

CS 61B

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Using Git

Author: Sarah Kim, with revisions by Josh Hug (mostly the narrative starter example) and Noah Adhikari

Preface: This guide assumes a basic understanding of the command line on your computer. If you've never used the command line, consider reading the section "the Terminal" of [Lab 1](#).

This guide will primarily serve as an intro to and surface-level reference for Git. If you're looking for something more like "oh no, something happened to my repository!" and want to see potential fixes, consult the [61B git-WTFS](#) (git weird technical failure scenarios) instead.

A. Intro to Version Control Systems

Version control systems are tools to keep track of changes to files over time. Version control allows you to view or revert back to previous iterations of files. Some aspects of version control are actually built into commonly used applications. Think of the `undo` command or how you can see the revision history of a Google document.

In the context of coding, version control systems can track the history of code revisions, from the current state of the code all the way back until it was first tracked. This allows users to reference older versions of their work and share code changes with other people, like fellow developers.

Version control has become a backbone of software development and collaboration in industry. In this class, we will be using [Git](#). Git has excellent [documentation](#) so we highly encourage those who are interested to read more about what will be summarized in the rest of this guide.

Intro to Git

Git is a [distributed version control system](#) as opposed to a centralized version control system. This means that every developer's computer stores the entire history (including all old versions) of the entire project! This is rather unlike tools like Dropbox, where old versions are stored on a remote server owned by someone else. We call the entire history of an entire project a "repository". The fact that the repository is stored locally leads to our ability to use Git locally on our own computers, even without an internet connection.

The lab computers already have Git installed on the command line, and the [Lab 1 setup](#) guide explains how to install git on your own computer. In addition to the text based interface that we'll learning to use in this guide, there is also a [Git GUI \(Graphical User Interface\)](#). We will not officially support usage of the graphical GUI.

B. Local Repositories (Narrative Introduction)

Let's go through a narrative example of how we might use git. We'll be using lots of unfamiliar terms and ideas in this story. For a video version of this narrative example, see [this video](#).

Suppose we want to store recipes of various kinds on our computer, and also want to keep track of the history of these recipes as we change them. We might start by creating directories for both seitan and tofu recipes, then creating each recipe using Sublime (invoked using the `subl` command on my computer).

We're assuming that you're just reading this, rather than trying the commands out yourself. If you'd like to follow along by typing everything out, you'll need to use a text editor installed on your computer instead of `subl`.

```
$ cd /users/sandra
$ mkdir recipes
$ cd recipes
$ mkdir seitan
$ mkdir tofu
$ cd seitan
$ subl smoky_carrot_tahini_seitan_slaw.txt
$ subl boiled_seitan.txt
$ cd ../tofu
$ subl kung_pao_tofu.txt
$ subl basil_ginger_tofu.txt
```

[Copy](#)

Now we have four recipes, two for tofu, and two for seitan. To set up our git repository to store the histories of our recipes as they evolve, we'd use the following commands:

```
$ cd /users/sandra/recipes
$ git init
```

[Copy](#)

What `git init` does is tells the git version control system that we want to track the history of the current directory, in this case `/users/sandra/recipes`. However, at this point, **NOTHING IS STORED IN THE REPOSITORY**. It's like we've purchased a safe, but we haven't put anything in it yet.

To store everything in the repository, we need to first `add` files. For example, we might do the following:

```
git add tofu/kung_pao_tofu.txt
```

[Copy](#)

Now here's where git is going to start seeming weird. Even after calling the `add` command, we *still* haven't stored our recipe in the repository (i.e. in the safe).

Instead, what we've done is added `kung_pao_tofu.txt` to the list of files to track (i.e. to be added to the safe later). The idea is that you might not want to necessarily track every single file in the `/users/sandra/recipes` folder, so the `add` command tells git which ones it should be tracking. We can see the effect of this command using `git status`.

```
$ git status
```

[Copy](#)

In which case, you'd see the following in response:

```
On branch main
```

[Copy](#)

```
No commits yet
```

```
Changes to be committed:
```

```
(use "git rm --cached <file>..." to unstage)
```

```
new file:   tofu/kung_pao_tofu.txt
```

```
Untracked files:
```

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

```
seitan/
```

```
tofu/basil_ginger_tofu.txt
```

The “changes to be committed” portion of the output lists all files that are currently being tracked and whose changes are ready to be committed (i.e. that are ready to be put in the safe). We also see that there are some untracked files; namely, the `seitan/` folder and the `tofu/basil_ginger_tofu.txt` file. These are untracked because we have not added them using `git add`.

Note: Adding is also referred to as *staging* (`stage` is equivalent to `add`).

Let's try adding `tofu/basil_ginger_tofu.txt` and checking the status once more:

```
$ git add tofu/basil_ginger_tofu.txt
```

[Copy](#)

```
$ git status
```

```
On branch main
```

```
No commits yet
```

```
Changes to be committed:
```

```
(use "git rm --cached <file>..." to unstage)
```

```
new file:   tofu/basil_ginger_tofu.txt
```

```
new file:   tofu/kung_pao_tofu.txt
```

```
Untracked files:
```

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

```
seitan/
```

We see that both tofu recipes are tracked, but neither seitan recipe is tracked. We will next use the `commit` command to stick copies of our tofu recipes into the repository (i.e. into the safe). To do this, we use the `git commit` command, as shown below:

```
$ git commit -m "add tofu recipes"
```

[Copy](#)

When executed, the `commit` command stores a snapshot of all staged changes (in this case, our tofu recipes) into the repository. Because we did not use `git add` on the seitan recipes, they were not included in the snapshot that was placed in the repository.

This snapshot of our work is now safe forever and ever (as long as our computer's hard drive doesn't fail or we don't damage the secret repository files). The `-m` flag lets us add a message to

the commit, so we can remember what was most important about this commit (Git actually won't let you commit without a message). It is common convention to use the [imperative form](#) of the verb rather than the past tense. So for example, the commit message above says "add tofu recipes" rather than "added tofu recipes".

As another analogy, you can think of the whole process like taking a panoramic picture on a camera. The `add` command captures one portion of the image, and the `commit` command stitches all "added" items together into a single panorama and throws this panorama into a safe. And just as a panorama only includes things you point at (not the entire 360 degree circle around you), the `commit` command only ensafes those files which have been added using the `add` command (and not all files in the recipes directory).

After committing, you'll note that `git status` no longer lists files under "Changes to be committed". This is similar to how after you finish taking a panoramic photo, all of the temporary tiny image files are thrown away. The result of `git status` at this point is shown below:

```
$ git status
On branch main
Untracked files:
  (use "git add <file>..." to include in what will be committed)

    seitan/

nothing added to commit but untracked files present (use "git add" to track)
```

Copy

As you may guess from how many times we've used it, `status` is very useful for seeing what's currently happening inside your repository. If you ever run into unexpected behavior, `git status` is the first place to look!

If you look at the files in the `tofu/` folder, you'll see that the commit process did NOT affect the original files on our computer. This is much like how when you take a panoramic photo of your friends, they do not get sucked into a cyber hellscape inside your phone.

