Week 1: overview / review

NRSC 7657 Workshop in Advanced Programming for Neuroscientists

Course outline

- Python and MATLAB
- Didactic and practical
  - Language specifics
  - General concepts in computing (version control, debugging, unit testing, scaling)
- Independent project
  - Work with real data; preferably your own (whatever it is!) or choose a public data set (see next slide)
  - Develop an idea; ****Schedule a meeting with Dan this week****

    https://doodle.com/meeting/participate/id/azmXJmre

June 13	Week 1 – overview / review	Course overview: theory of computing, landscape of computing options. Basic usage in python and MATLAB; basic data types; environments Style guidelines (ten simple rules); git and version control
June 20	Week 2 – language fundamentals	Functions; Objects and Classes; Workspaces Typical data formats: working with tabular data, images, and time series. NeurodataWithoutBorders format
June 27	Week 3 – workflow management and outputs	Importing and exporting Plotting and visualization - from bar charts to 3D animation
July 11	Week 4 – usability	Troubleshooting and debugging; unit testing
July 18	Week 5 – scaling	Iteration and code profiling; parallel computing. Code quality-of-life topics
July 25	Week 6 – collaboration	Cloud-based tools: AWS, GCC, Colab, jupyterhub, deepnote. Overview of some available SAAS tools, python focused.
		Group programming time
August 1	Week 7 – applications/flex topic	Applications: image processing (ES)
		Group programming time
August 8	Week 8 – applications/flex topic	Applications: spike sorting (DD)
		Group programming time
August 15	Week 9 – applications/flex topic	Applications: DeepLabCut and cloud ML
		Group programming time
August 22	Week 10 – Final presentations and code review	Final pres. and code review
		Final pres. and code review

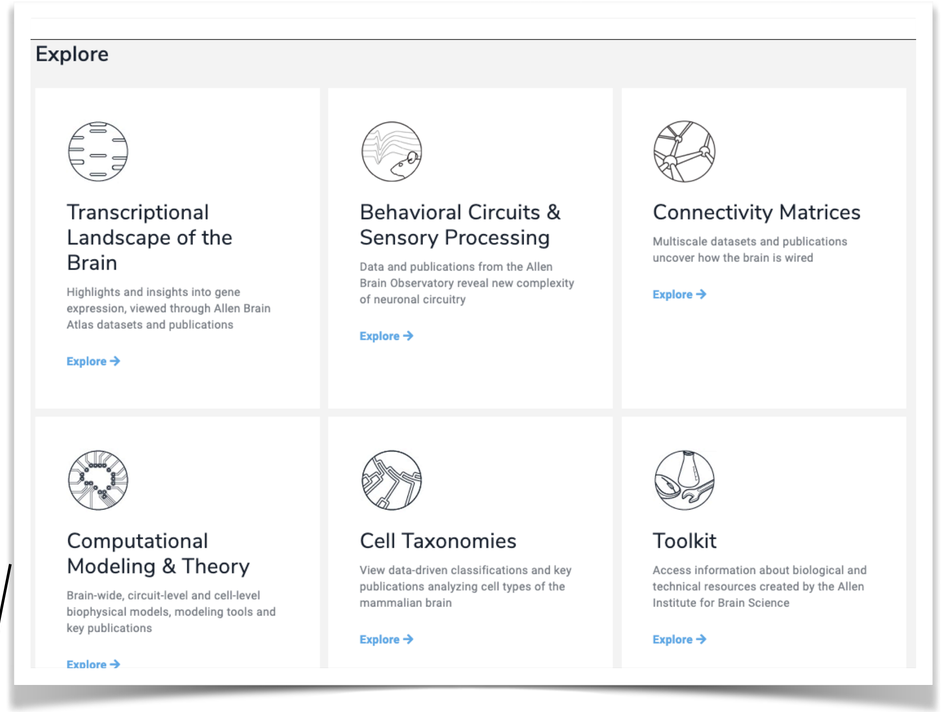
Project datasets

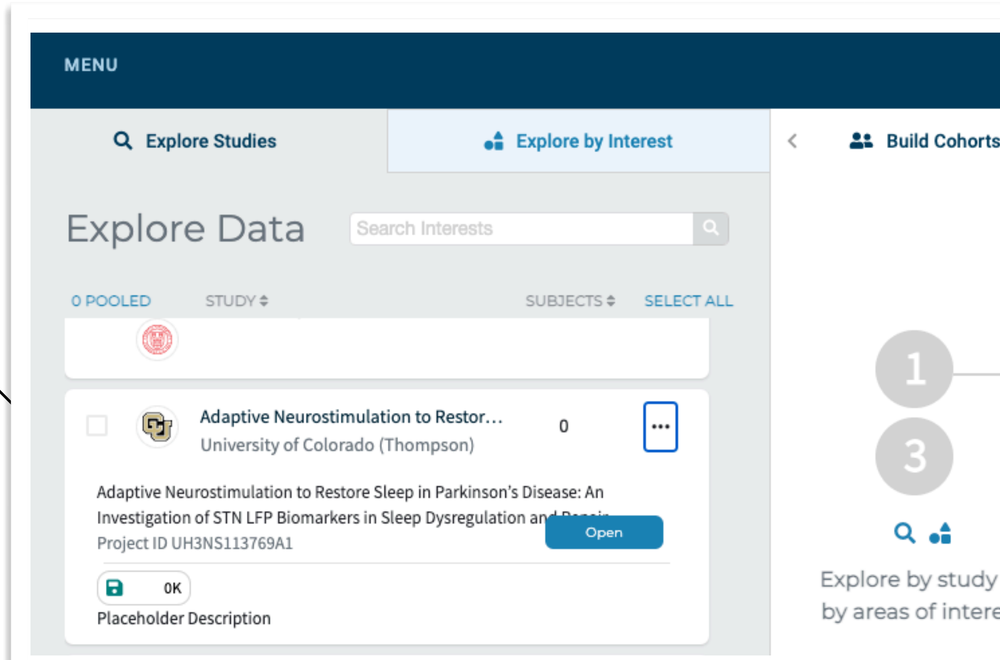
- Yours!
- Someone from your lab

Public datasets

(Suggestions, incomplete list)

- Allen Institute for Brain Science brain-map.org
- DABI Data Archive BRAIN Initiative https://dabi.loni.usc.edu/home





What this course is **not**

- Computational neuroscience
- Mathematics
- Computer science

What this course is

Each session:

- Some slides (0 - 60 minutes)

- Working through a notebook or interactive coding together

- Independent coding. We’re going to do your science, with a computer. Maybe your computer, or maybe a cloud computer. Definitely your science.

