

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/poll/ebzksbi3su8dt9cw?utm_source=poll&utm_medium=link

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
Week 2 – language fundamentals	Functions; Objects and Classes; Workspaces Typical data formats: working with tabular data, images, and time series. NeurodataWithoutBorders format
Week 3 – workflow management and outputs	Importing and exporting Plotting and visualization - from bar charts to 3D animation
Week 4 – usability	Troubleshooting and debugging; unit testing
Week 5 – scaling	Iteration and code profiling; parallel computing. Code quality-of-life topics
Week 6 – collaboration	Cloud-based tools: AWS, GCC, Colab, jupyterhub, deepnote. Overview of some available SAAS tools, python focused. Group programming time
Week 7 – applications/flex topic	Applications: image processing (ES) Group programming time
Week 8 – applications/flex topic	Applications: spike sorting (DD) Group programming time
Week 9 – applications/flex topic	Applications: flex Group programming time
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)

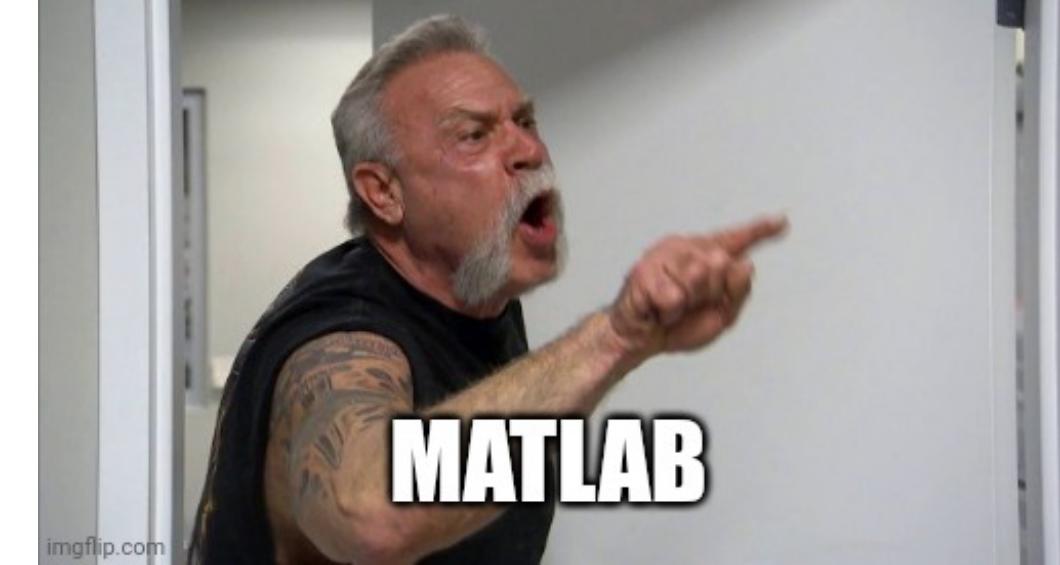
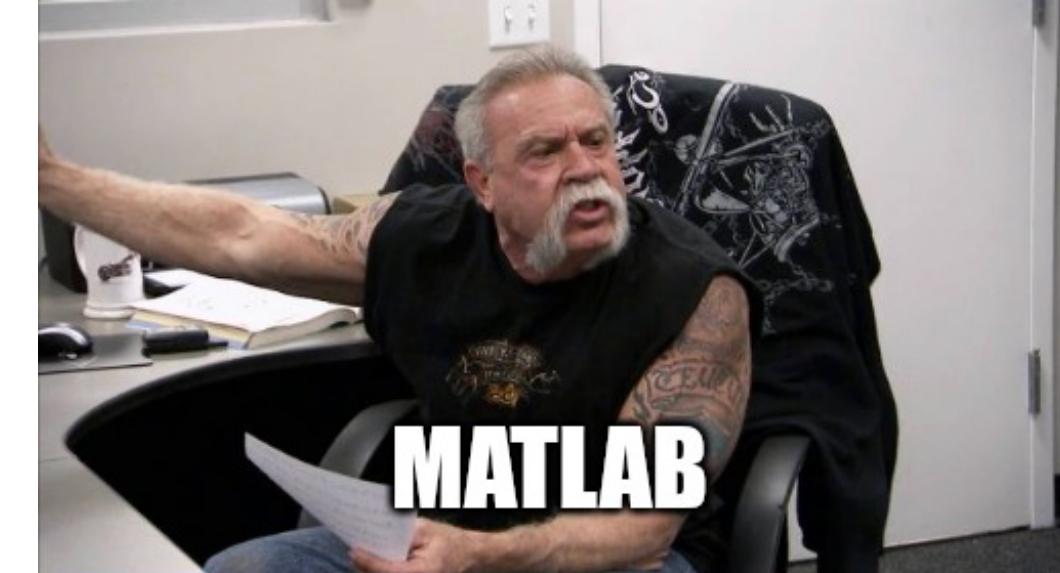
- Allen Institute for Brain Science brain-map.org
- DABI Data Archive BRAIN Initiative <https://dabi.loni.usc.edu/home>

The screenshot shows a grid of project datasets. The first row contains three items: 'Transcriptional Landscape of the Brain' (with an icon of a brain grid), 'Behavioral Circuits & Sensory Processing' (with an icon of brain waves), and 'Connectivity Matrices' (with an icon of a brain network). The second row contains two items: 'Computational Modeling & Theory' (with an icon of a brain model) and 'Cell Taxonomies' (with an icon of a brain cell). Each item has a brief description and a blue 'Explore' button.

The screenshot shows a 'MENU' bar with options like 'Explore Studies' and 'Explore by Interest'. Below it is a 'Explore Data' section with a search bar labeled 'Search Interests'. A list of studies is displayed, including 'Adaptive Neurostimulation to Restore...' by University of Colorado (Thompson). A call-to-action button 'Open' is shown at the bottom right. On the right side, there are circular icons numbered 1 and 3, and a footer text 'Explore by study by areas of interest'.

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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Ask questions!



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

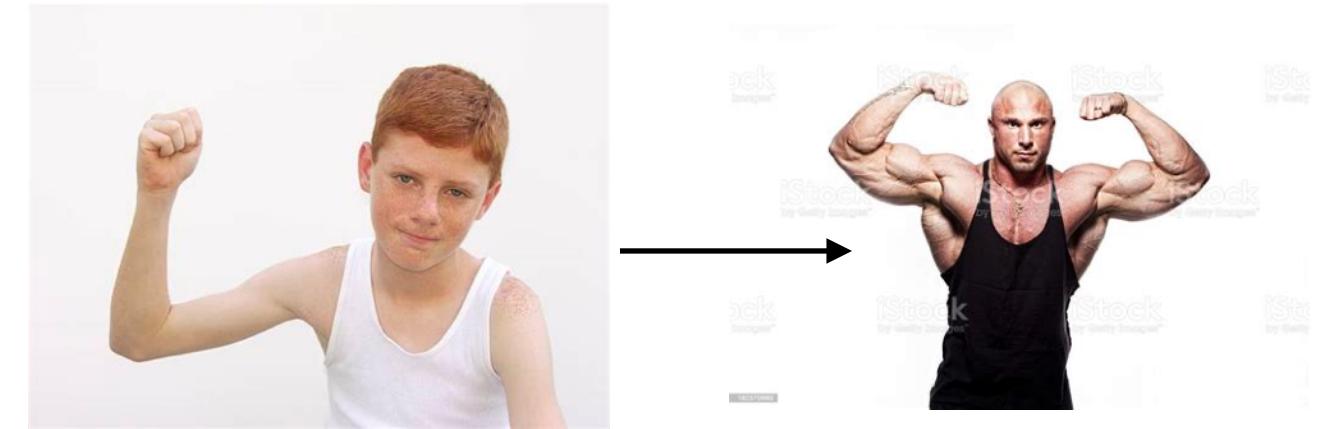
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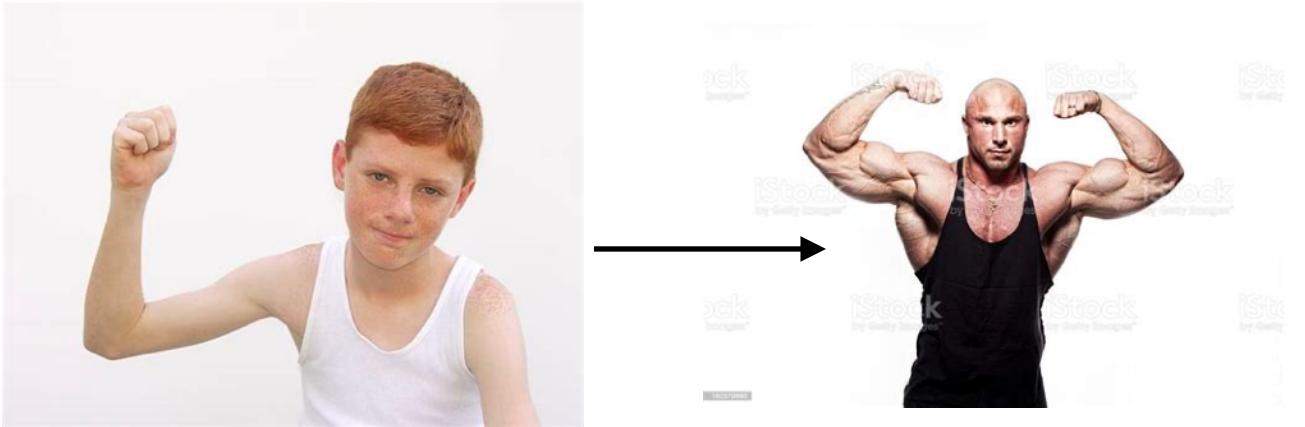


