue is reflected to the eye piece

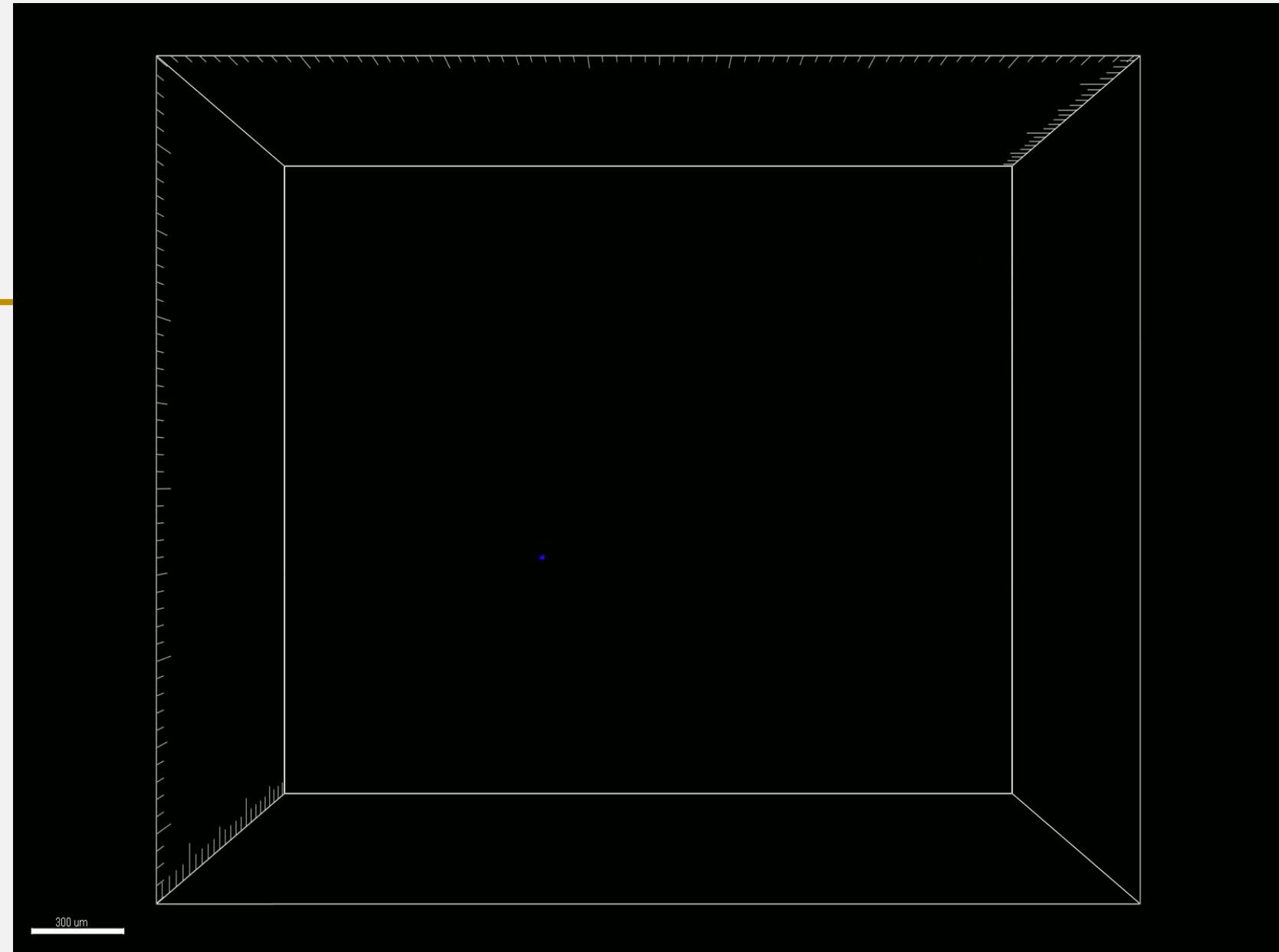
Confocal Microscope

- Pinhole eliminates out-of-focus light, allowing visualization of a single focal plane
- Reconstruct images from different focal planes