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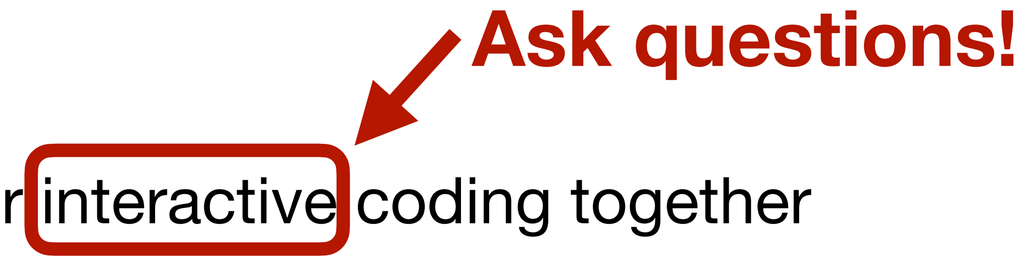

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Goals of this course

- Exposure to differing approaches to computing in neuroscience
- Develop confidence in independent coding skills
- Complete a project using data relevant to your thesis work

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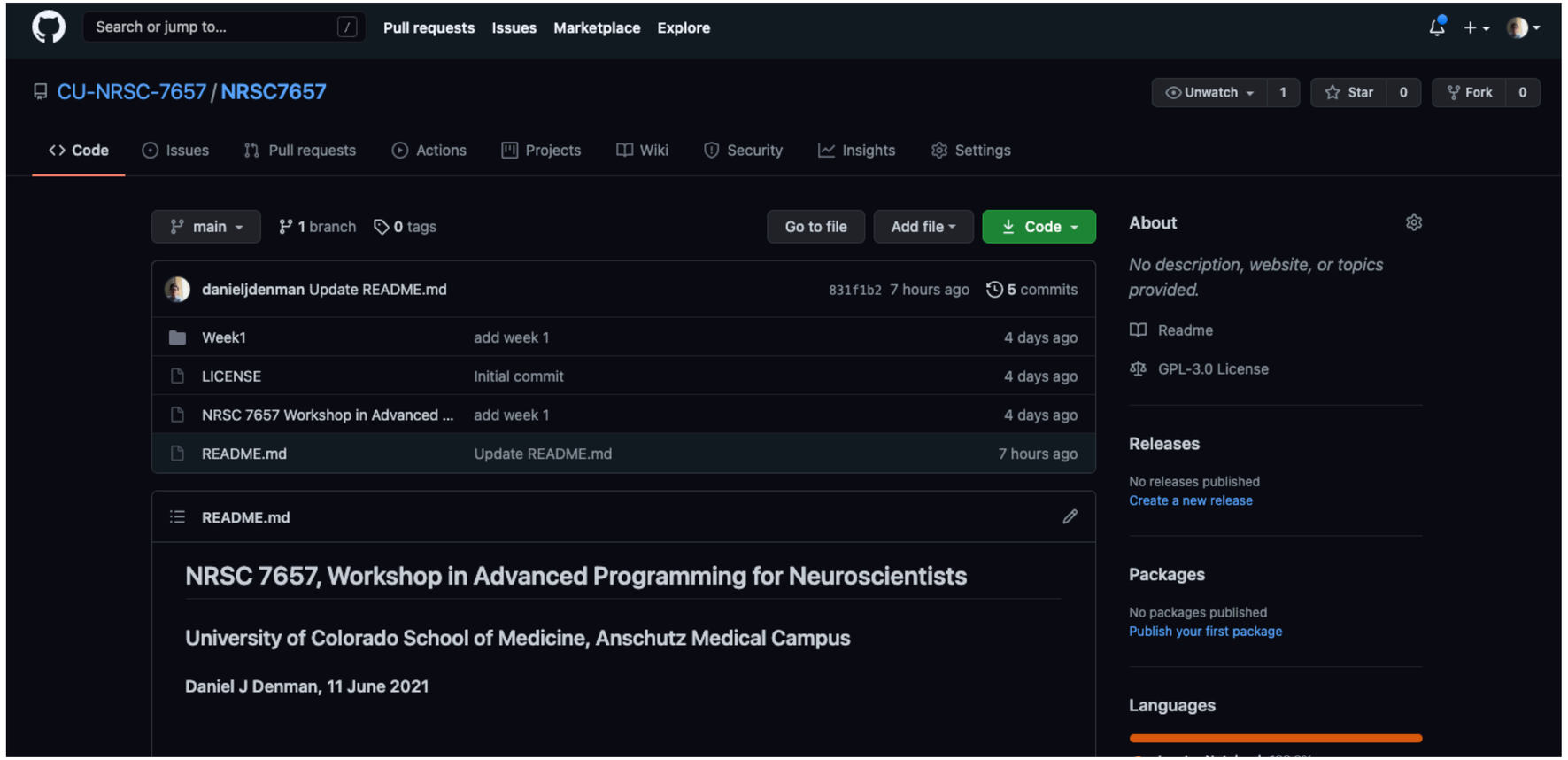
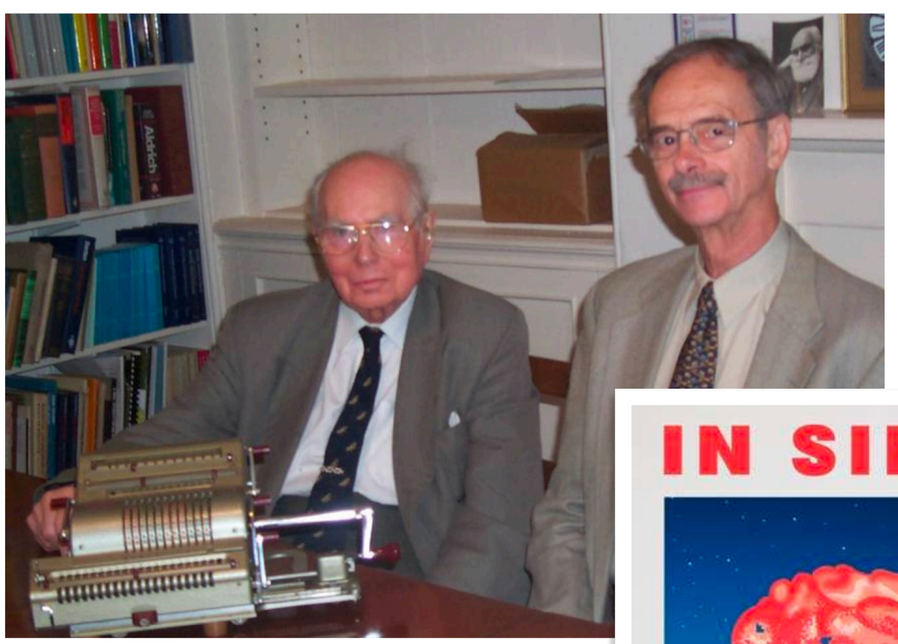
Final practicalities

- GitHub: https://github.com/CU-NRSC-7657/NRSC7657



Computing in neuroscience

- Hodkin-Huxley's mechanical computer
- Computer based analysis / replacing chart measurements
- NEURON simulations; single neuron modeling
- …
- "data science", open data
- Blue brain project, *In silico*



Computing in neuroscience

An example: code written by neuroscientists for one experiment

planning

Probe trajectory: MATLAB

Model prediction: python - jupyter notebook

experimental control

Acquisition hardware: FPGA gate array programming

Acquisition software: C++; python plugin; [Julia]

Visual stimuli: python script; embedded python in React

Video monitoring: python script

“pre-processing”