We can see evidence of our snapshot by using the special `git log` command.

```
$ git log

commit 9f955d85359fc8e4504d7220f13fad34f8f2c62b
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
```

Copy

Date: Sun Jan 17 19:06:48 2016 -0800

```
add tofu recipes
```

That giant string of characters 9f955d85359fc8e4504d7220f13fad34f8f2c62b is the ID of the commit. We can use the `git show` command to peek inside of this commit.

```
$ git show 9f955d85359fc8e4504d7220f13fad34f8f2c62b
```

[Copy](#)

```
commit 9f955d85359fc8e4504d7220f13fad34f8f2c62b
```

```
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
```

```
Date: Sun Jan 17 19:06:48 2016 -0800
```

```
add tofu recipes
```

```
diff --git a/tofu/basil_ginger_tofu.txt b/tofu/basil_ginger_tofu.txt
```

```
new file mode 100644
```

```
index 0000000..9a56e7a
```

```
--- /dev/null
```

```
+++ b/tofu/basil_ginger_tofu.txt
```

```
@@ -0,0 +1,3 @@
```

```
+basil
```

```
+ginger
```

```
+tofu
```

```
diff --git a/tofu/kung_pao_tofu.txt b/tofu/kung_pao_tofu.txt
```

```
new file mode 100644 index
```

```
0000000..dad9bd9
```

```
--- /dev/null
```

```
+++ b/tofu/kung_pao_tofu.txt
```

```
@@ -0,0 +1,3 @@
```

```
+szechuan peppers
```

```
+tofu
```

```
+peanuts
```

```
+kung
```

```
+pao
```

The `git show` command lets us peer right into the beating heart of a commit. We don't expect all of its innards to make sense to you, but you can maybe glean that the commit is a snapshot of

both the names and contents of the files.

Note: You will rarely use `show` in real life or in 61B, but it's useful here for peeking inside a commit to get a better sense of what they are.

Suppose we now want to revise our kung pao recipe, because we decided it should have bok choy in it.

```
$ subl tofu/kung_pao_tofu.txt
```

[Copy](#)

The changes we just made to `kung_pao_tofu.txt` are not saved in the repository. In fact, if we do `git status` again, we'll get:

```
$ git status
```

[Copy](#)

On branch main

Changes not staged for commit:

(use "git add <file>..." to update what will be committed)

(use "git restore <file>..." to discard changes in working directory)

```
modified:   tofu/kung_pao_tofu.txt
```

Untracked files:

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

```
seitan/
```

You might think to yourself "OK, we'll just do commit again". However, if we try to commit, git will say that there's nothing to do:

```
$ git commit -m "add bok choy"
```

[Copy](#)

On branch main

Changes not staged for commit:

```
modified:   tofu/kung_pao_tofu.txt
```

Untracked files:

```
seitan/
```

no changes added to commit

This is because even though `kung_pao_tofu.txt` is being *tracked*, we have not *staged* our changes for commit. To store our changes in the repository, we first need to use the `add` command again, which will stage the changes for commit (or in other words, we need to take a picture of our new `kung_pao_tofu.txt` before we can create the new panorama that we want to put in the safe).

```
$ git add tofu/kung_pao_tofu.txt
$ git status
```

[Copy](#)

On branch main

Changes to be committed:

```
(use "git restore --staged <file>..." to unstage)
    modified:   tofu/kung_pao_tofu.txt
```

Untracked files:

```
(use "git add <file>..." to include in what will be committed)
    seitan/
```

We see that our change to `kung_pao_tofu.txt` is now "to be committed" (it has been staged), meaning that the next commit will include changes to this file. We commit just like before, and use `git log` to see the list of all snapshots that have been taken.

```
$ git commit -m "add bok choy"
$ git log
```

[Copy](#)

```
commit cfcc8cbd88a763712dec2d6bd541b2783fa1f23b
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
Date:   Sun Jan 17 19:24:45 2016 -0800
```

```
    add bok choy
```

```
commit 9f955d85359fc8e4504d7220f13fad34f8f2c62b
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
Date:   Sun Jan 17 19:06:48 2016 -0800
```



```
add tofu recipes
```

We now see that there are TWO commits. We could again use `show` to see what changed in `cfcc8cbd88a763712dec2d6bd541b2783fa1f23b`, but we won't in this guide.

Suppose we later decide bok choy is gross, and want to restore our recipe to its initial version. We can roll back our files using the `git restore` command, as shown below:

```
$ git restore --source=9f955d85359fc8e4504d7220f13fad34f8f2c62b tofu/kung_pao_toфу.txt
```

Think of the `restore` command as a robot that goes to our safe, figures out what the kung pao tofu recipe looked like back when the newest panorama was `9f955d85359fc8e4504d7220f13fad34f8f2c62b`, and finally modifies the actual `tofu/kung_pao_toфу.txt` file so that it is exactly like it was at the time snapshot `9f955d85359fc8e4504d7220f13fad34f8f2c62b` was created. If we now look at the contents of `kung_pao_toфу.txt` after running this command, we'll see that bok choy is gone (phew)!

```
$ cat tofu/kung_pao_toфу.txt
szechuan
peppers
tofu
peanuts
kung
pao
```

[Copy](#)

Important: `restore` *does not change the commit history!* Or, in other words, the safe containing our panoramic photos is entirely unaffected by the `restore` command. The entire point of git is to create a log of everything that has EVER happened to our files. In other words, if you took a panoramic photo of your room in 2014 and in 2015 and put them in a safe, then decided in 2016 to put it exactly back like it was in 2014, you would not set the panoramic photo from the year 2015 on fire. Nor would you a picture of it in 2016 magically appear inside your safe. If you wanted to record what it looked like in 2016, you'd need to take another photo (with the appropriate `-m` message to remember what you just did).

If we want to actually save a snapshot of the most up-to-date kung pao tofu recipe (which no longer has bok choy), we'd have to commit. Remember that we need to stage this change first!

```
$ git add tofu/kung_pao_tofu.txt
$ git commit -m "restore the original recipe with no bok choy"
$ git log
```

[Copy](#)

```
commit 4be06747886d0a270bf1d618d58f3273f0219a69
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
Date:   Sun Jan 17 19:32:37 2016 -0800
```

```
    restore the original recipe with no bok choy
```

```
commit cfcc8cbd88a763712dec2d6bd541b2783fa1f23b
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
Date:   Sun Jan 17 19:24:45 2016 -0800
```

```
    add bok choy
```

```
commit 9f955d85359fc8e4504d7220f13fad34f8f2c62b
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
Date:   Sun Jan 17 19:06:48 2016 -0800
```

```
    add tofu recipes
```

We could then use `show` to see the contents of this most recent commit.

```
$ git show 4be06747886d0a270bf1d618d58f3273f0219a69
```

[Copy](#)

```
commit 4be06747886d0a270bf1d618d58f3273f0219a69
Author: Sandra Upson <sandra@Sandras-MacBook-Air.local>
Date:   Sun Jan 17 19:32:37 2016 -0800
```

```
    restore the original recipe with no bok choy
```

```
diff --git a/tofu/kung_pao_tofu.txt b/tofu/kung_pao_tofu.txt
index 35a9e71..dad9bd9 100644
--- a/tofu/kung_pao_tofu.txt
+++ b/tofu/kung_pao_tofu.txt
@@ -1,4 +1,3 @@
```

```
szechuan  
peppers  
tofu  
peanuts  
kung  
pao  
-bok choy  
\\ No newline at end of file
```

This is the foundation of git. To summarize, using our photo analogy:

- `git init` : Creates a box (repository) which permanently stores panoramic photos (commits).
- `git add` : Takes a temporary photo of (stages) something that can be assembled into a panoramic photo later.
- `git commit` : Assembles all available temporary photos (staged changes) into a panoramic photo. Also destroys all temporary photos.
- `git log` : Lists all the panoramic photos we've ever taken.
- `git show` : Inspects the contents of a particular panoramic photo.
- `git restore` : Rearranges files back to how they looked in a given panoramic photo. Does not affect the panoramic photos in your box in any way.

