COGS138: Neural Data Science

Lecture 7

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(Based on a course created by Prof. Bradley Voytek)

Plan for today

- Announcements
- Assignment 1 overview
- Review - Last time
- Data

Announcements

- Final reminder to check on your FinAID status
- A1 - due **a week from release**, which will be tonight or tomorrow
- Reading 1 - Released on canvas and in web site password protected area soon, lecture quiz due **a week from release**, released tonight
- **Group formation** - time to start choosing who you want to work with for your project group

Last time

Course links

Website	http://casimpkinsjr.radiantdolphinpress.com/pages/cogs138_sp23	Main face of the course and everything will be linked from here. Lectures, Readings, Handouts, Files, links
GitHub	https://github.com/drsimpkins-teaching	files/data, additional materials & final projects
datahub	https://datahub.ucsd.edu	assignment submission
Piazza	https://piazza.com/ucsd/spring2023/cogs138_sp23_a00/home (course code on canvas home page)	questions, discussion, and regrade requests
Canvas	https://canvas.ucsd.edu/courses/44897	grades, lecture videos
Anonymous Feedback	Will be able to submit via google form	If I ever offend you, use an example you are uncomfortable with, or to provide general feedback. Please remain constructive and polite

That’s a lot of data!

- How do you deal with it all, standardize, organize, communicate it?
- How can you talk across disciplines?
- How do you collaborate and work in teams with this?
- How can you ask questions with all that data and the results generated?

Data science questions, hypothesis generation (automated), Genes/gene expression, animal models, FAIR, Neurodata Without Borders (NWB), Brain Imaging Data Structure (BIDS), DANDI

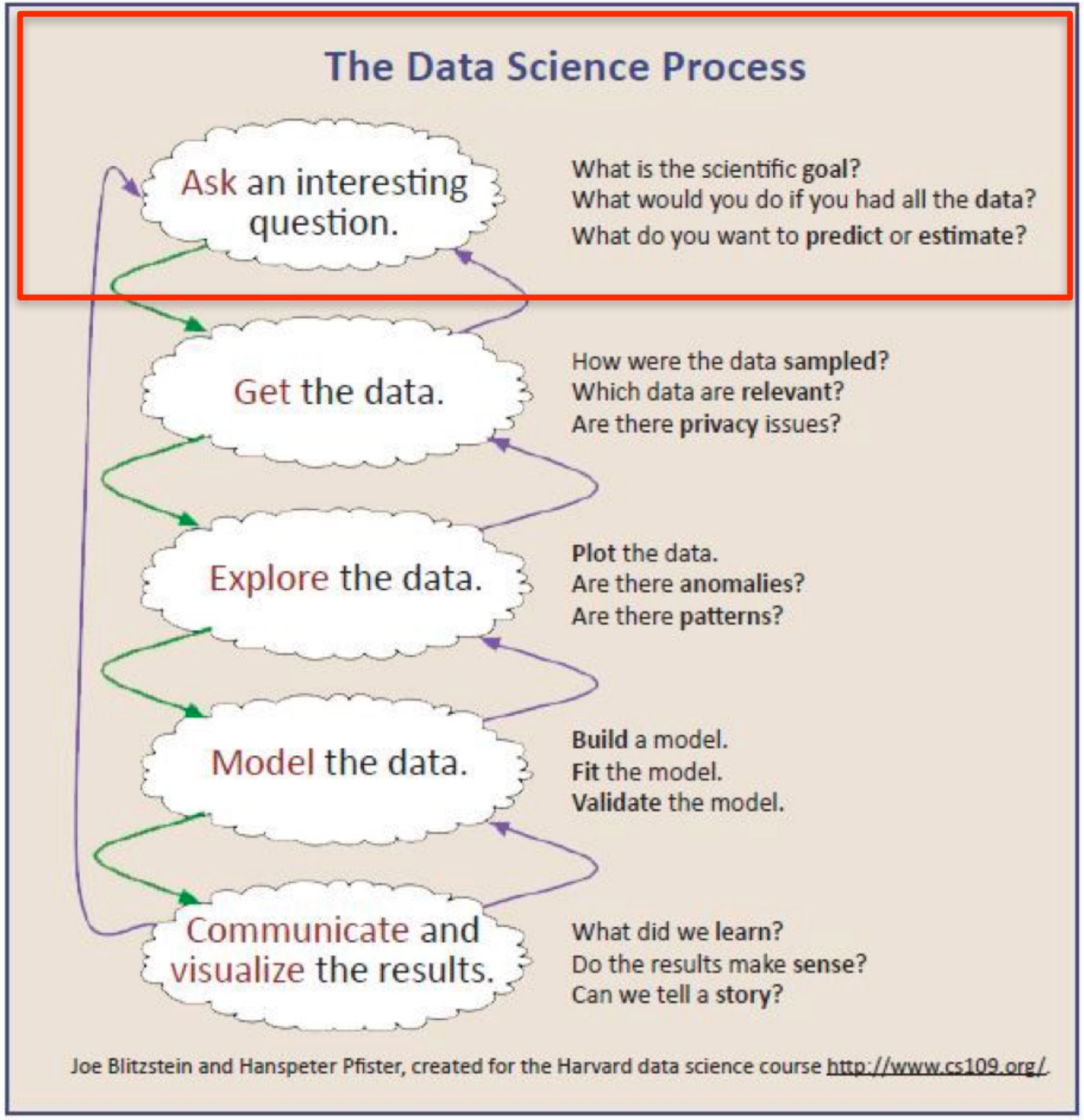
Formulating Data Science Questions

When you and your group sit down to figure out what you're going to do for your final project in this class, you'll have to formulate a strong question. It should be:

1. **Specific**,

2. Can be answered with **data**,

3. And makes **clear what** exactly **is** being **measured**.


The Data Science Process
Ask an interesting question.
What is the scientific goal?
What would you do if you had all the data?
What do you want to predict or estimate?
Get the data.
How were the data sampled?
Which data are relevant?
Are there privacy issues?
Explore the data.
Plot the data.
Are there anomalies?
Are there patterns?
Model the data.
Build a model.
Fit the model.
Validate the model.
Communicate and visualize the results.
What did we learn?
Do the results make sense?
Can we tell a story?
Joe Blitzstein and Hanspeter Pfister, created for the Harvard data science course http://www.cs109.org/

Neurodata **W**ithout **B**orders (N.W.B.)

Introduction, tools, definitions and relevance

Use **NWB** for

- Use this for **cellular neurophysiology**, such as electrophysiology and optical physiology

NWB Definition

- https://www.nwb.org/
- “**Neurodata Without Borders (NWB)** is a ***data standard*** for neurophysiology, providing neuroscientists with a common standard to share, archive, use, and build analysis tools for neurophysiology data. NWB is designed to store a variety of neurophysiology data, including data from intracellular and extracellular electrophysiology experiments, data from optical physiology experiments, and tracking and stimulus data.” [www.nwb.org]

NWB Introduction

- https://www.nwb.org/
- https://nwb-overview.readthedocs.io/en/latest/
- So essentially
  - A data format for sharing/archiving
  - Standardized (set of rules and best practices)
  - Packages Data and Metadata together so human- and machine-readable

NWB Introduction

- Take advantage of established techniques for processing, analysis, visualization tools
- Makes data easier to reuse - additional scientific insights
- Essential step to getting data into the DANDI archive (https://dandiarchive.org/)

Brain **I**maging **D**ata **S**tructure
(B.I.D.S.)

Introduction, tools, definitions and relevance

Use **BIDS** for

- Use for **neuroimaging data** such as MRI

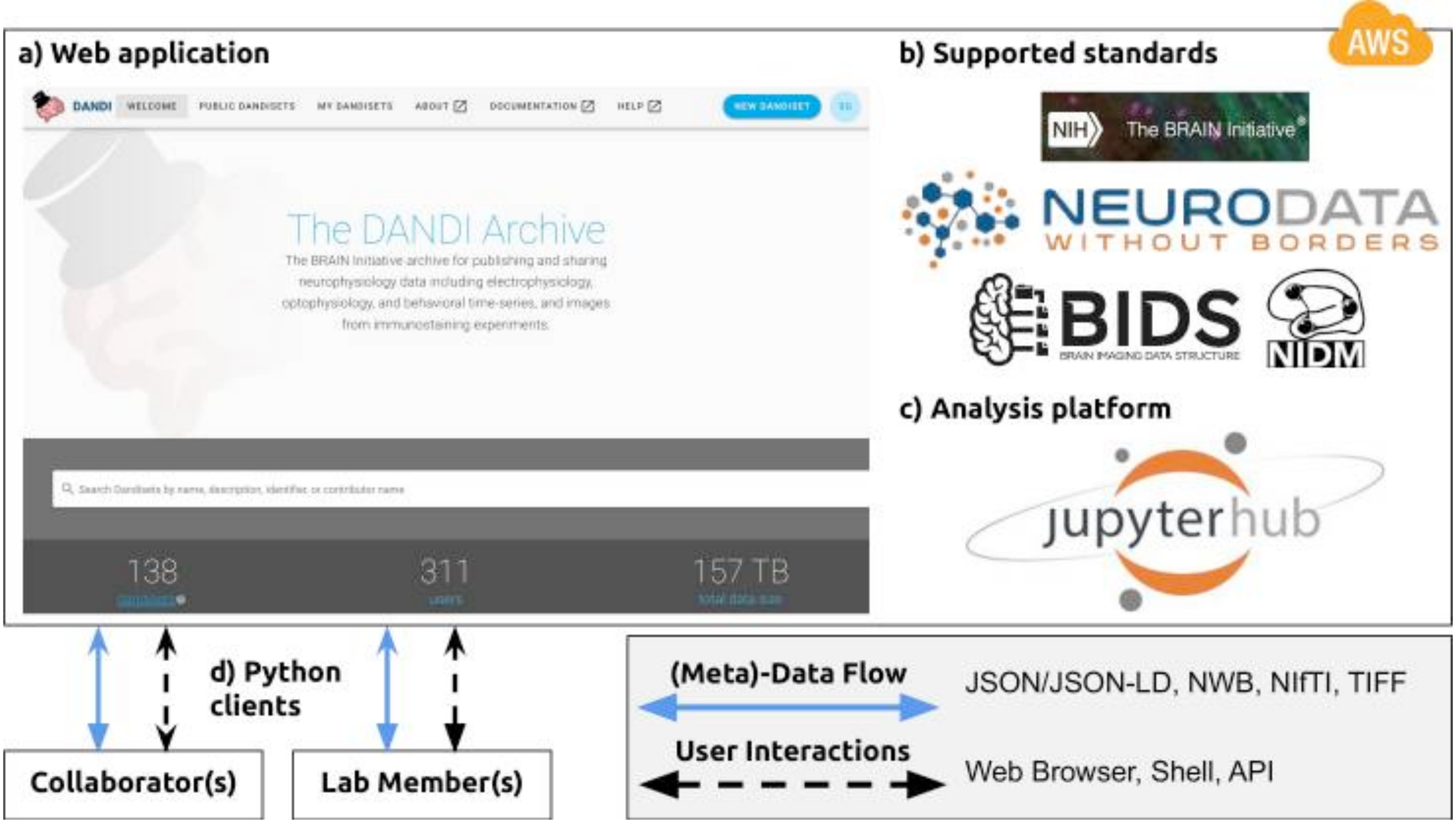
Brain Imaging Data Structure

- https://bids.neuroimaging.io/
- A second data standard

Distributed **A**rchives for **N**europhysiology **D**ata **I**ntegration (D.A.N.D.I.)

What is DANDI?

- The BRAIN Initiative archive for publishing and sharing neurophysiology data including
  - Electrophysiology, Optophysiology, Behavioral time-series, Images from immunostaining experiments.
- A persistent, versioned, and growing collection of standardized datasets
- A place to house data to collaborate across research sites
- Supported by the BRAIN Initiative and the AWS Public dataset programs


a) Web application
DANDI
WELCOME
PUBLIC DANDISETS
MY DANDISETS
ABOUT
DOCUMENTATION
HELP
NEW DANDISET
The DANDI Archive
The BRAIN Initiative archive for publishing and sharing neurophysiology data including electrophysiology, optophysiology, and behavioral time-series, and images from immunostaining experiments.
Search Dandisets by name, description, identifier, or contributor name
138
311
157 TB
b) Supported standards
AWS
NIH
The BRAIN Initiative
NEURODATA
WITHOUT BORDERS
BIDS
BRAIN IMAGING DATA STRUCTURE
NIDM
c) Analysis platform
jupyterhub
d) Python clients
Collaborator(s)
Lab Member(s)
(Meta)-Data Flow
JSON/JSON-LD, NWB, NIfTI, TIFF
User Interactions
Web Browser, Shell, API

Benefits of DANDI

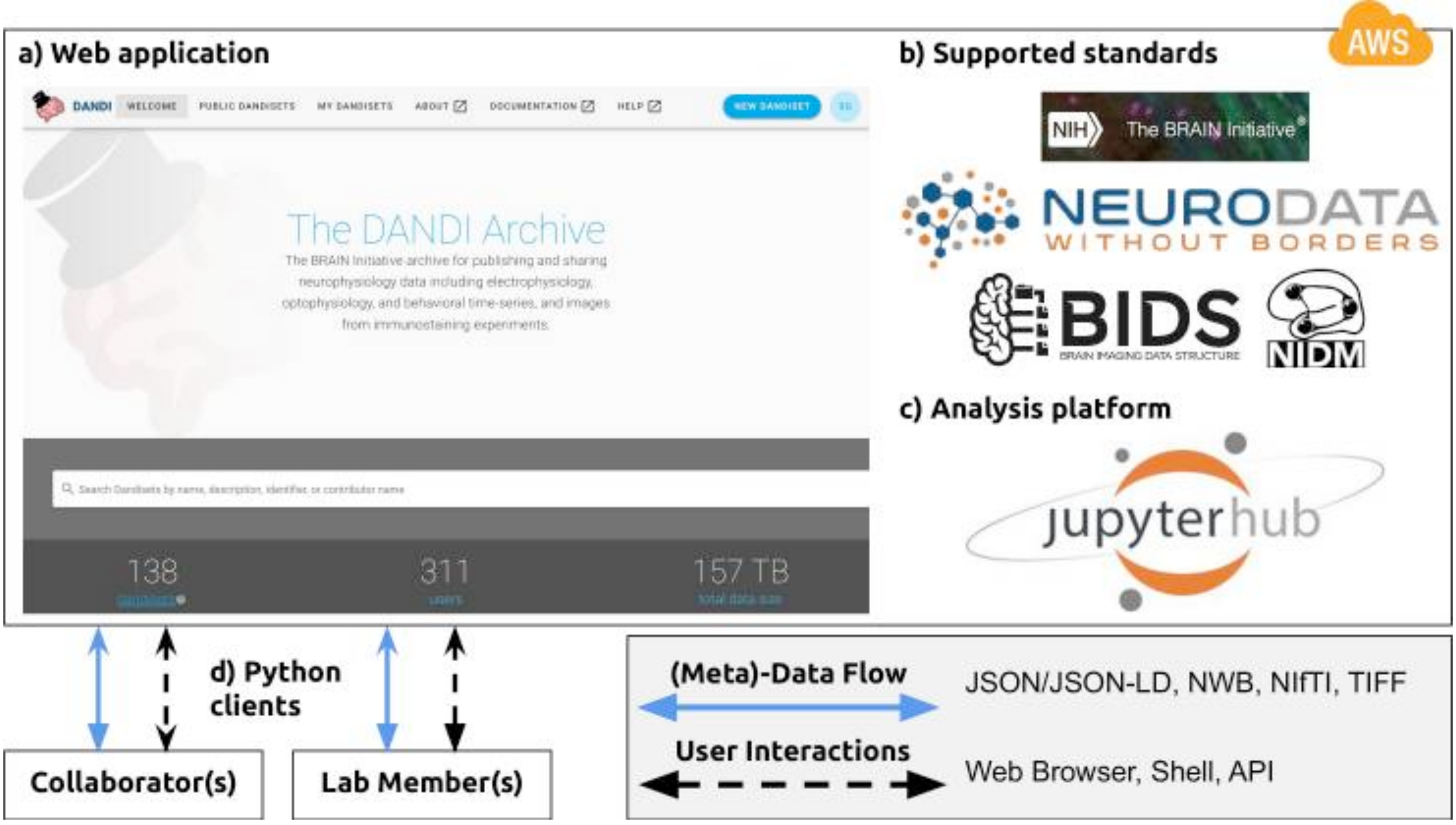
- A FAIR (Findable, Accessible, Interoperable, Reusable) data archive to house standardized neurophysiology and associated data
- Rich metadata to support search across data
- Consistent and transparent data standards to simplify data reuse and software development.
  - Uses NWB, BIDS, Neuroimaging Data Model (NIDM), and other BRAIN Initiative standards to organize and search the data.
  - The data can be accessed programmatically allowing for software to work directly with data in the cloud
- The infrastructure is built on a software stack of open source products, thus enriching the ecosystem

DANDI compatibility

- Uses NWB for core data language
- “Dandisets” - DANDI datasets - collection of NWB files recorded over multiple sessions, organized together
- Viewable from a web browser
- Can interact through Jupyterhub interface for exploring, visualizing and analyzing the data stored in the archive

DANDI python client

- Organize data locally into the required structure
- Download/upload data from/to the DANDI archive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User Interactions
Web Browser, Shell, API

DANDI archive

- **Public DANDI sets:** https://dandiarchive.org/dandiset
- **Documentation:** https://www.dandiarchive.org/handbook/10_using_dandi/

DANDI Properties

- **Data identifiers:** The archive provides persistent identifiers for versioned datasets and assets, thus improving reproducibility of neurophysiology research

- **Data storage:** Cloud-based platform on AWS. Data are available from a public S3 bucket. Data from embargoed datasets are available from a private bucket to owners only

- **Type of data:** The archive accepts cellular neurophysiology data including electrophysiology, optophysiology, and behavioral time-series, and images from immunostaining experiments and other associated data (e.g. participant information, MRI or other modalities)

- **Accepted Standards** and Data File Formats: NWB (HDF5), BIDS (NIfTI, JSON, PNG, TIF, OME.TIF, OME.BTF, OME.ZARR) (see Data Standards for more details)

Neurophysiology Informatics Challenges and DANDI Solutions

Challenges	Solutions
Most raw data stays in laboratories.	DANDI provides a public archive for dissemination of raw and derived data.
Non-standardized datasets lead to significant resource needs to understand and adapt code to these datasets.	DANDI standardizes all data using NWB and BIDS standards.
The multitude of different hardware platforms and custom binary formats requires significant effort to consolidate into reusable datasets.	The DANDI ecosystem provides tools for converting data from different instruments into NWB and BIDS.
There are many domain general places to house data (e.g. Open Science Framework, G-Node, Dropbox, Google drive), but it is difficult to find relevant scientific metadata.	DANDI is focused on neurophysiology data and related metadata.
Datasets are growing larger, requiring compute services to be closer to data.	DANDI provides Dandihub, a JupyterHub instance close to the data.
Neurotechnology is evolving and requires changes to metadata and data storage.	DANDI works with community members to improve data standards and formats.
Consolidating and creating robust algorithms (e.g. spike sorting) requires varied data sources.	DANDI provides access to many different datasets.

DANDI archive

- https://elifesciences.org/articles/78362

- **Oliver Rübel, Andrew Tritt, Ryan Ly, Benjamin K Dichter, Satrajit Ghosh, Lawrence Niu, Pamela Baker, Ivan Soltesz, Lydia Ng, Karel Svoboda, Loren Frank, Kristofer E Bouchard (2022) The Neurodata Without Borders ecosystem for neurophysiological data science eLife 11:e78362**

- https://doi.org/10.7554/eLife.78362

Version control, git, github

This sucks

main_simple_bak9-pretty-good.c	Aug 1, 2008, 1:01 AM	33 KB	C Source
main_simple_bak9-pretty-good.o	Aug 1, 2008, 1:00 AM	303 KB	object code
main_simple_bak9-pretty-goodv2.c	Aug 2, 2008, 1:16 AM	33 KB	C Source
main_simple_bak10.c	Sep 28, 2008, 1:16 PM	33 KB	C Source
main_simple_bak11-workingUART_correctspeed.c	Aug 30, 2008, 2:49 AM	27 KB	C Source
main_simple_bak11-workingUART_correctspeed.o	Aug 2, 2008, 1:17 AM	303 KB	object code
main_simple_bak12_willspin.c	Aug 2, 2008, 1:30 AM	28 KB	C Source
main_simple_bak12_willspin.o	Aug 2, 2008, 2:35 AM	301 KB	object code
main_simple_bak13-worksA-D-nonoise-spins.c	Aug 7, 2008, 12:57 PM	26 KB	C Source
main_simple_bak14-widersinefunctionsworkingrotation.c	Aug 8, 2008, 5:02 PM	26 KB	C Source
main_simple_bak15-spins-stillneedsquadrantfixed.c	Aug 15, 2008, 7:32 PM	30 KB	C Source
main_simple_bak16-15backup-spins-needs-improvement.c	Oct 15, 2008, 8:54 PM	31 KB	C Source
main_simple_bak17-smoother-stillnostandingstart.c	Aug 16, 2008, 6:50 PM	30 KB	C Source
main_simple_bak17-smoother-stillnostandingstart.o	Aug 18, 2008, 9:41 PM	305 KB	object code
main_simple_bak18-notgood.c	Aug 18, 2008, 9:42 PM	31 KB	C Source
main_simple_bak20SIMPLE-DCnotbrushless.c	Sep 17, 2009, 11:02 PM	27 KB	C Source
main_simple_bak20WORKS_PWM_COMMAND_CONTROL.c	Aug 19, 2008, 12:54 AM	29 KB	C Source
main_simple_timer_intrpt_bak.c	Aug 12, 2008, 12:16 AM	13 KB	C Source
main_simple_timer_intrpt_bak2.c	Aug 12, 2008, 2:00 PM	13 KB	C Source
main_simple_timer_intrpt_bak3.c	Aug 18, 2008, 12:14 AM	13 KB	C Source
main_simple_timer_intrpt.c	Aug 18, 2008, 12:17 AM	13 KB	C Source
main_simple_workingHWPWM.c	Aug 18, 2008, 7:19 PM	15 KB	C Source
main_simple.c	Sep 17, 2009, 11:02 PM	29 KB	C Source

Yup, this sucks too.

