CS 45, Lecture 8
Version Control

Winter 2023

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Outline

1. Review
2. Version Control
3. Git
4. GitHub

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Computer Networks

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- How computers can use a network to talk to each other
- How information gets sent from one place to another over the internet

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- How information gets sent from one place to another over the internet

In this lecture, we will see:

- How to safely store your files (code or text)
- How to collaboratively on files with others over the internet
- How to avoid losing all your homework!

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- As you change these files over time, you'll eventually want some way to keep track of different “versions” of the file.
- What we need is a “version control system”.

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2.1 Version Control Systems

2.2 Comparison of VCSs

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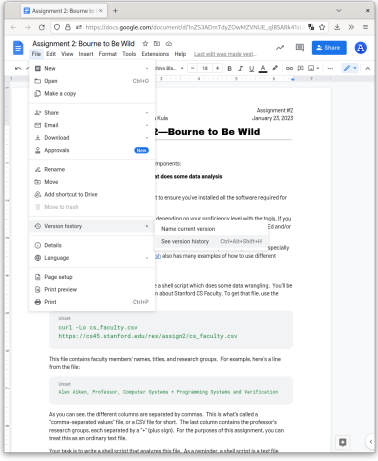
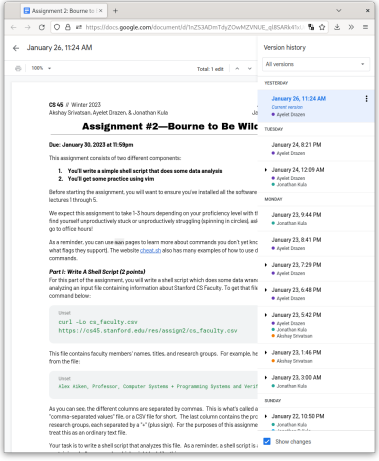
- You've seen these before!

Version Control Systems





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- Will let you collaborate on files with other people
- Will combine the different versions of the files produced by different people sanely

Outline

Google Docs

Google Docs automatically keeps track of file history in a basic VCS.

Pros:

- Great for rich text
- Allows real-time collaboration
- Saved on the cloud automatically

Cons:

- Bad for plain text (especially code)
- Requires an internet connection
- Only supports a single “current” version of a single file

Copying Files

You can make a bunch of copies of files or folders with `cp` as a simple form of version control. You can compare versions with `diff`.

Pros:

- Works on either rich or plain text (or anything else)
- It's simple and makes it easy to move data between versions

Cons:

- It's messy and a lot of manual work
- It's hard to tell what the relationship between different versions is
- It takes a lot of hard drive space

Zip Files

Instead of just `cp`ing folders, we could bundle them up into a Zip file (a single file which can be “unzipped” into a folder).

Pros:

- Tracks versions for an entire folder at once
- Easy to share a version with someone else (email)

Cons:

- It's still a lot of manual work
- It's hard to tell what the relationship between different versions is
- It's hard to extract a single file from an old version

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- The tool could track the relationships between different versions, so we can have multiple “current” versions at the same time.
- If we want to combine different versions, the tool can automatically do it for us (instead of us copying and pasting the parts together).

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- If we want to combine multiple people's work, we can ask Git to automatically merge them together. If it can't for some reason, it'll ask us to manually merge them.

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3.1 Linear History

3.2 Branching Workflow

3.3 Combining Branches

3.4 When/How to Commit

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6. Repeat from 3

You can use `git log` to see your commit history, and use `git status` to see the current state of staged/unstaged/untracked changes.

Basic Workflow

Demo

Let's practice how to:

- Create a new Git repository
- Commit a new file
- Commit changes to files
- Revert commits
- Look at an old version of a file
- Compare two versions of files
- See your commit history

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1. Make sure your repository is “clean” (i.e., you have no uncommitted changes).
2. `git checkout -b <branch>` to create a new branch and move to it; at this point, the new branch will be identical to the old one.
3. Make changes, `git add`, `git commit` as usual
4. `git checkout` to switch between branches

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Combining Branches

Now that we have multiple branches, we probably want to join them back together at some point.