Spike sorting: MATLAB

Unit quality: python - jupyter notebook

Depth: python - jupyter notebook

analysis

Histology registration to 3D brain: python

Stimulus responses: python

Population statistics: MATLAB *and* python

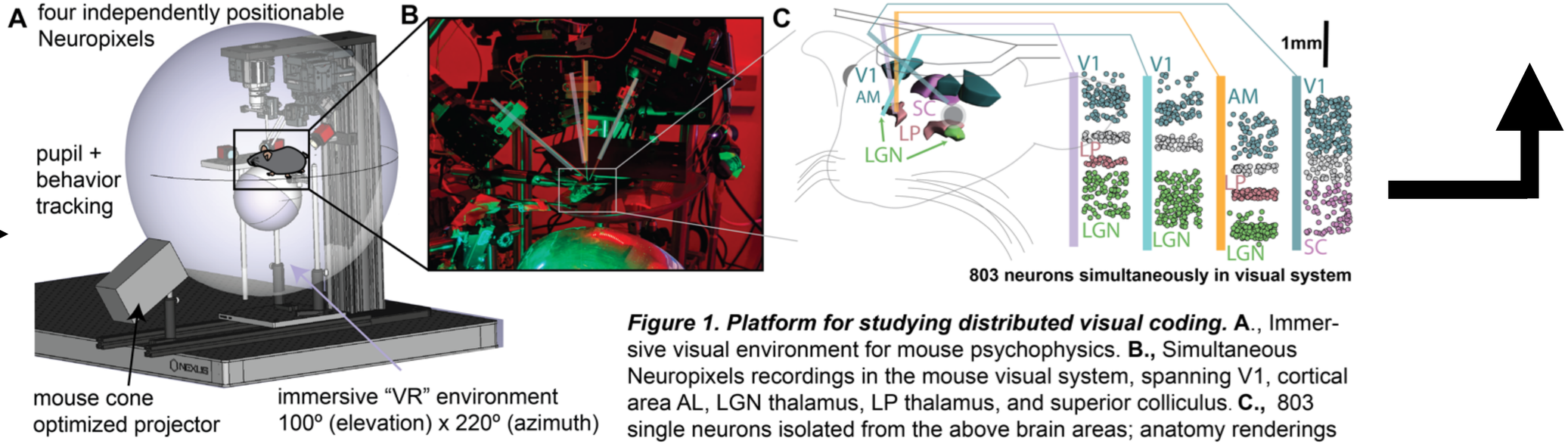


Figure 1. Platform for studying distributed visual coding. **A**., Immersive visual environment for mouse psychophysics. **B.,** Simultaneous Neuropixels recordings in the mouse visual system, spanning V1, cortical area AL, LGN thalamus, LP thalamus, and superior colliculus. **C.,** 803 single neurons isolated from the above brain areas; anatomy renderings from the Allen Reference Atlas (brain-map.org).

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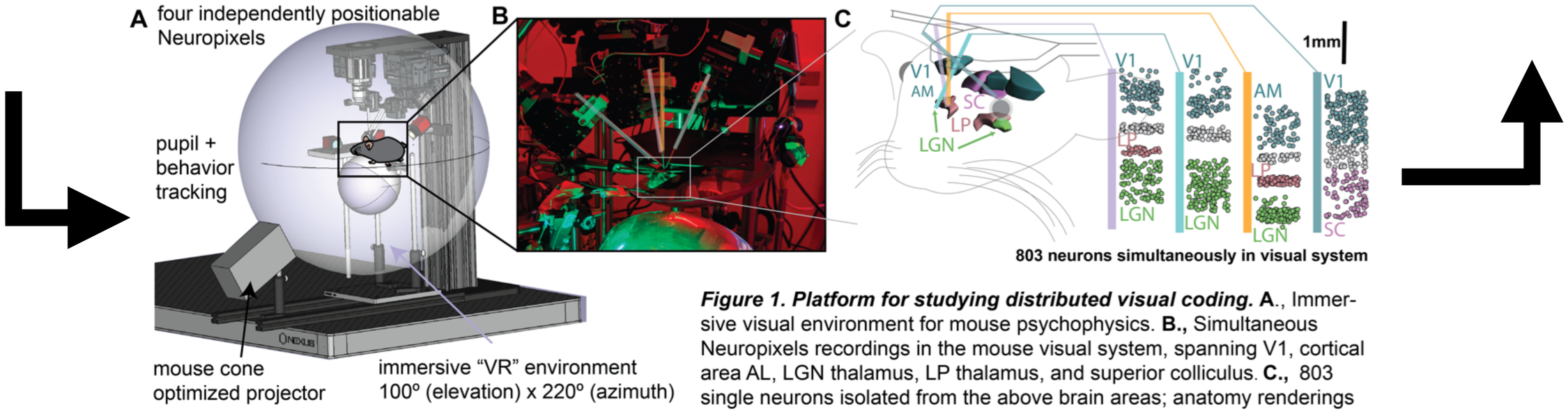

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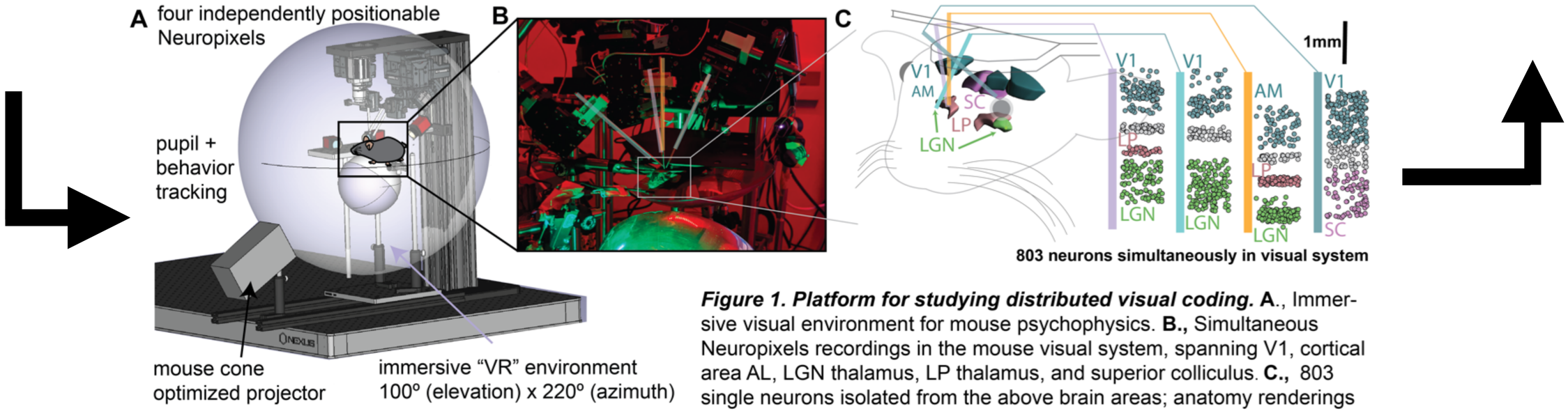