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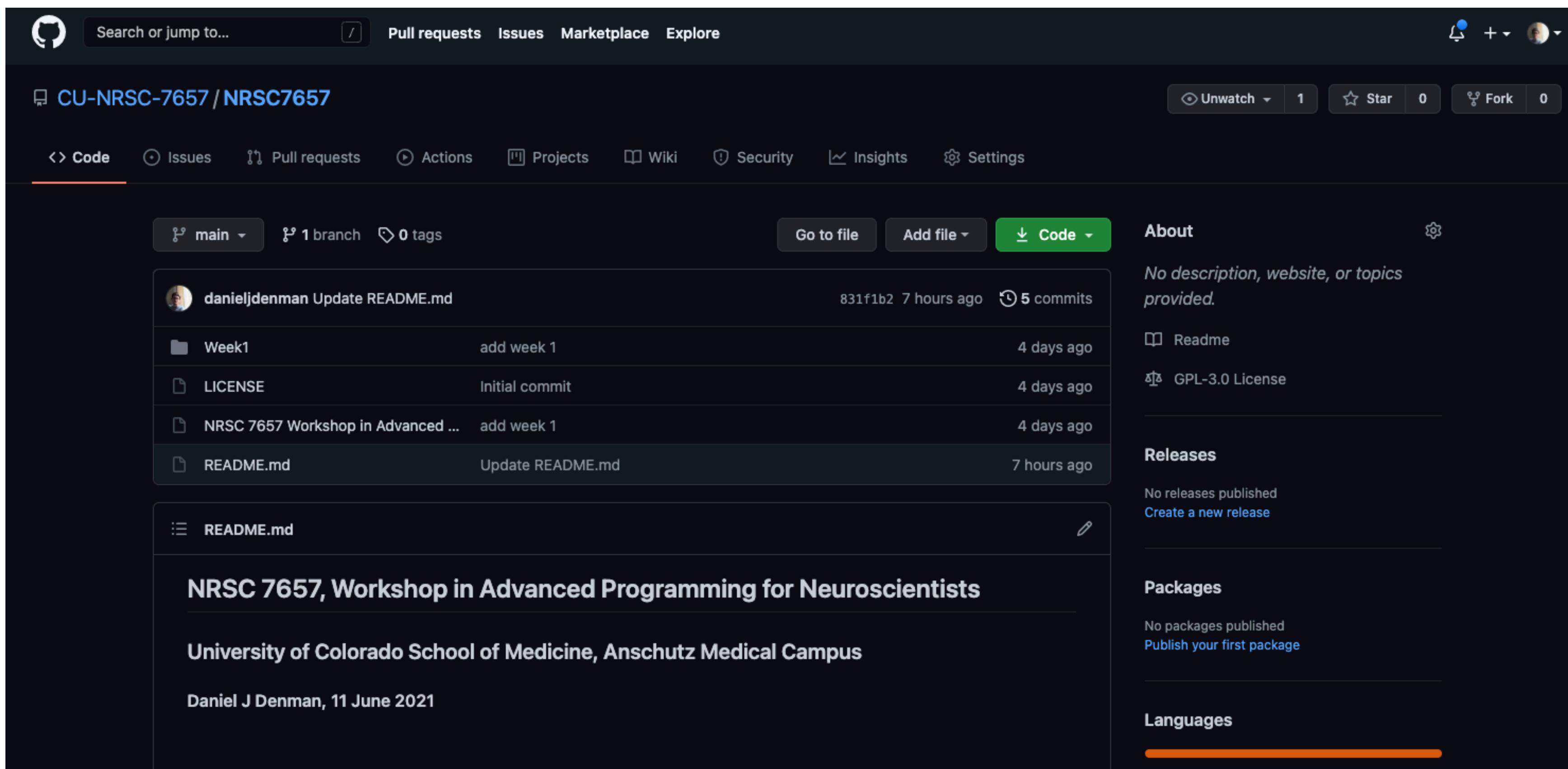


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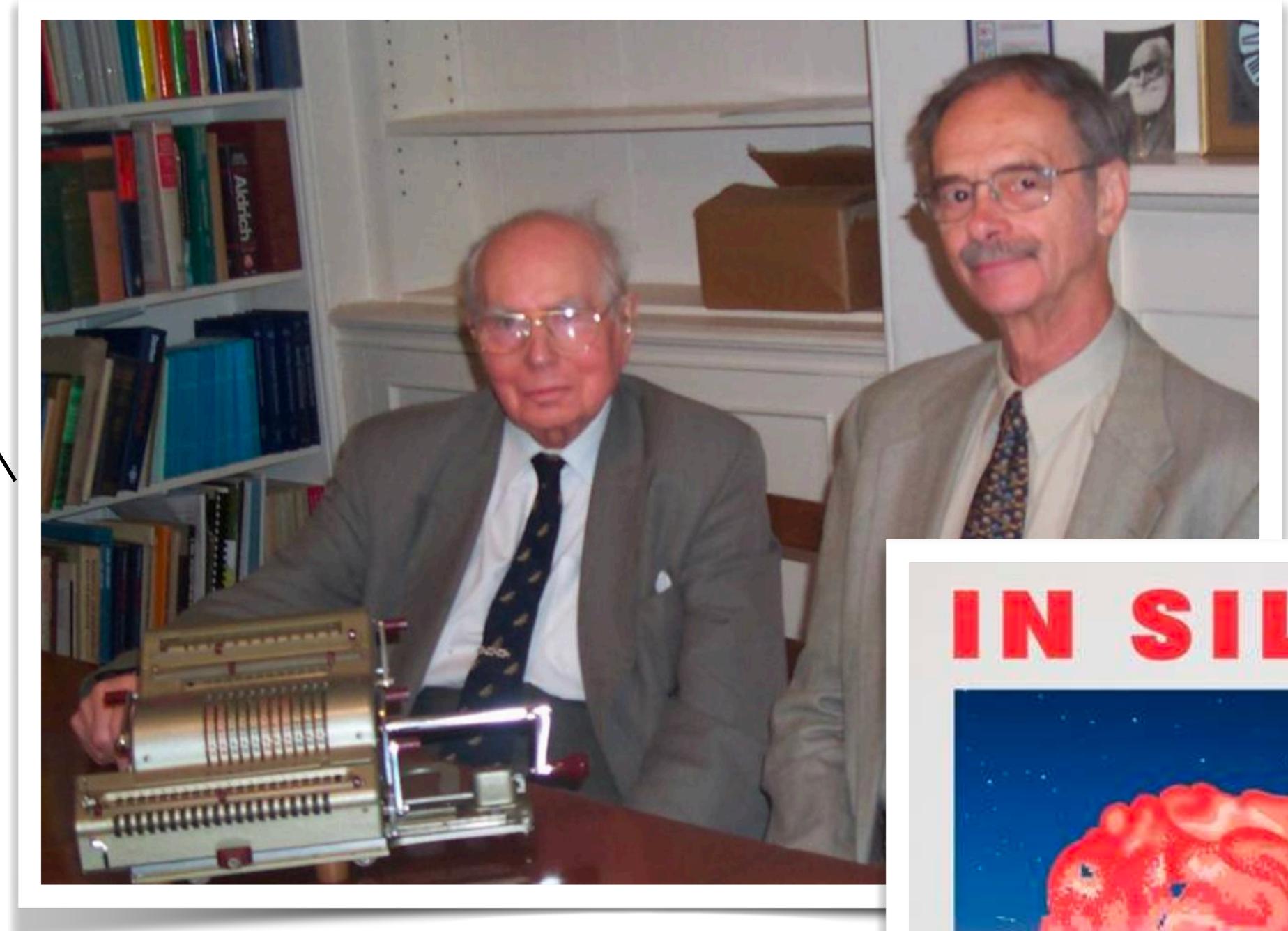
Final practicalities