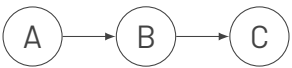
There are several ways to do this:

- `git merge` two branches into one
- `git merge --fast-forward` a long branch onto a shorter version of itself
- `git rebase` one branch onto another branch
- `git cherry-pick` a specific commit from one branch to another

Branching Workflow

Fast Forwarding

The simplest case of MERGING is called FAST-FORWARDING.



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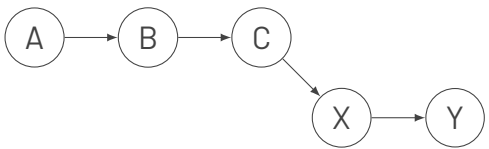

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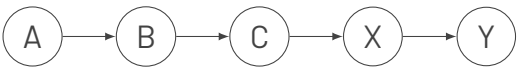

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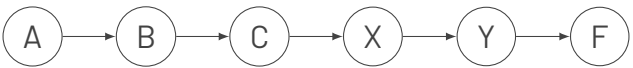

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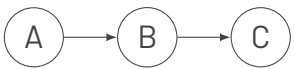

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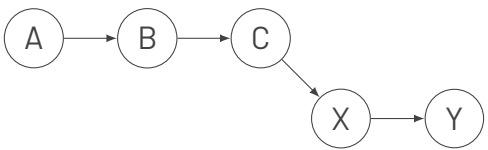

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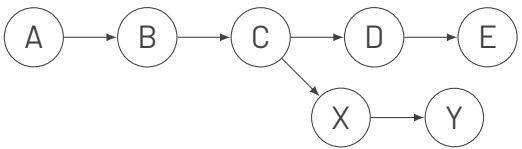

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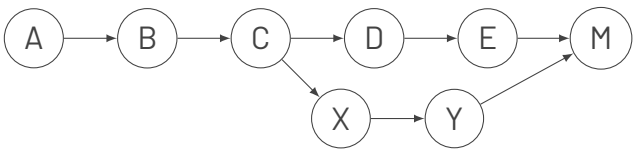

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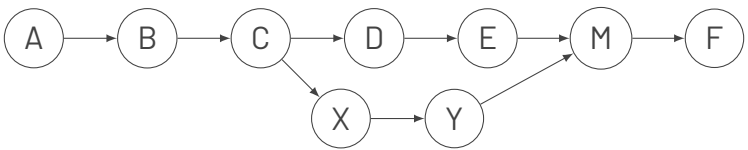

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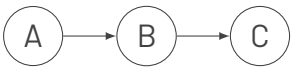

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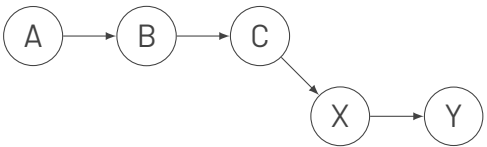

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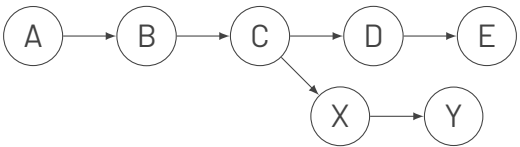

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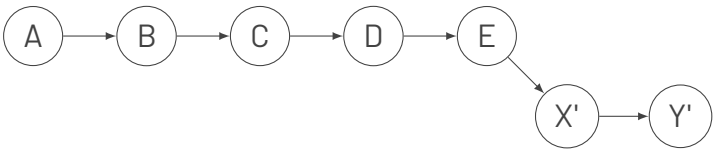

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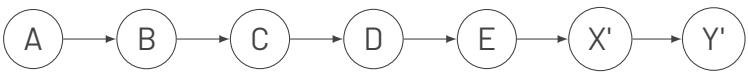

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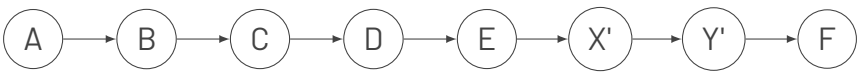

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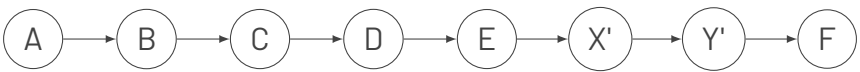

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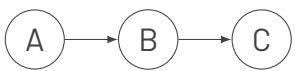