Thanks for chatting with me earlier today. I added the link to the visualization project into my resume and attached the resume. Thanks for any connections you can make for me. I'd love to know where you send it, so I can keep track of that. Thanks again!

Best,

May 11

[redacted]

May 11

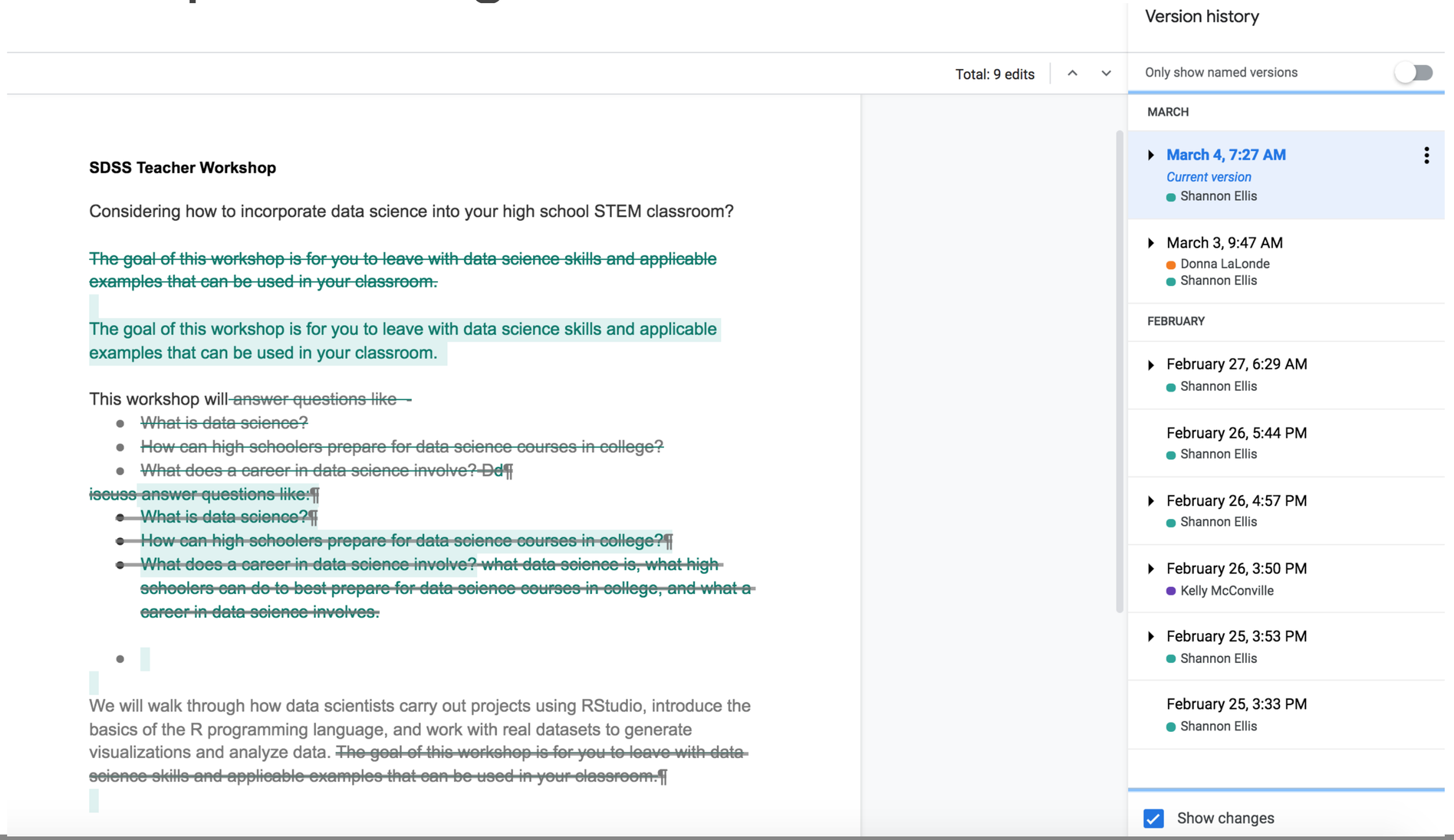
Actually, please use this one. I fixed a typo that was previously missed. Thanks!

[redacted]

May 11

Final copy, I swear. Thanks for helping out.

This is a step in the right direction

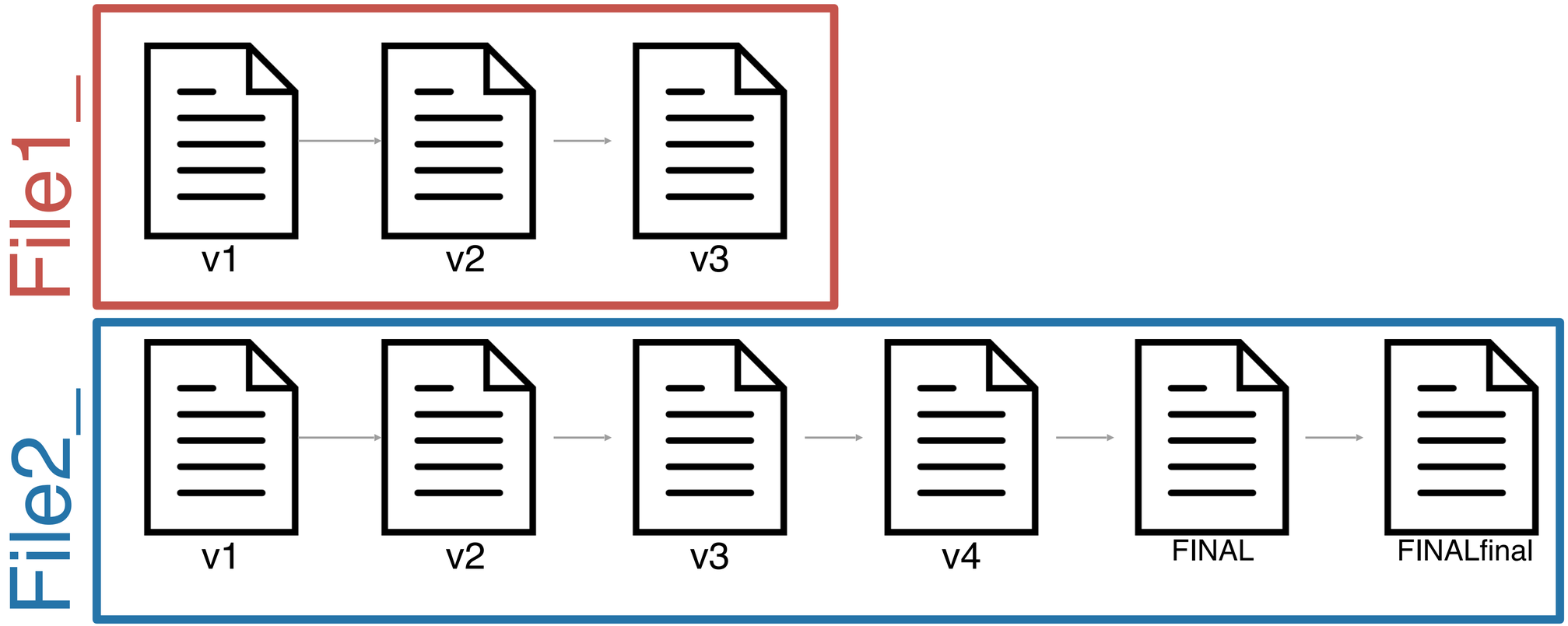


Version Control

- Enables multiple people to simultaneously work on a single project.
- Each person edits their own copy of the files and chooses when to share those changes with the rest of the team.
- Thus, temporary or partial edits by one person do not interfere with another person's work

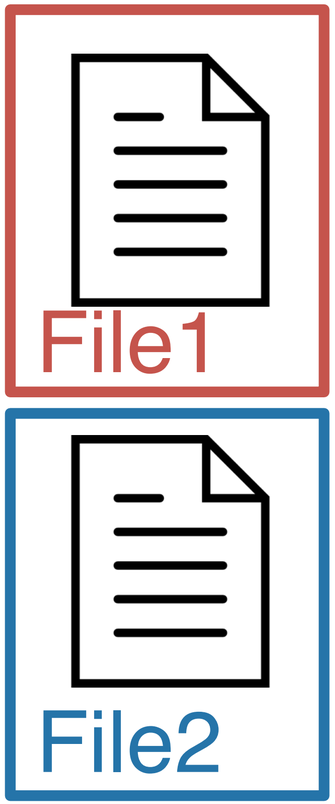
What is version control?

A way to manage the evolution of a set of files



What is version control?

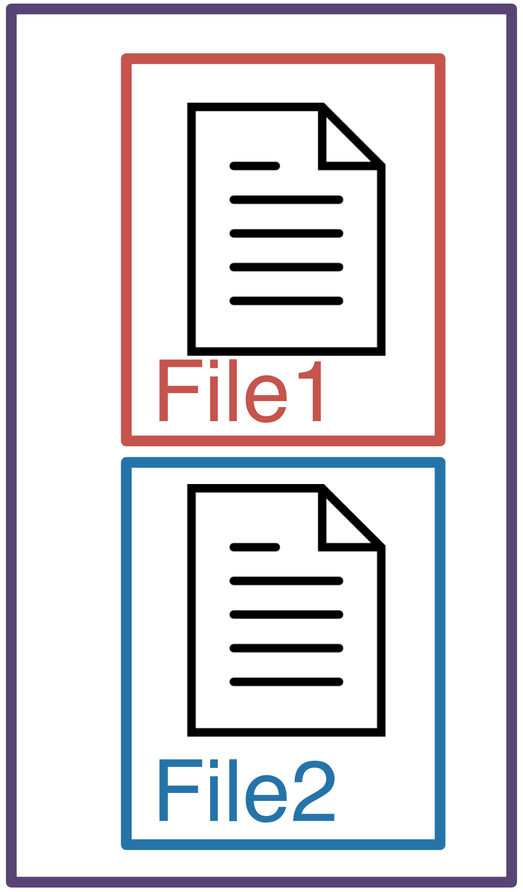
A way to manage the evolution of a set of files



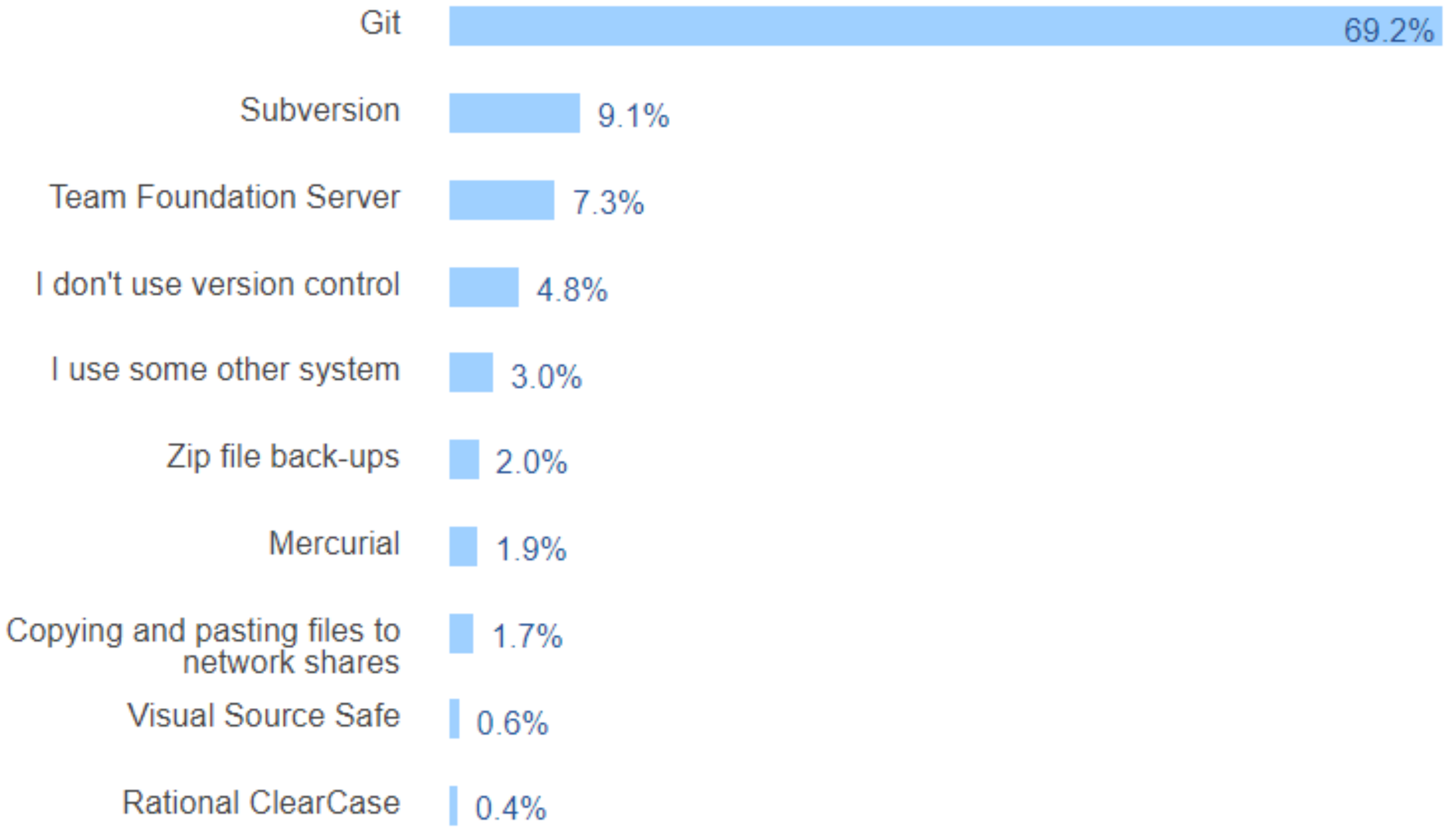
When using a version control system, you have **one copy of each file** and the *version control system tracks the changes* that have occurred over time

What is version control?

A way to manage the evolution of a set of files



The set of files is referred to as a **repository (repo)**



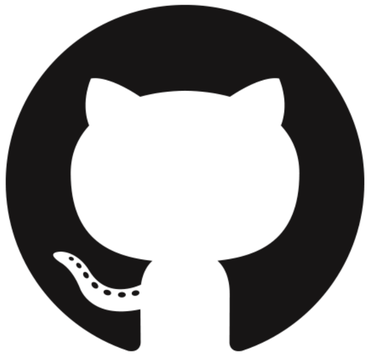
https://insights.stackoverflow.com/survey/2017#work-version-control

git & GitHub

git

the version control system

~ Track Changes from Microsoft Word….on steroids



GitHub (or Bitbucket or GitLab) is the home **where your git-based projects live** on the Internet.

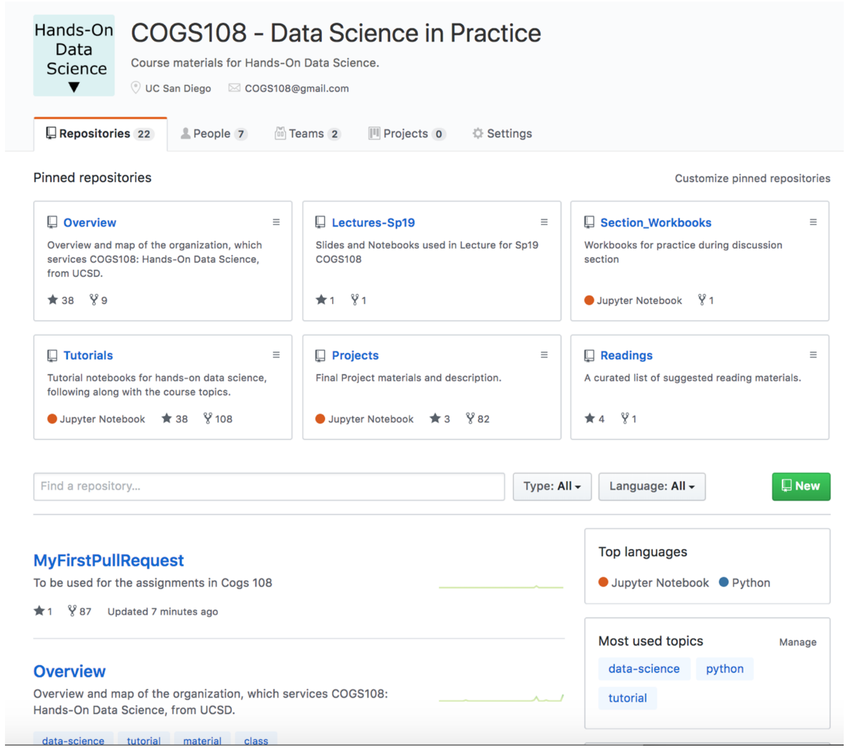
~ Dropbox….but way better

What version control looks like

```
$ git clone https://www.github.com/username/repo.git
$ git pull
$ git add -A
$ git commit -m “informative commit message”
$ git push
```

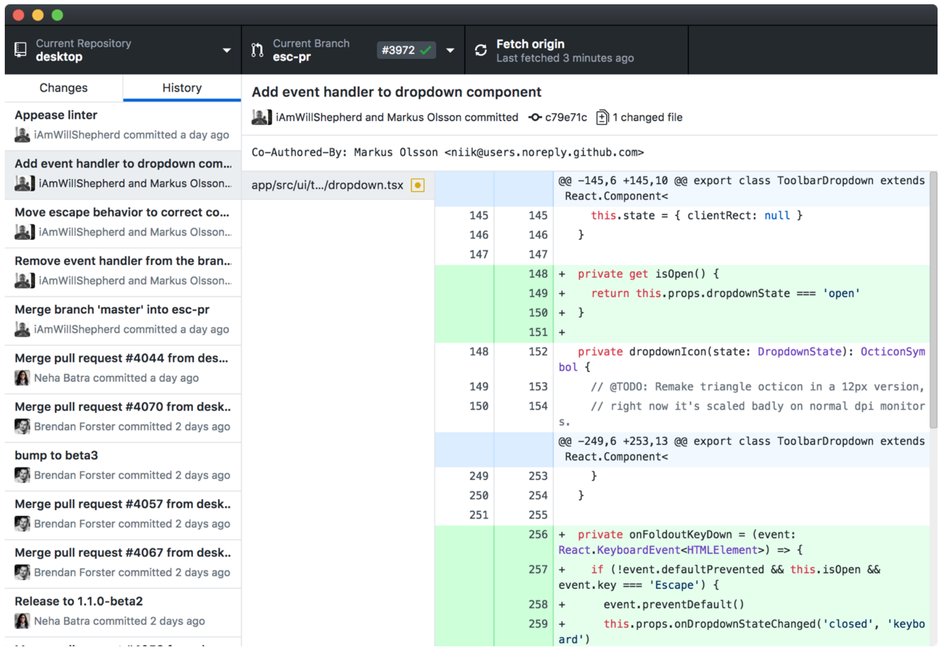
Terminal

git

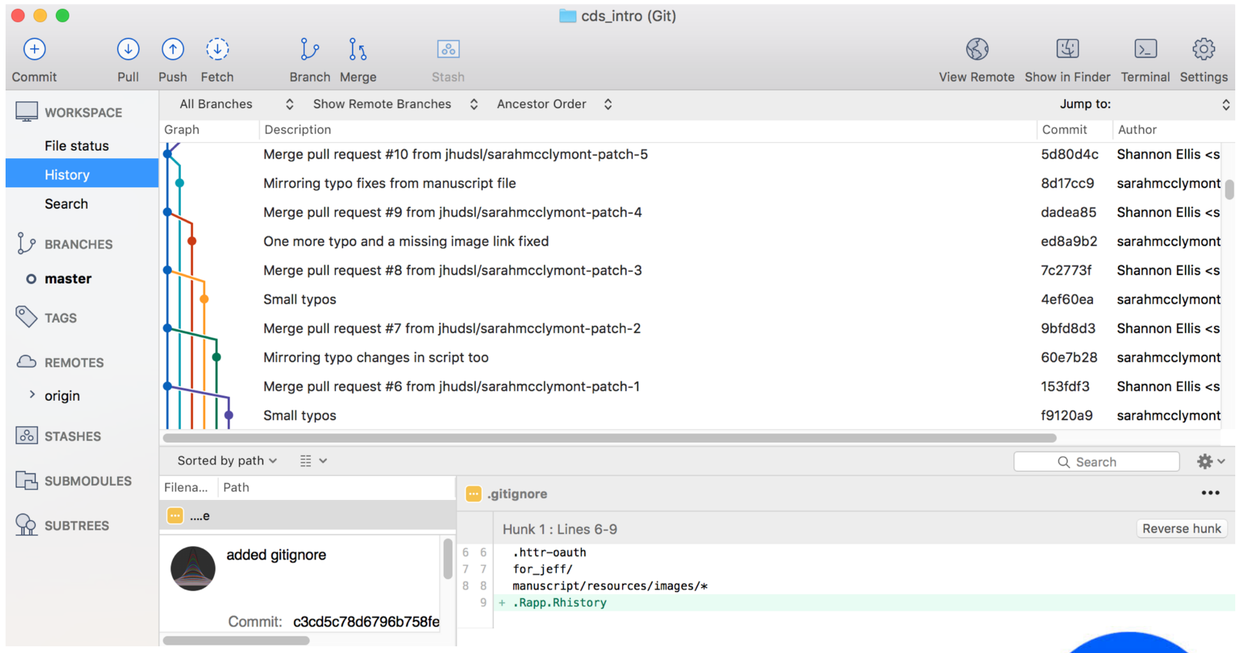


GitHub

GUIs can be helpful when working with version control

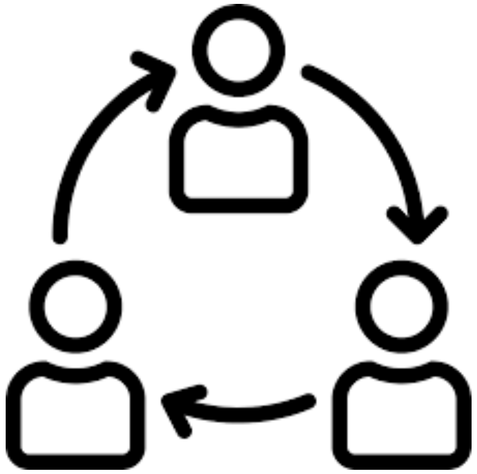


GitHub Desktop



SourceTree

Why version control with git and GitHub?