There's more to learn about git, but before we get there, let's give a more formal explanation of what we've just done.

C. Local Repositories (Technical Overview)

Initializing Local Repositories

Let's first start off with the *local repository*. As mentioned above, a repository stores files as well as the history of changes to those files. In order to begin, you must initialize a Git repository by typing the following command into your terminal *while in the directory whose history you want to store in a local repository*. If you're using Windows, you should be using a Git Bash terminal window while you type these commands. Reminder: If you're unsure of how to use a terminal window, consider checking out the "Learning to Use the Terminal" section of [Lab 1 setup](#).

```
$ git init
```

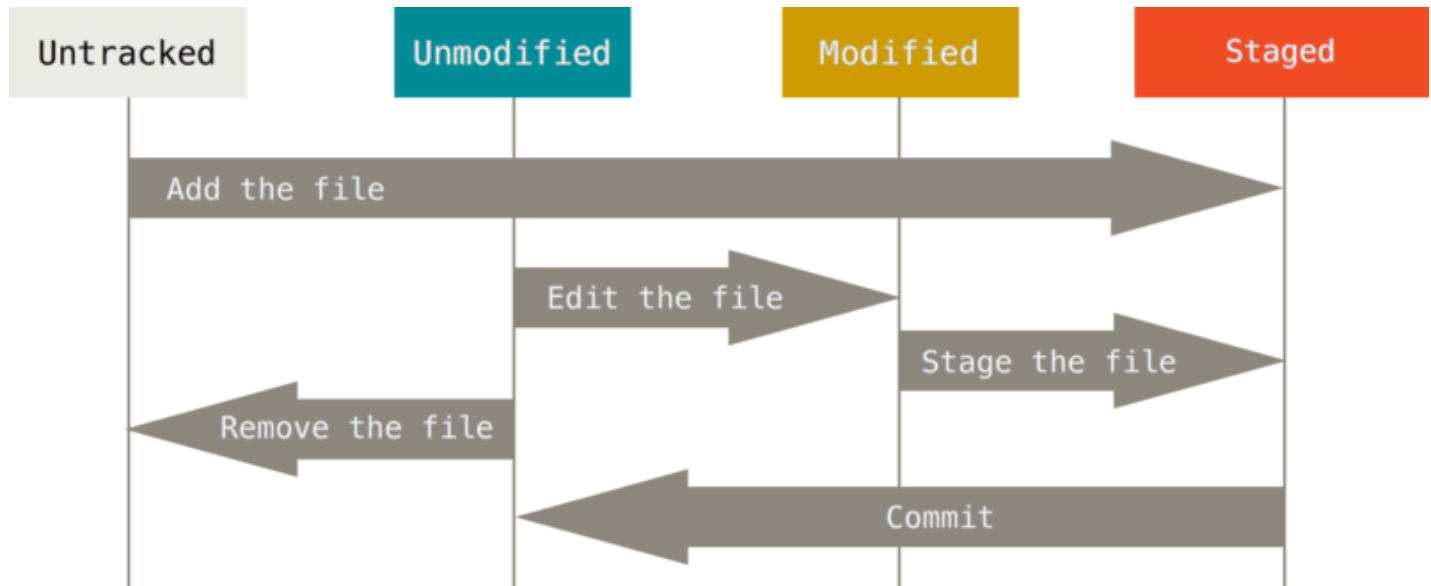
[Copy](#)

Extra for experts: When you initialize a Git repository, Git creates a `.git` subdirectory. Inside this directory it will store a bunch of metadata, as well as old the actual snapshots of the files. However, you'll never need to actually open the contents of this `.git` directory, and you should DEFINITELY not change anything inside directly!

Depending on your operating system, you may not see the folder, because folders whose names start with `"."` are not shown by your OS by default. The UNIX command `ls -la` will list all directories, including your `.git` directory, so you can use this command to check that your repo has been initialized properly.

Tracked vs. Untracked Files

Git repos start off not tracking any files. In order to save the revision history of a file, you need to track it. The Git documentation has an excellent section on [recording changes](#). An image from that section is placed here for your convenience:



As this figure shows, files fall into two main categories:

- 1 *untracked* files: These files have either never been tracked or were removed from tracking. Git is not maintaining history for these files.
- 2 *tracked* files: These files have been added to the Git repository and can be in various stages of modification: unmodified, modified, or staged.
 - a An *unmodified* file is one that has had no new changes since the last version of the files was added to the Git repo.
 - b A *modified* file is one that is different from the last one Git has saved.

- c A *staged* file is one that a user has designated as part of a future commit (usually through use of the `git add` command). We can think of these as files which have lights shining upon them.

The following Git command allows you see the status of each file, i.e. whether it is untracked, unmodified, modified, or staged:

```
$ git status
```

[Copy](#)

The `git status` command is extremely useful for determining the exact status of each file in your repository. If you are confused about what has changed and what needs to be committed, it can remind you of what to do next.

Staging & Committing

A *commit* is a specific snapshot of your working directory at a particular time. Users must specify what exactly composes the snapshot by *staging* files.

The `add` command lets you stage a file (without the square brackets).

```
$ git add [file]
```

[Copy](#)

You can also stage an entire folder, which will recursively stage all files and subfolders in it (this is also true of many git commands, just replace the file with a folder). Once you have staged all the files you would like to include in your snapshot, you can commit them as one block with a message.

```
$ git commit -m "your commit message here"
```

[Copy](#)

Your message should be descriptive and explain what changes your commit makes to your code. You may want to quickly describe bug fixes, implemented classes, etc. so that your messages are helpful later when looking through your commit log.

In order to see previous commits, you can use the `log` command:

```
$ git log
```

[Copy](#)

The Git reference guide has a helpful section on [viewing commit history](#) and filtering log results when searching for particular commits. It might also be worth checking out `gitk`, which is a GUI

prompted by the command line.

As a side note on development workflow, it is a good idea to commit your code as often as possible. Whenever you make significant (or even minor) changes to your code, make a commit. If you are trying something out that you might not stick with, commit it (perhaps to a different branch, which will be explained below).

Rule of Thumb: If you commit, you can always restore your old code or change it. However, if you don't commit, you won't be able to get old versions back. So commit often!

