Git and GitHub guide

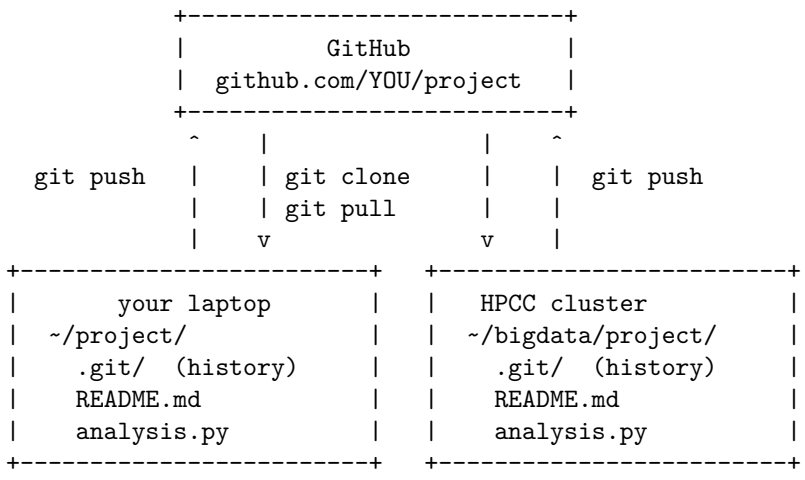
Git is a program that keeps track of every version of the files in a folder: what changed, when, and why. **GitHub** is a website that stores a copy of that history online, so you can back it up, move it between computers, share it, and turn in homework. In this class you will use both every week.

This guide goes from one-time setup to everyday commands, with copy-and-paste recipes for the common tasks.

Contents

How the pieces fit together

A **repository** ("repo") is a folder whose history git is tracking. The history lives in a hidden `.git` folder inside it. You usually have a copy of the repository on GitHub and one or more copies on the computers where you work:



- `git clone` makes a new local copy of a GitHub repository (once per computer).
- `git commit` saves a snapshot **in your local copy only**.
- `git push` sends your new commits up to GitHub.
- `git pull` brings down commits that were pushed from somewhere else.

Every copy has the full history, so you can work offline and push later.

One-time setup

Do this once on **each computer** you use (your laptop and the cluster). Git is already installed on the cluster and on Macs (run `git --version`; a Mac may offer to install the developer tools). On Windows install Git for Windows, which includes Git Bash.

Tell git who you are. This name and email are recorded in every commit you make. Use the email address that is on your GitHub account:

```
git config --global user.name "Your Name"
git config --global user.email "yourname@ucr.edu"
git config --global init.defaultBranch main    # call the first branch "main"
git config --global core.editor nano           # editor for commit messages (optional)
git config --global --list                     # check your settings
```

```
user.name=Your Name
user.email=yourname@ucr.edu
init.defaultbranch=main
core.editor=nano
```

Logging in: SSH keys, tokens, and gh

GitHub needs to know it's you when you `push` (and when you `clone` a private repository). **Your GitHub password does not work on the command line.** Use one of these three methods instead:

	SSH key	Personal access token (PAT)	GitHub CLI (`gh auth login`)
What it is	A key pair; the public half is added to your GitHub account	A long random password you create on github.com	A program that logs you in through your web browser and stores a token for you
Repository URLs look like	`git@github.com:YOU/project.git`	`https://github.com/YOU/project.git`	either (you choose SSH or HTTPS)
Set up once per	computer	token (they expire)	computer
Best for	the **cluster**, and anywhere you already use SSH	automated scripts; a fallback when nothing else works	your **laptop**; easiest to set up
Watch out for	the private key must stay secret	treat it like a password; set an expiration; never put it in a file you commit	must be installed; the stored token can be revoked on github.com

Recommendation for this class: on your laptop, install `gh` and run `gh auth login`. On the cluster, make an SSH key *on the cluster* and add it to GitHub (see below). Both are one-time setups.