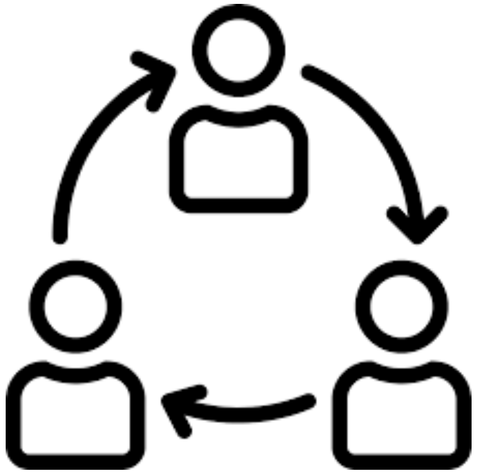
Collaboration

Returning to a safe state

Exposure for your work

Tracking others' work

Collaborate like you do with Google Docs



Collaboration

Each person is making changes **locally**
(on their computer)

Make changes locally, while knowing a stable copy exists

Returning to a safe state

You're free and safe to **try things out locally**. You'll only send changes to the repo when you're at a stable point

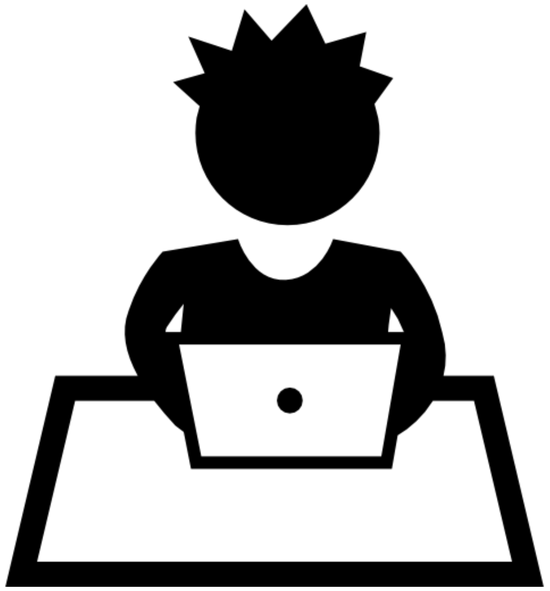
Your repositories will be visible to others!

Exposure for your work

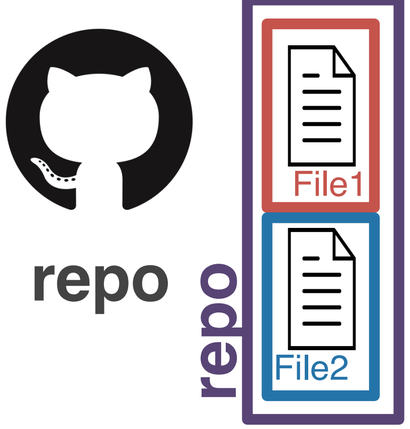
Your public GitHub repos are your coding social media

Keep up with others’ work easily

Tracking others’ work

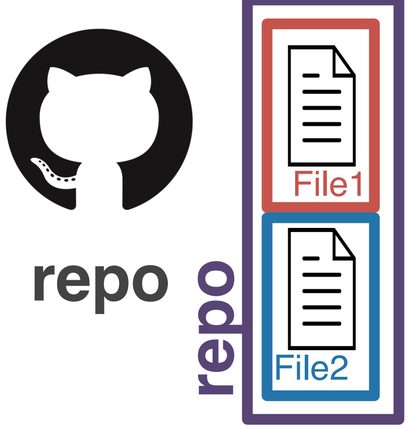


As a social platform, you can see others’ work too!



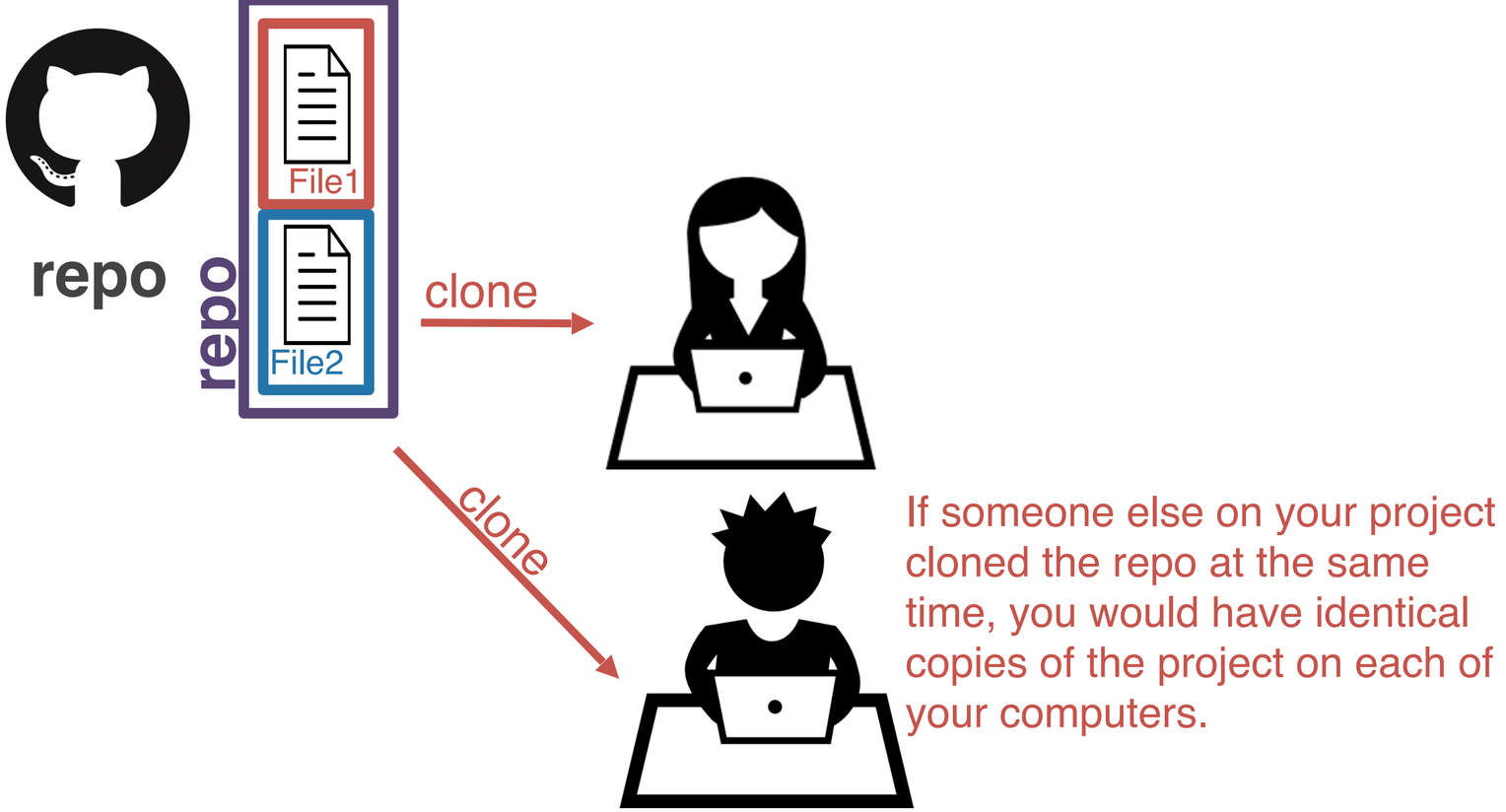
A **GitHub repo** contains all the files and folders for your project.

GitHub is a **remote host**. The files are geographically distant from any files on your computer.

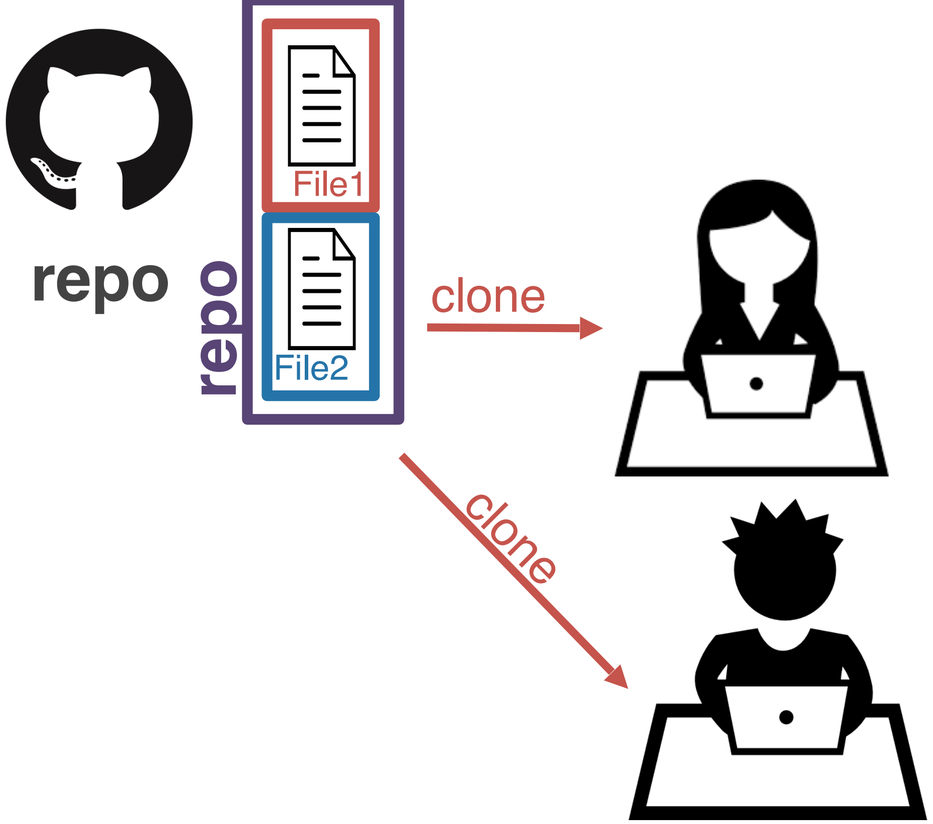


clone

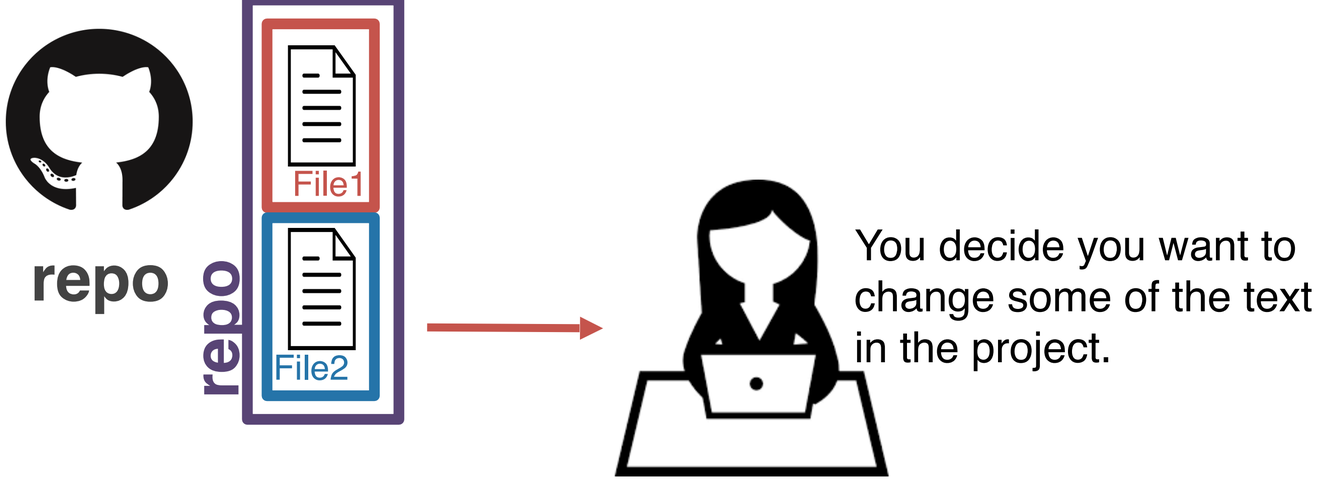
When you first make a copy onto your local computer (read: laptop), you **clone** the repository.

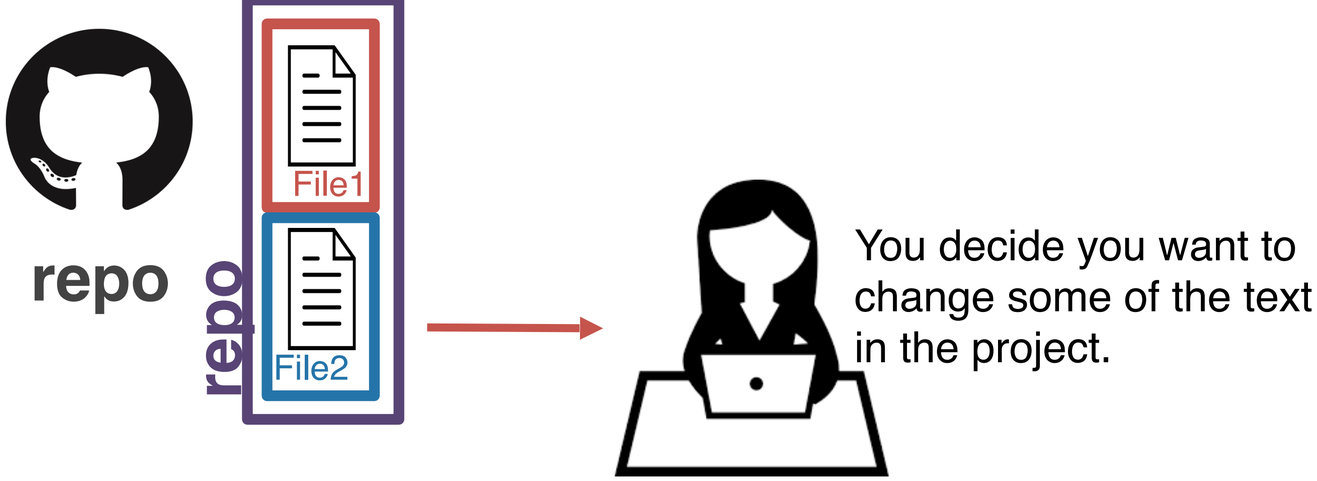


If someone else on your project cloned the repo at the same time, you would have identical copies of the project on each of your computers.



Yay! Everyone can work on the project!