Undoing Changes

The Git reference has a great section on [undoing things](#). Please note that while Git revolves around the concept of history, it is possible to lose your work if you revert with some of these undo commands. Thus, be careful and read about the effects of your changes before undoing your work.

- Unstage a file that you haven't yet committed:

```
$ git restore --staged [file]
```

[Copy](#)

This will take the `file`'s status back to modified, leaving changes intact. Don't worry about this command undoing any work. This command is the equivalent of deleting one of the temporary images that you're going to combine into a panorama.

Why might we need to use this command? Let's say you accidentally started tracking a file that you didn't want to track. (an embarrassing video of yourself, for instance.) Or you were made some changes to a file that you thought you would commit but no longer want to commit quite yet.

- Amend latest commit (changing commit message or add forgotten files):

```
$ git add [forgotten-file]
$ git commit --amend
```

[Copy](#)

Please note that this new amended commit will replace the previous commit.

- Restore a file to its state at the time of the most recent commit (**use with caution!**):

```
$ git restore [file]
```

[Copy](#)

If the `file` has been staged, you'll need to unstage it first.

This command is useful if you would like to legitimately undo your work. For example, if you accidentally modified a certain file since committing previously, and would like to change it back to how it was.

Be careful with this command! **Any changes made to the file since the last commit will be lost.** If you want to be safe, stage and commit your changes first and then restore to a previous version using one of the commands below.

Getting previous versions of files

Suppose you're working on a lab, and halfway through, you realize you've been doing it all wrong. If only there was a way to get back the skeleton code so you can start over!

If you haven't committed yet, you can use the previous command - but what if you've already committed some changes? Rather than restoring the files in the latest commit, you can use the more powerful

```
git restore --source=[commit or branch] [file or folder]
```

[Copy](#)

which can get files from an arbitrary point in time. For example, let's say you've accidentally deleted `lab1000/`, and committed that change. Oh no! To fix this, you can get back the skeleton code with

```
git restore --source=skeleton/main lab1000/
```

[Copy](#)

This allows you to restart from the skeleton code for `lab1000`.

Now consider a scenario where you've made some progress on `lab1000/Cheese.txt`, and want to get back the version of that file from a few commits ago. You can find the correct commit with `git log` and then run

```
git restore --source=abcd1234efgh7890abcd1234c7ee5e7890c7ee5e lab1000/Cheese.txt
```

[Copy](#)

where `abcd1234efgh7890abcd1234c7ee5e7890c7ee5e` is the ID from `git log` of the commit that contains the version of `lab1000/Cheese.txt` we want to restore.

Remember that you'll need to re-stage the file for the next commit to track your restoration!

WARNING

If you're working on lab 1, it's time to return and do the git exercise.

D. Remote Repositories

One especially handy feature of Git is the ability to store copies of your repository on computers other than your own. Recall that our snapshots are all stored on our computer in a secret folder. That means if our computer is damaged or destroyed, so are all our snapshots.

Suppose we wanted to push our tofu and seitan recipes to another computer, we'd typically use the following command.

```
$ git push origin main
```

[Copy](#)

However, if we tried that out, we'd simply get the message below:

```
fatal: 'origin' does not appear to be a git repository
fatal: Could not read from remote repository.
```

[Copy](#)

Please make sure you have the correct access rights and the repository exists.

This is because we have not yet told git where to send the files. As it happens, there is a for-profit private company called GitHub that has made a business out of storing copies of people's repositories.

In 61B, we'll use GitHub to store our repositories. To create a repository on GitHub, you'd probably use their web interface. However, we've already done this for you.

The most important remote repository commands are listed below, along with a technical description that might not make sense yet. If you're working on lab 1, head back to the lab to learn more about these commands.

- `git clone [remote-repo-URL]` : Makes a copy of the specified repository, but on your local computer. Also creates a working directory that has files arranged exactly like the most recent snapshot in the download repository. Also records the URL of the remote repository for subsequent network data transfers, and gives it the special remote-repo-name "origin".
- `git remote add [remote-repo-name] [remote-repo-URL]` : Records a new location for network data transfers.

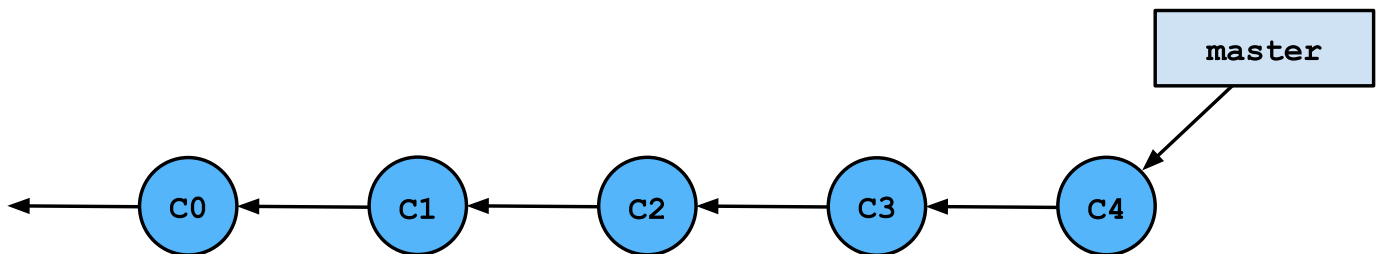
- `git remote -v` : Lists all locations for network data transfers.
- `git pull [remote-repo-name] main` : Get the most recent copy of the files as seen in `remote-repo-name` .
- `git push [remote-repo-name] main` : Uploads the most recent copy of your files to `remote-repo-name` .

For most of this course, you'll only have two remote repositories: *origin*, which is the remote for saving and submitting your individual work, and *skeleton*, which is the remote from which you'll receive skeleton code.

E. Git Branching (advanced Git) (optional)

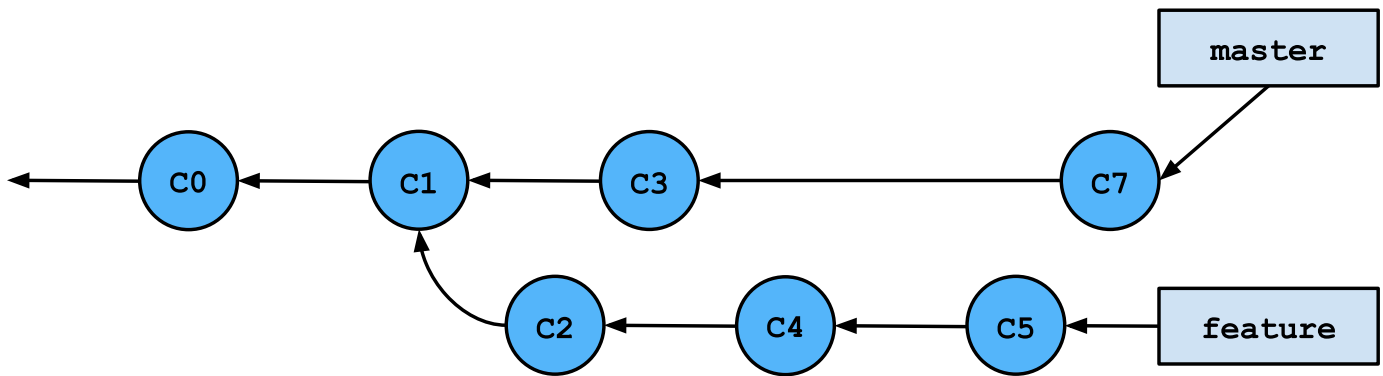
Everything below this line is optional for 61B.