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

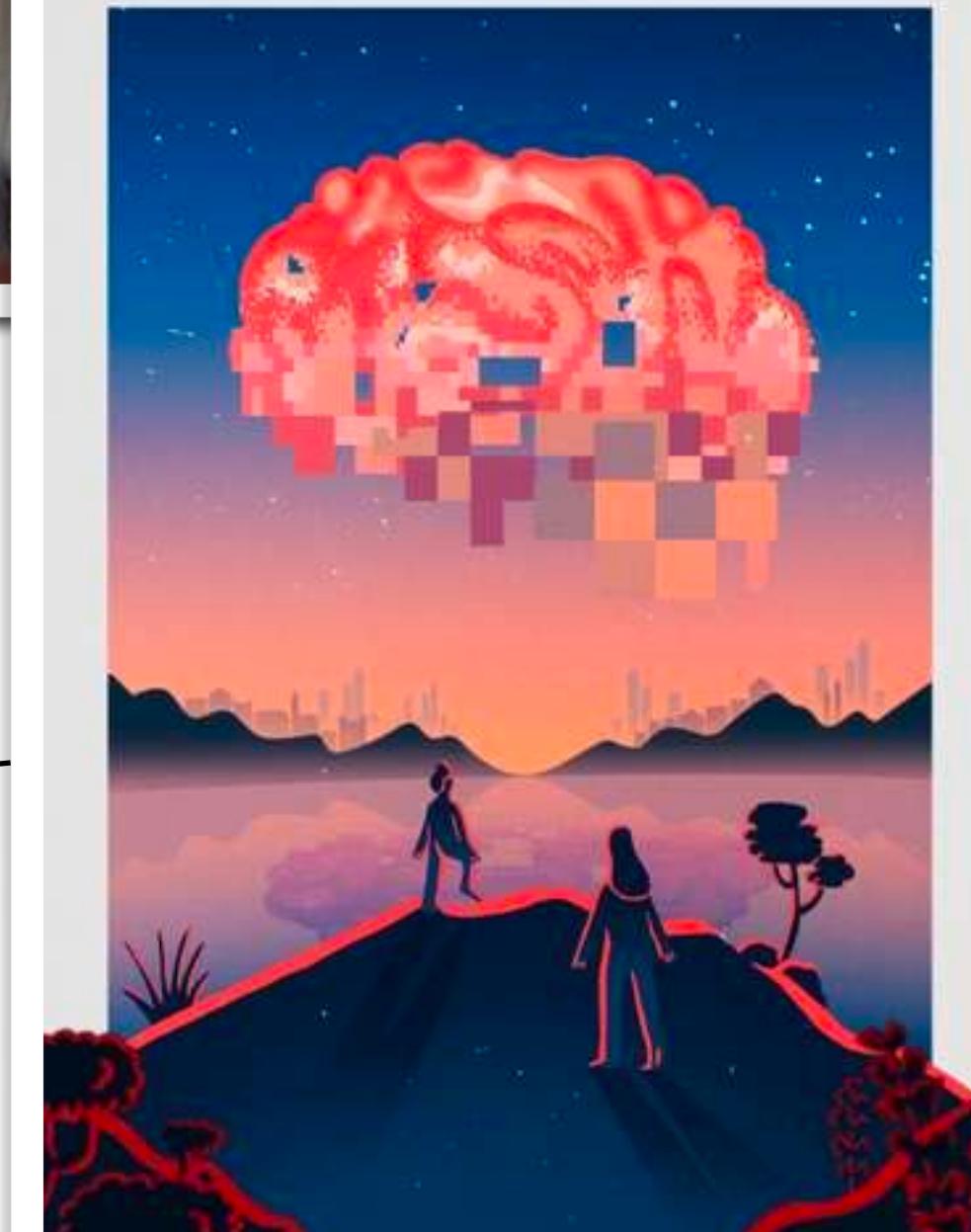


Computing in neuroscience

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



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

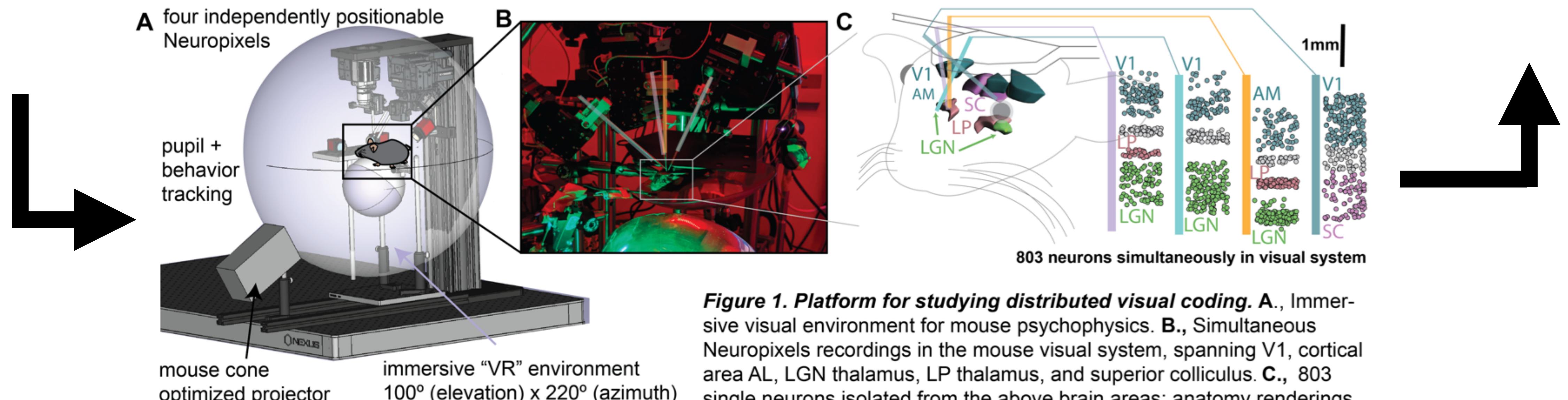


Figure 1. Platform for studying distributed visual coding. **A.**, Immersive visual environment for mouse psychophysics. **B.**, Simultaneous Neuropixels recordings in the mouse visual system, spanning V1, cortical area AL, LGN thalamus, LP thalamus, and superior colliculus. **C.**, 803 single neurons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

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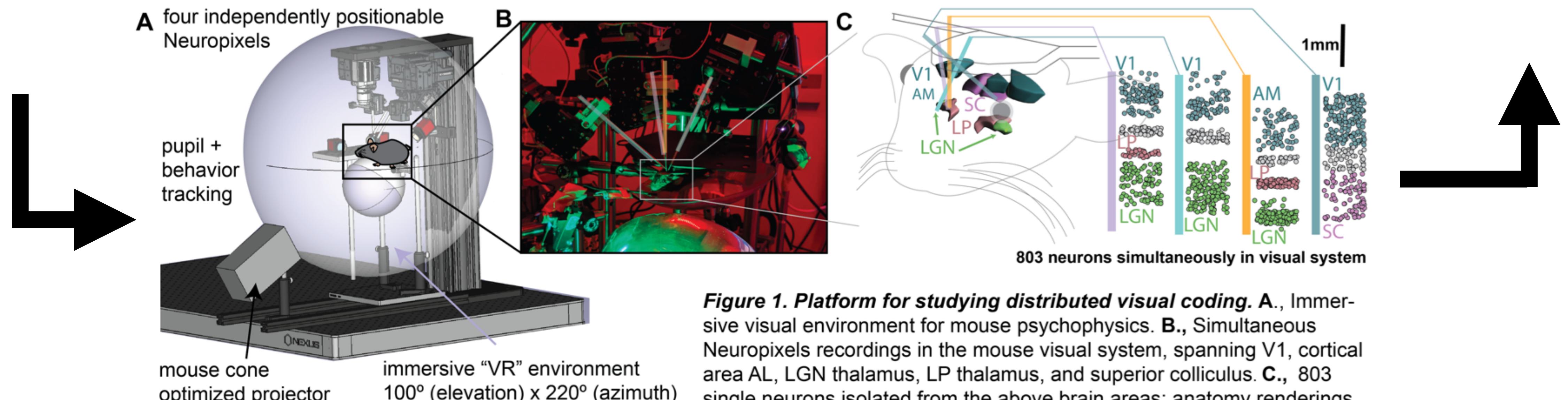


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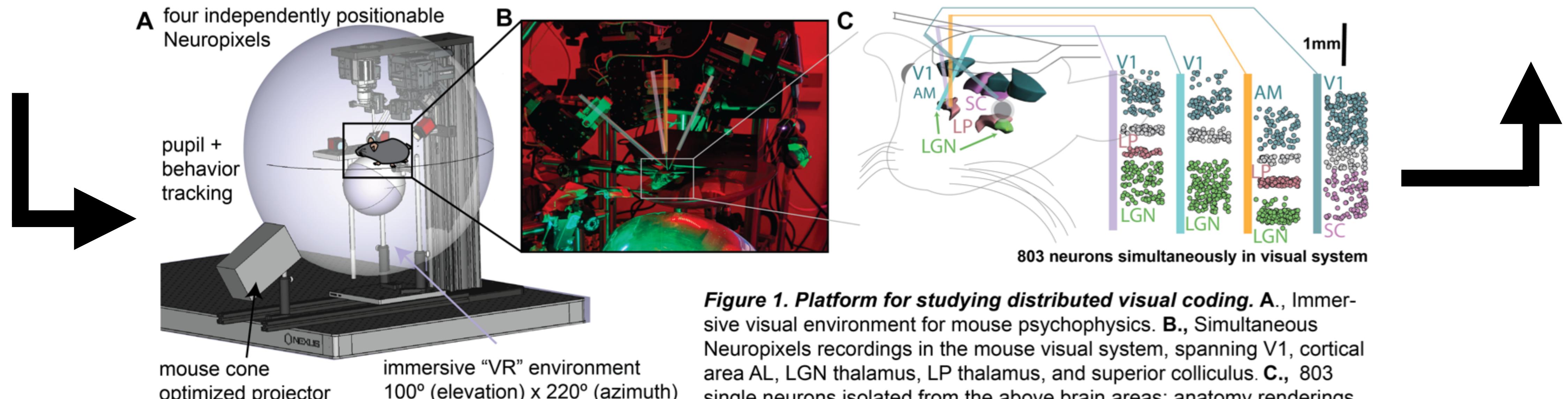
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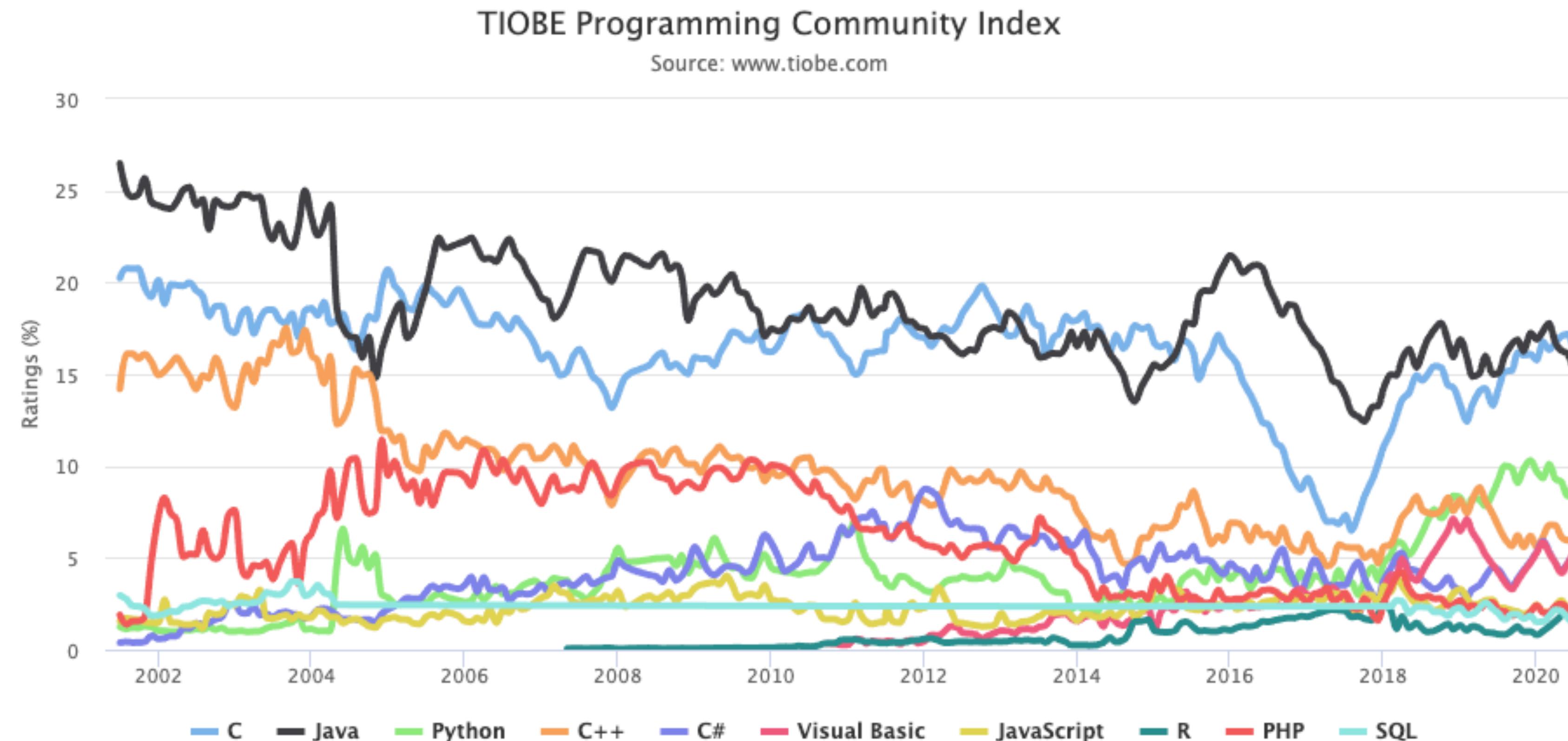
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Stimulus responses: python