repo
repo
File1
File2
You decide you want to change some of the text in the project.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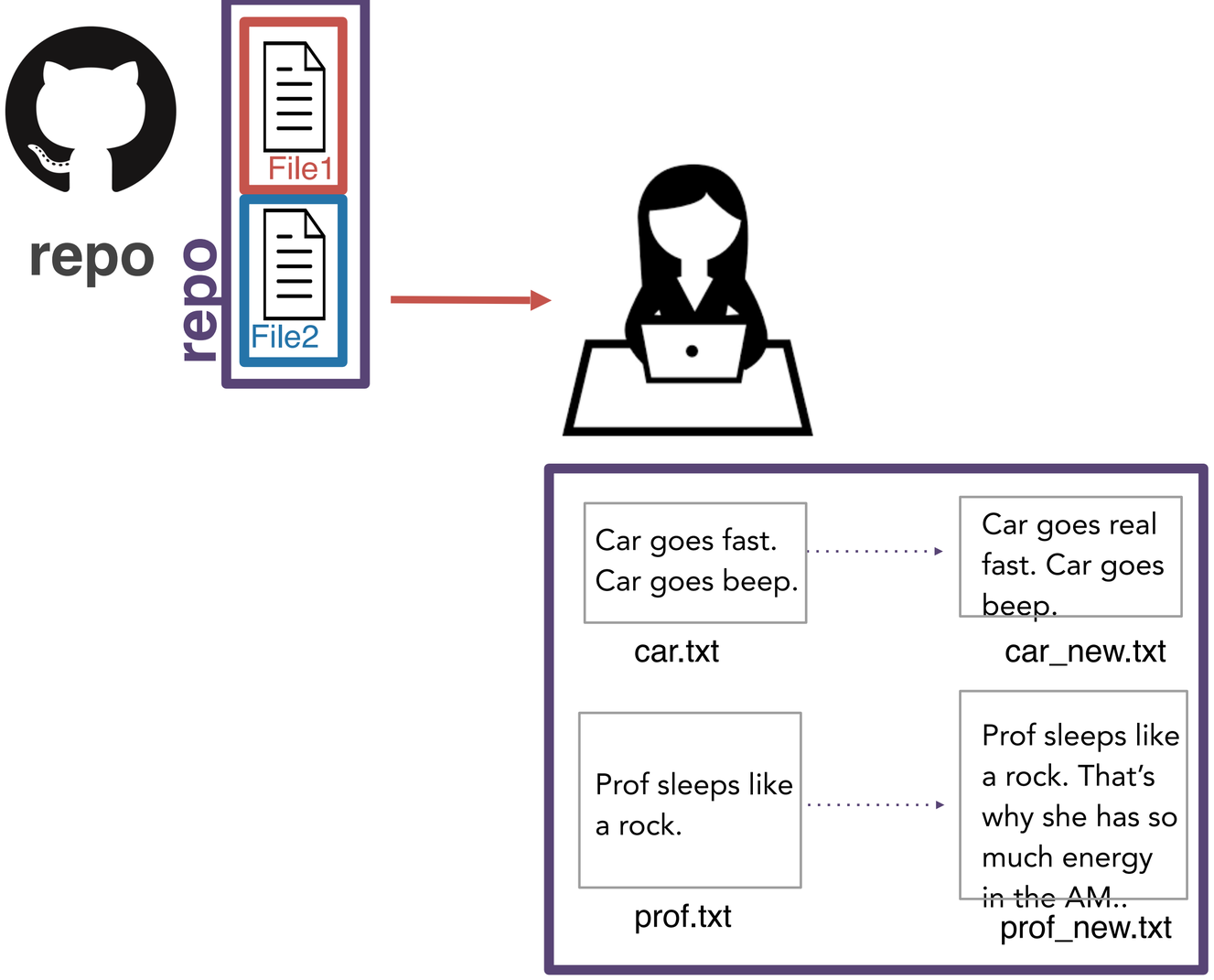
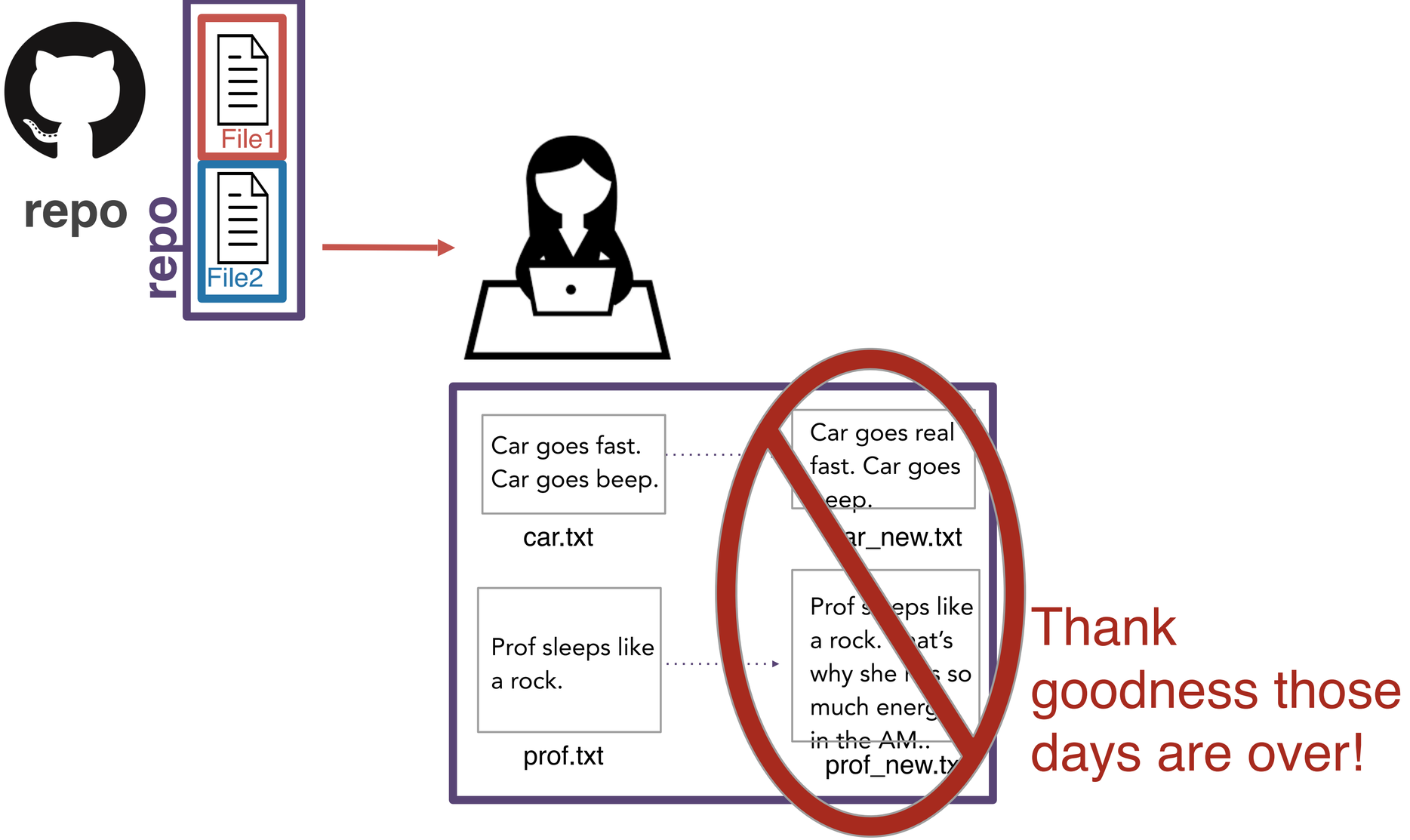
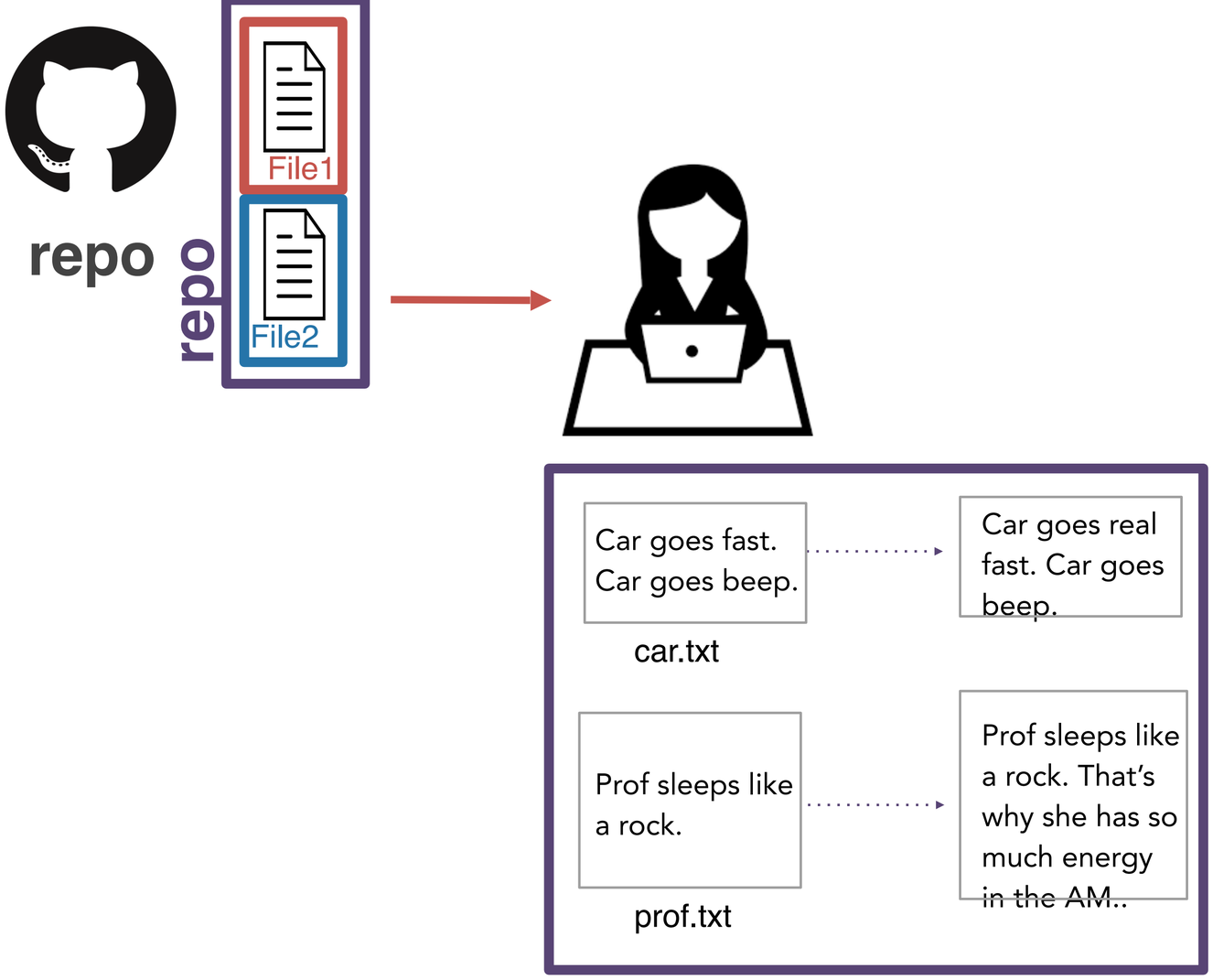


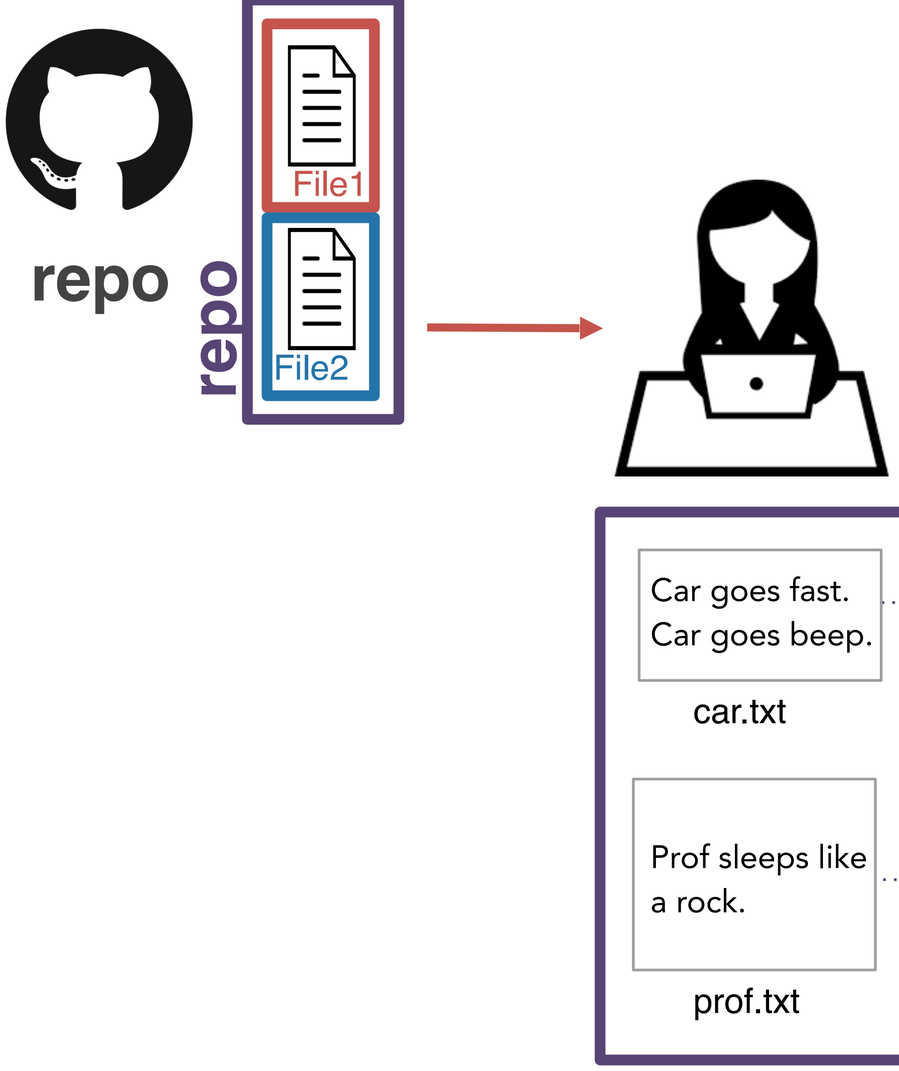
without git…you'd likely rename these files….



Thank goodness those days are over!

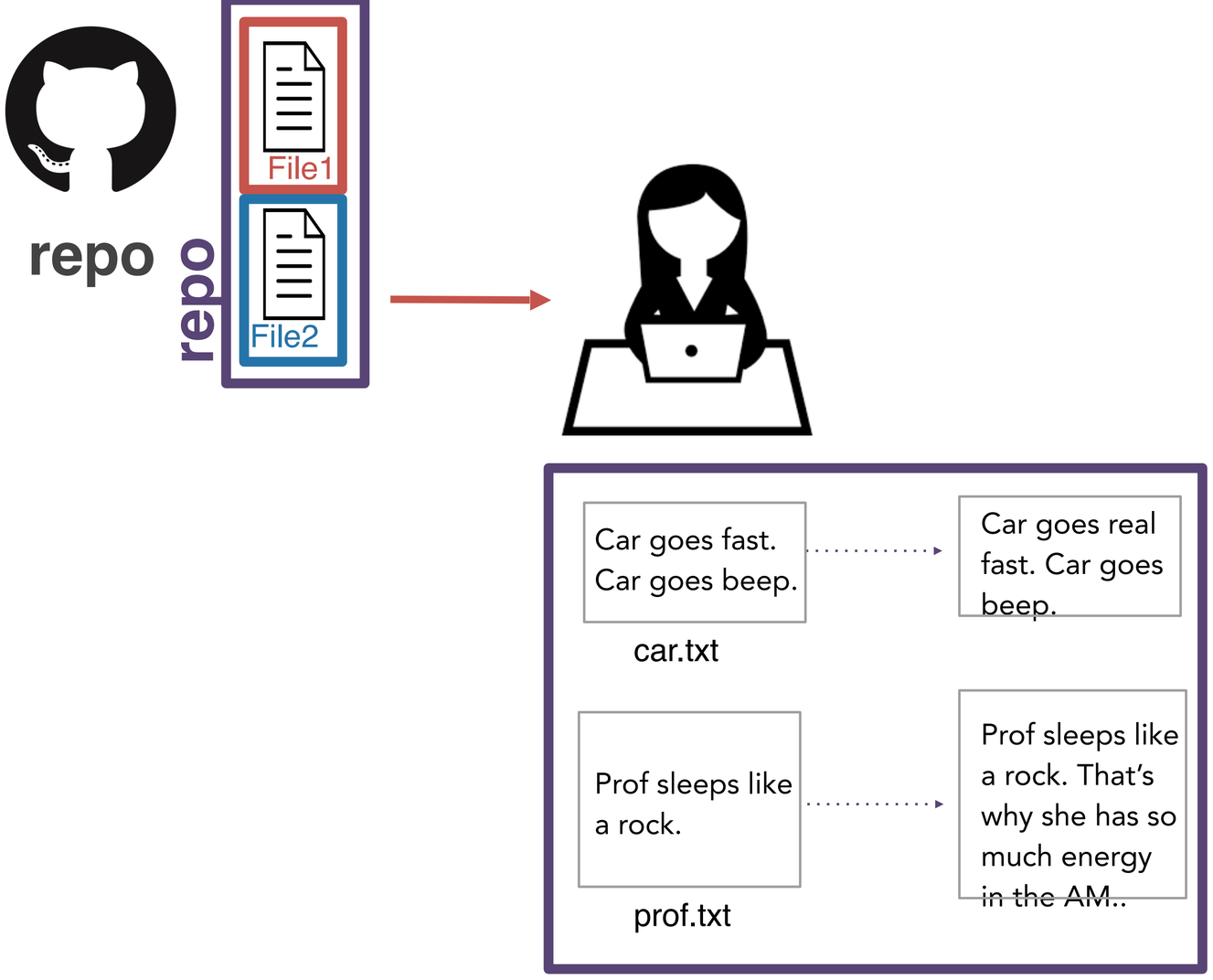


Instead, you tell git which files you'd like to keep track of using **add**. This process is called *staging*.

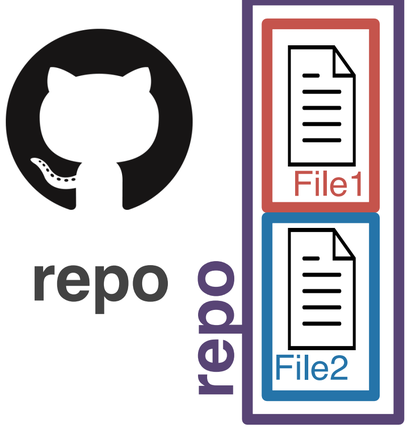


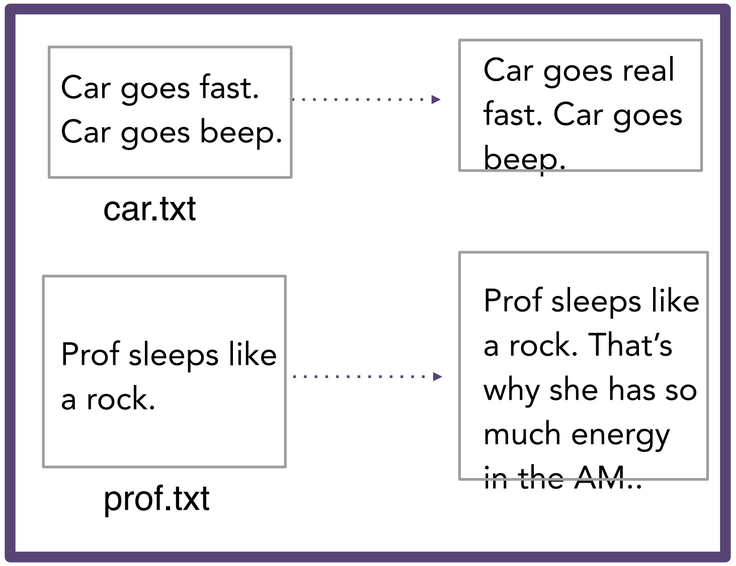
`git add file`	stages specified file (or folder)
`git add .`	stages new and modified files
`git add -u`	stages modified and deleted files
`git add -A`	stages new, modified, and deleted files
`git add *.csv`	Stages any files with .csv extension
`git add *`	Use with caution: stages everything

Instead, you tell git which files you'd like to keep track of using **add**. This process is called *staging*.



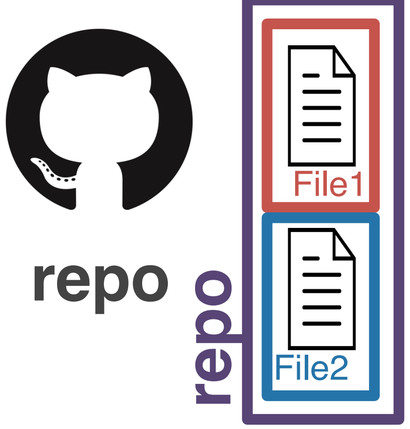
Then, you create a snapshot of your files at this point. This snapshot is called a **commit**.

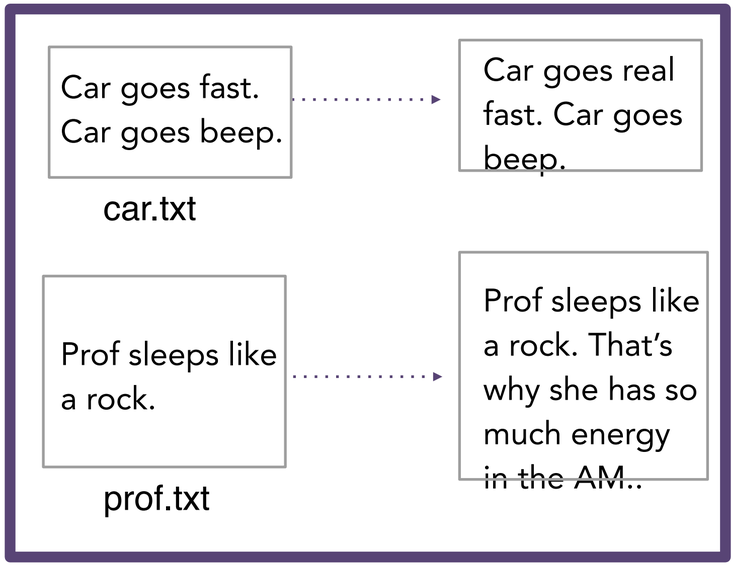




Then, you create a snapshot of your files at this point. This snapshot is called a **commit**.

A **commit** tracks who, what, and when



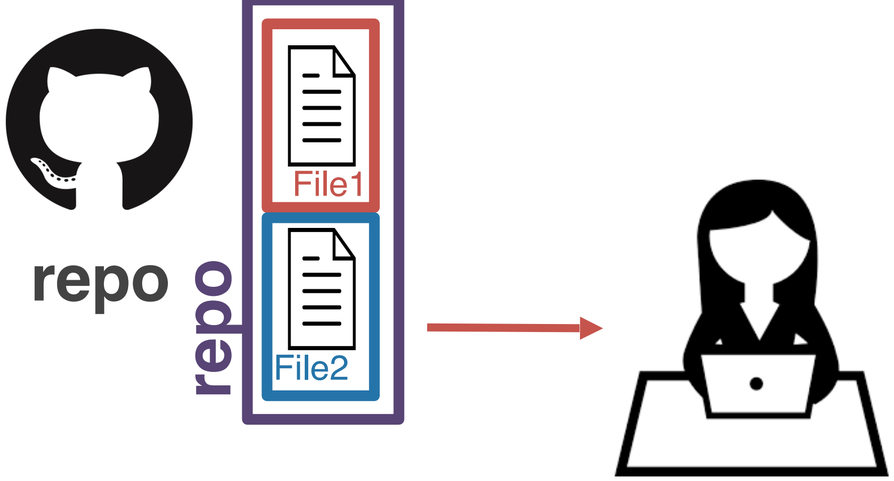


You can make commits more informative by adding a **commit message**.