Note: In 2020, Git changed the default branch name from `master` to `main` . The graphics below have not been updated accordingly - for now, just think of `master` as `main` 's outdated equivalent.



Every command that we've covered so far was working with the default branch. This branch is conventionally called the `main` branch. However, there are cases when you may want to create branches in your code.

Branches allow you to keep track of multiple different versions of your work simultaneously. One way to think of branches are as alternate dimensions. Perhaps one branch is the result of choosing to use a linked list while another branch is the result of choosing to use an array.



Reasons for Branching

Here are some cases when it may be a good idea to branch.

- You may want to make a dramatic change to your existing code (called refactoring) but it will break other parts of your project. But you want to be able to simultaneously work on other parts or you have partners, and you don't want to break the code for them.
- You want to start working on a new part of the project, but you aren't sure yet if your changes will work and make it to the final product.
- You are working with partners and don't want to mix up your current work with theirs, even if you want to bring your work together later in the future.

Creating a branch will let you keep track of multiple different versions of your code, and you can easily switch between versions and merge branches together once you've finished working on a section and want it to join the rest of your code.

An Example Scenario

For example, let's say that you've finished half of a project so far. There is a difficult part still left to do, and you're not sure how to do it. Perhaps you have three different ideas for how to do it, and you're not sure which will work. At this point, it might be a good idea to create a branch off of `main` and try out your first idea.

- If your code works, you can merge the branch back to your main code (on the `main` branch) and submit your project.
- If your code doesn't work, don't worry about reverting your code and having to manipulate Git history. You can simply switch back to `main`, which won't have any of your changes, create another branch, and try out your second idea.

This can continue till you figure out the best way to write your code, and you only need to merge the branches that work back into `main` in the end.

The Git reference has a section on [branching and merging](#) with some figures of how branches are represented in Git's underlying data structure. It turns out that Git keeps track of commit history as a graph with branch pointers and commits as nodes within the graph. (Hence the tree-related terminology.)

Creating, Deleting, & Switching Branches

A special branch pointer called the `HEAD` references the branch you currently have as your working directory. Branching instructions modify branches and change what your `HEAD` points to so that you see a different version of your files.

- The following command will create a branch off of your current branch.

```
$ git branch [new-branch-name]
```

[Copy](#)

- This command lets you switch from one branch to another by changing which branch your `HEAD` pointer references.

```
$ git switch [destination-branch]
```

[Copy](#)

By default, your initial branch is called `main`. It is advised that you stick with this convention. Every other branch, however, can be named whatever you'd like. It's generally a good idea to call your branch something descriptive like `fixing-ai-heuristics` so that you can remember what commits it contains.

- You can combine the previous two commands which create a new branch and then switch to it with this single command:

```
$ git switch -c [new-branch-name]
```

[Copy](#)

- You can delete branches with the following command:

```
$ git branch -d [branch-to-delete]
```

[Copy](#)

- You can easily figure out which branch you are on with this command:

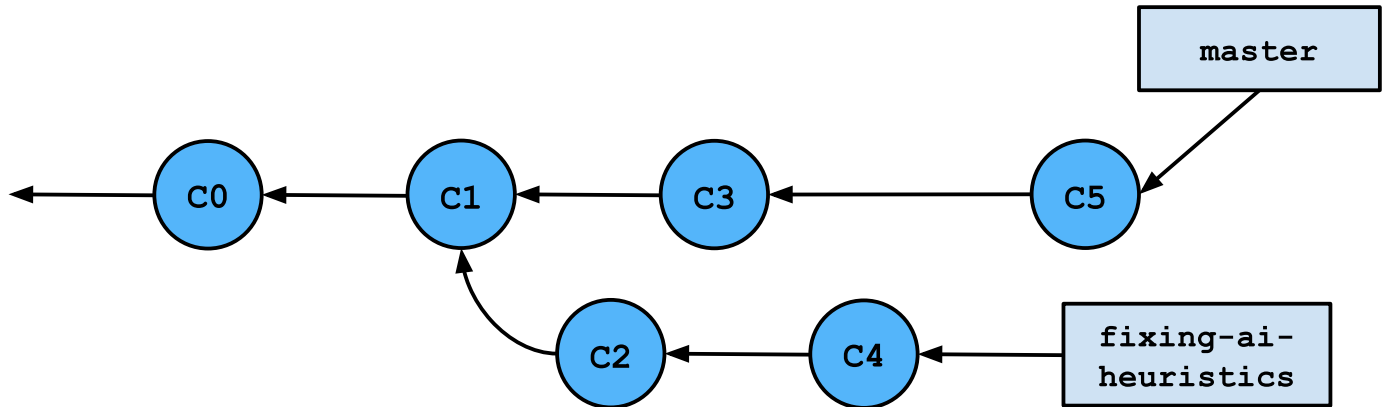
```
$ git branch -v
```

[Copy](#)

More particular, the `-v` flag will list the last commit on each branch as well.

Merging

There are often times when you'd like to merge one branch into another. For example, let's say that you like the work you've done on `fixing-ai-heuristics`. Your AI is now super-boss, and you'd like your `main` branch to see the commits you've made on `fixing-ai-heuristics` and delete the `fixing-ai-heuristics` branch.

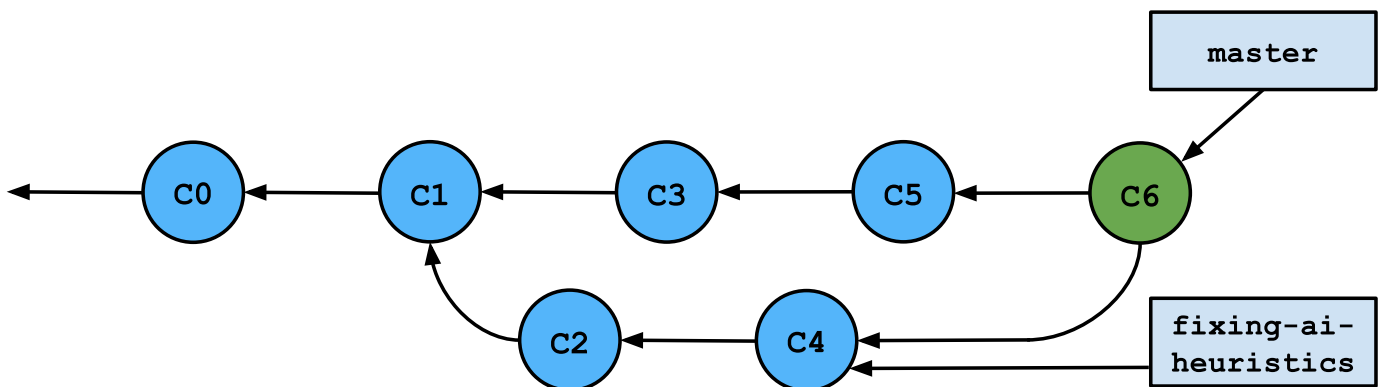


In this case, you should switch to the `main` branch and merge `fixing-ai-heuristics` into `main`.

```
$ git switch main  
$ git merge fixing-ai-heuristics
```

[Copy](#)

This `merge` command will create a new commit that joins the two branches together and change each branch's pointer to reference this new commit. While most commits have only one parent commit, this new merge commit has two parent commits. The commit on the `main` branch is called its *first parent* and the commit on the `fixing-ai-heuristics` branch is called its *second parent*.