Population statistics: **MATLAB and python**



history: languages used for neuroscience



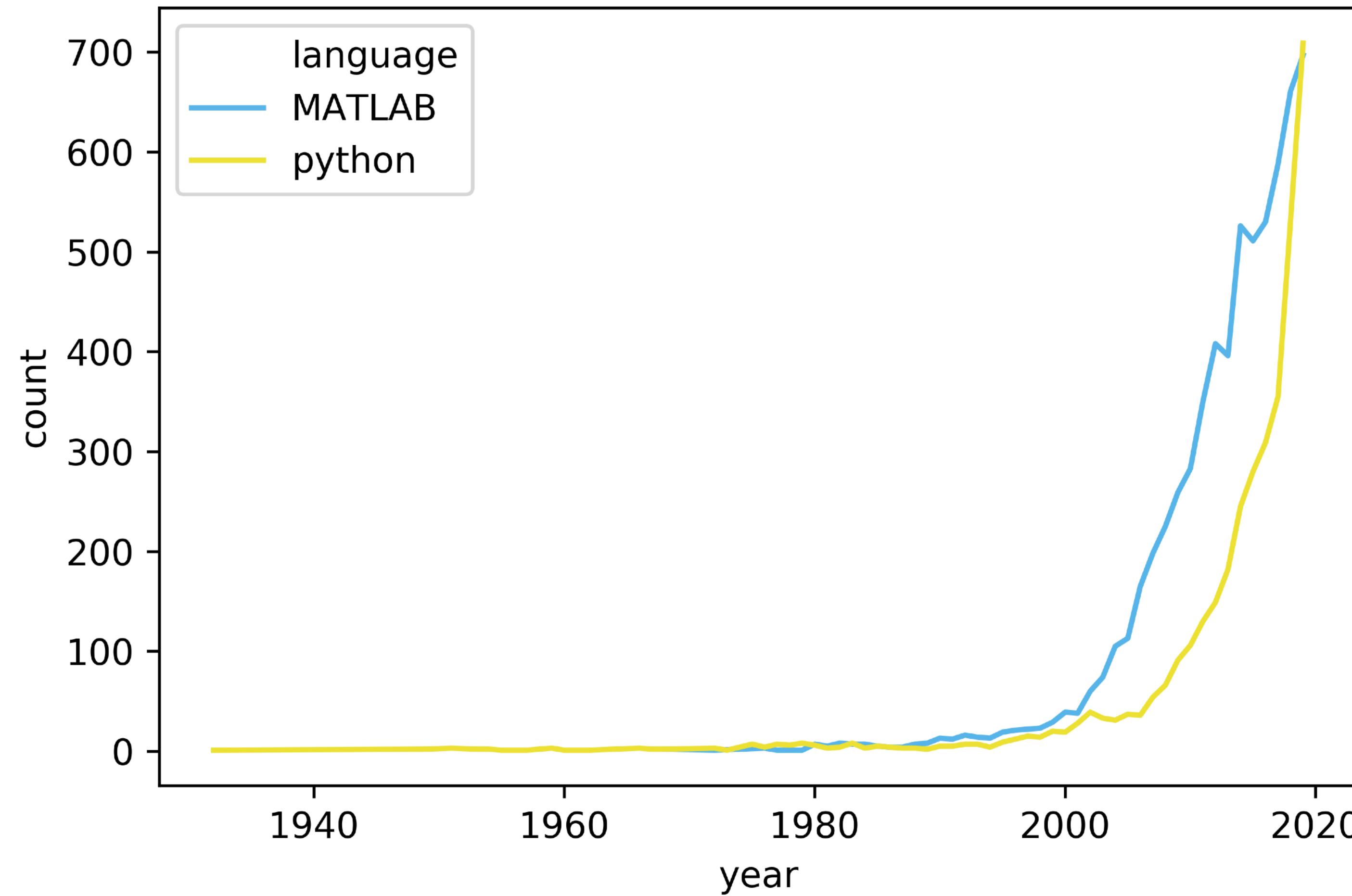
history: languages used for neuroscience

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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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Volume 16 Issue 12, December 2019



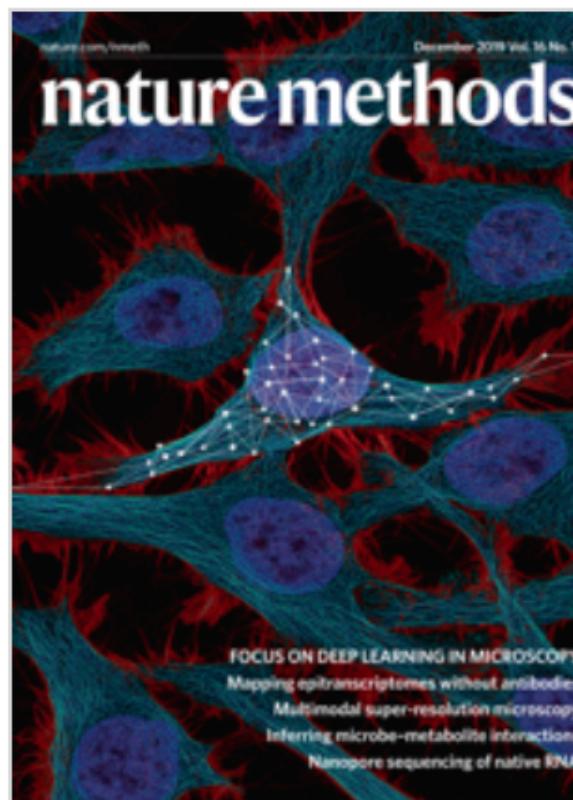
Focus on Deep Learning in Microscopy

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 Haghghi, 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

Volume 16 Issue 12, December 2019



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Artwork representing the application of deep learning methods in microscopy.

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

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- 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”
- Support for Python2.7 ended Jan 1, 2020



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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

overview

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

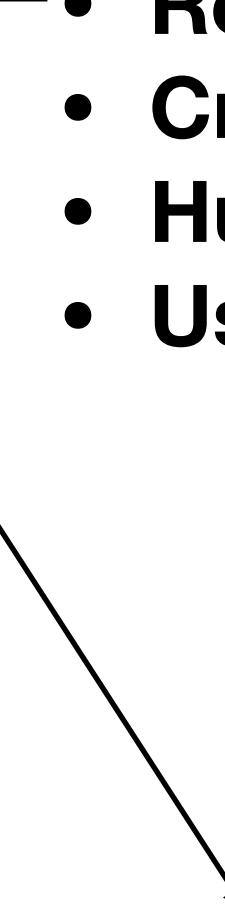
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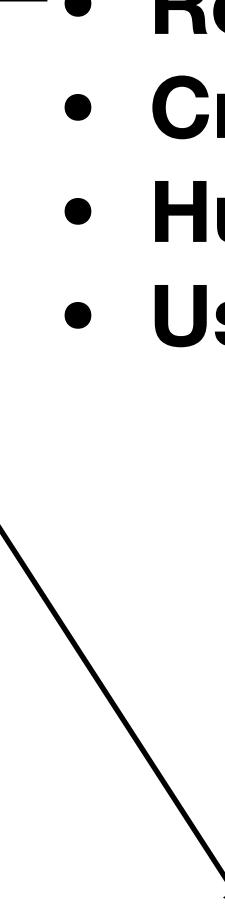
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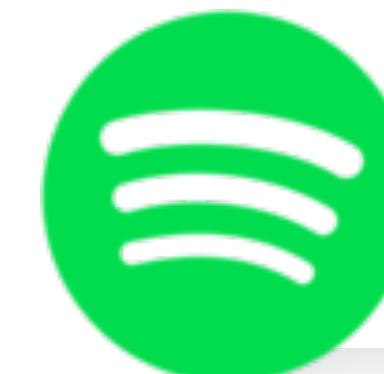
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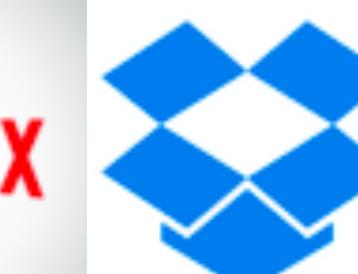
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amazon



NETFLIX



You Tube

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overview: packages

Find, install and publish Python packages
with the Python Package Index

Search projects



Or [browse projects](#)