Example: `git commit -m 'fix typos in car and prof'`

Then, you create a snapshot of your files at this point. This snapshot is called a **commit**.

A **commit** tracks who, what, and when

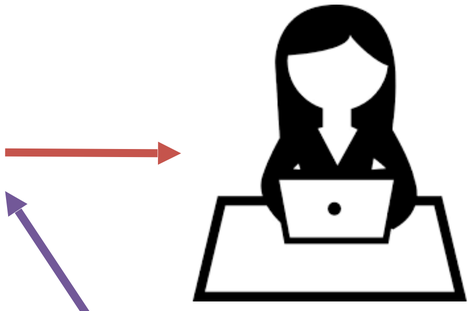


Shannon Ellis
3/28/21 3:28pm

fix typos in car and prof

repo

repo

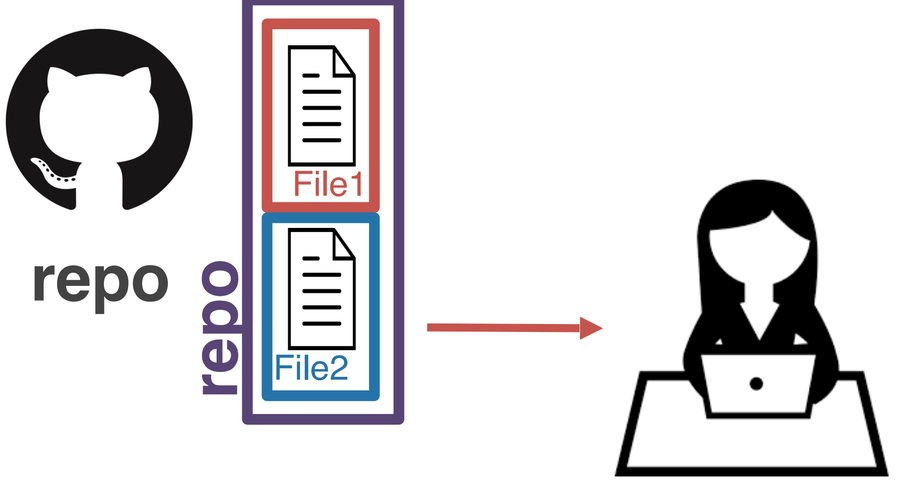


push

Remember, you're not the only one working on this project though! You want your teammates to have access to these changes! You **push** these changes back to the remote.

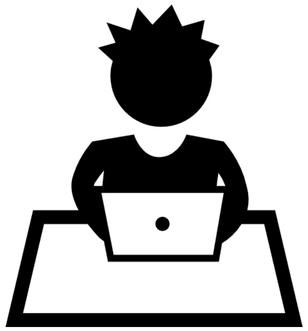
Shannon Ellis
3/28/21 3:28pm

fix typos in car and prof



Shannon Ellis
3/28/21 3:28pm

fix typos in car and prof



Your teammate is still working with the (out-of-date) copy he cloned earlier!

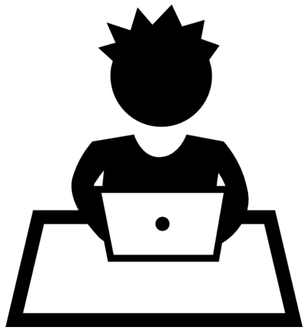
Shannon Ellis
3/28/21 3:28pm

fix typos in car and prof

To catch up, your teammate will have to **pull** the changes from GitHub (remote)

Shannon Ellis
3/28/21 3:28pm

fix typos in car and prof



Your teammate is still working with the (out-of-date) copy he cloned earlier!

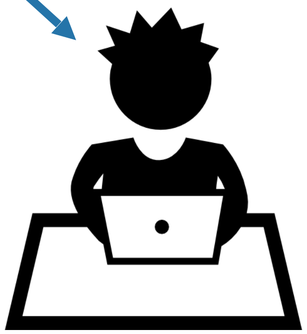
Shannon Ellis
3/28/21 3:28pm

fix typos in car and prof

repo

repo

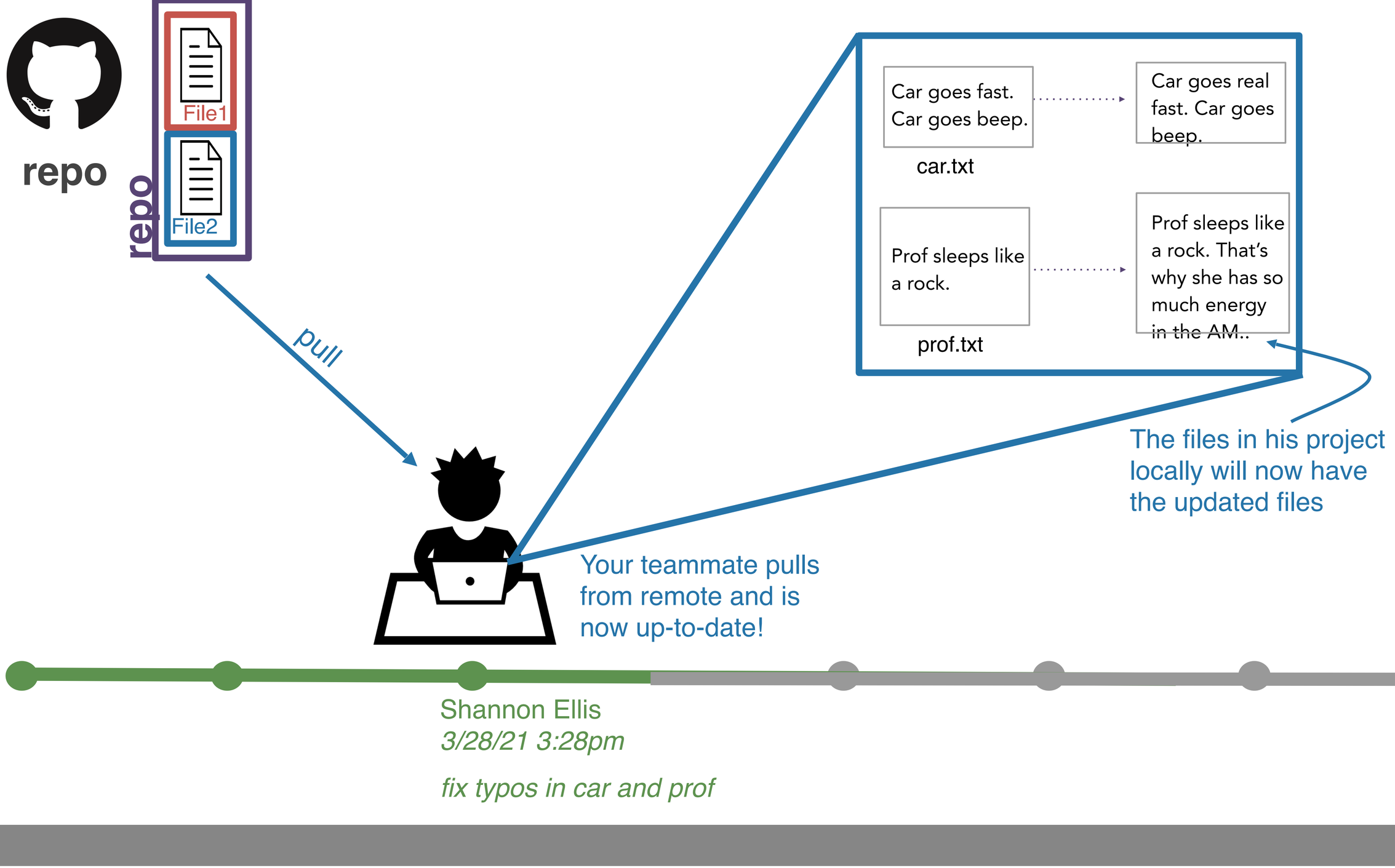
pull

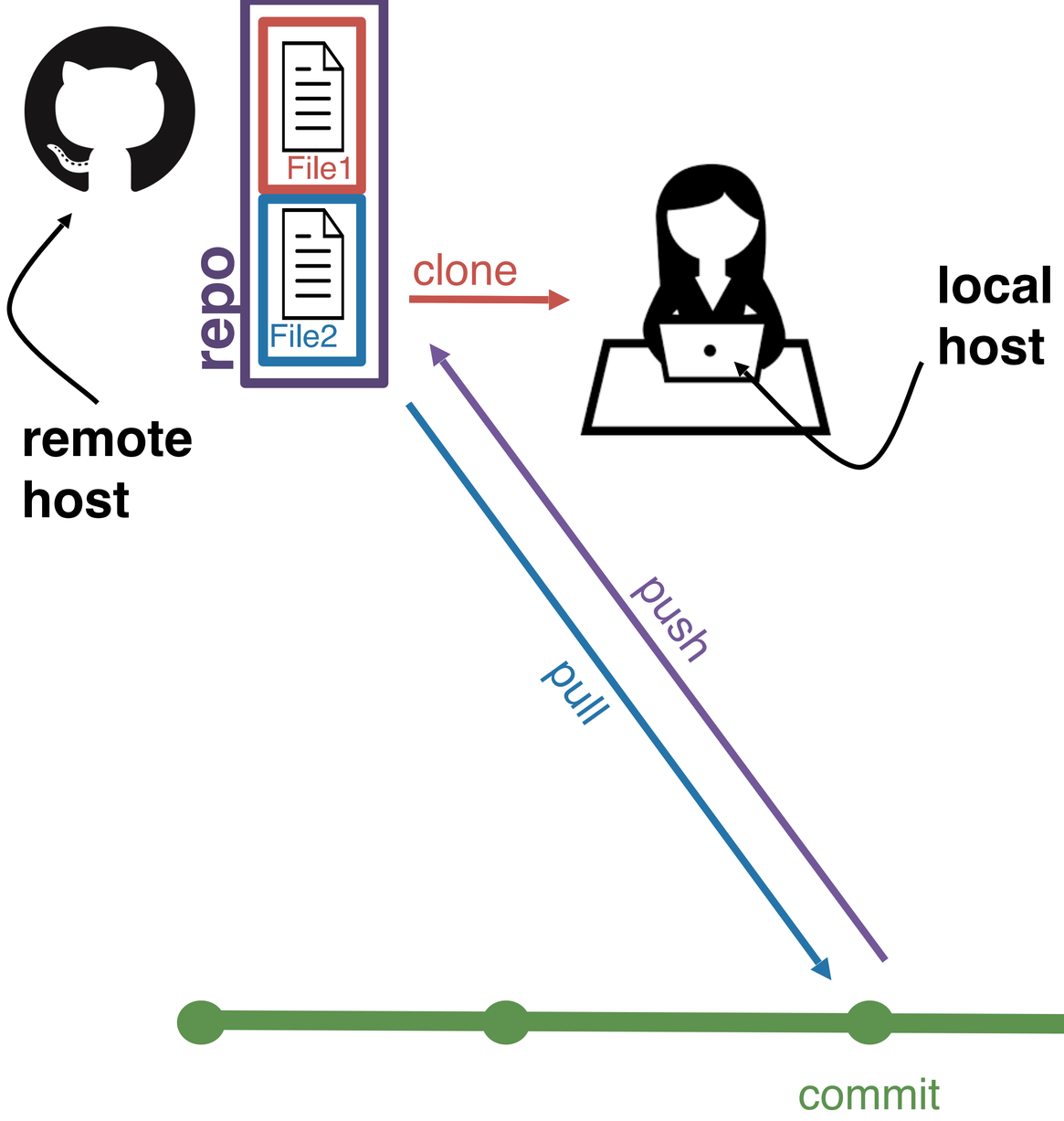


Your teammate pulls from remote and is now up-to-date!

Shannon Ellis
3/28/21 3:28pm

fix typos in car and prof


repo
repo
File1
File2
pull
Car goes fast. Car goes beep.
car.txt
Car goes real fast. Car goes beep.
Prof sleeps like a rock.
prof.txt
Prof sleeps like a rock. That's why she has so much energy in the AM..
The files in his project locally will now have the updated files
Your teammate pulls from remote and is now up-to-date!
Shannon Ellis
3/28/21 3:28pm
fix typos in car and prof



Let's recap real quick!

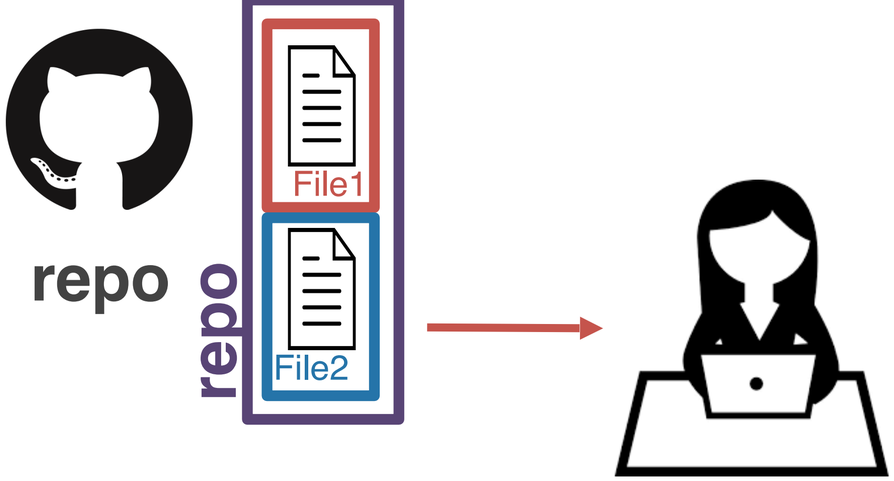
repo - set of files and folders for a project
remote - where the repo lives
clone - get the repo from the remote for the first time
add - specify which files you want to stage (add to repo)
commit - snapshot of your files at a point in time
pull - get new commits to the repo from the remote
push - send your new commits to the remote

```
(base) sellis:Projects shannonellis$ git status
On branch master
Your branch is up to date with 'origin/master'.

Untracked files:
  (use "git add <file>..." to include in what will be committed)

        FinalProject_Guidelines.pdf

nothing added to commit but untracked files present (use "git add" to track)
(base) sellis:Projects shannonellis$ git add FinalProject_Guidelines.pdf
(base) sellis:Projects shannonellis$ git commit -m "update Project Guidelines"
[master 264e91a] update Project Guidelines
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 FinalProject_Guidelines.pdf
(base) sellis:Projects shannonellis$ git push
Counting objects: 3, done.
Delta compression using up to 8 threads.
Compressing objects: 100% (3/3), done.
Writing objects: 100% (3/3), 148.21 KiB | 29.64 MiB/s, done.
Total 3 (delta 1), reused 0 (delta 0)
remote: Resolving deltas: 100% (1/1), completed with 1 local object.
To https://github.com/COGS108/Projects.git
   6931768..264e91a  master -> master
```



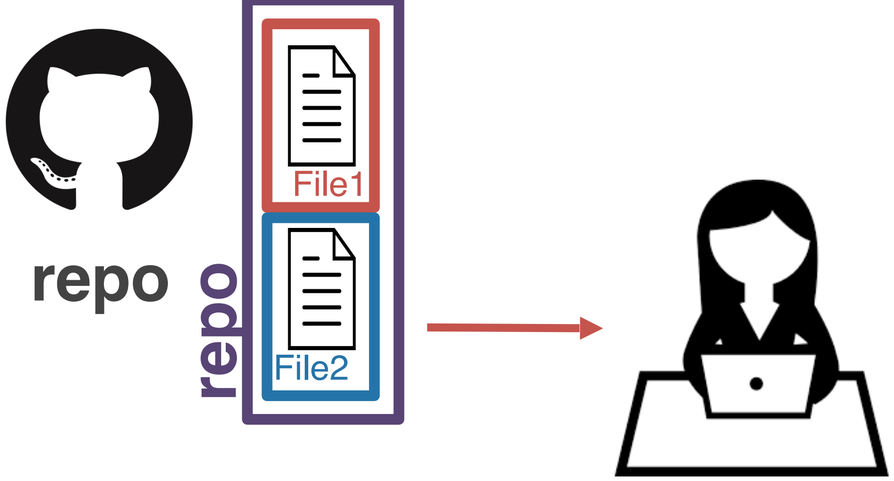
Each time you create a commit, git tracks the changes made automatically.

Kevin Malone
3/26/18 9:10am
Initial commit

Angela Martin
3/26/21 11:11am
Included analysis files

Shannon Ellis
3/28/21 3:28pm
fix typos in car and prof

Shannon Ellis
3/28/21 5:08pm
edited to include survival analysis



By committing each time you make changes, git allows you to time travel!

repo

repo

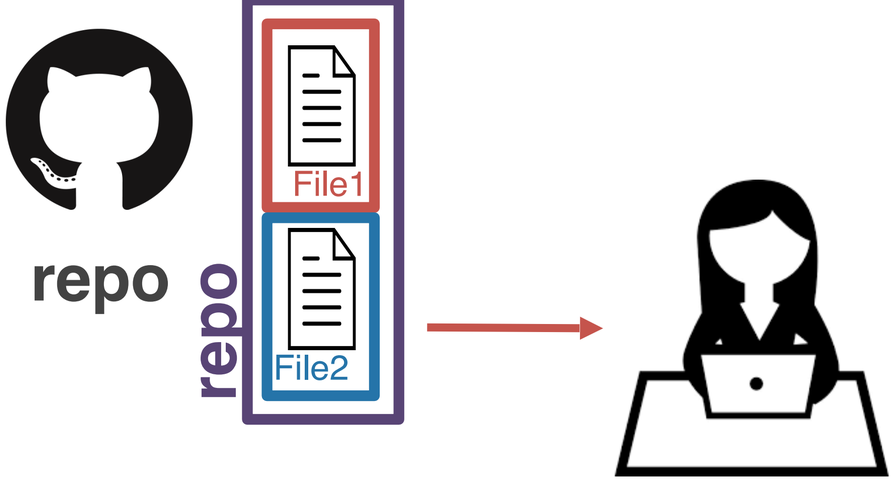
By committing each time you make changes, git allows you to time travel!

377dfcd00dd057542b112cf13be6cf1380b292ad

439301fe69e8f875c049ad0718386516b4878e22

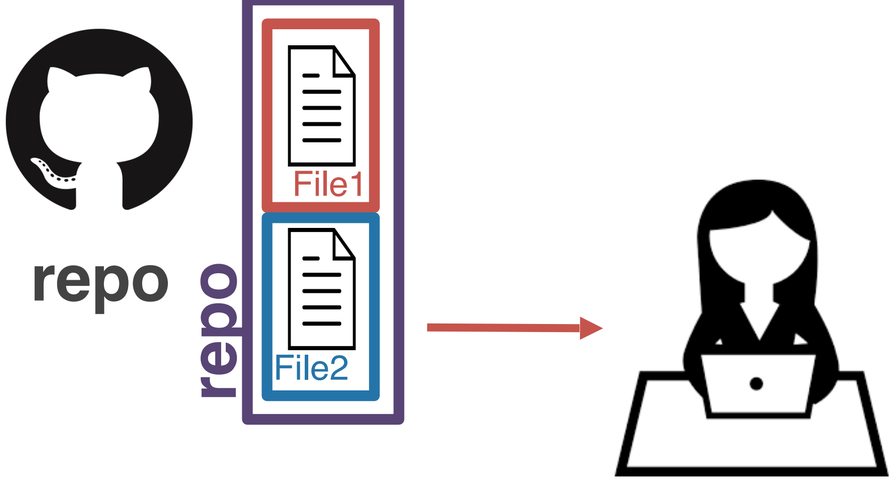
456722223e9f9e0ee0a92917ba80163028d89251

There’s a unique id, known as a **hash**, associated with each commit.