Merge Conflicts

It may happen that two branches you are trying to merge have conflicting information. This can occur if commits on the two branches changed the same files. Git is sophisticated enough to resolve many changes, even when they occur in the same file (though distinct places).

However, there are times that conflicts cannot be resolved by Git because changes impact the same methods/lines of code. In these cases, it will present both changes from the different branches to you as a *merge conflict*.

Resolving Merge Conflicts

Git will tell you which files have conflicts. You need to open the files that have conflicts and resolve them manually. After doing this, you must commit to complete the merge of the two branches.

The files with conflicts will contain segments that look something like this:

```
<<<<<< HEAD
for (int i = 0; i < results.length; i++) {
    println(results[i]);
    println("FIX ME!");
}
=====
int[] final = int[results.length];
for (int i = 0; i < results.length - 1; i++) {
    final[i] = results[i] + 1;
    println(final[i]);
}
>>>>>> fixing-ai-heuristics
```

Copy

Basically, you'll see two segments with similar pieces of code:

- 1 The top code snippet is from the branch you originally had switched to when you ran the `merge` command. It's called `HEAD` because the `HEAD` pointer was referencing this branch at the time of the `merge`. Continuing our example above, this code would be from the `main` branch.
- 2 The bottom code snippet is from the branch you were merging into the branch you switched to. This is why it shows that the code is from `fixing-ai-heuristics`.

Basically, you'll need to go through all marked sections and pick which snippet of code you'd like to keep.

In the previous example, I like the bottom piece of code better because I just fixed the AI while the top piece still prints "FIX ME!" Thus, I will delete the top segment as well as the extraneous lines to get this:

```
int[] final = int[results.length];  
for (int i = 0; i < results.length - 1; i++) {  
    final[i] = results[i] + 1;  
    println(final[i]);  
}
```

[Copy](#)

Random Note: I have no idea how this code supposedly fixes the AI heuristics. Don't use it for your project! It is useless, I tell you. Useless!

Doing this for all segments demarcated by conflict-resolution markers resolves your conflict. After doing this for all conflicting files, you can commit. This will complete your merge.

F. Other Git Features

There are tons of other cool Git commands. Unfortunately, we need to continue on to discuss remote repositories. Thus, this segment will just list some other interesting features that you are encouraged to explore in your own time:

- [Stashing](#)

Stashing allows you to save your changes onto a stack without making a more permanent commit. It is equivalent to picking up your work-in-progress and placing it in a box to get back to later. In the meantime, your desk is now clean.

Why might you want to use this?

- Your files may be in a disorganized state, and you don't want to commit yet, but you also don't want to get rid of your changes.
- You modified multiple files, but you dislike your changes and you would just like to get things back to how they were after your most recent commit. Then you can `stash` your code and then drop that stash rather than having to manually revert multiple files. (Be careful with this usage!)
- You modified files but accidentally modified them on the wrong branch. Then you can `stash` your changes, switch branches, and `unstash` your changes so that they are all in the

new branch.

- [Rewriting History](#)

Let's say you want to do more than change your last commit or drop changes to your files before your most recent commit. What if you want to do something crazy like rewrite history? You can change multiple commit messages, split one commit into two, and reorder commits.

- [Rebasing](#)

Rebasing changes the parent commit of a specific commit. In doing this, it changes the commits so that it is no longer the same.

`Rebase` can be used as an alternative to `merge` for integrating changes from one branch to another. It is quite different from `merge` in that `merge` creates a new commit that has both parent branch commits as parents. Rebasing takes one set of commits from a branch and places them all at the end of the other branch.

There are different reasons why you would want to use `merge` versus `rebase`. One of these reasons is that `rebase` leads to a cleaner history when working with many different branches and team members.

- [Reset](#)

Perhaps you decide that you want things to be how they were a certain number of commits ago. You can use `reset` if you are absolutely sure that you don't want the last few commits. `Reset` is quite a nuanced command, so read carefully before attempting use.

- [Stack Overflow on git reset](#)
- [Reset Demystified](#)

- [Revert](#)

`Revert` allows you to reverse the changes introduced by certain commits by recording new commits to undo the changes. This is a safer option than simply throwing away past commits. But again, use this with caution.

- [Cherry Pick](#)

`Cherry pick` allows you to apply the changes introduced by some existing commits. For example, if you have two different branches, and your current branch lacks one or two commits that would be helpful but are only in the other branch, then you can `cherry pick` to grab those commits without merging or rebasing to get all the commits.

There are far more features and commands not mentioned here. Feel free to explore more and search for answers. There most likely exists a Git command for nearly everything you would want to do.

G. Remote Repositories (Advanced)

Private vs. Public Repos

By default, repositories on GitHub are public, rather than private. This means that anyone on the Internet can view the code in a public repo. For all class assignments, you are required to use private repositories.

Hosting school code in a public repo is a violation of the academic honesty policies of this class (and most other Berkeley EECS classes). Please keep this in mind when using sites like GitHub for collaboration.

As of 01/07/2019, [GitHub is offering free unlimited private repositories](#), so there should be no excuse for anyone to post their code in a public repo.

Adding Remotes

Adding a remote repository means that you are telling git where the repo is located. You do not necessarily have read/write access to every repo you can add. Actually accessing and modifying files in a remote is discussed later and relies on having added the remote.

```
$ git remote add [short-name] [remote-url]
```

[Copy](#)

The remote URL will look something like `https://github.com/berkeley-cs61b/skeleton.git` if you are using HTTP or `git@github.com:berkeley-cs61b/skeleton.git` if you are using SSH.

By convention, the name of the primary remote is called `origin` (for original remote repository). So either of the following two commands would allow me to add the `berkeley-cs61b/skeleton` repository as a remote.

```
$ git remote add origin https://github.com/berkeley-cs61b/skeleton.git
$ git remote add origin git@github.com:berkeley-cs61b/skeleton.git
```

[Copy](#)

After adding a remote, all other commands use its associated short name.

Renaming, Deleting, & Listing Remotes

- You can rename your remote by using this command:

```
$ git remote rename [old-name] [new-name]
```

[Copy](#)

- You can also remove a remote if you are no longer using it:

```
$ git remote rm [remote-name]
```

[Copy](#)

- To see what remotes you have, you can list them. The `-v` flag tells you the URL of each remote (not just its name).

```
$ git remote -v
```

[Copy](#)

You can read more about [working with remotes](#) in the Pro Git book.