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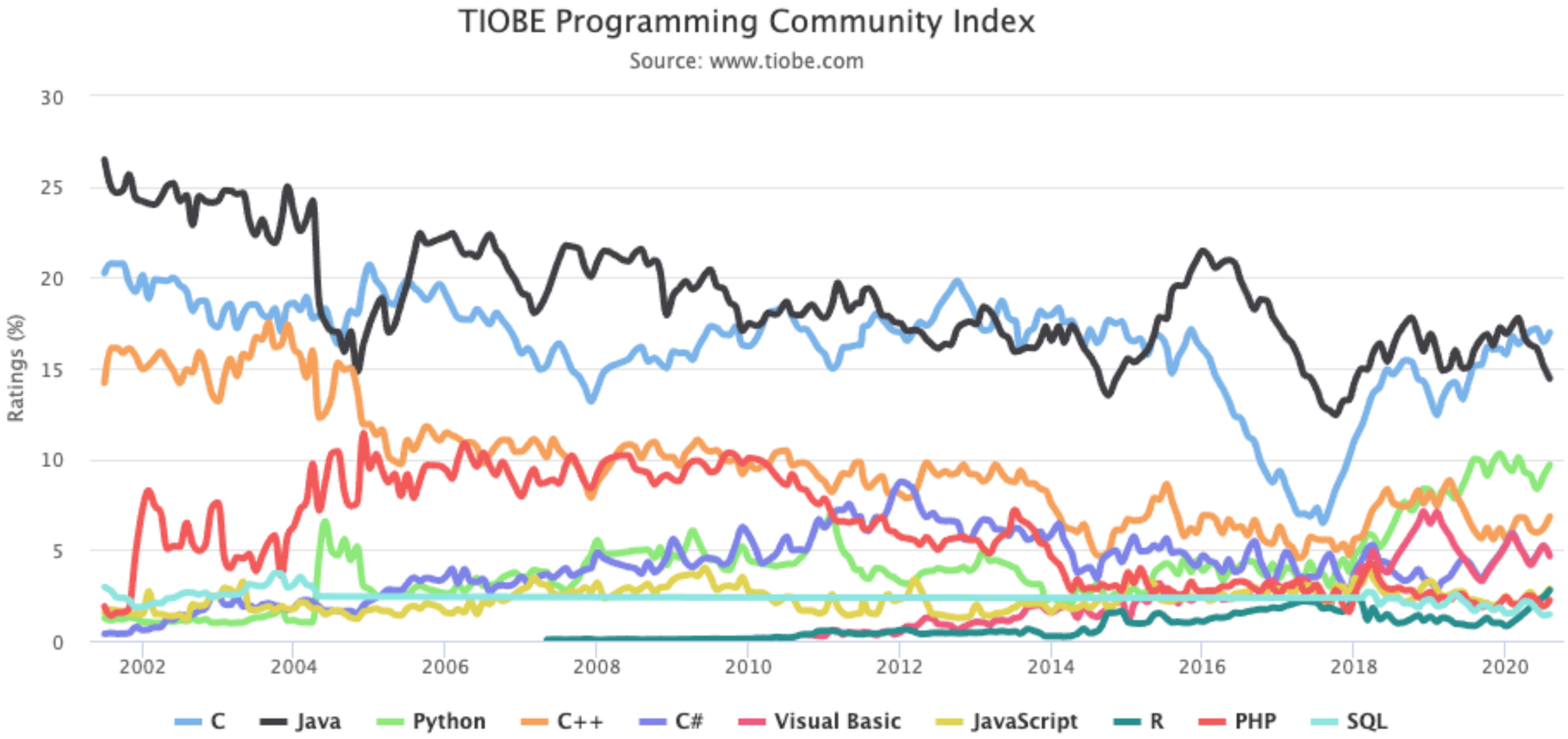
history: languages used for neuroscience



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Aug 2020	Aug 2019	Change	Programming Language	Ratings	Change
1	2	↑	C	16.98%	+1.83%
2	1	↓	Java	14.43%	-1.60%
3	3		Python	9.69%	-0.33%
4	4		C++	6.84%	+0.78%
5	5		C#	4.68%	+0.83%
6	6		Visual Basic	4.66%	+0.97%
7	7		JavaScript	2.87%	+0.62%
8	20	⇈	R	2.79%	+1.97%
9	8	↓	PHP	2.24%	+0.17%
10	10		SQL	1.46%	-0.17%
11	17	⇈	Go	1.43%	+0.45%
12	18	⇈	Swift	1.42%	+0.53%
13	19	⇈	Perl	1.11%	+0.25%
14	15	↑	Assembly language	1.04%	-0.07%
15	11	⇊	Ruby	1.03%	-0.28%
16	12	⇊	MATLAB	0.86%	-0.41%

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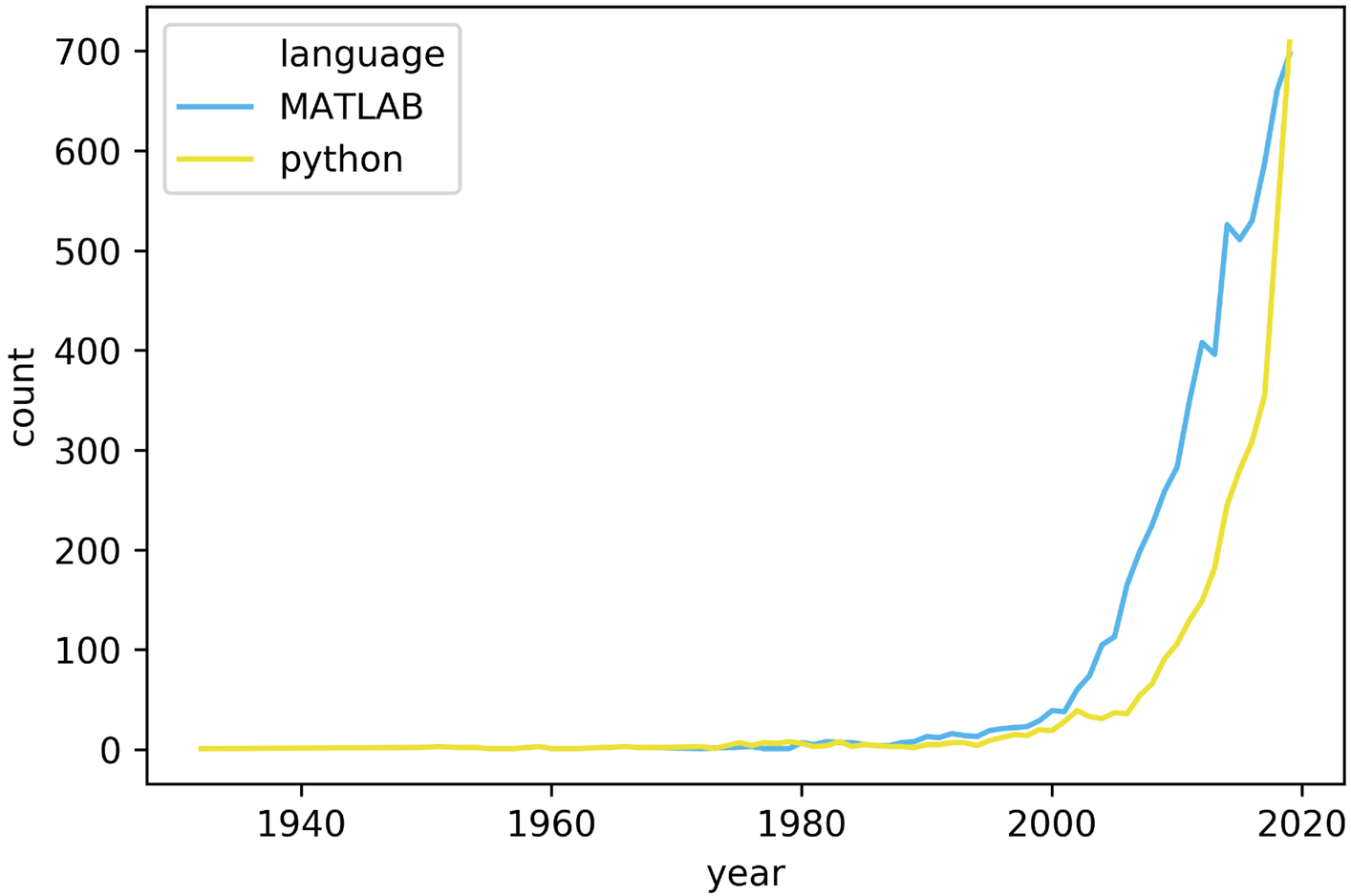

history: languages used for neuroscience

Volume 16 Issue 12, December 2019

Focus on Deep Learning in Microscopy

Artwork representing the application of deep learning methods in microscopy.