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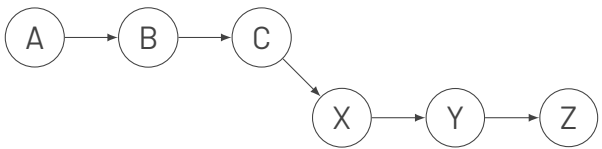

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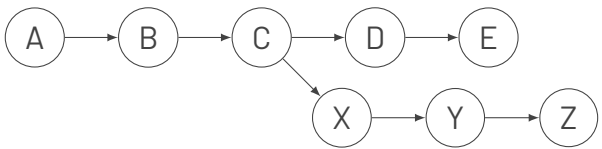

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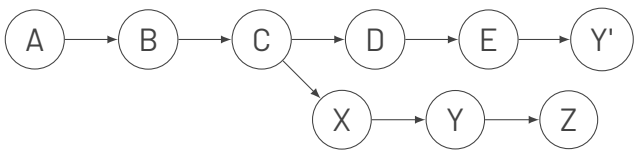

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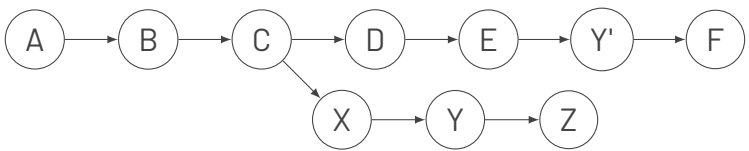

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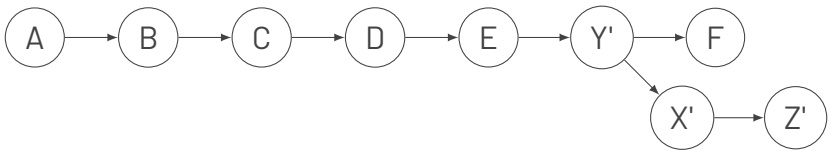

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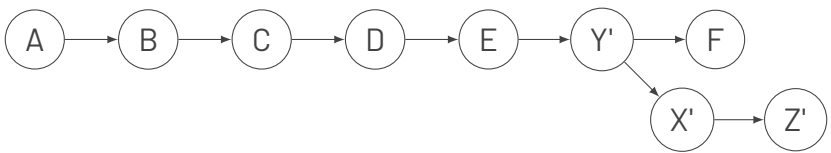
CHERRY-PICKING copies a *single commit* from one branch to another branch. CHERRY-PICKING and rebasing is a good way to move a single commit from one branch to another.



Branching Workflow

When to merge/rebase/cherry-pick?

- **fast-forward** when possible (`git merge --ff-only`).
- **rebase and then fast-forward** if possible, i.e., if you're the only one working on the branch; **never** rebase a branch other people are using (`git rebase` and `git merge --ff-only`).
- **merge** if neither of the above are possible (`git merge`).
- **cherry-pick** if you want to copy a specific commit to another branch (`git cherry-pick`)[1].

[1] This is pretty rare, I've only used it a handful of times.

Branching Workflow

Branching Demo

Let's practice how to:

- Split our repository into two branches
- Switch between branches
- Make commits on either branch
- Merge two branches together

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Definition (merge conflict)

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- If Git doesn't know what to do, it'll ask you to resolve the conflict.

Merge Conflicts

Definition (merge conflict)

A merge conflict is what happens when you try to combine two contradictory branches. Git can't always figure out how to resolve the contradiction, so it'll ask the user (you).

- Git normally resolves merge conflicts automatically.
- Some conflicts have multiple valid resolutions (e.g., what if one person edited a file that another person deleted?).
- If Git doesn't know what to do, it'll ask you to resolve the conflict.

Merge Conflicts

Git will tell you which files conflicted, and tell you to resolve the commits and commit the results:

```
Auto-merging hello.txt
CONFLICT (content): Merge conflict in hello.txt
Automatic merge failed; fix conflicts and then commit the result.
```

Merge Conflicts

Conflict Markers

Git will also add conflict markers to the files:

```
Hello, my name is Akshay Srivatsan.
<<<<<<< HEAD
I'm doing my PhD in the Stanford CS department.
=======
I am a PhD student studying CS at Stanford.
>>>>>>> add-major
I'm currently co-teaching CS45 and doing research.
```

This might look scary, but it's not that bad!