Cloning a Remote

There are often remote repos with code that you would like to copy to your own computer. In these cases, you can easily download the entire repo with its commit history by cloning the remote:

```
$ git clone [remote-url]
$ git clone [remote-url] [directory-name]
```

[Copy](#)

The top command will create a directory of the same name as the remote repo. The second command allows you to specify a different name for the copied repository.

When you clone a remote, the cloned remote is associated with your local repo by the name `origin`. This is by default because the cloned remote was the `origin` for your local repo.

Pushing Commits

You may wish to update the contents of a remote repo by adding some commits that you made locally. You can do this by `pushing` your commits:

```
$ git push [remote-name] [remote-branch]
```

[Copy](#)

Note that you will be pushing to the remote branch from the branch your `HEAD` pointer is currently referencing. For example, let's say that I cloned a repo then made some changes on the `main` branch. I can give the remote my local changes with this command:

```
$ git push origin main
```

[Copy](#)

Fetching & Pulling Commits

There are also times that you'd like to get some new commits from a remote that are not currently on your local repo. For example, you may have cloned a remote created by a partner and wish to get his/her newest changes. You can get those changes by fetching or pulling from the remote.

- `fetch` : This is analogous to downloading the commits. It does not incorporate them into your own code.

```
$ git fetch [remote-name]
```

[Copy](#)

Why might you use this? Your partner may have created some changes that you'd like to review but keep separate from your own code. Fetching the changes will only update your local copy of the remote code but not merge the changes into your own code.

For a more particular example, let's say that your partner creates a new branch on the remote called `fixing-ai-heuristics`. You can view that branch's commits with the following steps:

```
$ git fetch origin
$ git branch review-ai-fix origin/fixing-ai-heuristics
$ git switch review-ai-fix
```

[Copy](#)

The second command creates a new branch called `review-ai-fix` that *tracks* the `fixing-ai-heuristics` branch on the `origin` remote.

- `pull` : This is equivalent to a `fetch + merge`. Not only will `pull` fetch the most recent changes, it will also merge the changes into your `HEAD` branch.

```
$ git pull [remote-name] [remote-branch-name]
```

[Copy](#)

Let's say that my boss partner has pushed some commits to the `main` branch of our shared remote that fix our AI heuristics. I happen to know that it won't break my code, so I can just pull it and merge it into my own code right away.

```
$ git pull origin main
```

[Copy](#)

H. Remote Repository Exercise

For this follow-along example, you will need a partner. You will be working with your partner on a remote repository and have to deal with things like merge conflicts. Also note that both of you will need accounts on the same service, whether it be GitHub or Bitbucket.

- 1 Partner 1 will create a private repository on GitHub or Bitbucket and add Partner 2 as a collaborator. This repo can be called `learning-git`.

Note: [GitHub Education](#) discount requests take some time to process, so it is acceptable to use a public repo for just this lab. For all other assignments, you must use a private repo.

Also, please do not add your partner to your personal repo in the [Berkeley-CS61B](#) organization.

- 2 Partner 2 will create a `README` file, commit the file, and push this commit to the `learning-git` remote.

```
wellington:Desktop sarahjkim$ mkdir learning-git
wellington:Desktop sarahjkim$ cd learning-git/
wellington:learning-git sarahjkim$ echo "Doo bee doo bee doo" > README
wellington:learning-git sarahjkim$ git init
Initialized empty Git repository in /Users/sarahjkim/Desktop/learning-git/.git/
wellington:learning-git sarahjkim$ git add README
wellington:learning-git sarahjkim$ git commit -m "Added README"
[master (root-commit) 7a6ba87] Added README
 1 file changed, 1 insertion(+)
 create mode 100644 README
wellington:learning-git sarahjkim$ git log
commit 7a6ba87db7c36271d866a11b765f158bedffe4a0
Author: Sarah Kim
Date: Mon Jan 12 00:44:18 2015 -0800
```

```
Added README
wellington:learning-git sarahjkim$ █
```



Partner 2

- 3 Partner 2 will also add the remote that Partner 1 created and push this new commit.

 sarahjkim / learning-git

Unwatch 1 Star 0

Quick setup — if you've done this kind of thing before

 or **HTTPS** **SSH** `https://github.com/sarahjkim/learning-git.git` 

We recommend every repository include a [README](#), [LICENSE](#), and [.gitignore](#).

<> Code

Issues 0

Pull Requests 0

With either GitHub or Bitbucket, you can find the remote URL on the repo's main page.

```

wellington:learning-git sarahjkim$ git remote add origin https://github.com/sarahjkim/learning-git.git
wellington:learning-git sarahjkim$ git push origin master
Counting objects: 3, done.
Writing objects: 100% (3/3), 228 bytes | 0 bytes/s, done.
Total 3 (delta 0), reused 0 (delta 0)
To https://github.com/sarahjkim/learning-git.git
 * [new branch]      master -> master
wellington:learning-git sarahjkim$ █

```

Partner 2

- 4 Partner 1 will now clone the remote repo to their own machine then add a line to the bottom of README. (Note: At this point, the pictures may get a bit confusing because I'm pretending to be both partners.)

```

wellington:Documents sarahjkim$ git clone https://github.com/sarahjkim/learning-git.git
Cloning into 'learning-git'...
remote: Counting objects: 3, done.
remote: Total 3 (delta 0), reused 3 (delta 0)
Unpacking objects: 100% (3/3), done.
Checking connectivity... done.
wellington:Documents sarahjkim$ cd learning-git/
wellington:learning-git sarahjkim$ vim README
wellington:learning-git sarahjkim$ cat README
Doo bee doo bee doo
I am Partner 1!
wellington:learning-git sarahjkim$ █

```

Partner 1

- 5 Partner 1 will commit this change and push it back to the remote.

```

wellington:learning-git sarahjkim$ git add README
wellington:learning-git sarahjkim$ git commit -m "Added Partner 1 line"
[master e6344dc] Added Partner 1 line
 1 file changed, 1 insertion(+)
wellington:learning-git sarahjkim$ git push origin master
Counting objects: 5, done.
Writing objects: 100% (3/3), 274 bytes | 0 bytes/s, done.
Total 3 (delta 0), reused 0 (delta 0)
To https://github.com/sarahjkim/learning-git.git
 7a6ba87..e6344dc  master -> master

```

Partner 1

- 6 Partner 2 will similarly add a line to the bottom of their README and commit this change.

```

wellington:learning-git sarahjkim$ vim README
wellington:learning-git sarahjkim$ cat README
Doo bee doo bee doo
I am Partner 2!
wellington:learning-git sarahjkim$ git add README
wellington:learning-git sarahjkim$ git commit -m "Added Partner 2 line"
[master cd41b3b] Added Partner 2 line
 1 file changed, 1 insertion(+)
wellington:learning-git sarahjkim$ █