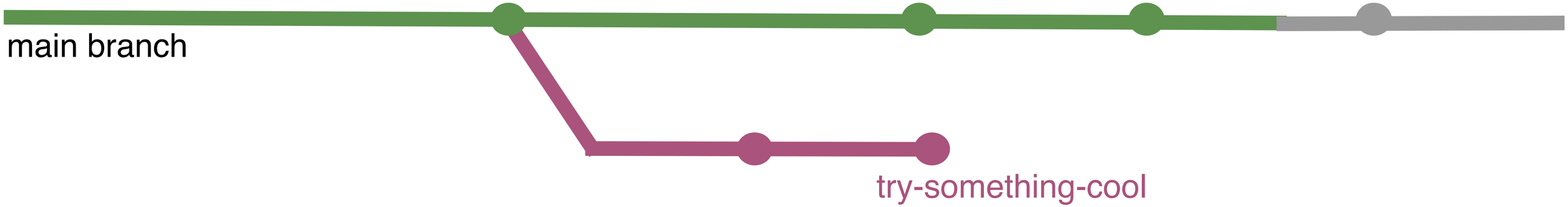


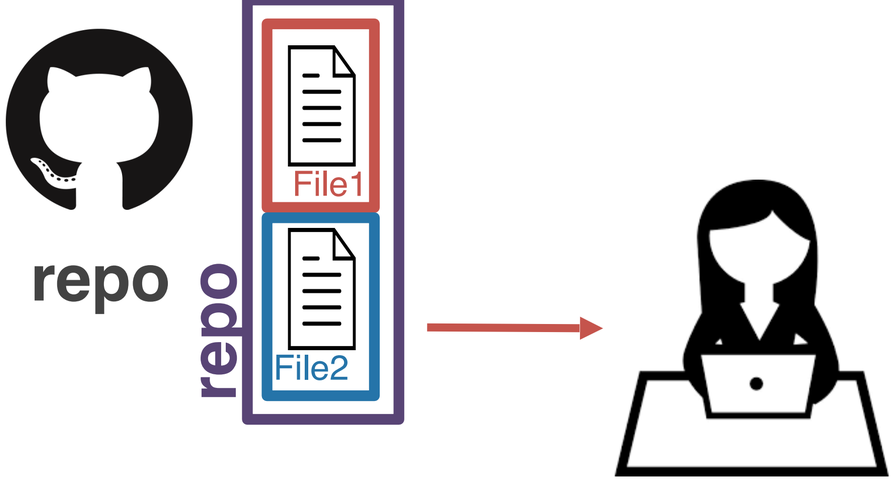
You can return to the state of the repository at any commit. Future commits don’t disappear. They just aren’t visible when you **check out** an older commit.

377dfcd00dd057542b112cf13be6cf1380b292ad

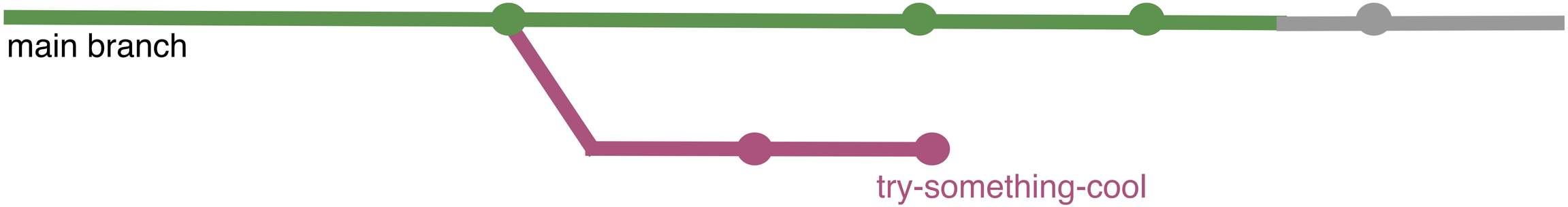


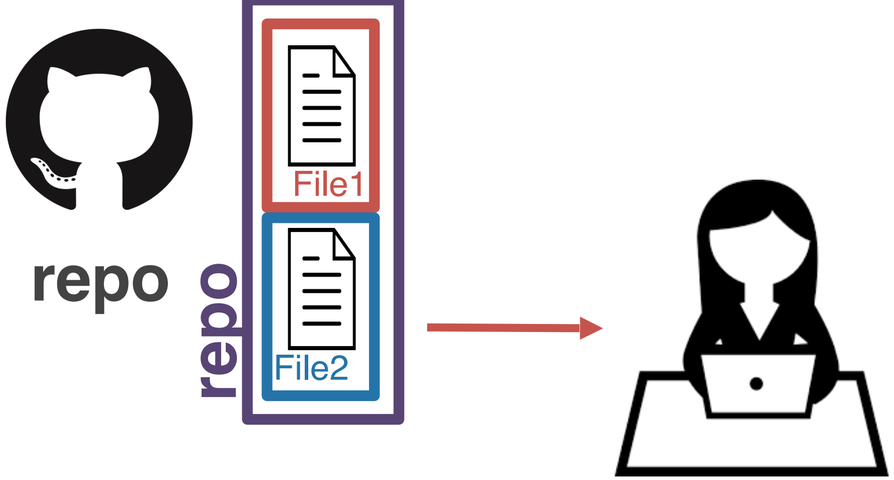
But...not everything is always linear. Sometimes you want to try something out and you're not sure it's going to work. This is where you'll want to use a **branch**.



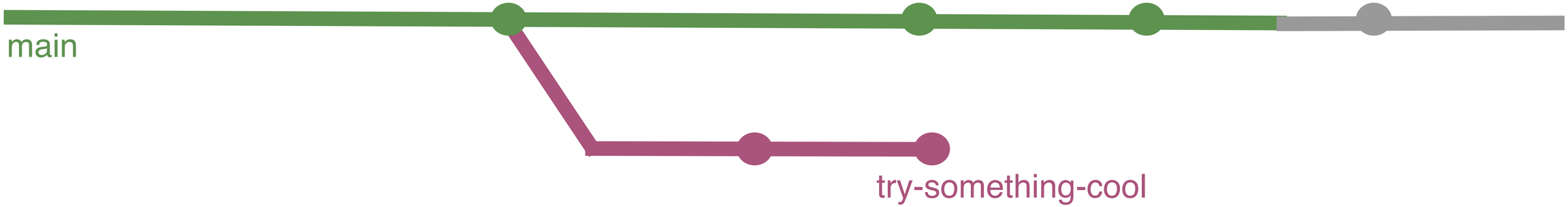


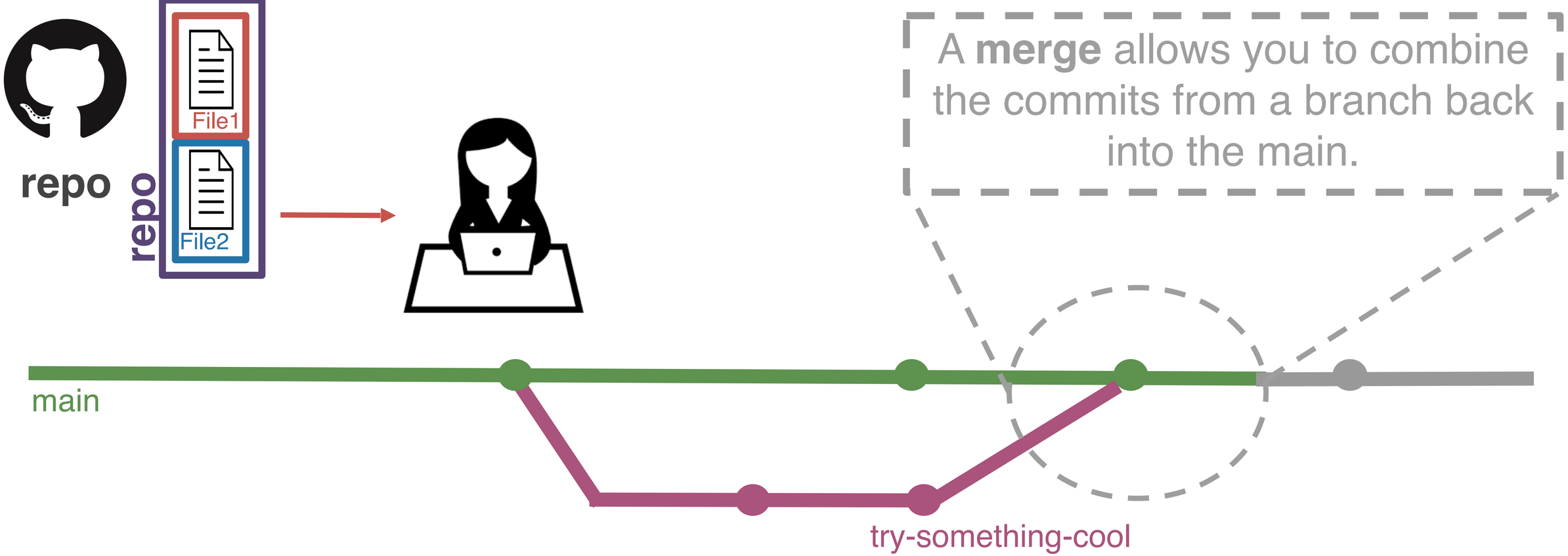
It’s a good way to experiment. It’s pretty easy to get rid of a branch later on should you not want to include the commits on that branch.



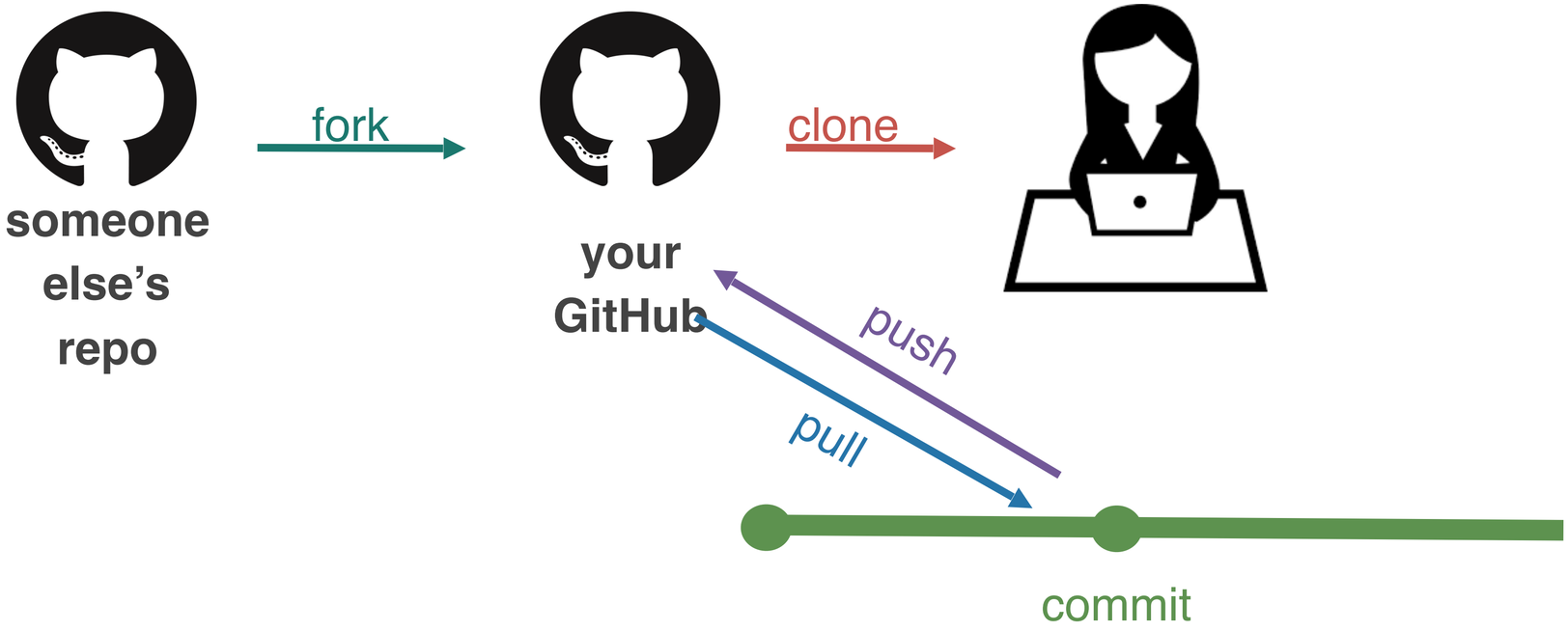


But...what if you DO want to include the changes you've made on your try-something-cool branch into the main branch?

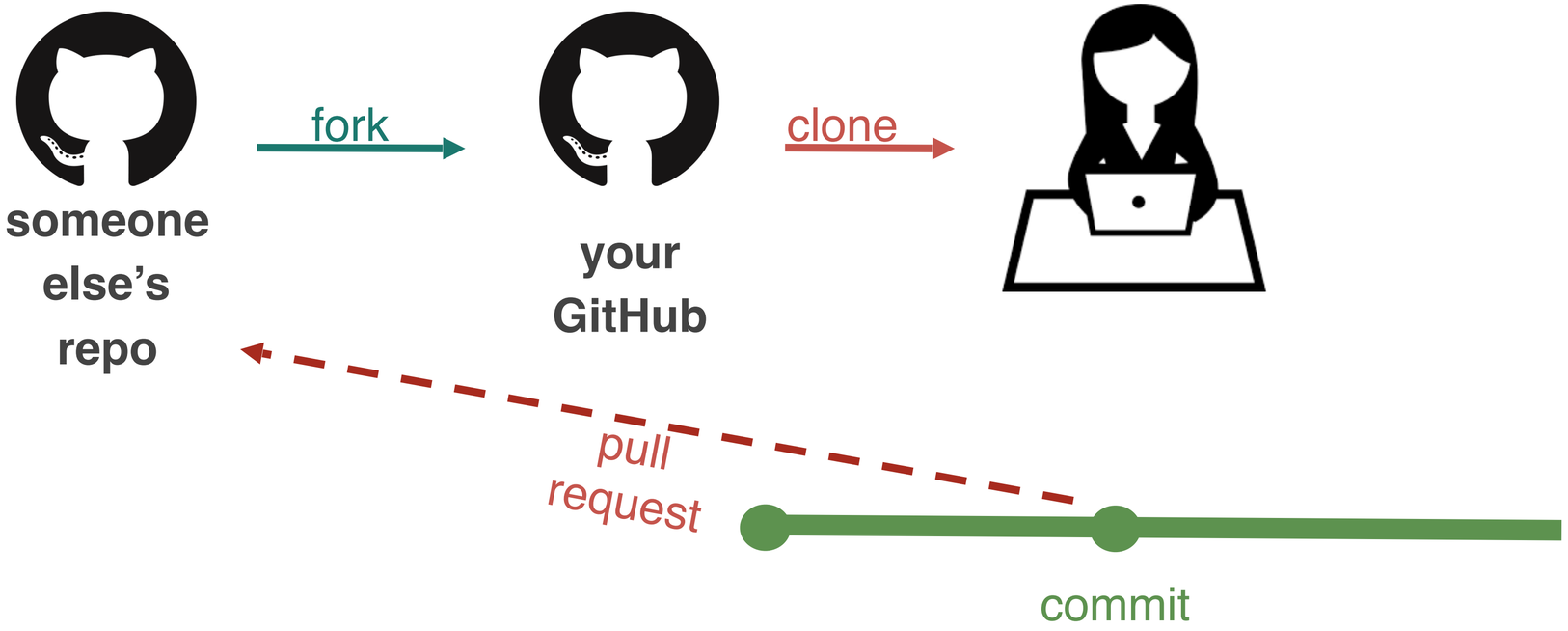



repo
repo
File1
File2
A **merge** allows you to combine the commits from a branch back into the main.
main
try-something-cool

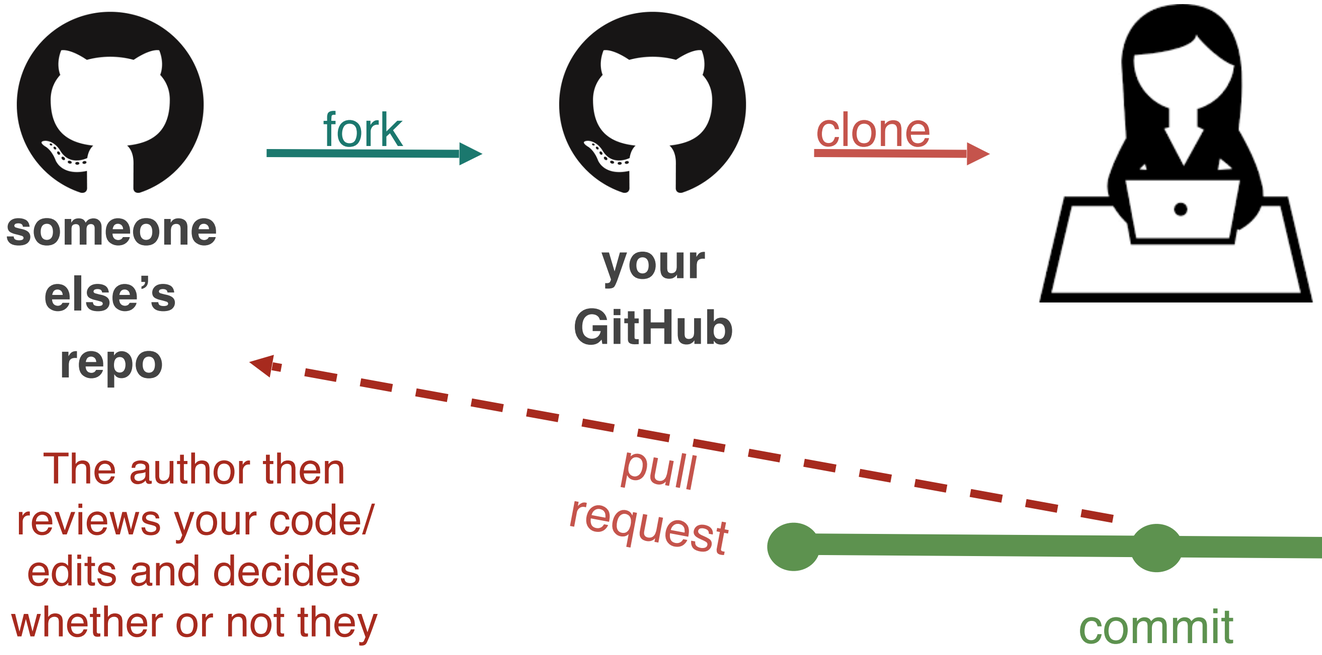
What if someone else is working on something cool and you want to play around with it? You'll have to **fork** their repo.



After you fork their repo, you can play around with it however you want, using the workflow we've already discussed.



But what if you think you've found a bug in their code, a typo, or want to add a new feature to their software? For this, you'll submit a **pull request** (aka **PR**).



But what if you think you've found a bug in their code, a typo, or want to add a new feature to their software? For this, you'll submit a **pull request** (aka **PR**).

someone else's repo

Last but not least...what if you find a bug in someone else's code OR you want to make a suggestion but aren't going to submit a suggestion with a PR. For this, you can file an **issue** on GitHub.

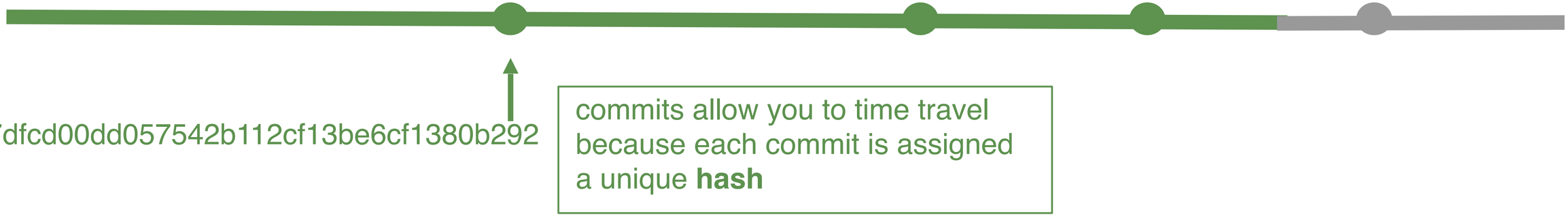
someone else's repo

Last but not least...what if you find a bug in someone else's code OR you want to make a suggestion but aren't going to submit a suggestion with a PR. For this, you can file an **issue** on GitHub.

Issues are *bug trackers*. While, they can include bugs, they can also include feature requests, to-dos, whatever you want, really!

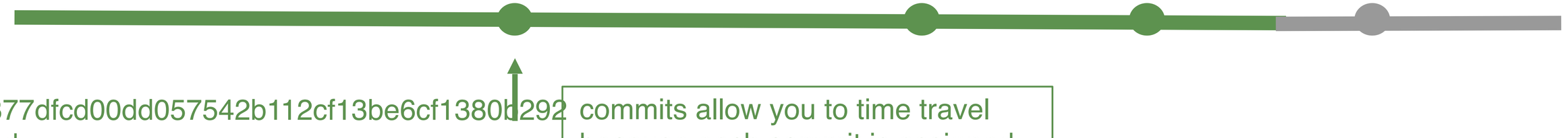
They can be assigned to people.

They can be closed once addressed ….or if the software maintainer doesn't like the suggestion

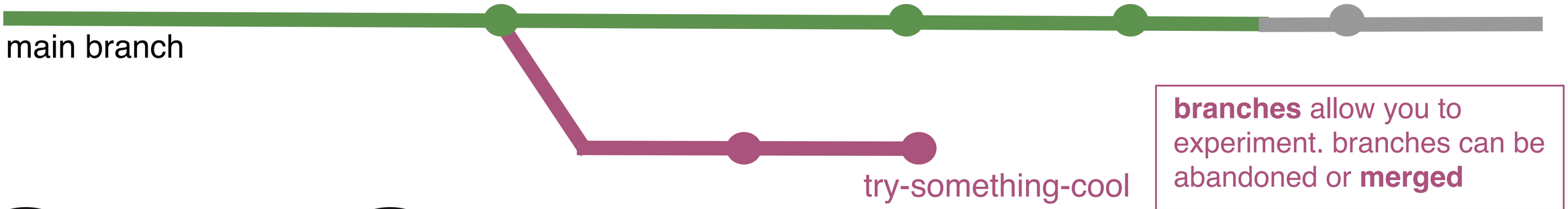


One more git recap...