211,372 projects

1,607,586 releases

2,417,893 files

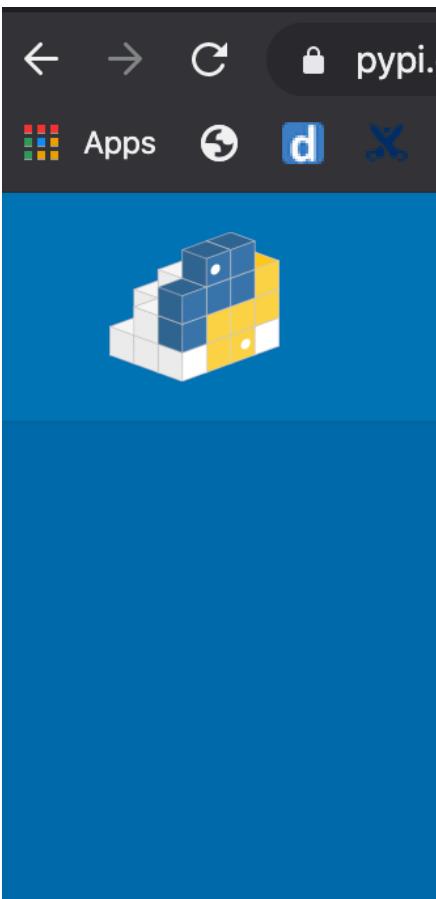
394,404 users

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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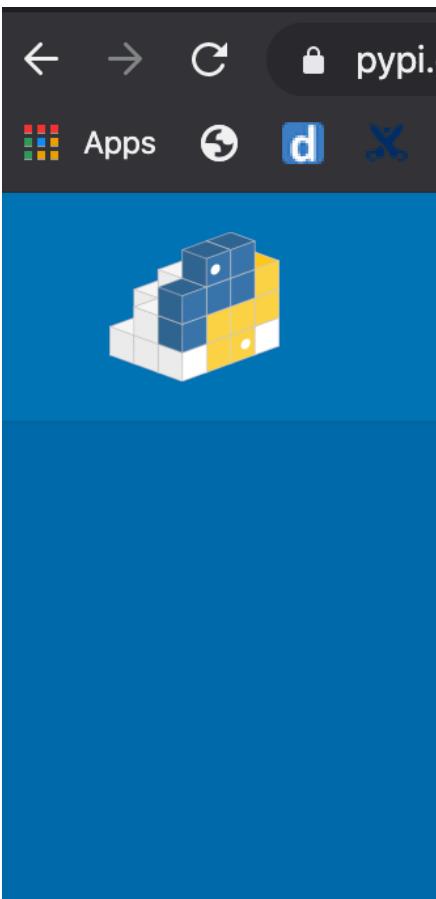
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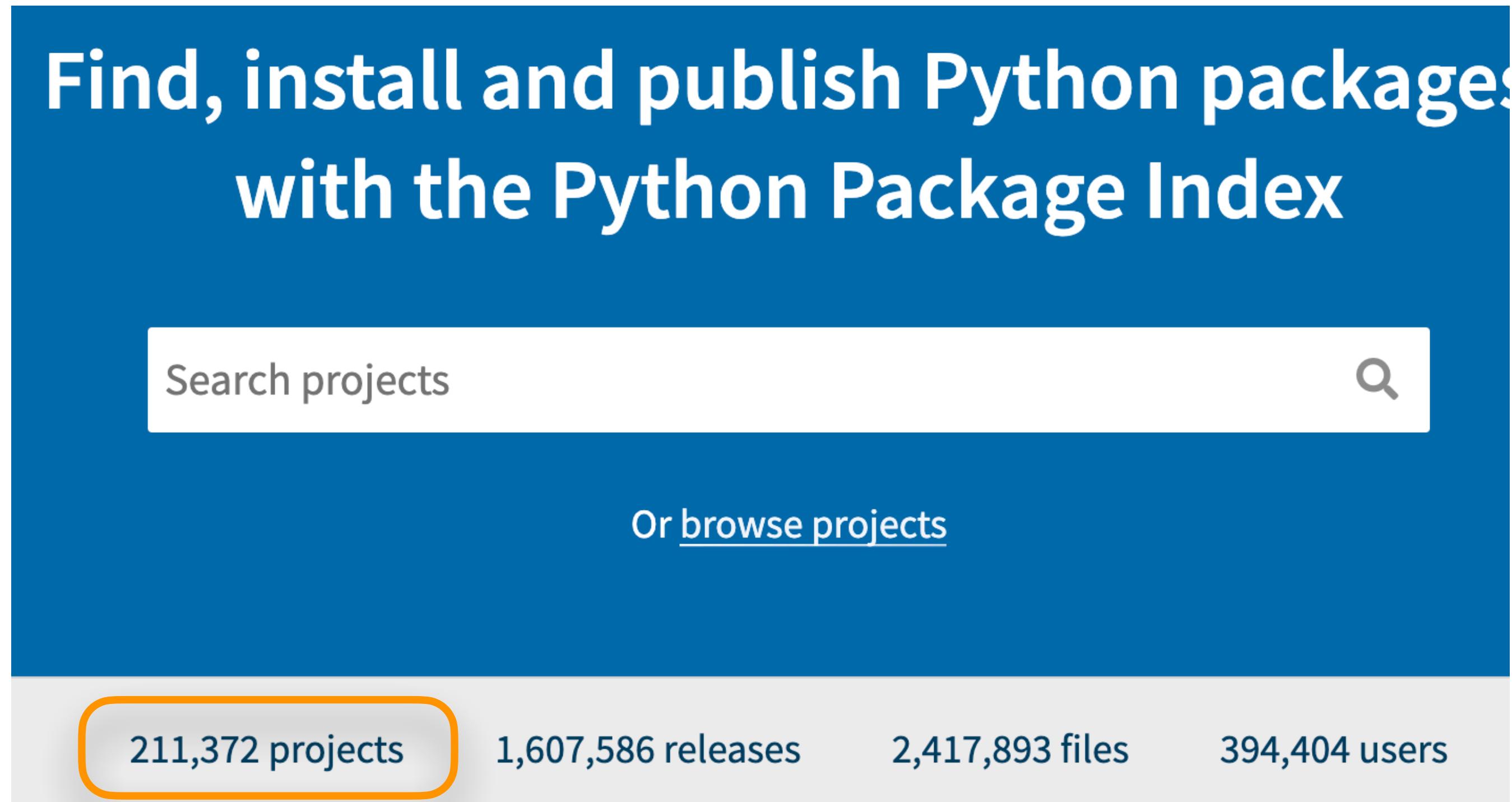
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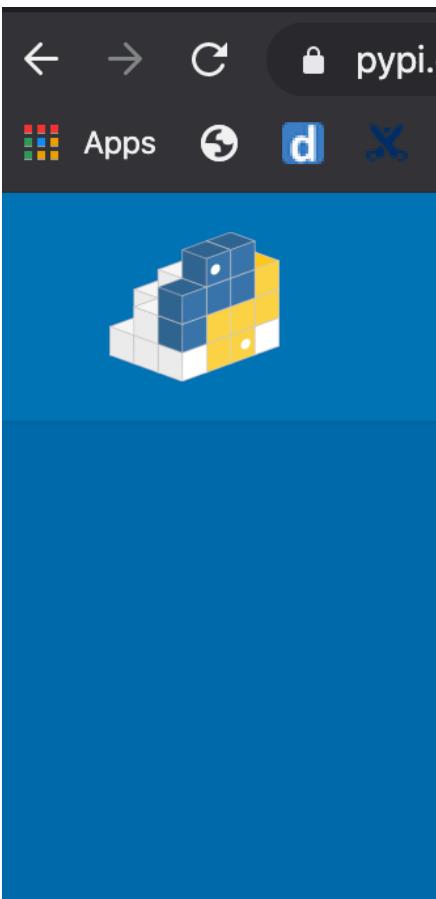


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overview: levels



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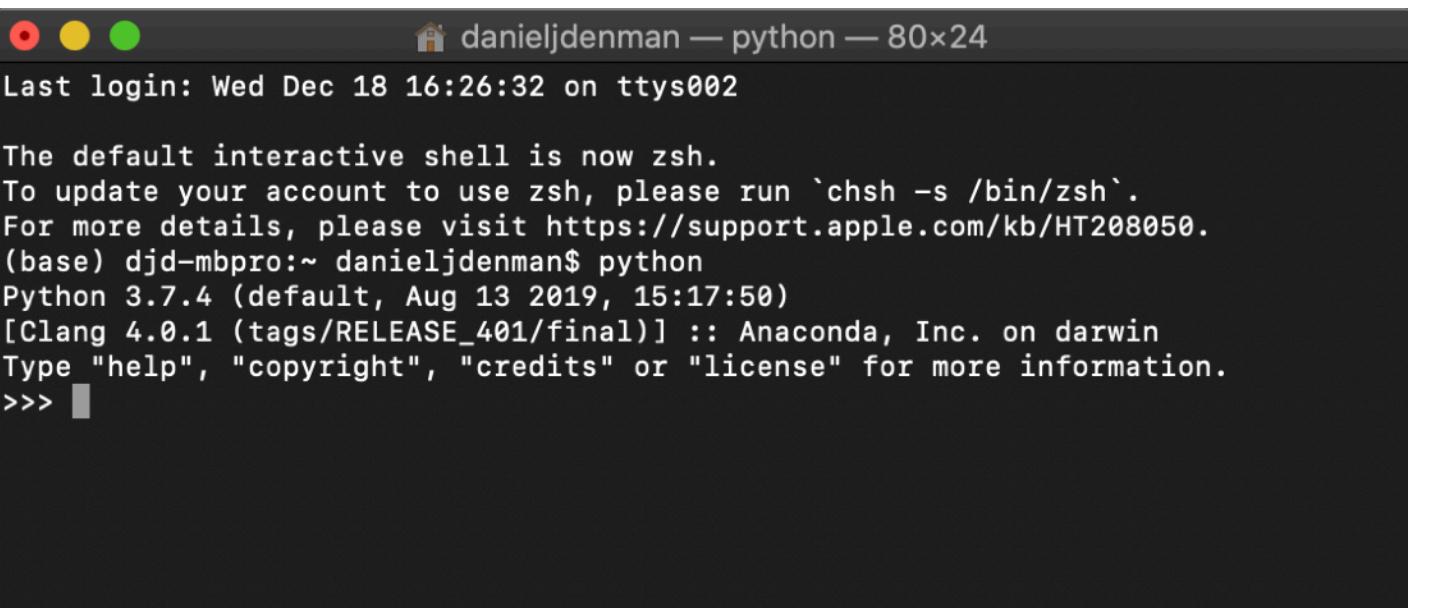
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The default interactive shell is now zsh.
To update your account to use zsh, please run `chsh -s /bin/zsh`.
For more details, please visit https://support.apple.com/kb/HT208050.
(base) djd-mbpro:~ danieljdenman$ python
Python 3.7.4 (default, Aug 13 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.
>>> 
```

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



overview: levels

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A screenshot of a Mac OS X terminal window titled "danieljdenman — python — 80x24". The window shows the following text:

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Package Managers Environments





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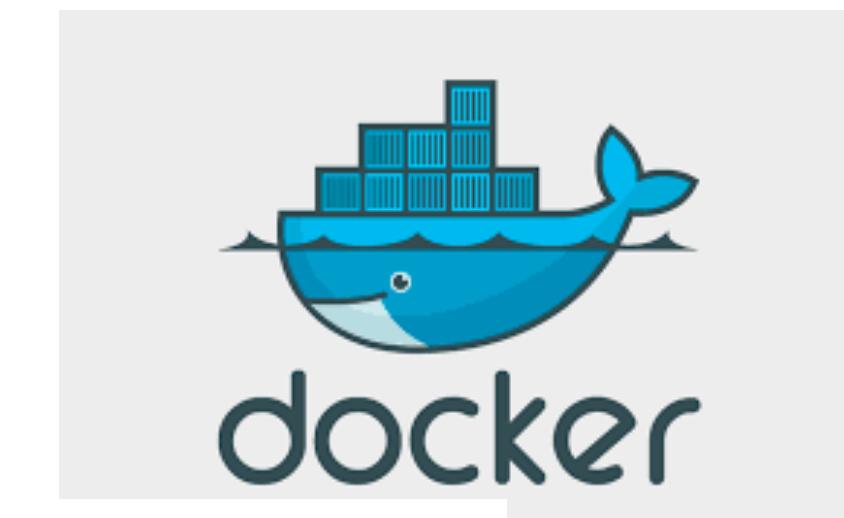
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Package Managers Environments



Containerized





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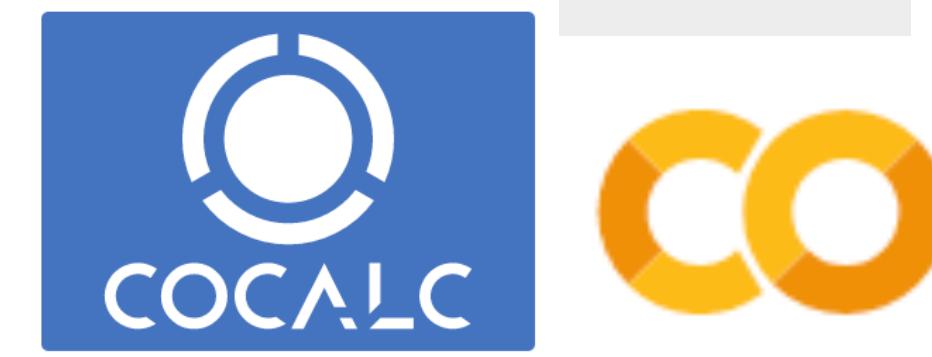
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Scripts