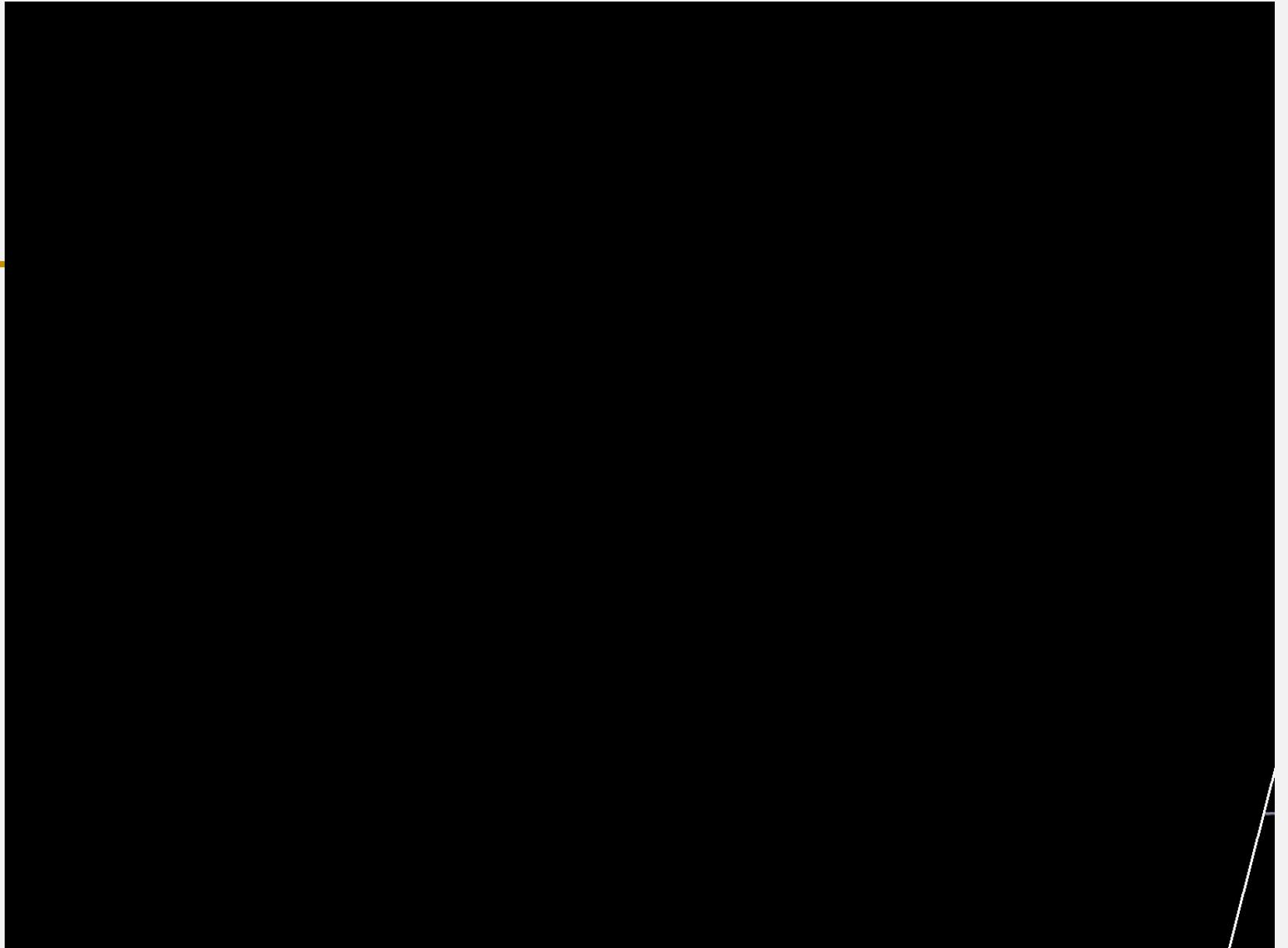
CLARITY

- *Mouse hippocampus*
 - YFP – neurons
 - Immunohistochemistry
 - parvalbumin interneurons
 - GFAP+ Astrocytes