Image: National Institutes of Health/Stocktrek Images/Getty. Cover design: Erin DeWalt

history: languages used for neuroscience

Volume 16 Issue 12, December 2019

Analysis | Published: 21 October 2019

Nucleus segmentation across imaging experiments: the 2018 Data Science Bowl

Juan C. Caicedo, Allen Goodman, Kyle W. Karhohs, Beth A. Cimini, Jeanelle Ackerman, Marzieh Haghighi, CherKeng Heng, Tim Becker, Minh Doan, Claire McQuin, Mohammad Rohban, Shantanu Singh & Anne E. Carpenter

Nature Methods **16**, 1247–1253(2019) | Cite this article

3257 Accesses | **1** Citations | **41** Altmetric | Metrics

2 out top 3 entries used python

history: languages used for neuroscience

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Artwork representing the application of deep learning methods in microscopy.

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history

- First released in 1991
- A “scripting” or “high-level” language, designed for readability and productivity
  - simple syntax, use of white space

- Major release: Python 2.7, July 2010
- Use increases
- “data science” after era of “Big Data”
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If there is something you are doing over and over again, especially in your analysis, script it!

overview

Some plusses

Some minuses

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- **Free**
- **Readable syntax**
- **Cross platform**
- **Huge community**
- **Used across science *_and_* outside of science**

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- Slow[er] to execute (than C)
- White space matters (which some find to be a pain)
- *Sometimes problematic + insular culture; see “BDFL”

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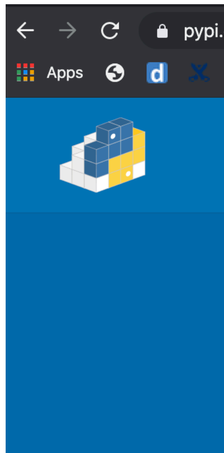
overview: packages

Packages

In addition to the standard library, the true power of python is the extensive world of packages available. These are sets of tools you can use with Python to do just about anything!

Some are general tools, the hammers or screwdrivers of using python for science: **numpy**, **matplotlib, pandas, seaborn**

Others are specialized: **scikit-learn, PIL, scanpy, Suite2P, DeepLabCut, PyTom**



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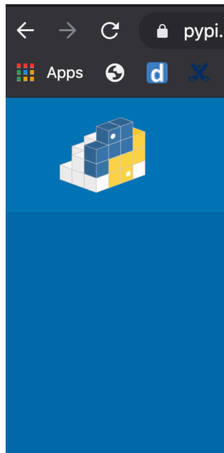

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Week 3

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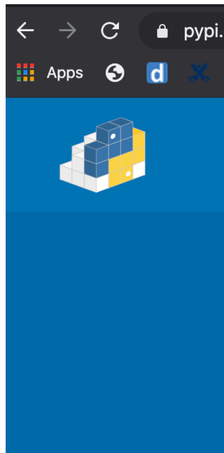

overview: levels

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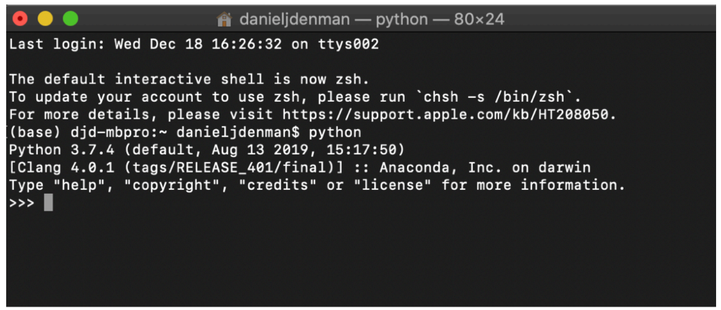
System



Native in Mac OS X, Linux; in Windows store (free)

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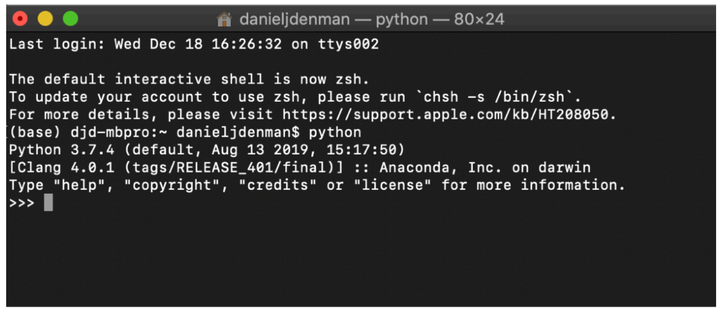

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Package Managers
Environments

ANACONDA®

overview: levels

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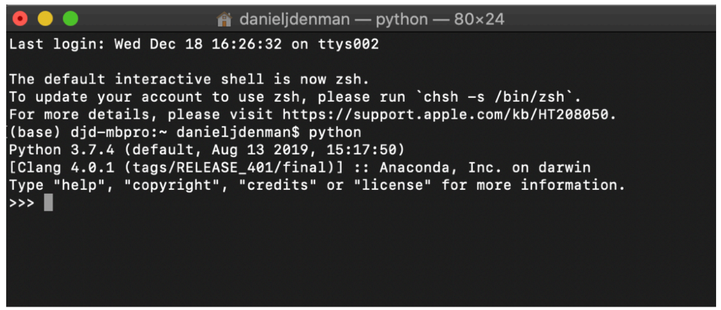

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Package Managers Environments

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Containerized

docker

COCALC

CO

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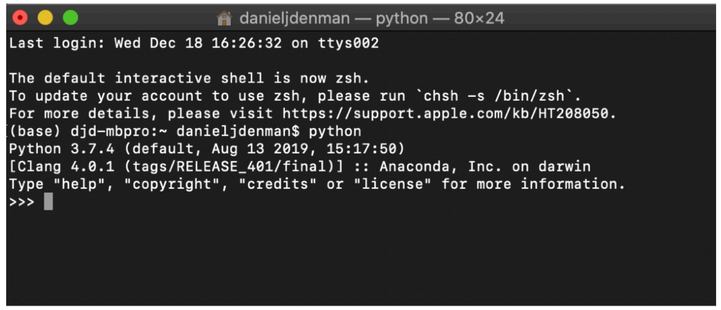

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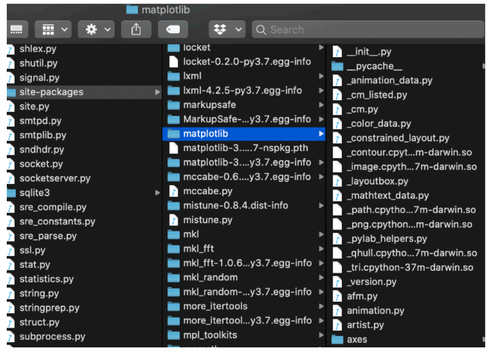

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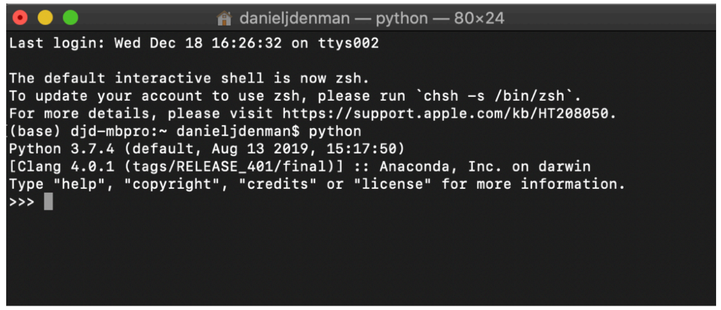