```
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.
```

overview: levels

Containerized



Package Managers Environments





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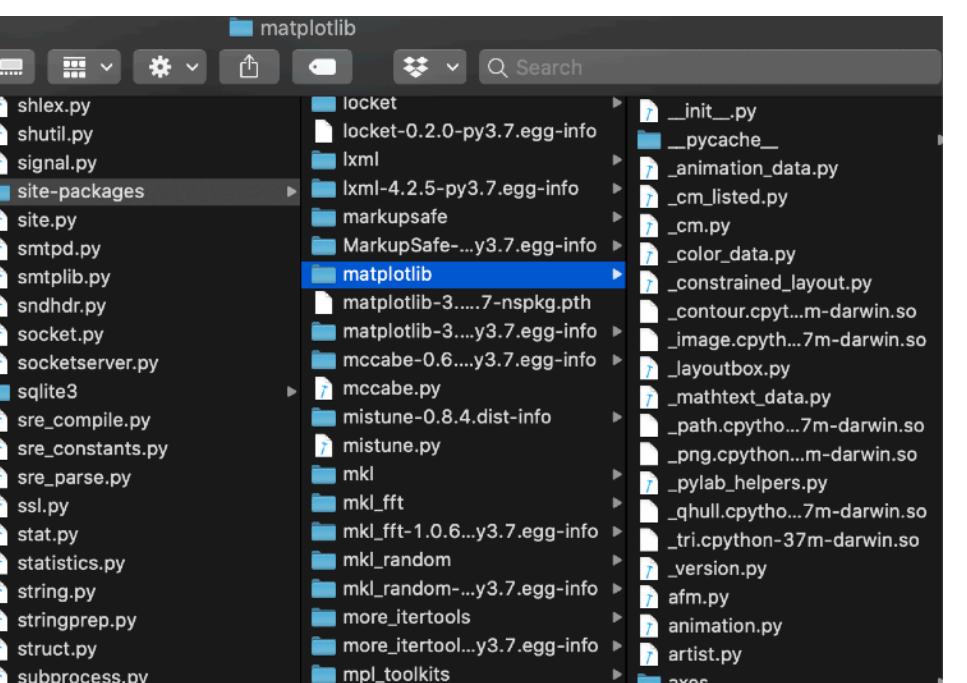
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Type "help", "copyright", "credits" or "license" for more information.
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Packages

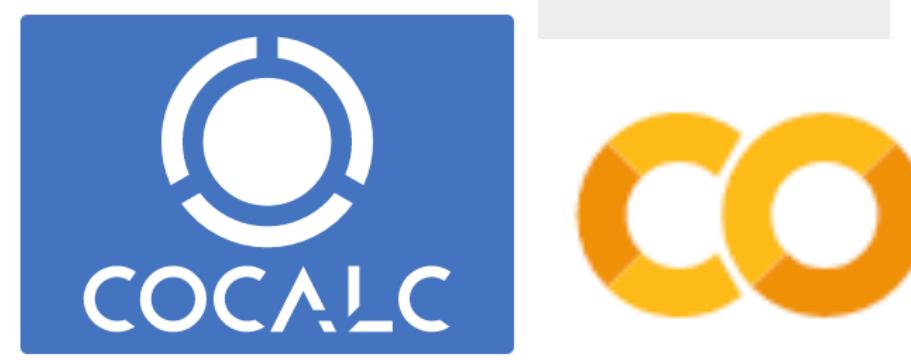


overview: levels

Package Managers Environments

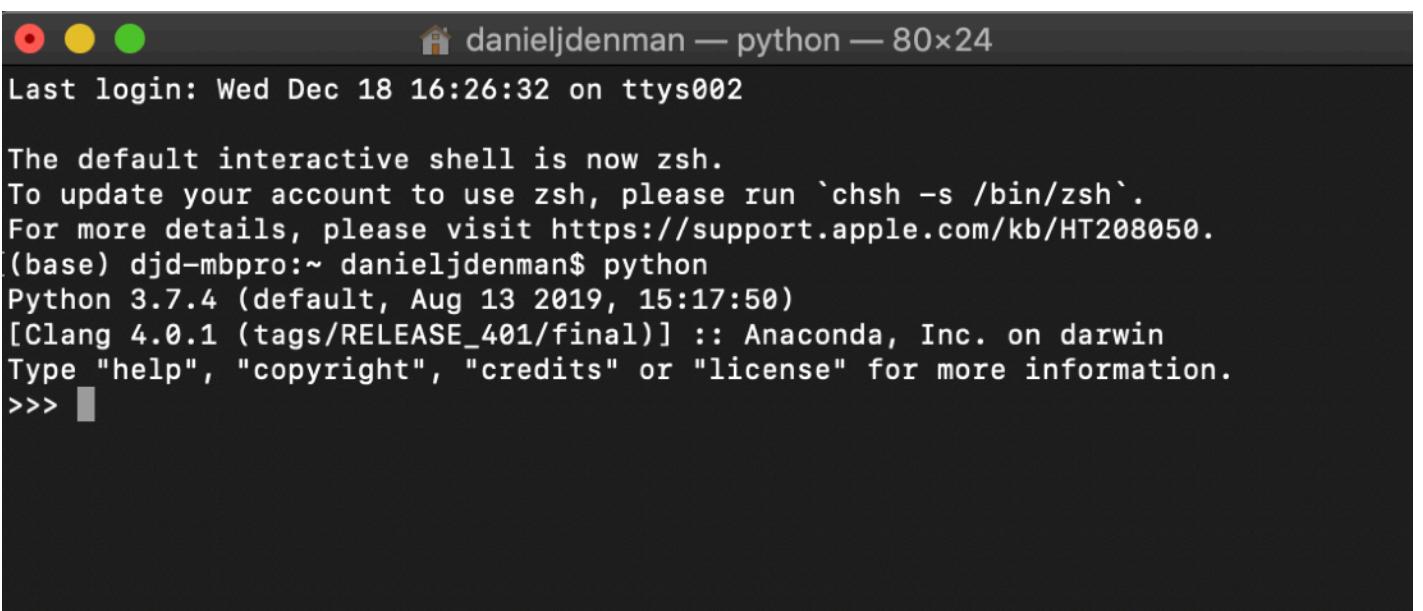


Containerized





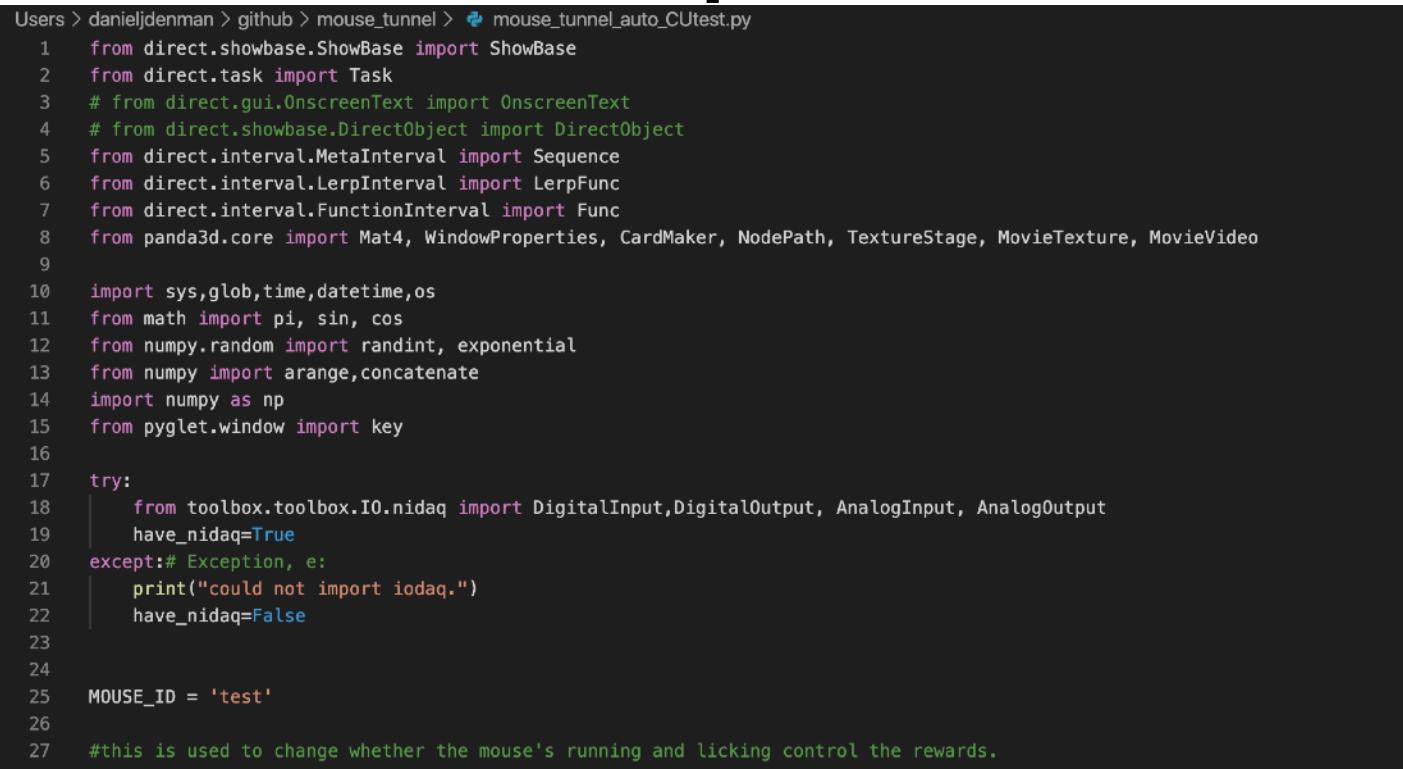
System