CLARITY

- *Abnormal connections between parvalbumin interneurons in an autistic brain*



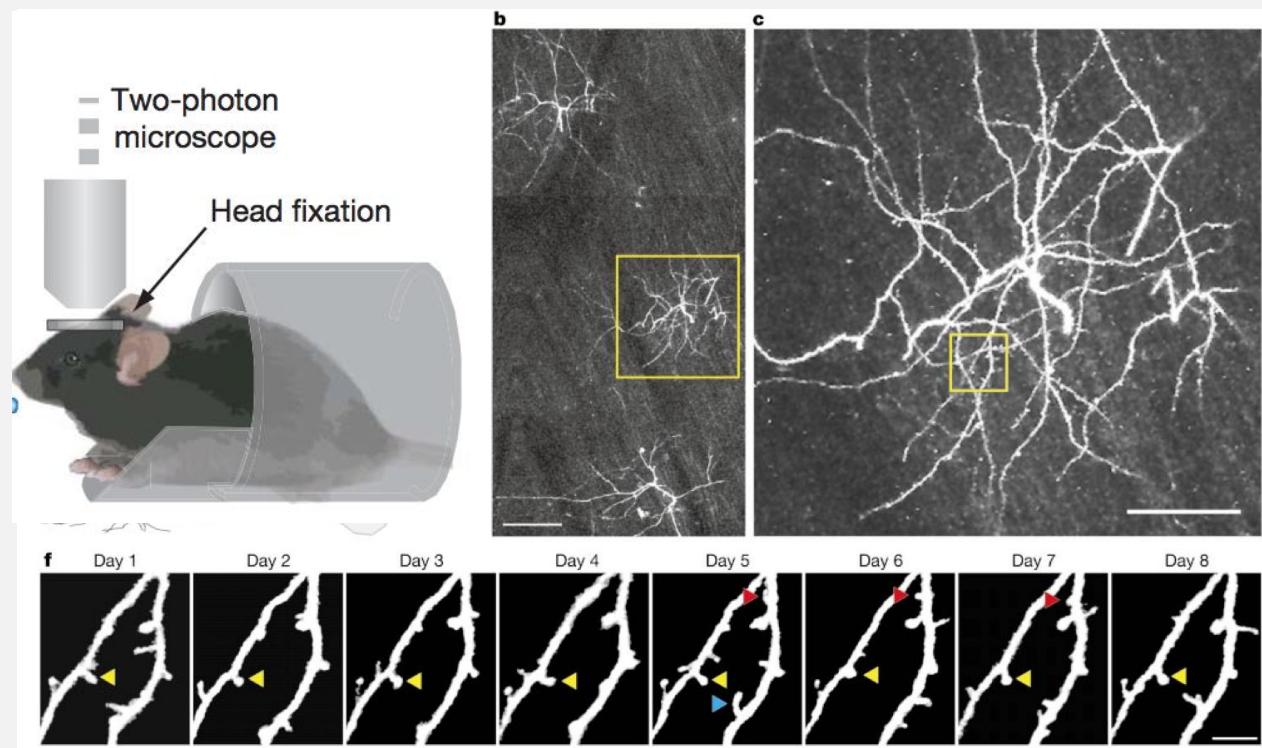
In vivo microscopy of GFP neurons

CLARITY

- Dead tissue
- Weakness: Neurons are not static
- Must image living tissue to see changes over time

2 photon microscopes

- Image deep into tissue through dura (100s μm)
- In yellow: stable mushroom spines
- In blue: spine gone within a day
- In red: slowly retracting spines