Merge Conflicts

Conflict Markers: The Base Branch

The top part (labeled `HEAD`) are the changes in the base branch (the branch you're currently on):

```
Hello, my name is Akshay Srivatsan.
<<<<<<< HEAD
I'm doing my PhD in the Stanford CS department.
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I am a PhD student studying CS at Stanford.
>>>>>>> add-major
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```

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Conflict Markers: The Incoming Branch

The top part (labeled with a branch name) are the changes in the other (incoming) branch:

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Hello, my name is Akshay Srivatsan.
<<<<<<< HEAD
I'm doing my PhD in the Stanford CS department.
=======
I am a PhD student studying CS at Stanford.
>>>>>>> add-major
I'm currently co-teaching CS45 and doing research.
```

Merge Conflicts

Resolving a Conflict

Pick how you want to resolve the conflict (i.e., decide what the “correct” result of the merge is), and make the file look that way!

```
Hello, my name is Akshay Srivatsan.
I'm a PhD student in the Stanford CS department.
I'm currently co-teaching CS45 and doing research.
```

In this case, I mixed together both versions. The “correct” answer depends on what you're doing, which is why Git can't figure it out for you.

Merge Conflicts

Commiting the Merge

Resolve all the conflicts in all the files however you want, then:

1. `git add` your changes to track them
2. `git commit` the changes (with no message)

Git will auto-generate a message, and open your `$EDITOR` to have you confirm it:

```
Merge branch 'add-major'
```

Save the file in your editor and close it (`:wq` in Vim), and Git will save the merge commit. That's it—the merge conflict is gone!

Merge Conflicts

Rebase Conflicts

Resolve all the conflicts in all the files however you want, then:

1. `git add` your changes to tell Git you fixed them
2. `git rebase --continue`

Since rebasing doesn't create a merge commit, you don't have to run `git commit`; use `git rebase --continue` instead!

Resolving Merge Conflicts

To resolve a merge conflict:

1. Don't panic!
2. Look at the files in conflict (run `git status` to see what's going on).
3. Fix each conflict, one-by-one.
4. When you're done, `git add` all the fixed files and `git commit`.

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Let's practice!

Merge conflicts usually happen in shared repos, so let's CLONE one of my repos onto your computer:

```
git clone https://github.com/Akshay-Srivatsan/cs45-23win-demo-repo.git
```

Pulling Changes

You might have seen references to the `git pull` command before. This is a combination of two commands, but the exact two depends on your Git version and configuration:

`git pull --ff-only`: `git fetch` and `git merge --ff-only` (Default)

`git pull --no-rebase`: `git fetch` and `git merge` (Old Default)

`git pull --rebase` `git fetch` and `git rebase`

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`git pull --rebase` `git fetch` and `git rebase`

Depending on your preferences, you can configure `git pull` to do any of these.

Outline

1. Review

2. Version Control

3. Git

3.1 Linear History

3.2 Branching Workflow

3.3 Combining Branches

3.4 When/How to Commit

4. GitHub

Commit Messages

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Writing good commit messages is part of being a good programmer!

Squashing Commits

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Editing History

Interactive rebasing edits history! Don't do this on a branch you share with other people (like `main`). In general, only do this on commits you **have not** pushed. Otherwise, you'll have to FORCE-PUSH (`git push --force`) your changes, which will **destroy** everyone else's changes.

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You can start an interactive rebase using the command `git rebase --interactive <base>`; for example, `git rebase --interactive main` will let you edit every commit that's in your branch but not in `main`.

Interactive Rebasing

Git will open `$EDITOR` with a list of actions (which you can edit!).

```
pick 0cd3296 start working on new file
pick 594a80c continue working
pick 162392b almost done
pick bf45520 done
pick c545ae9 oops, had a bug
pick 9b3d056 fix the bug for real this time
```

Each line represents one commit. The first word is a "command"; `pick` keeps the commit, `reword` lets you edit the commit message, `edit` lets you change the commit contents, `squash` and `fixup` both squash the commit into the previous one, and `drop` removes the commit completely.

Squash and Fixup Commits

Squash commits let you specify that two commits are closely related, so they should be combined into a single commit with both messages.

Fixup commits let you specify that a particular commit just “fixes” a previous one, and therefore should be absorbed into the previous commit.

```
reword 0cd3296 start working on new file
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```

Rewording Commits

When you want to `reword` a commit, Git will open `$EDITOR` and ask you for a new commit message. Enter the message you want, save, and quit.