One more git recap...



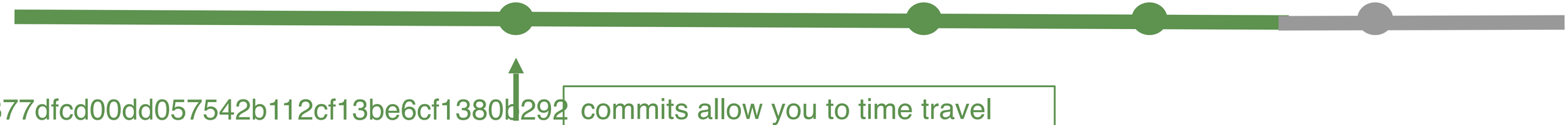
commits allow you to time travel because each commit is assigned a unique **hash**



branches allow you to experiment. branches can be abandoned or **merged**

You can work on others' repos by first **forking** their repository onto your GitHub

One more git recap...



377dfcd00dd057542b112cf13be6cf1380b292ad

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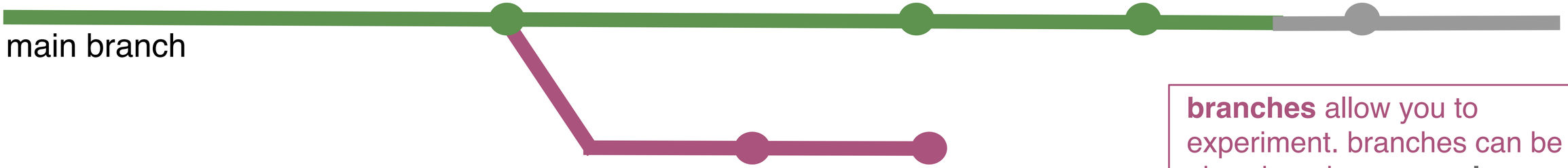
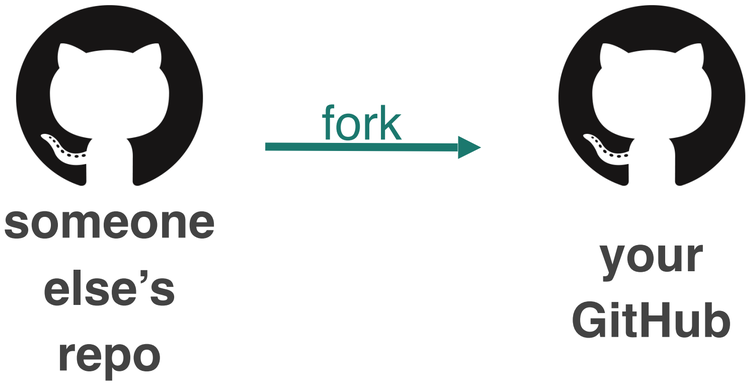


branches allow you to experiment. branches can be abandoned or **merged**



You can work on others' repos by first **forking** their repository onto your GitHub

Pull requests allow you to make specific edits to others' repos

Issues allow you to make general suggestions to your/others' repos

One more git recap...

On to today…

Data structures (Types, Tidy Data, Data Intuition), Data Cleaning

Neural data and structures

- Neural data science generates and processes large amounts of data
- Data must be stored in some organized way for analysis - “Structure”
  - There are three classes of data storage we will discuss - *structured*, *semi-structured*, *unstructured*

Data Structures Review

Structured data

- Can be stored in database SQL
- Tables with rows and columns
- Requires a relational key
- 5-10% of all data

Semi-structured data

- Doesn't reside in a relational database
- Has organizational properties (easier to analyze)
- CSV, XML, JSON

Unstructured

- Non-tabular data
- 80% of the world's data
- Images, text, audio, videos

Question

- Why do we do this? What do you think?
- Could we perform neural data science without understanding data structure or giving it any thought?

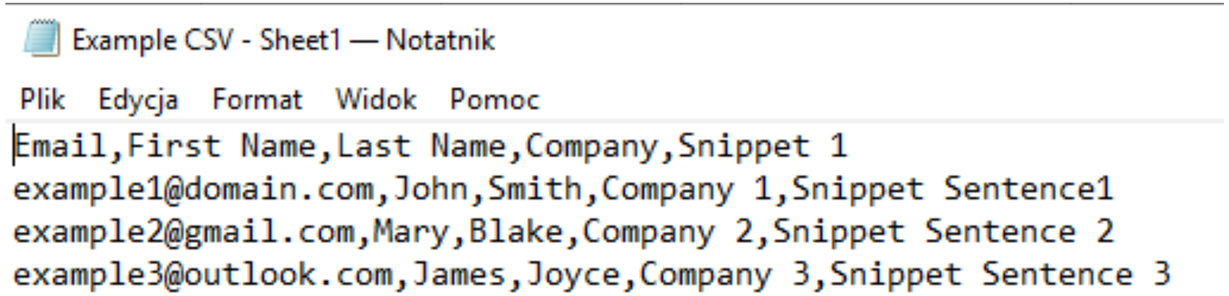
(Semi-)Structured Data

Data that is stored in such a way that it is easy to search and work with. These data are stored in a particular format that adheres to organization principles imposed by the file format. These are the data structures data scientists work with most often.

CSV files

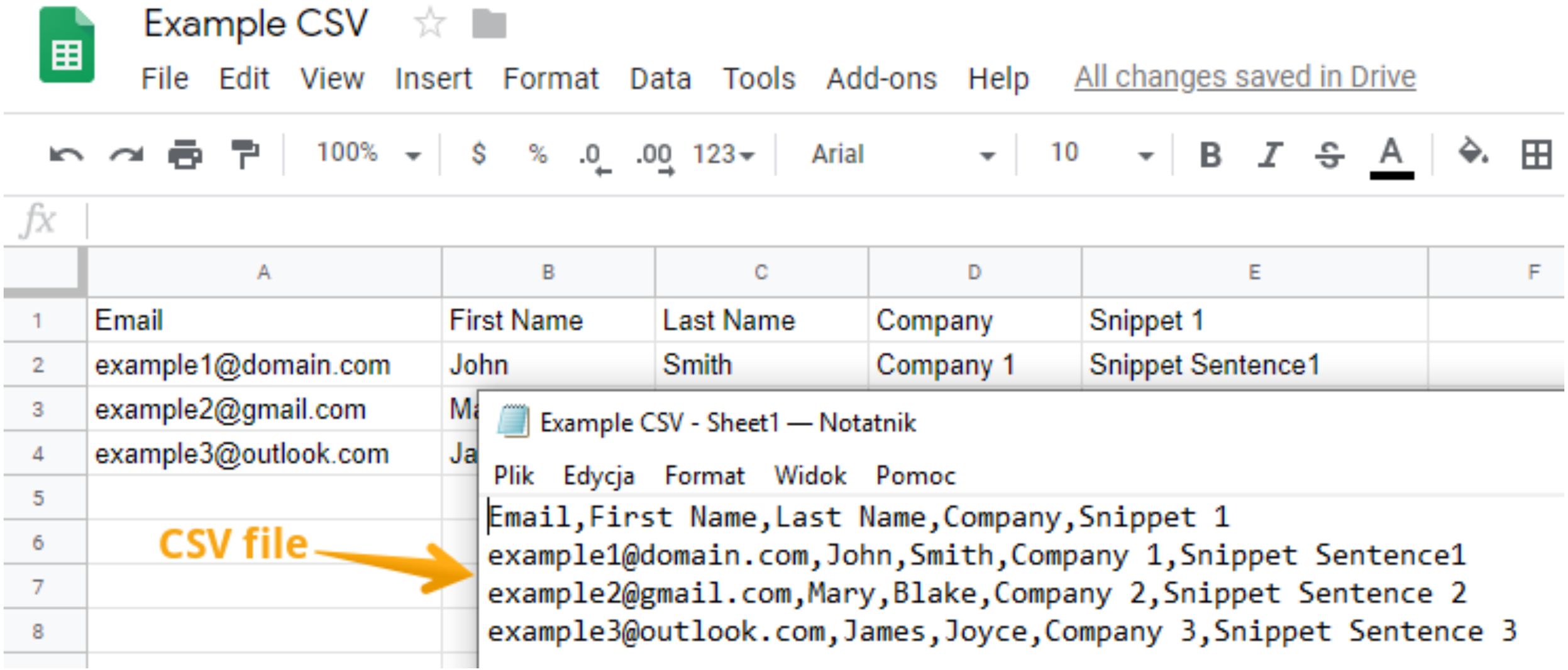
Each column separated by a comma

Has the extension “.csv”



Each row is separated by a new line

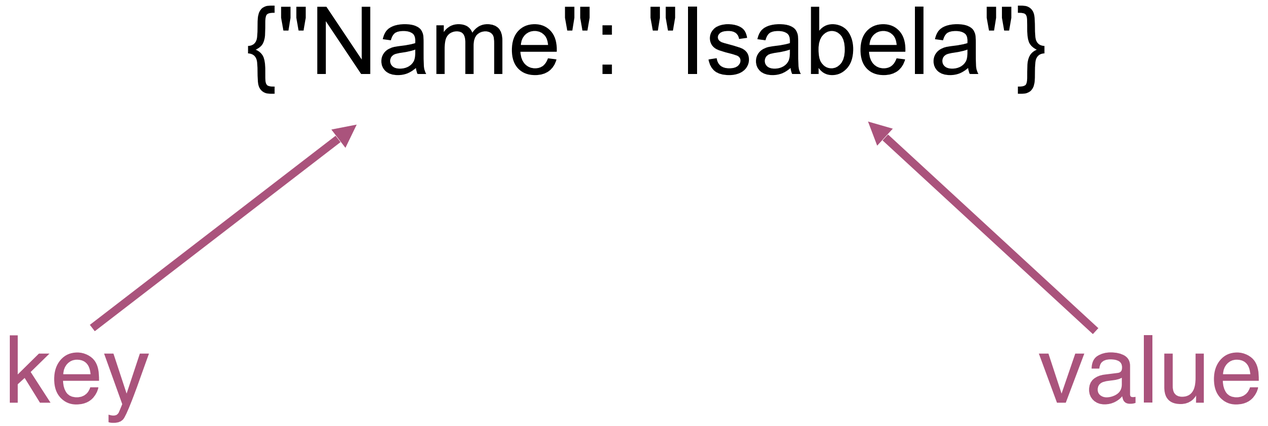
CSV

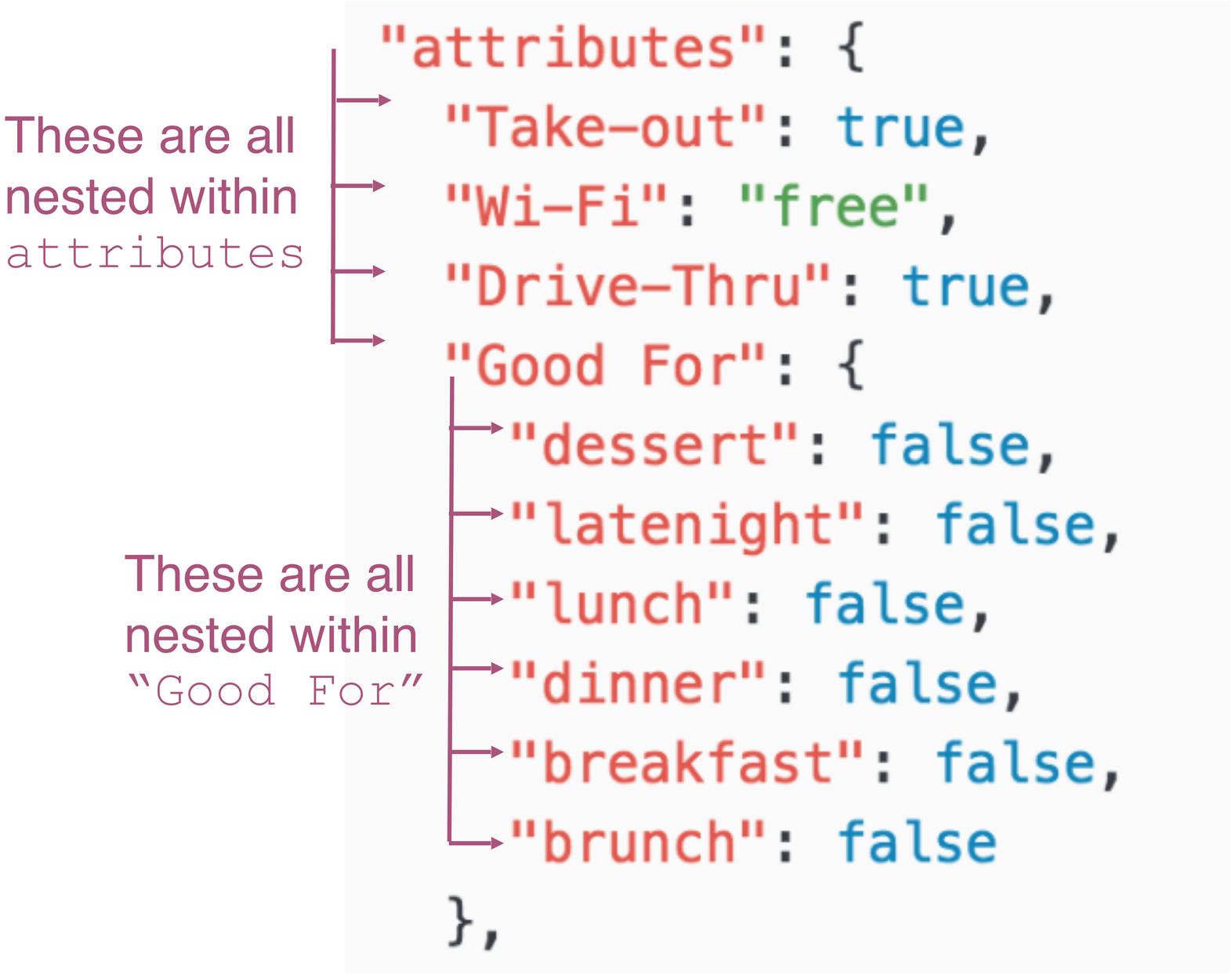

Example CSV
File Edit View Insert Format Data Tools Add-ons Help
All changes saved in Drive
100% $ % .0 .00 123 Arial 10
fx
A B C D E F
1 Email First Name Last Name Company Snippet 1
2 example1@domain.com John Smith Company 1 Snippet Sentence1
3 example2@gmail.com
4 example3@outlook.com
5
6
7
8
CSV file
Example CSV - Sheet1 — Notatnik
Plik Edycja Format Widok Pomoc
Email,First Name,Last Name,Company,Snippet 1
example1@domain.com,John,Smith,Company 1,Snippet Sentence1
example2@gmail.com,Mary,Blake,Company 2,Snippet Sentence 2
example3@outlook.com,James,Joyce,Company 3,Snippet Sentence 3

CSV

JSON: key-value pairs

nested/hierarchical data



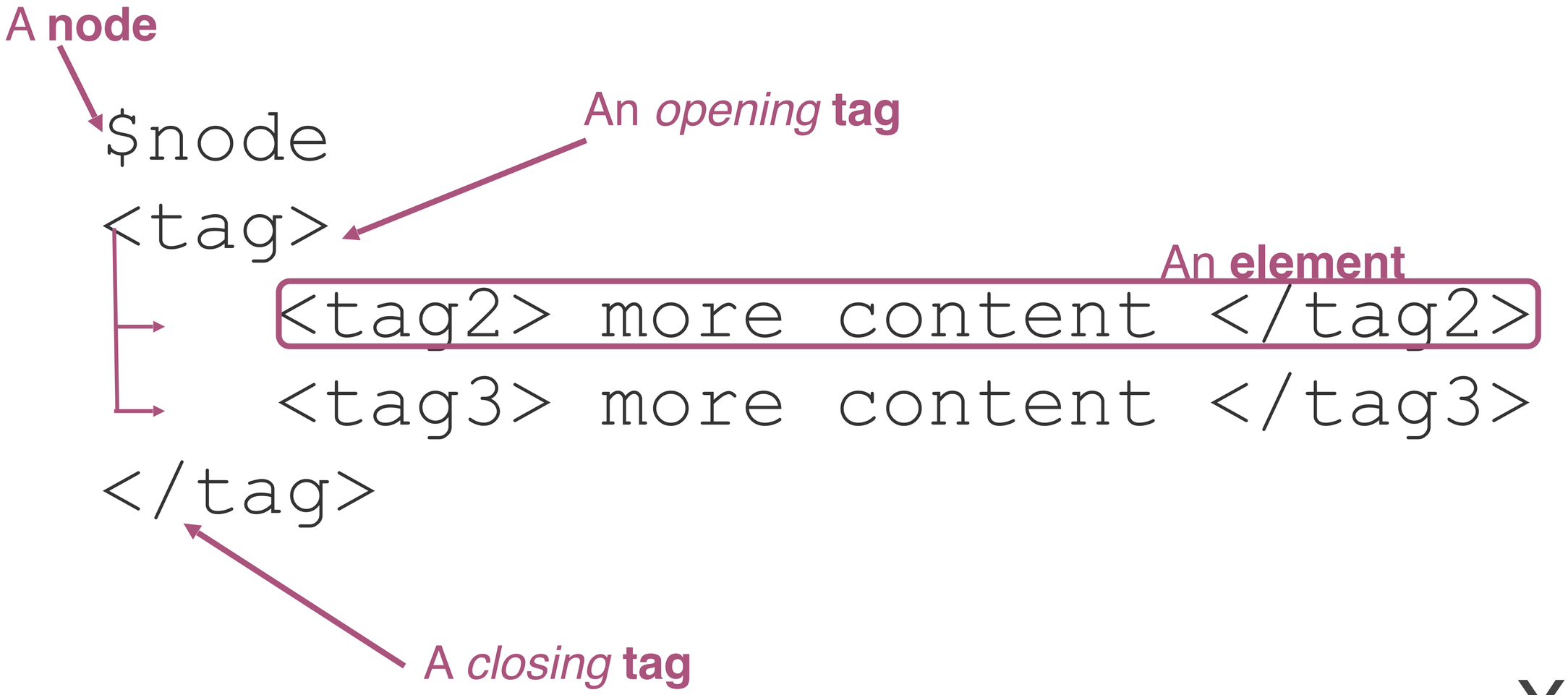


JSON

https://blog.exploratory.io/working-with-json-data-in-very-simple-way-ad7ebcc0bb89

Extensible Markup Language (XML): nodes, tags, and elements

nested/hierarchical data

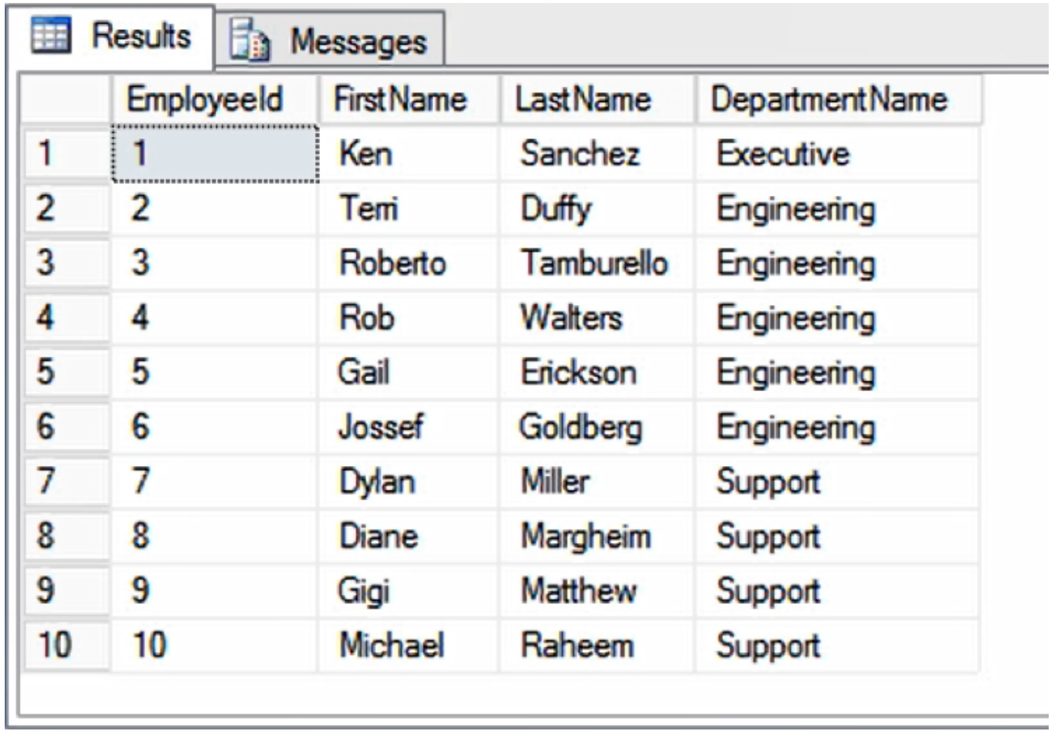


```xml
<?xml version="1.0" encoding="UTF-8"?>
<customers>
    <customer>
        <customer_id>1</customer_id>
        <first_name>John</first_name>
        <last_name>Doe</last_name>
        <email>john.doe@example.com</email>
    </customer>
    <customer>
        <customer_id>2</customer_id>
        <first_name>Sam</first_name>
        <last_name>Smith</last_name>
        <email>sam.smith@example.com</email>
    </customer>
    <customer>
        <customer_id>3</customer_id>
        <first_name>Jane</first_name>
        <last_name>Doe</last_name>
        <email>jane.doe@example.com</email>
    </customer>
</customers>
```