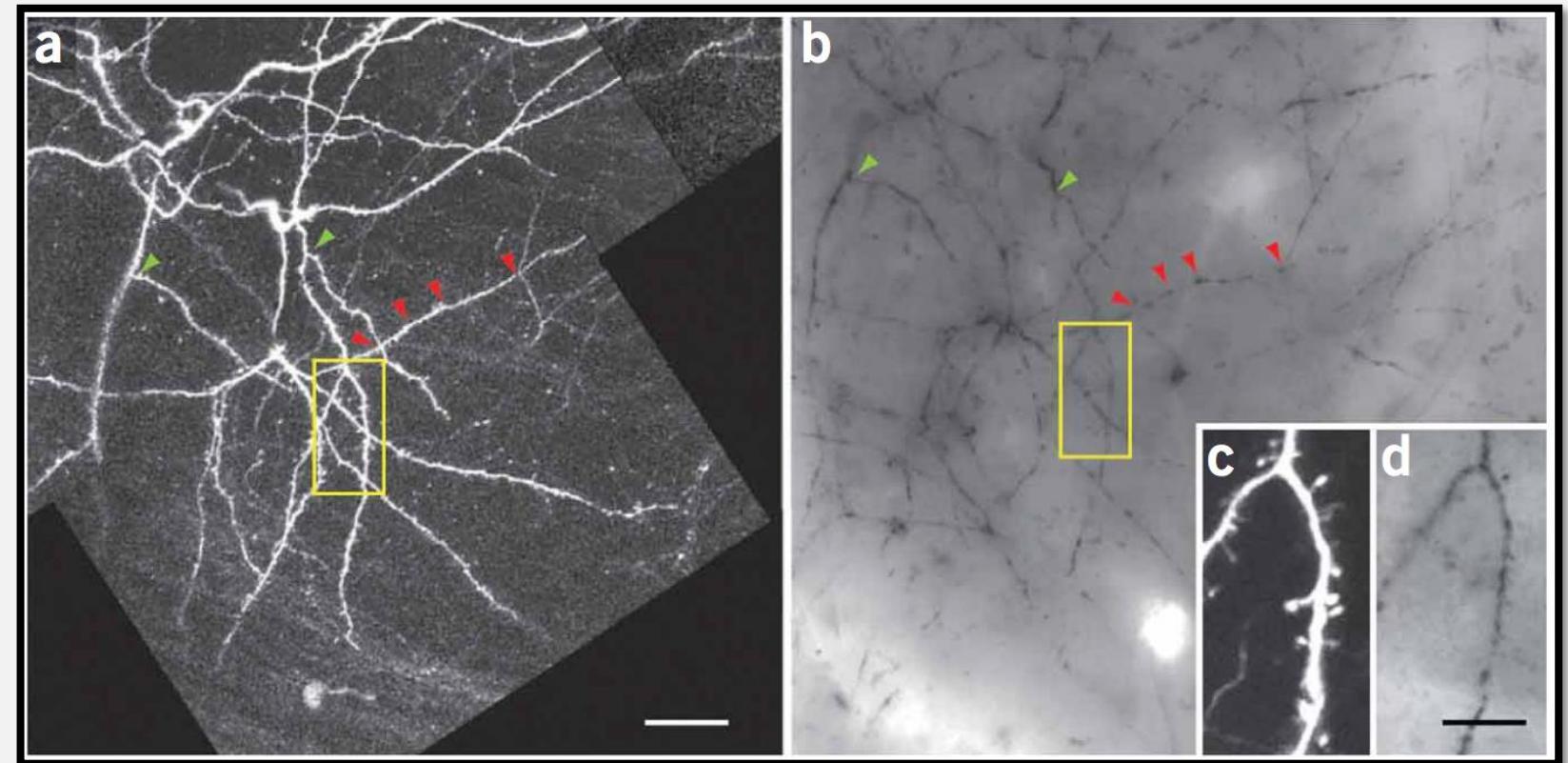


But, are these spines sites of functional synapses?