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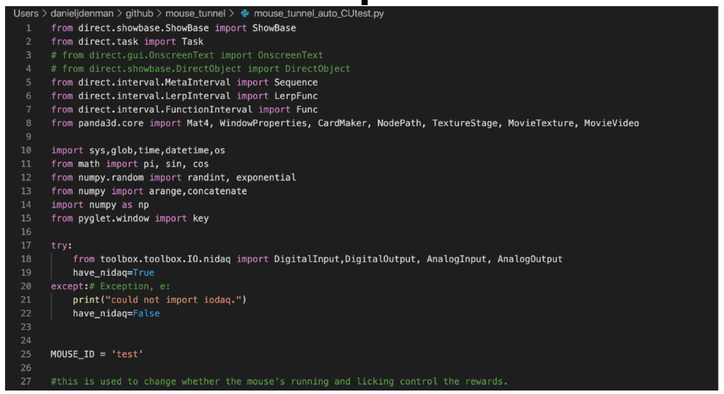
Scripts



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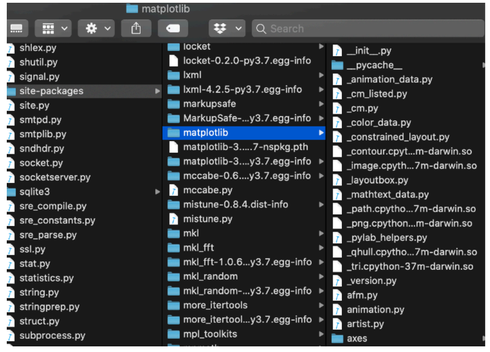

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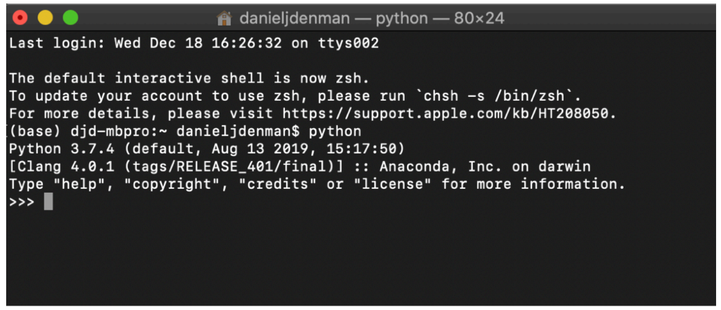

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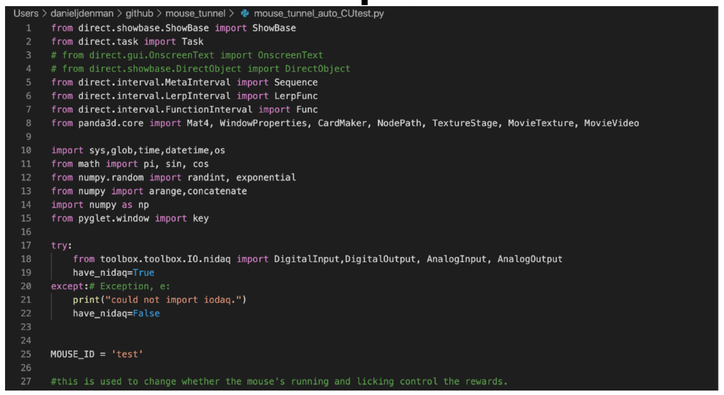
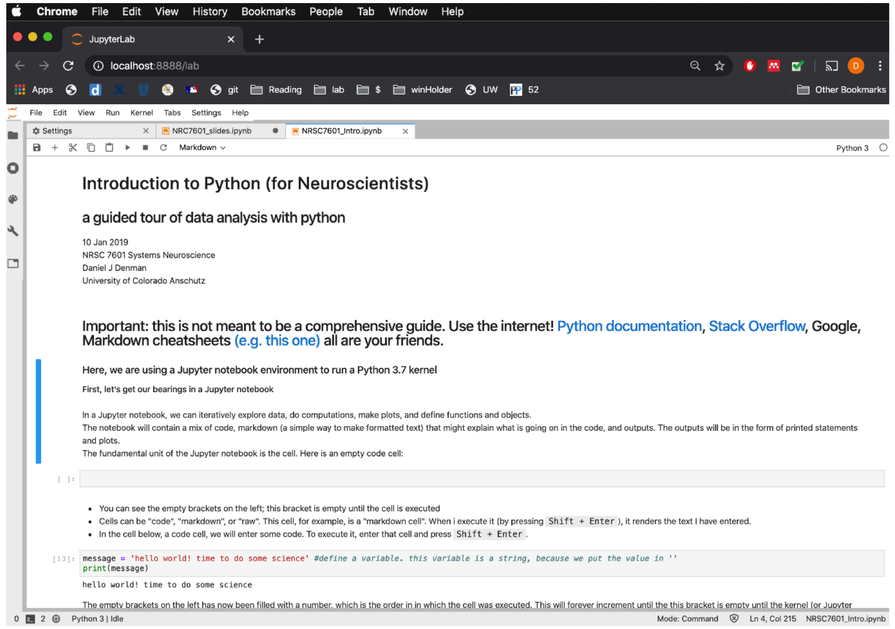
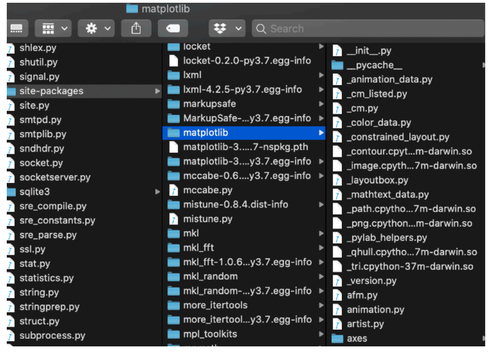


Notebooks (IPython, Jupyter, Jupyter Lab)

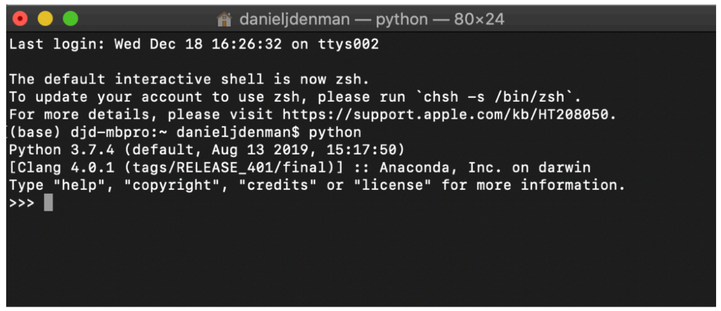


Packages



overview: levels

System



Native in Mac OS X, Linux; in Windows store (free)