```

Partner 2

- 7 Partner 2 will now pull and find that there are merge conflicts.

```

wellington:learning-git sarahjkim$ git pull origin master
remote: Counting objects: 3, done.
remote: Total 3 (delta 0), reused 3 (delta 0)
Unpacking objects: 100% (3/3), done.
From https://github.com/sarahjkim/learning-git
 * branch                master      -> FETCH_HEAD
    7a6ba87..e6344dc      master      -> origin/master
Auto-merging README
CONFLICT (content): Merge conflict in README
Automatic merge failed; fix conflicts and then commit the result.
wellington:learning-git sarahjkim$ cat README
Doo bee doo bee doo
<<<<<<< HEAD
I am Partner 2!
=====
I am Partner 1!
>>>>>>> e6344dc02c5e2ad7d141369dea2da613f7e55dbf
wellington:learning-git sarahjkim$ █

```

Partner 2

- 8 Partner 2 should resolve the merge conflicts by rearranging the lines. Then Partner 2 should add README and commit and push to finish.

```

wellington:learning-git sarahjkim$ vim README
wellington:learning-git sarahjkim$ cat README
Doo bee doo bee doo
I am Partner 1!
I am Partner 2!
wellington:learning-git sarahjkim$ git status
On branch master
You have unmerged paths.
  (fix conflicts and run "git commit")

Unmerged paths:
  (use "git add <file>..." to mark resolution)

    both modified:   README

no changes added to commit (use "git add" and/or "git commit -a")
wellington:learning-git sarahjkim$ git add README
wellington:learning-git sarahjkim$ git commit
[master 4e79d18] Merge branch 'master' of https://github.com/sarahjkim/learning-git
t
wellington:learning-git sarahjkim$ git push origin master
Counting objects: 10, done.
Delta compression using up to 8 threads.
Compressing objects: 100% (3/3), done.
Writing objects: 100% (6/6), 602 bytes | 0 bytes/s, done.
Total 6 (delta 0), reused 0 (delta 0)
To https://github.com/sarahjkim/learning-git.git
    e6344dc..4e79d18  master -> master

```

Partner 2

- 9 Partner 1 can now pull and get two new commits - the added line & the merge commit. Now both partners are up to date.

```

wellington:learning-git sarahjkim$ git pull origin master
remote: Counting objects: 6, done.
remote: Compressing objects: 100% (3/3), done.
remote: Total 6 (delta 0), reused 6 (delta 0)
Unpacking objects: 100% (6/6), done.
From https://github.com/sarahjkim/learning-git
 * branch                master      -> FETCH_HEAD
   e6344dc..4e79d18      master      -> origin/master
Updating e6344dc..4e79d18
Fast-forward
 README | 1 +
 1 file changed, 1 insertion(+)
wellington:learning-git sarahjkim$ git log
commit 4e79d18ae8df42b59602fd992020cc9362d6e423
Merge: cd41b3b e6344dc
Author: Sarah Kim
Date:   Mon Jan 12 01:09:33 2015 -0800

```

Merge branch 'master' of https://github.com/sarahjkim/learning-git

Conflicts:
README

```

commit cd41b3bce92bc8f17e0d22b416af4543db49d631
Author: Sarah Kim
Date:   Mon Jan 12 01:04:56 2015 -0800

```

Added Partner 2 line

Partner 1

I. Conclusion

More with Remotes

These simple commands to add/remove remotes, push commits, and fetch/pull changes can be combined with all the commands you've learned in regards to local repositories to give you a powerful toolkit in working collaboratively with others.

GitHub has some other really cool features that can be helpful for in project development:

- [Forking a Repo](#)
- [Syncing a Fork](#)
- [Using Pull Requests](#)
- [Using Issues](#)

Extra Reading

For those of you who found this topic interesting, check out these extra resources! Keep in mind, however, that the best way to learn to use Git effectively is to just start incorporating it into your own coding workflow! Good luck, and have an octotastic day!

- 1 [Git Documentation](#) is really quite good and clear, and there is a great Pro Git book by Scott Chacon.
- 2 [Hacker's Guide to Git](#) is a very friendly introduction to how Git works. It gives a peek at the structure of commits & branches and explains how some commands work.
- 3 [Learn Git Branching](#) is a fun and interactive tutorial that visualizes Git commands.

J. Advanced Git Features

Here are some more advanced features that might make your life a little easier. Once you get the hang of the basic features of git, you'll start to notice some common tasks are a bit tedious. Here are some built-in features that you might consider using.

Rebasing

Git is all about collaborative programming, so more often than not, you'll find yourself dealing with merge-conflicts. In most cases, the changes you've made are separated from the conflicting commits such that you can just put your commit right on top of all the new commits. However, git will merge the two versions and add an extra commit letting you know that you merged. This is pretty annoying and leads to a pretty messy commit history. This is where the magic of **rebasing** comes into play.

When you push changes onto Github and the remote copy has been modified, you'll be asked to pull in the changes. This is where you usually get a merge-conflict. Instead, pull with the rebase flag:

```
$ git pull --rebase origin main
```

[Copy](#)

It's as simple as that! The changes from the server will be applied onto your working copy and your commit will be stacked on top.

Squashing Commits

You might find yourself in a situation where you've created many small commits with tiny related changes that could really be stored in a single commit. Here, you'll want to squash your commits using the **rebase** command. Suppose you have four commits that I want to combine. You would enter the following:

```
$ git rebase -i HEAD~4
```

[Copy](#)

From here, you would be prompted to pick a commit to collapse the other commits into, and pick which commits should be combined:

```
pick 01d1124 Adding license
pick 6340aaa Moving license into its own file
pick ebfd367 Jekyll has become self-aware.
pick 30e0ccb Changed the tagline in the binary, too.

# Rebase 60709da..30e0ccb onto 60709da
#
# Commands:
# p, pick = use commit
# e, edit = use commit, but stop for amending
# s, squash = use commit, but meld into previous commit
#
# If you remove a line here THAT COMMIT WILL BE LOST.
# However, if you remove everything, the rebase will be aborted.
#
```

[Copy](#)

It's best to pick the topmost commit and squash the rest into it. You can do this by changing the text file to this:

```
pick 01d1124 Adding license
squash 6340aaa Moving license into its own file
squash ebfd367 Jekyll has become self-aware.
squash 30e0ccb Changed the tagline in the binary, too.

# Rebase 60709da..30e0ccb onto 60709da
#
# Commands:
# p, pick = use commit
# e, edit = use commit, but stop for amending
# s, squash = use commit, but meld into previous commit
#
# If you remove a line here THAT COMMIT WILL BE LOST.
# However, if you remove everything, the rebase will be aborted.
#
```

[Copy](#)

Voila! All those tiny commits have collapsed into a single commit and you have a cleaner log file.

The Nuclear Option: Clone a Fresh Copy of Your Repo

If all else fails and you just want to be able to push and submit your code, one option is to:

- 1 Close IntelliJ.
- 2 Rename your old repository folder (e.g. from sp23-s208 to sp23-s208-busted).
- 3 Clone a new copy of your repo (e.g. sp23-s208) using the lab 1 directions.
- 4 Copy over the desired files from the busted copy to the fresh copy.

A video demo of this process is available [in this video](#).