```
Add a file providing more information about the project

# Please enter the commit message for your changes. Lines starting
# with '#' will be ignored, and an empty message aborts the commit.
#
# Date:      Fri Feb 3 22:34:02 2023 -0800
```

Amending Commits

If you want to edit the commit you just made, you can skip the rebase and just AMEND it, using `git commit --amend`.

This will also let you edit the commit message of the last commit.

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If you want to amend an earlier commit but don't want to do the full interactive rebase yet, you can use `git commit --fixup <hash>` to mark a commit as being a fixup commit of an earlier commit.

You can then use `git rebase --interactive --autosquash <base>` to automatically absorb your fixup commits into the original commits.

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Again, only do this if **no one else** is using your branch.

Good Commit Messages

From Stanford Stagecast: Proleptic:

```
5a64e14     2022-12-05  Add jaccard similarity index [Akshay
↪  Srivatsan]
565f686     2022-11-30  Add constant metronome to piano roll
↪  split-ear program [Akshay Srivatsan]
f4554ad     2022-11-30  Add full-piano split-ear program [Akshay
↪  Srivatsan]
75dd1f7     2022-11-30  Add MIDI-to-piano program [Keith Winstein]
62ba612     2022-11-30  Initial synth benchmark [yasmitch]
42df5fd     2022-11-30  midi-recorder.cc: print time in decimal
↪  [Keith Winstein]
d8478b0     2022-11-30  midi-recorder.cc: pop event each time (and
↪  flush output each line) [Keith Winstein]
```

Bad Commit Messages

From CS 140E, Winter 2023:

```
bd8771f     2023-02-02  minor [engler]
88452fa     2023-02-02  minor [engler]
504175b     2023-02-02  minor [engler]
d190a50     2023-02-02  Merge branch 'main' of
 ↪  github.com:dddrrreee/cs140e-23win into main more [engler]
f59cf98     2023-02-02  fixed [engler]
1552052     2023-02-02  minor [Akshay Srivatsan]
5860c92     2023-02-02  minor [engler]
f269ea4     2023-02-02  Merge branch 'main' of
 ↪  github.com:dddrrreee/cs140e-23win into main dd [engler]
89d3dc9     2023-02-02  minor [engler]
63b1f52     2023-02-02  minor [Akshay Srivatsan]
```

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- You MERGE or REBASE your changes to `main` into `origin/main`.
- You PUSH your new `origin/main` back to the remote, which updates its `main`.

GitHub Demo

Let's create a new repository on GitHub!

You'll need the `git` command and the GitHub CLI.

1. Go to `https://github.com/new` and pick a name.
2. Click “Create repository” to continue.
3. Run `git clone` with the URL of your new repo.
4. Run `gh auth login` from inside your new clone. Tell `gh` that you want to use it to authenticate with `git`.
5. Make some changes (add a file), and run `git push` to upload them!

GitHub Demo

Let's start collaborating!

1. On the GitHub website for your repo, go to “Settings” and click on “Collaborators”.
2. Add the person sitting next to you as a collaborator!
3. Make a clone of their repo, make some changes, then commit and push them. Use `git fetch` or `git pull` to download their changes to your repo.
4. What happens if you both try to edit the same file at the same time?
5. Can you push a new branch to your partner's repo?[2]

[2] Hint: you might have to use the `--set-upstream` flag; Git will tell you exactly what to do.

Pull Requests

- It's dangerous to give access to the `main` branch on your repo to everyone; someone might start messing with it!
- In "Settings/Branches", you can enable BRANCH PROTECTION for `main`. Specifically, you can enable "Require a pull request before merging".
- A PULL REQUEST[3] is a way to review a change before merging it. You (the repo owner/maintainer) can choose whether to approve or reject the request.
- To create a pull request: create a new branch, make your changes, push your new branch, then run `gh pr create`.

[3] This is misleadingly named, it's really a "merge request"

When to use Git

- When you want to look at past versions of a folder.
- When you want to be safe from accidentally overwriting your work.
- When you want to collaborate with other people asynchronously (use GitHub!).
- When you want to keep a backup copy of a folder with full history (use GitHub!).
- You want to “fork” a project already using Git/GitHub and contribute back to it.