```
Last login: Wed Dec 18 16:26:32 on ttys002
The default interactive shell is now zsh.
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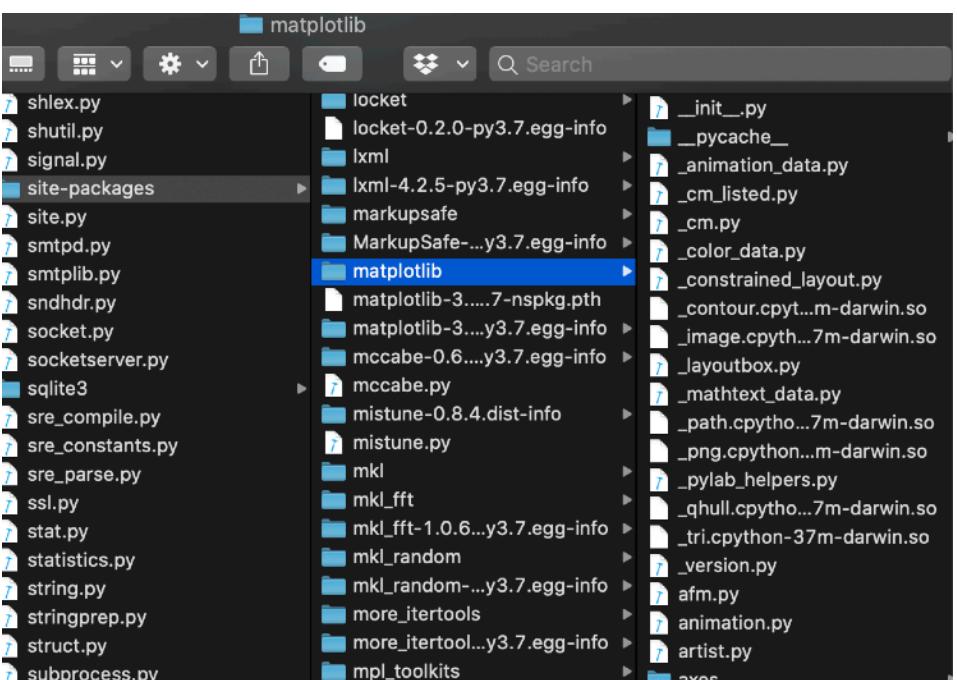
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Packages

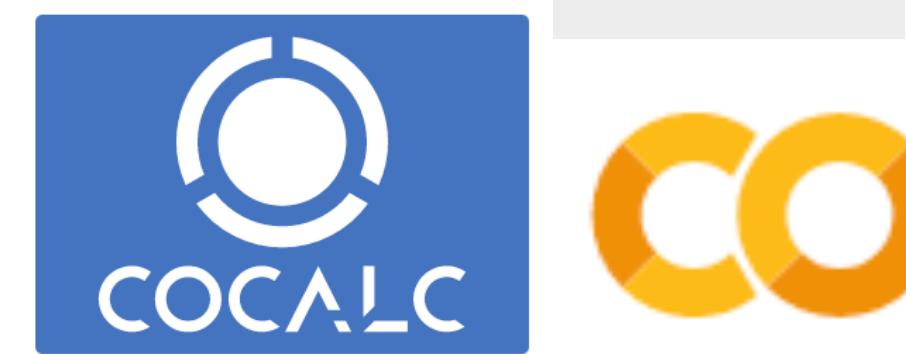


overview: levels

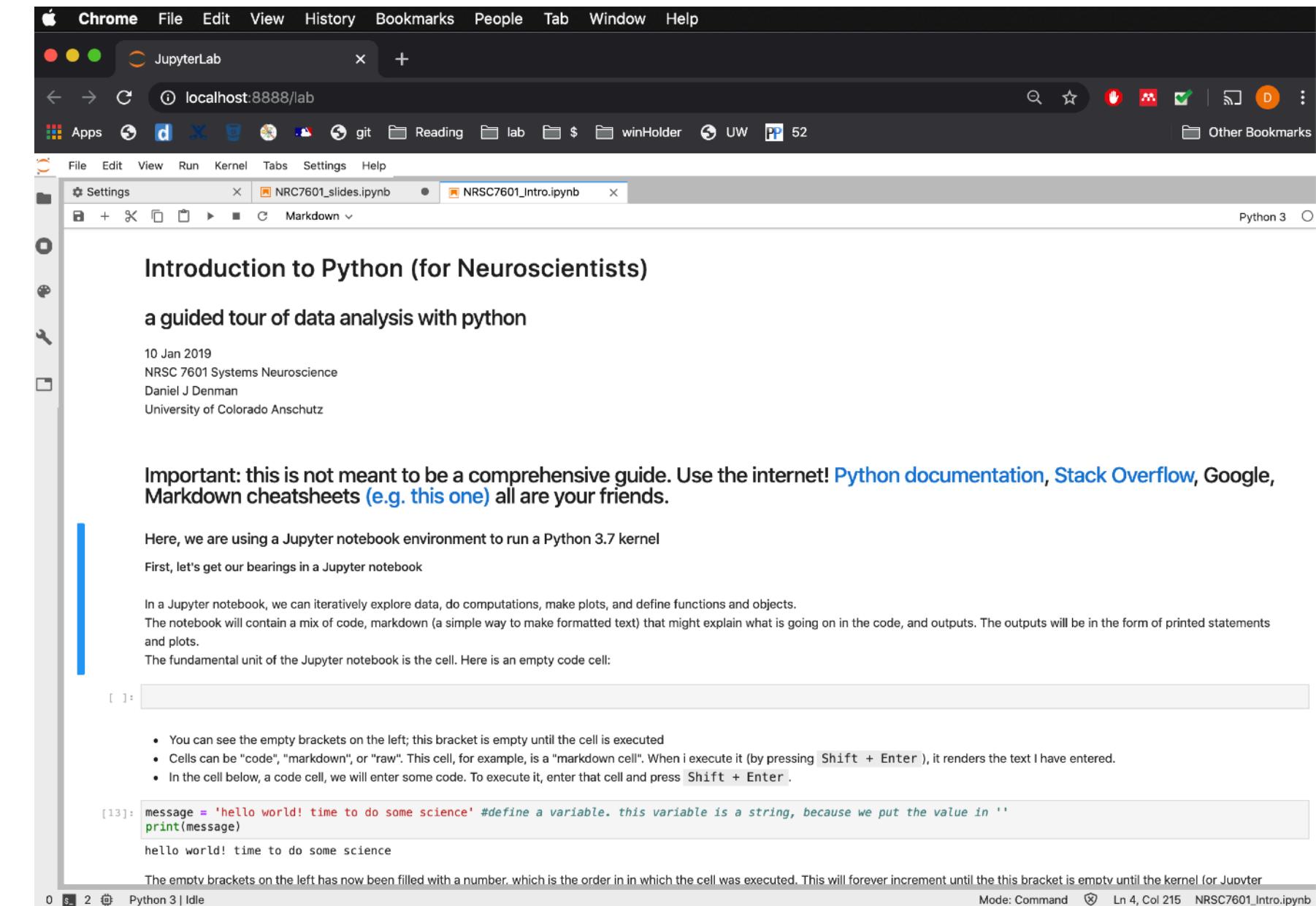
Containerized



Package Managers Environments



Notebooks (IPython, Jupyter, Jupyter Lab)



A screenshot of a Jupyter Notebook interface in a web browser. The title bar says 'JupyterLab' and the address bar shows 'localhost:8888/lab'. The main area displays a notebook titled 'NRC7601_intro.ipynb'. The first cell contains the text 'Introduction to Python (for Neuroscientists)' and 'a guided tour of data analysis with python'. It also includes a timestamp '10 Jan 2019', author information 'NRSC 7601 Systems Neuroscience', and 'Daniel J Denman', and the institution 'University of Colorado Anschutz'. The second cell contains the text 'Important: this is not meant to be a comprehensive guide. Use the internet! Python documentation, Stack Overflow, Google, Markdown cheatsheets (e.g. [this one](#)) all are your friends.' The third cell starts with 'Here, we are using a Jupyter notebook environment to run a Python 3.7 kernel'. Below it, a code cell shows the command 'print("Hello world! time to do some science")' and its output 'Hello world! time to do some science'. A note at the bottom states 'The empty brackets on the left have now been filled with a number, which is the order in which the cell was executed. This will forever increment until the this bracket is empty until the kernel for Jupyter'.