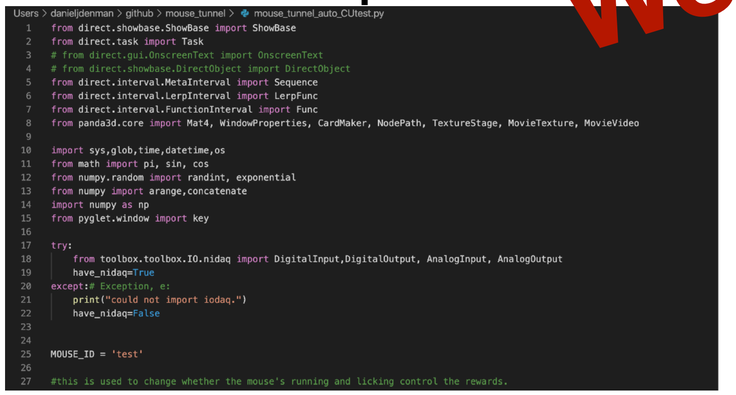
Package Managers
Environments

ANACONDA®

Containerized

Week 1

Scripts



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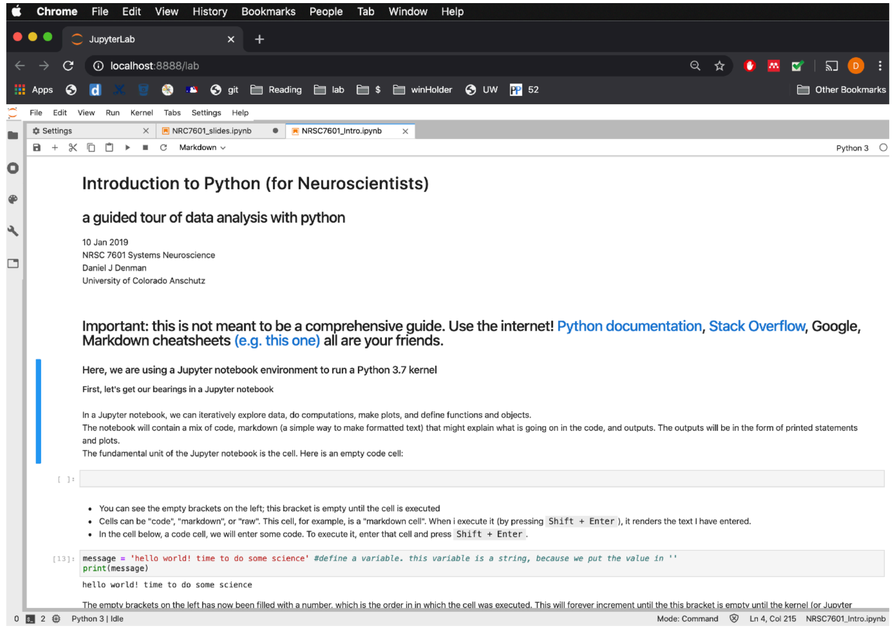
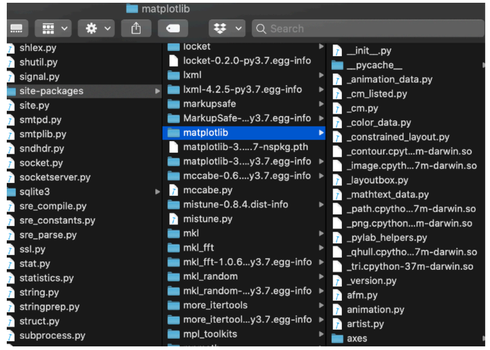


Packages



overview: levels

System

```
danieljdenman — python — 80×24
Last login: Wed Dec 18 16:26:32 on ttys002

The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
(base) djd-mbpro:~ danieljdenman$ python
Python 3.7.4 (default, Aug 13 2019, 15:17:50)
[Clang 4.0.1 (tags/RELEASE_401/final)] :: Anaconda, Inc. on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

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Package Managers
Environments

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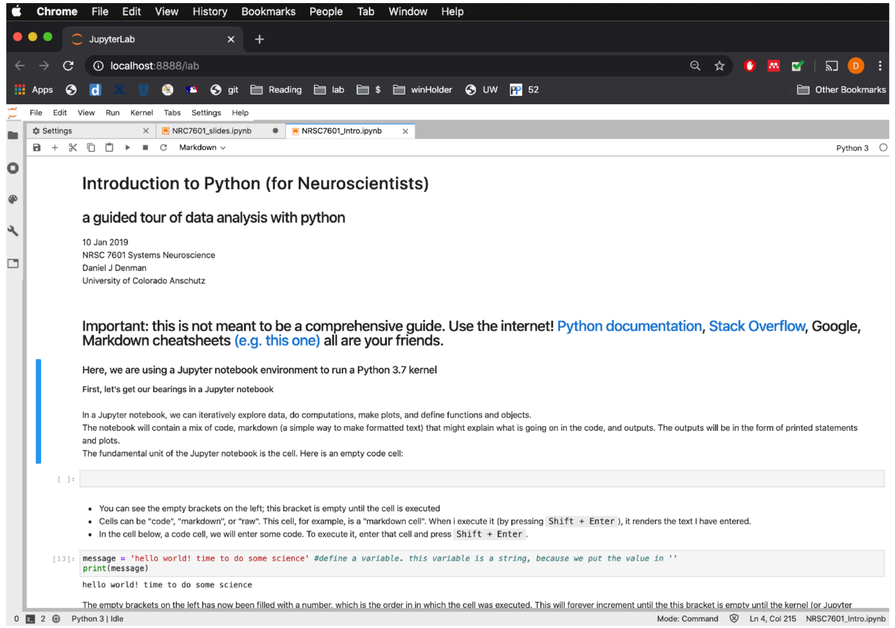
Week 6

Week 1

Scripts