Option 1: SSH keys

See the SSH keys guide for the full explanation with diagrams. In short, on the computer you want to push from:

```
ssh-keygen -t ed25519 -C "yourname@ucr.edu"    # press Enter, pick a passphrase
cat ~/.ssh/id_ed25519.pub                      # copy the one line this prints
```

Paste that line into github.com -> your picture -> **Settings** -> **SSH and GPG keys** -> **New SSH key**. Test it:

```
ssh -T git@github.com
```

```
Hi YOURGITHUBID! You've successfully authenticated, but GitHub does not provide shell access.
```

Then use the **SSH** URL when you clone (the green **Code** button on GitHub -> **SSH** tab):

```
git clone git@github.com:YOURGITHUBID/project.git
```

Option 2: GitHub CLI (`gh`)

gh is GitHub's command line tool. It can log you in, and it also creates repositories, opens pull requests, and more, without going to the website.

Install it: on a Mac `brew install gh`; on Windows `winget install --id GitHub.cli`; on Linux or the cluster see the install instructions (on the cluster, check `module avail gh`, or install it into a conda environment with `conda install -c conda-forge gh`).

```
gh auth login
```

Answer the questions: **GitHub.com**, your preferred protocol (**HTTPS** is simplest with `gh`; choose **SSH** if you already set up a key), and **Login with a web browser**. It shows a one-time code; paste it into the web page that opens. On the cluster there is no browser, so it prints a web address to open on your laptop instead.

```
gh auth status        # check that you are logged in
gh auth setup-git     # let plain git commands use gh's login for https URLs
```

Once you are logged in, `gh` can also upload an SSH public key for you: `gh ssh-key add ~/.ssh/id_ed25519.pub --title "HPCC cluster"`.

Option 3: Personal access tokens

If you clone with an `https://` URL and haven't set up `gh`, `git push` asks for a username and password. Your GitHub password will be refused; you need a **token** instead:

1. github.com -> your picture -> **Settings** -> **Developer settings** -> **Personal access tokens**.
2. Choose **Fine-grained tokens** (preferred: can be limited to specific repositories) or **Tokens (classic)** (the `repo` scope is needed for private repositories).
3. Set an **expiration date**, generate it, and copy it right away (GitHub shows it only once).
4. When `git push` asks for a password, paste the token.

To avoid pasting it every time, let git remember it: `git config --global credential.helper "cache --timeout=28800"` keeps it in memory for 8 hours (works on the cluster, nothing saved to disk), or save it permanently (`git config --global credential.helper osxkeychain` on a Mac, `store` on Linux, which saves it in a plain text file - acceptable on your own account, but `gh` or SSH is better). Never write a token into a script or any file in a repository.

Which URL is my repository using?

```
git remote -v
```

```
origin  git@github.com:YOURGITHUBID/project.git (fetch)
origin  git@github.com:YOURGITHUBID/project.git (push)
```

To switch an existing clone from HTTPS to SSH:

```
git remote set-url origin git@github.com:YOURGITHUBID/project.git
```

The basic idea: edit, add, commit, push

Git has three places a change can be. You edit files in your **working directory**. `git add` puts the changes you want into the **staging area** (a "draft" of the next snapshot). `git commit` saves the staged changes permanently in the repository history (the `.git` folder).

Each file moves through these states as you work:

Figures from Pro Git by Scott Chacon and Ben Straub, CC BY-NC-SA 3.0.

The everyday loop is:

```
git pull                      # 1. get any changes made elsewhere (skip for a brand new repo)
nano analysis.py              # 2. edit files
```