Method 5: Electron Microscopy

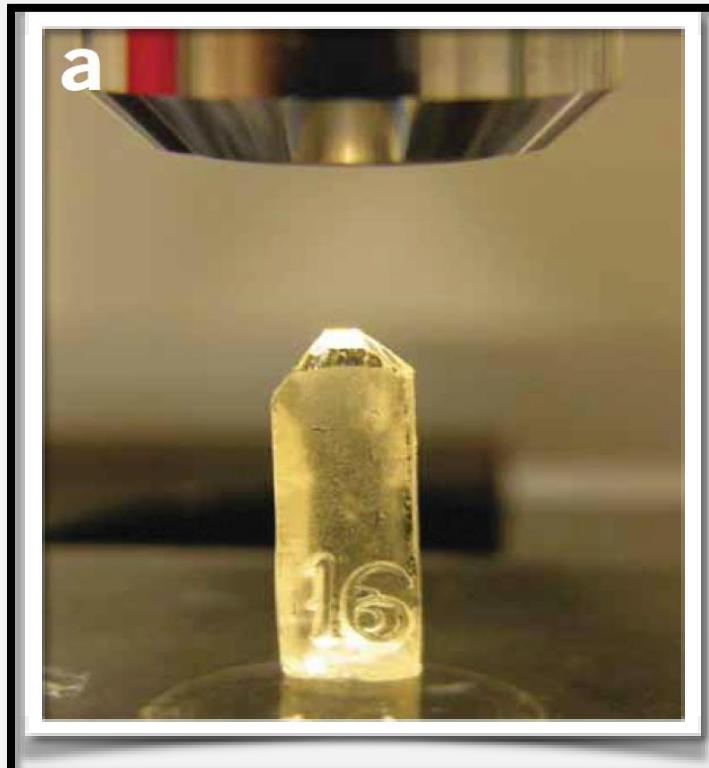
***Continuing from
previous GFP example***

- A) Fluorescent GFP
- B)
Immunohistochemical staining of GFP
 - Electron dense precipitate inside the GFP+ neurons

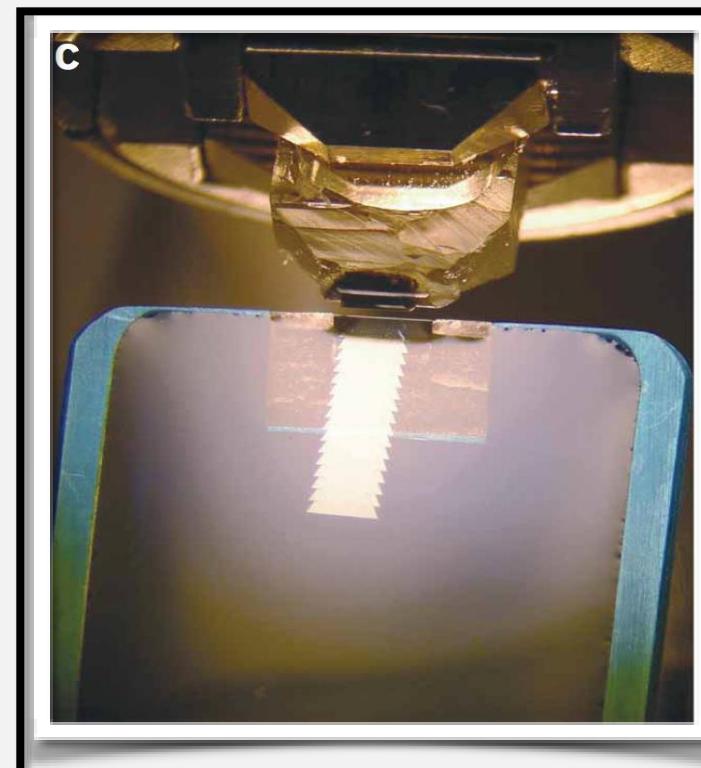


(EM can be combined with immunohistochemistry, FPs etc, or can use it on its own to examine detailed cellular anatomy with nm resolution)