```
Users > danieljdenman > github > mouse_tunnel > mouse_tunnel_auto_CUtest.py
1  from direct.showbase.ShowBase import ShowBase
2  from direct.task import Task
3  # from direct.gui.OnscreenText import OnscreenText
4  # from direct.showbase.DirectObject import DirectObject
5  from direct.interval.MetaInterval import Sequence
6  from direct.interval.LerpInterval import LerpFunc
7  from direct.interval.FunctionInterval import Func
8  from panda3d.core import Mat4, WindowProperties, CardMaker, NodePath, TextureStage, MovieTexture, MovieVideo
9
10 import sys,glob,time,datetime,os
11 from math import pi, sin, cos
12 from numpy.random import randint, exponential
13 from numpy import arange,concatenate
14 import numpy as np
15 from pyglet.window import key
16
17 try:
18     from toolbox.toolbox.IO.nidaq import DigitalInput,DigitalOutput, AnalogInput, AnalogOutput
19     have_nidaq=True
20 except:# Exception, e:
21     print("could not import iodaq.")
22     have_nidaq=False
23
24
25 MOUSE_ID = 'test'
26
27 #this is used to change whether the mouse's running and licking control the rewards.
```

Notebooks (IPython, Jupyter, Jupyter Lab)



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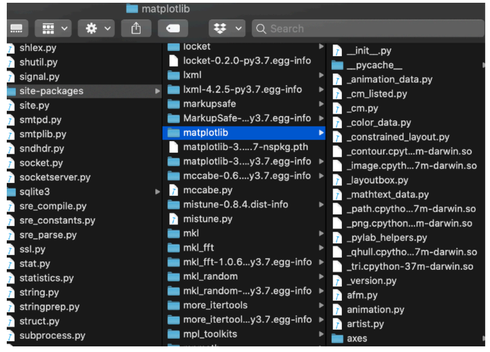

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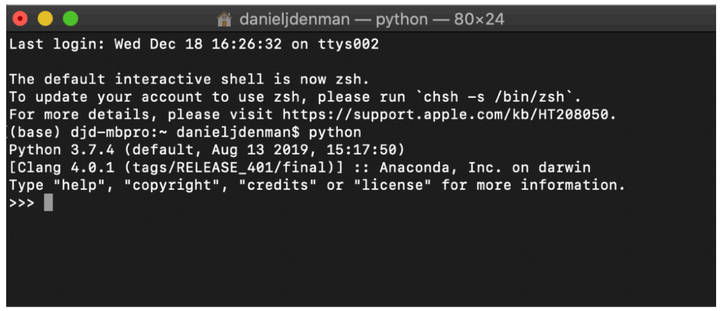

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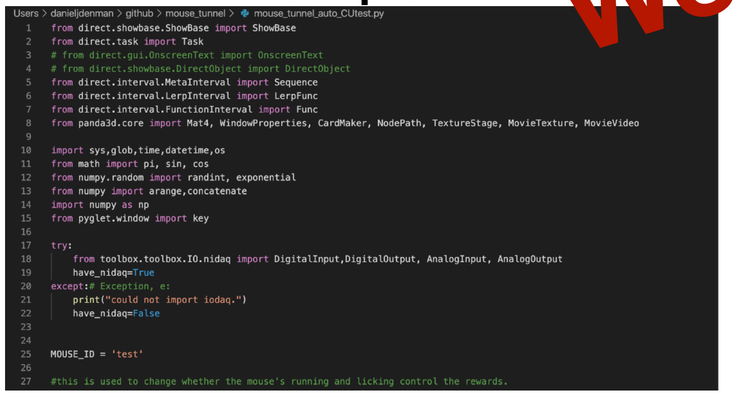
Week 1

Week 6

Scripts



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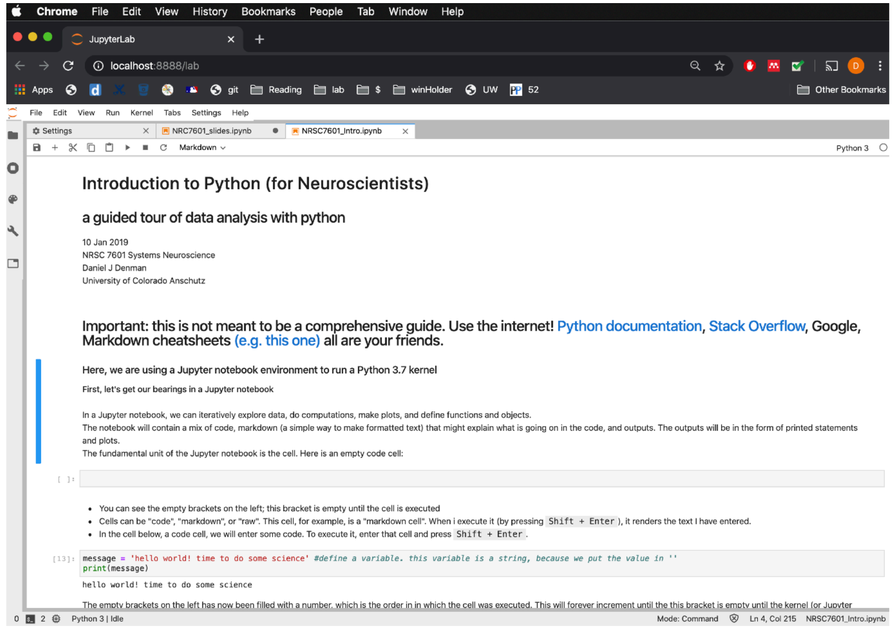
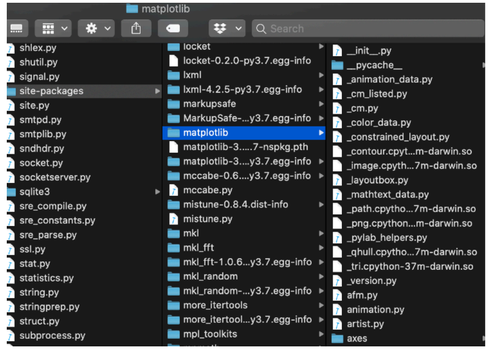


Week 3

Packages



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packages!

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Week 2

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Week 5

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Week 5

Week 6

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Week 2

Weeks 7-9

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Week 5

Week 6

MATLAB

- At this time, some understanding of both Python and MATLAB is extremely useful. We use both in the Denman Lab, but my primary expertise is in Python
- John T going to be MATLAB point person for the course

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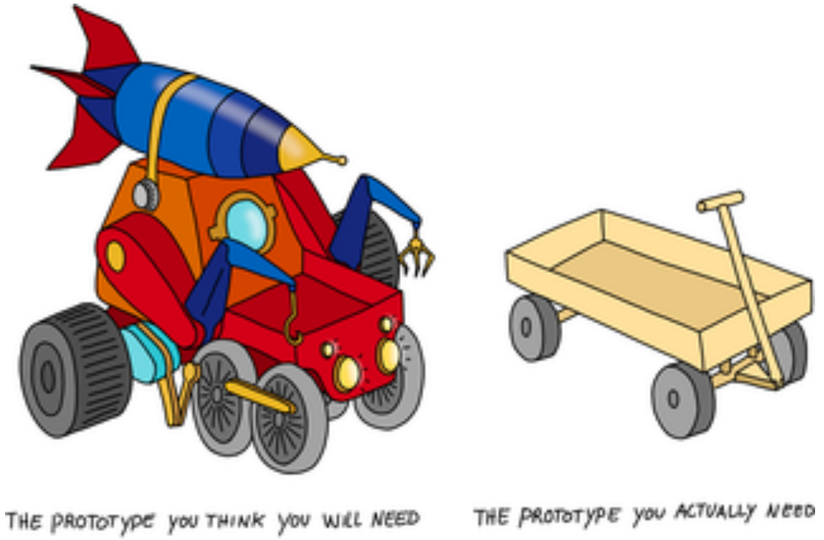
Week 1

- **Anaconda environments and where python is on your computer**
- **Command line: git, starting a jupyter notebook, running a script**
- **Basics and syntax**

Style and philosophy



- **Don't:** overoptimize; get it done first
- **Do:** document as you go
- Pay attention to variable names
- There is a slippery slope from the minimal functional code to unusable/unshareable code
- Read this PLoS paper this week!

PLOS COMPUTATIONAL BIOLOGY

OPEN ACCESS

EDITORIAL

Ten simple rules for quick and dirty scientific programming

Gabriel Balaban, Ivar Grytten, Knut Dagestad Rand, Lonneke Scheffer, Geir Kjetil Sandve

Published: March 11, 2021 • https://doi.org/10.1371/journal.pcbi.1008549

https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1008549

git

…and GitHub, are **version control**

- This is important. And not intuitive. It will likely make you frustrated and/or confused at some point.
- Version control is not optional; if you don't use git for version control, you are going to use something else (e.g,: analysis_script_v1.py, analysis_script_v2.py, analysis_script_v2_20210622.py, analysis_script_v3_07142021.py, analysis_script_final.py,analysis_script_final2.py,…, analysis_script_final2_for.py)
- Making git a part of your workflow can simplify and provide redundancy and flexibility; more advanced features also makes sharing simpler. Evaluation.
- git has to be installed, which we can use Anaconda to do (even if you are using MATLAB only for your project)
- Command-line is great, but if you are new to git we recommend using GitHub Desktop
- **We're going to go over some git interactively to get course materials today.**