XML

Relational Databases: A set of interdependent tables

1. Efficient Data Storage
2. Avoid Ambiguity
3. Increase Data Privacy



Results | Messages

	EmployeeId	FirstName	LastName	DepartmentName
1	1	Ken	Sanchez	Executive
2	2	Terri	Duffy	Engineering
3	3	Roberto	Tamburello	Engineering
4	4	Rob	Walters	Engineering
5	5	Gail	Erickson	Engineering
6	6	Jossef	Goldberg	Engineering
7	7	Dylan	Miller	Support
8	8	Diane	Margheim	Support
9	9	Gigi	Matthew	Support
10	10	Michael	Raheem	Support

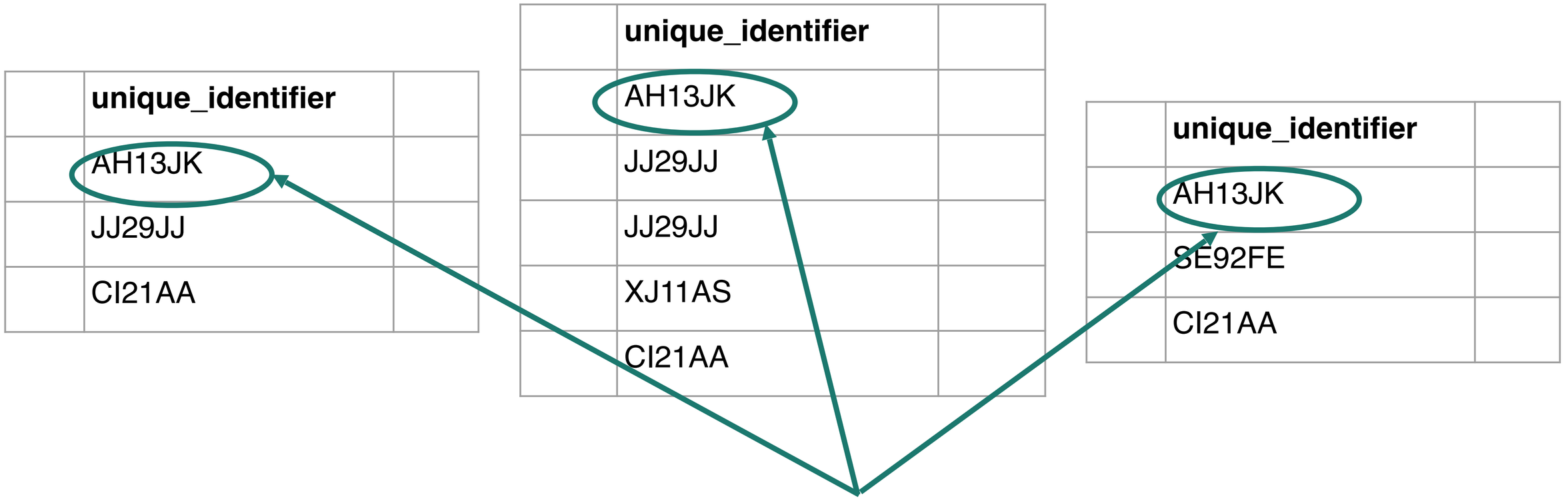
relational database

Information is stored across tables

	unique_identifier	
	AH13JK	
	JJ29JJ	
	CI21AA	

	unique_identifier	
	AH13JK	
	JJ29JJ	
	JJ29JJ	
	XJ11AS	
	CI21AA	

	unique_identifier	
	AH13JK	
	SE92FE	
	CI21AA	



entries are *related* to one another by their unique identifier

relational database

restaurant

name	id	address	type
Taco Stand	AH13JK	1 Main St.	Mexican
Pho Place	**JJ29JJ**	192 Street Rd.	Vietnamese
Taco Stand	XJ11AS	18 W. East St.	Fusion
Pizza Heaven	CI21AA	711 K Ave.	Italian

health inspections

id	inspection_date	inspector	score
AH13JK	2018-08-21	Sheila	97
JJ29JJ	2018-03-12	D'eonte	98
JJ29JJ	2018-01-02	Monica	66
XJ11AS	2018-12-16	Mark	43
CI21AA	2018-08-21	Anh	99

rating

id	stars
AH13JK	4.9
JJ29JJ	4.8
XJ11AS	4.2
CI21AA	4.7

relational database

restaurant

name	id	address	type
Taco Stand	AH13JK	1 Main St.	Mexican
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CI21AA	2018-08-21	Anh	99

rating

id	stars
AH13JK	4.9
JJ29JJ	4.8
XJ11AS	4.2
CI21AA	4.7

Two different restaurants with the same name will have different unique identifiers

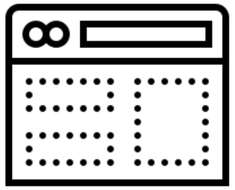
relational database

Unstructured Data

Some datasets record information about the state of the world, but in a more heterogeneous way. Perhaps it is a large text corpus with images and links like Wikipedia, or the complicated mix of notes and test results appearing in personal medical records.

Unstructured Data Types

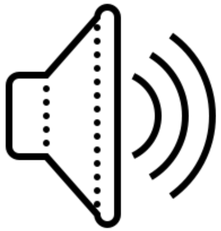
Text files and documents



Websites and applications

Sensor data

Image files



Audio files

Video files

Email data

Social media data

Tidy Data

"Good data scientists understand, in a deep way, that the heavy lifting of cleanup and preparation isn't something that gets in the way of solving the problem: it is the problem." - DJ Patil

untidy data

Australian Bureau of Statistics

1800.0 Australian Marriage Law Postal Survey, 2017

Released on 15 November 2017

Table 5 Participation by Federal Electoral Division(a), Males and Age — Gender apartheid

Table junk

Yeah NA

		18-19 years	20-24 years	25-29 years	30-34 years	35-39 years	40-44 years	45-49 years	50-54 years	55-59 years	60-64 years
Lingiari(c)	Total participants	292	1,058	1,465	1,653	1,515	1,516	1,710	1,730	1,753	1,574
	Eligible participants	572	2,910	3,789	3,996	3,607	3,506	3,645	3,331	2,960	2,456
	Participation rate (%)	51.0	36.4	38.7	41.4	42.0	43.2	46.9	51.9	59.2	64.1
Solomon	Total participants	442	1,461	2,066	2,357	2,188	2,057	2,224	2,108	2,134	1,772
	Eligible participants	750	2,991	3,994	4,155	3,634	3,398	3,427	3,066	2,931	2,355
	Participation rate (%)	58.9	48.8	51.7	56.7	60.2	60.5	64.9	68.8	72.8	75.2
Northern Territory (Total)	Total participants	734	2,519	3,531	4,010	3,703	3,573	3,934	3,838	3,887	3,346
	Eligible participants	1,322	5,901	7,783	8,151	7,241	6,904	7,072	6,397	5,891	4,811
	Participation rate (%)	55.5	42.7	45.4	49.2	51.1	51.8	55.6	60.0	66.0	69.5
Australian Capital Territory Divisions											
Canberra(d)	Total participants	1,764	4,789	4,817	4,973	4,626	4,453	5,074	4,826	5,169	4,394
	Eligible participants	2,260	6,471	6,448	6,509	5,983	5,805	6,302	5,902	6,044	5,057
	Participation rate (%)	78.1	74.0	74.7	76.4	77.3	76.7	80.5	81.8	85.5	86.9
Fenner(e)	Total participants	1,477	4,687	5,178	5,786	6,025	5,463	5,191	4,208	3,948	3,465
	Eligible participants	1,904	6,354	7,121	7,822	7,960	7,155	6,480	5,206	4,692	3,945
	Participation rate (%)	77.6	73.8	72.7	74.0	75.7	76.4	80.1	80.8	84.1	87.8
Australian Capital Territory (Total)	Total participants	3,241	9,476	9,995	10,759	10,651	9,916	10,265	9,034	9,117	7,859
	Eligible participants	4,164	12,825	13,569	14,331	13,943	12,960	12,782	11,108	10,736	9,002
	Participation rate (%)	77.8	73.9	73.7	75.1	76.4	76.5	80.3	81.3	84.9	87.3
Australia											
Total	Total participants	151,297	438,166	441,658	460,548	462,206	479,360	524,620	517,693	543,449	506,799
	Eligible participants	201,439	635,909	646,916	665,250	656,446	660,841	693,850	659,150	664,720	597,386
	Participation rate (%)	75.1	68.9	68.3	69.2	70.4	72.5	75.6	78.5	81.8	84.8

Primary keynotes

Merged cells

Comma on

Covariate as Subheading

Summary of data inside data

NA Yeah

(a) The Federal Electoral Divisions are current as at 24 August 2017
(b) Includes those whose age is unknown
(c) Includes Christmas Island and the Cocos (Keeling) Islands
(d) Includes Norfolk Island
(e) Includes Jervis Bay

Return of the table junk

MS Excel or Die

data wrangling

tidy data

	area	gender	age	State	Area (sq km)	Eligible participants	Participation rate (%)	Total participants	Total Paticipants
1	Adelaide	Female	18-19 years	SA	76	1341	83.5	1120	1120
2	Adelaide	Female	20-24 years	SA	76	4620	81.2	3750	3750
3	Adelaide	Female	25-29 years	SA	76	4897	81.8	4004	4004
4	Adelaide	Female	30-34 years	SA	76	4784	79.8	3820	3820
5	Adelaide	Female	35-39 years	SA	76	4319	79	3411	3411
6	Adelaide	Female	40-44 years	SA	76	4310	80.6	3472	3472
7	Adelaide	Female	45-49 years	SA	76	4579	81.4	3728	3728
8	Adelaide	Female	50-54 years	SA	76	4475	84.7	3791	3791
9	Adelaide	Female	55-59 years	SA	76	4622	87.3	4033	4033
10	Adelaide	Female	60-64 years	SA	76	4342	89.3	3879	3879
11	Adelaide	Female	65-69 years	SA	76	3970	90.7	3602	3602
12	Adelaide	Female	70-74 years	SA	76	3009	90.3	2716	2716
13	Adelaide	Female	75-79 years	SA	76	2156	88.5	1908	1908
14	Adelaide	Female	80-84 years	SA	76	1673	85.1	1423	1423

https://medium.com/@miles.mcbain/tidying-the-australian-same-sex-marriage-postal-survey-data-with-r-5d35cea07962

Tidy Data

1. Each variable you measure should be in a single column

	A	B	C	D	E	F	G
1	ID	LastName	FirstName	Sex	City	State	Occupation
2	1004	Smith	Jane	female	Frederick	MD	Welder
3	4587	Nayef	Mohammed	male	Upper Darby	PA	Nurse
4	1727	Doe	Janice	female	San Diego	CA	Doctor
5	6879	Jordan	Alex	male	Birmingham	AL	Teacher

2. Every observation of a variable should be in a different row

	A	B	C	D	E	F	G
1	ID	LastName	FirstName	Sex	City	State	Occupation
2	1004	Smith	Jane	female	Frederick	MD	Welder
3	4587	Nayef	Mohammed	male	Upper Darby	PA	Nurse
4	1727	Doe	Janice	female	San Diego	CA	Doctor
5	6879	Jordan	Alex	male	Birmingham	AL	Teacher

3. There should be one table for each type of data

Demographic Survey Data

	A	B	C	D	E	F	G
1	ID	LastName	FirstName	Sex	City	State	Occupation
2	1004	Smith	Jane	female	Frederick	MD	Welder
3	4587	Nayef	Mohammed	male	Upper Darby	PA	Nurse
4	1727	Doe	Janice	female	San Diego	CA	Doctor
5	6879	Jordan	Alex	male	Birmingham	AL	Teacher

Doctor's Office Measurements Data

	A	D	E	F	G
1	ID	Height_inches	Weight_lbs	Insulin	Glucose
2	1004	65	180	0.60	163
3	4587	75	215	1.46	150
4	1727	62	124	0.72	177
5	6879	77	160	1.23	205

4. If you have multiple tables, they should include a column in each *with the same column label* that allows them to be joined or merged

	A	B	C	D	E	F	G
1	ID	LastName	FirstName	Sex	City	State	Occupation
2	1004	Smith	Jane	female	Frederick	MD	Welder
3	4587	Nayef	Mohammed	male	Upper Darby	PA	Nurse
4	1727	Doe	Janice	female	San Diego	CA	Doctor
5	6879	Jordan	Alex	male	Birmingham	AL	Teacher

	A	D	E	F	G
1	ID	Height_inches	Weight_lbs	Insulin	Glucose
2	1004	65	180	0.60	163
3	4587	75	215	1.46	150
4	1727	62	124	0.72	177
5	6879	77	160	1.23	205

Tidy data == rectangular data

A

	A	B	C	D	E
1	id	sex	glucose	insulin	triglyc
2	101	Male	134.1	0.60	273.4
3	102	Female	120.0	1.18	243.6
4	103	Male	124.8	1.23	297.6
5	104	Male	83.1	1.16	142.4
6	105	Male	105.2	0.73	215.7

Broman KW, Woo KH. (2017) Data organization in spreadsheets. *PeerJ Preprints* 5:e3183v1 https://doi.org/10.7287/peerj.preprints.3183v1

Tidy Data Benefits

1. Consistent data structure
2. Foster tool development
3. Require only a small set of tools to be learned
4. Allow for datasets to be combined

Data Intuition

https://www.youtube.com/watch?v=0YzvupOX8Is

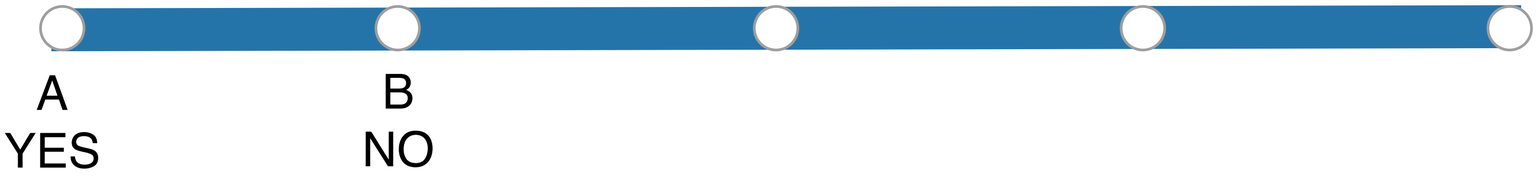
Has humanity produced enough paint to cover the entire land area of the Earth?

—Josh (Bolton, MA)

https://what-if.xkcd.com/84/

Fermi Estimation

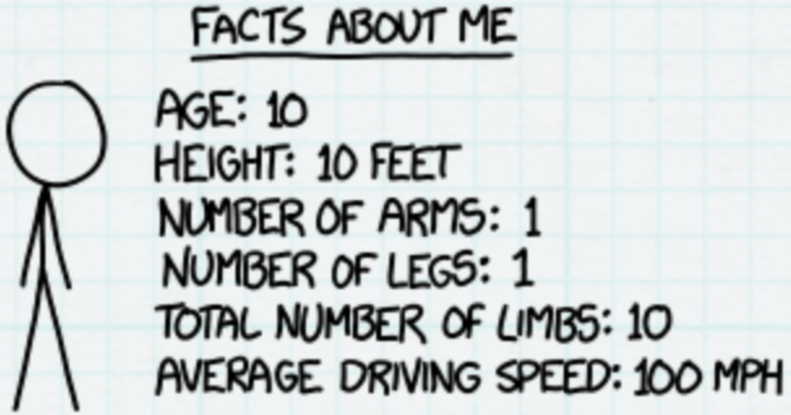
Has humanity produced enough paint to cover the entire land area of the Earth?



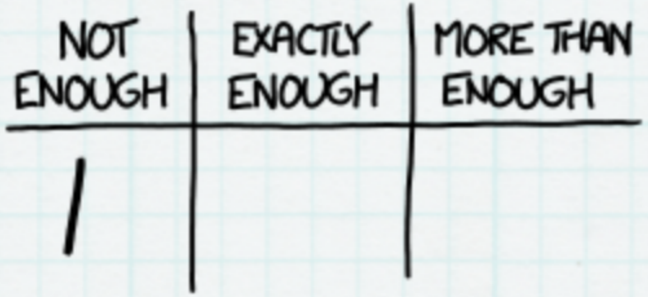
This answer is pretty straightforward. We can look up the size of the world's paint industry, extrapolate backward to figure out the total amount of paint produced. We'd also need to make some assumptions about how we're painting the ground. Note: When we get to the Sahara desert, I recommend not using a brush.

https://what-if.xkcd.com/84/

But first, let's think about different ways we might come up with a guess for what the answer will be. In this kind of thinking—often called **Fermi estimation**—all that matters is getting in the right ballpark; that is, the answer should have about the right number of digits. In Fermi estimation, you can round [1] all your answers to the nearest order of magnitude:



Let's suppose that, on average, everyone in the world is responsible for the existence of two rooms, and they're both painted. My living room has about 50 square meters of paintable area, and two of those would be 100 square meters. 7.15 billion people times 100 square meters per person is a little under a trillion square meters —an area smaller than Egypt.



Let's make a wild guess that, on average, one person out of every thousand spends their working life painting things. If I assume it would take me three hours to paint the room I'm in,[2] and 100 billion people have ever lived, and each of them spent 30 years painting things for 8 hours a day, we come up with 150 trillion square meters ... just about exactly the land area of the Earth.

How much paint does it take to paint a house? I'm not enough of an adult to have any idea, so let's take another Fermi guess.

Based on my impressions from walking down the aisles, home improvement stores stock about as many light bulbs as cans of paint. A normal house might have about 20 light bulbs, so let's assume a house needs about 20 gallons of paint.[3] Sure, that sounds about right.

The average US home costs about $200,000. Assuming each gallon of paint covers about 300 square feet, that's a square meter of paint per $300 of real estate. I vaguely remember that the world's real estate has a combined value of something like $100 trillion,[4] which suggests there's about 300 billion square meters of paint on the world's real estate. That's about one New Mexico.

Of course, both of the building-related guesses could be overestimates (lots of buildings are not painted) or underestimates (lots of things that are not buildings [5] are painted) But from these wild Fermi estimates, my guess would be that there probably isn't enough paint to cover all the land.

So, how did Fermi do?

According to the report **The State of the Global Coatings Industry**, the world produced 34 billion liters of paints and coatings in 2012.

There's a neat trick that can help us here. If some quantity—say, the world economy—has been growing for a while at an annual rate of **n**—say, 3% (0.03)—then the most recent year's share of the whole total so far is $1 - \frac{1}{1+n}$, and the whole total so far is the most recent year's amount times $1 + \frac{1}{n}$.

If we assume paint production has, in recent decades, followed the economy and grown at about 3% per year, that means the total amount of paint produced equals the current yearly production times 34.[6] That comes out to a little over a trillion liters of paint. At 30 square meters per gallon,[7] that's enough to cover 9 trillion square meters—about the area of the United States.

So the answer is no; there's not enough paint to cover the Earth's land, and—at this rate—probably won't be enough until the year 2100.

Data Intuition

1. Think about your question and your expectations
2. Do some Fermi calculations (back of the envelope calculations)
3. Write code & look at outputs <- think about those outputs
4. Use your gut instinct / background knowledge to guide you
5. Review code & fix bugs
6. Create test cases - “Sanity checks”

What is data cleaning?

- Fixing/removing incorrect, corrupted, incorrectly formatted, duplicate, incomplete, data within a dataset
- Many issues combining data sources and types, researcher styles, standards, recording errors, etc

Consequences of poorly cleaned data

- Unreliable outcomes and algorithms
- Difficult to detect these issues
- Biased results
- Failure to process algorithms (for example NANs causing errors)

Variability in cleaning

- There is no one process to clean data
- Varies from set to set, project to project, software to software
- But can establish a ‘template’ procedure/process of ‘check-offs’ to make sure you’ve done your best to address it

Methods can be

- Interactive through ‘wrangling tools’
- Automated through scripts, programs or other software (batch processing)