Electron Microscopy



Tissue embedded in
a block of resin



Cut into 60 nanometer-
thick sections

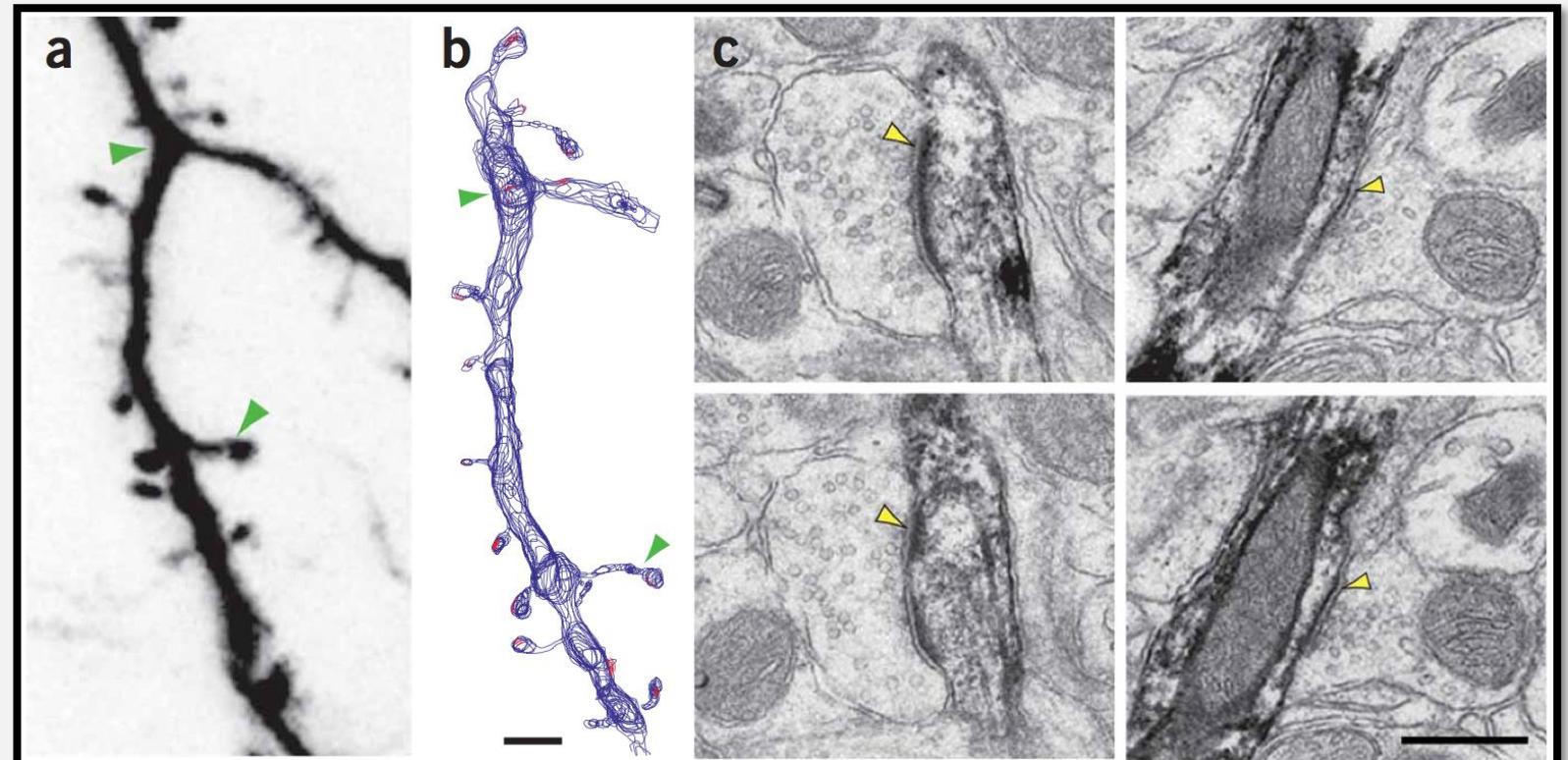


Imaged on electron
microscope

Electron Microscopy

Knott, 2009, Nature Protocols

- Best resolution
- Needs: an electron microscope (\$\$\$) and a technician (\$\$)
- Cons:
 - Time consuming
 - 12+ years to map connectivity of 302 neurons of the *C-elegans* NS
 - Often need to be done in a vacuum – molecules in air can scatter electrons
 - Stable environment



original GFP
(2-photon image)

reconstructed from
EM sections

images from individual EM sections,
showing bona fide synapses in spines
that were previously imaged ⁵⁸ *in vivo*



End!