System

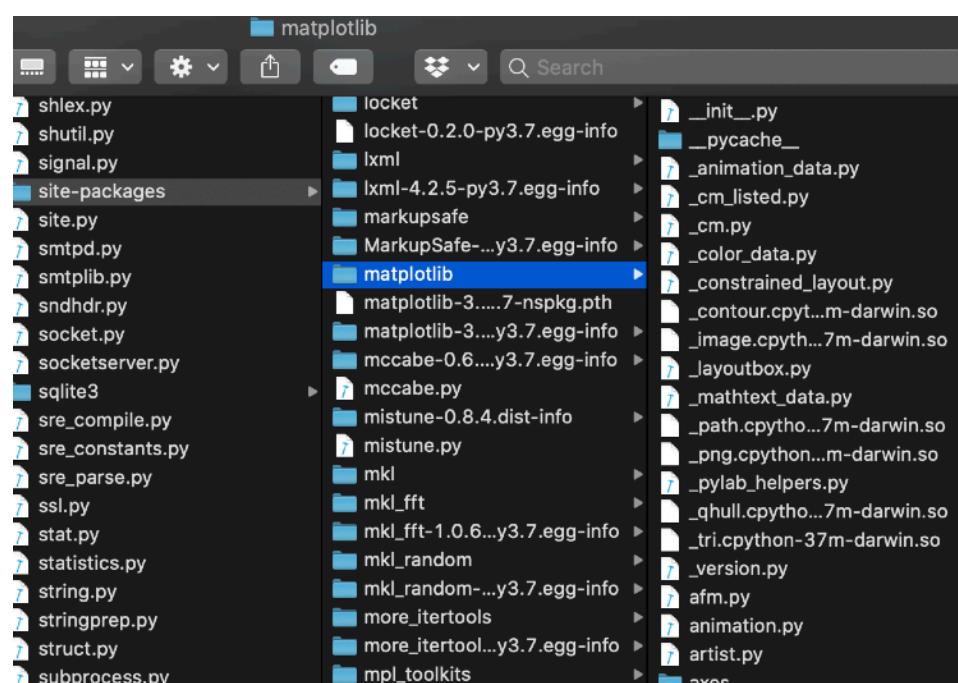
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Packages



overview: levels

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Package Managers Environments



Week 1

Notebooks (IPython, Jupyter, Jupyter Lab)

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System



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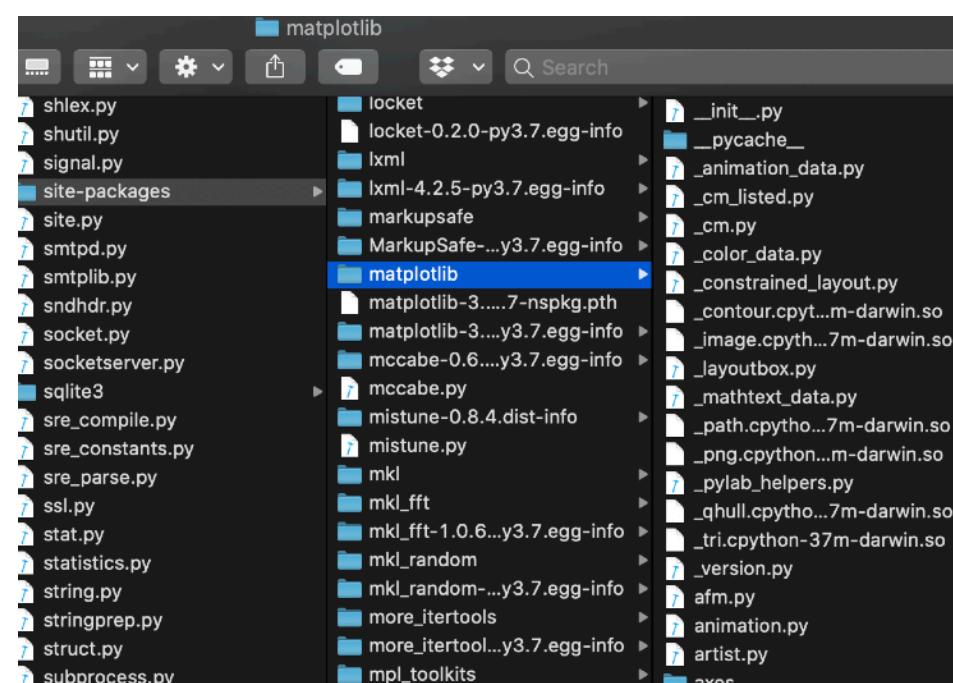
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Packages



overview: levels

Package Managers Environments



Containerized



Week 6

Notebooks (IPython, Jupyter, Jupyter Lab)

Introduction to Python (for Neuroscientists)
a guided tour of data analysis with python
10 Jan 2019
NRSC 7601 Systems Neuroscience
Daniel J Denman
University of Colorado Anschutz

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[13]: message = 'Hello world! Time to do some science' #define a variable. this variable is a string, because we put the value in '
print(message)
Hello world! Time to do some science
```

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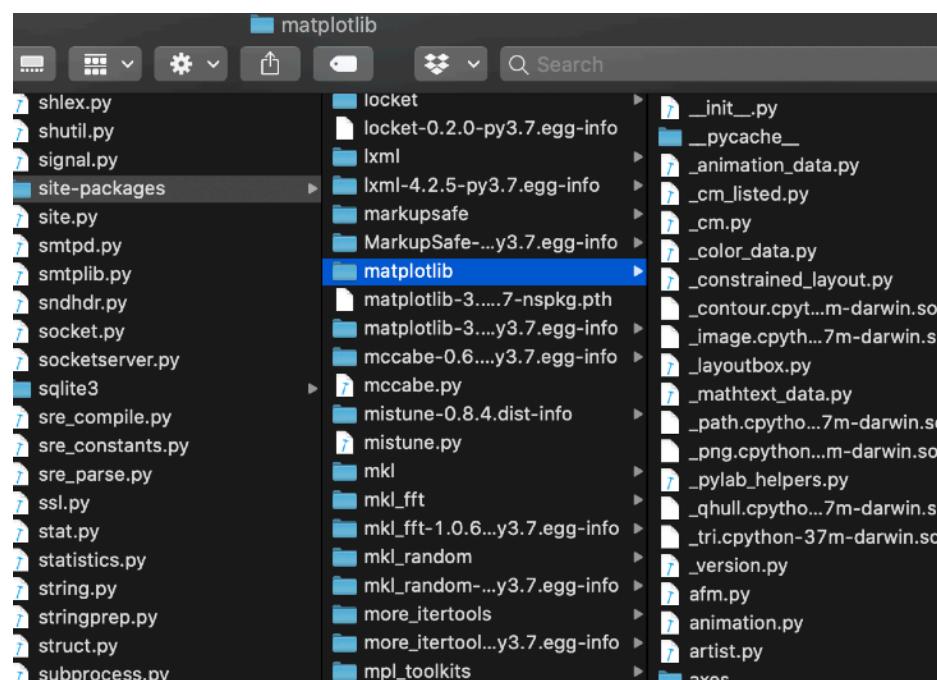
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Week 3

Packages



overview: levels

Package Managers Environments



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why is it good for doing neuroscience?

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- Do analyses that would be a whole PhD to implement yourself (i.e., ML)
 - automate boring stuff / use other people's hard work
- packages!

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Stack Overflow <— not cheating!

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also it is free —> democratizing science

in this realm, cloud resources (data, compute) also open science to a wider group that aren't collecting their own data and running their own super computers

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Hardware control

RaspberryPi

Arduino

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...many APIs...

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Sharing

Docker
Google Colab
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Week 2

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Week 2

Sharing
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Week 5

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Week 2

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Week 5
Week 6

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Weeks 7-9

Data science

scikit-learn
Pandas
TensorFlow



Week 2

Sharing

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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

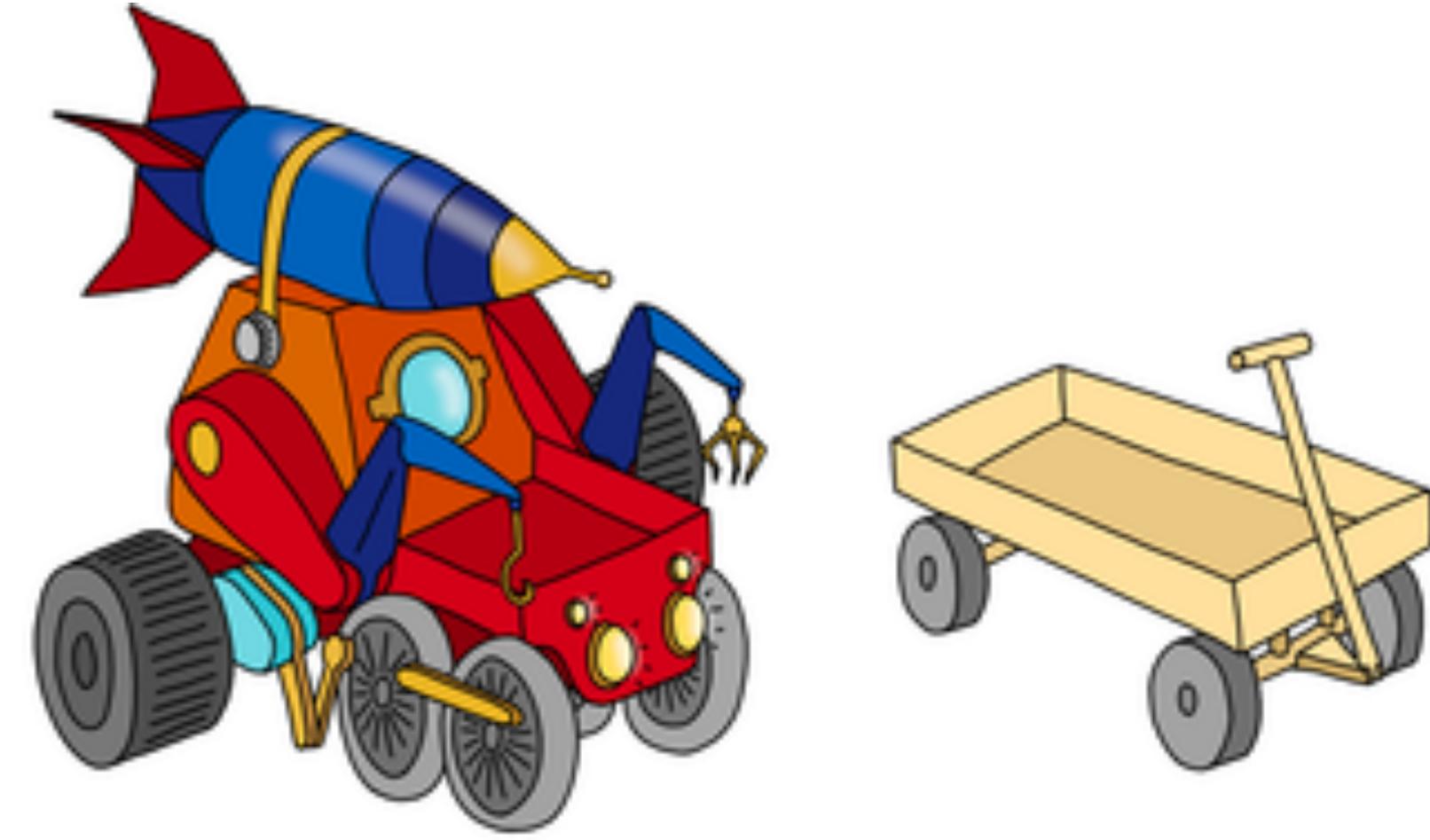
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EDITORIAL

Ten simple rules for quick and dirty scientific programming

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[https://journals.plos.org/ploscompbiol/
article?id=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.**