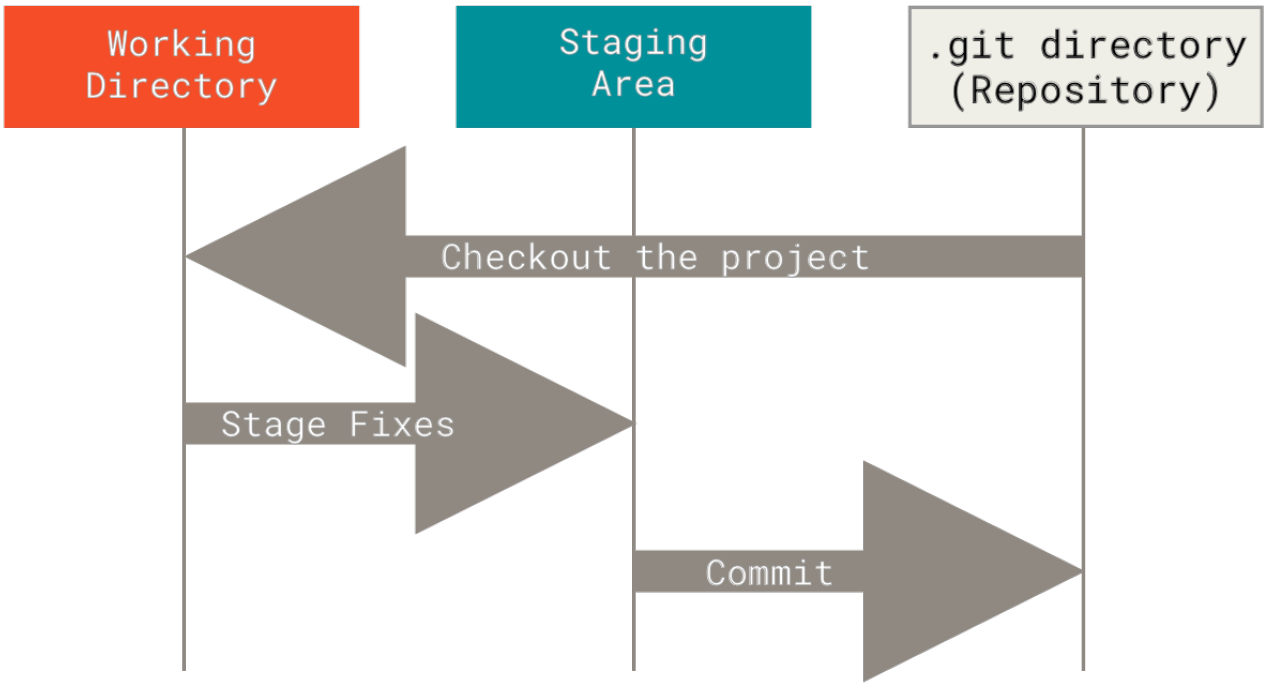


Figure 1: The working directory, staging area, and .git directory

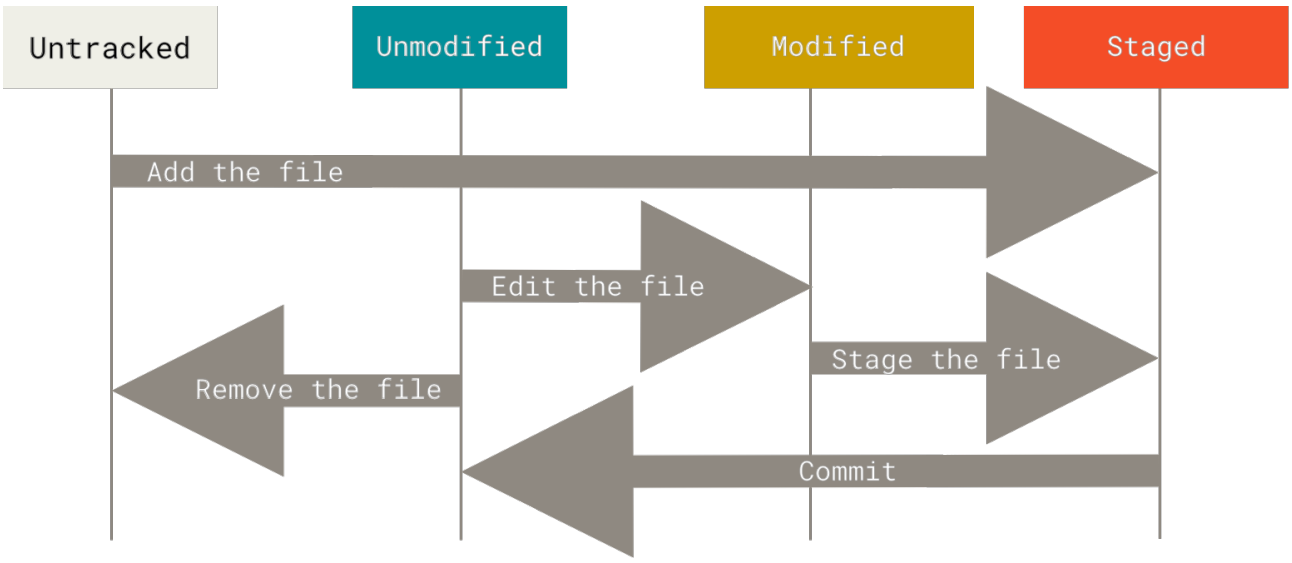


Figure 2: The lifecycle of the status of your files

```
git status                      # 3. see what changed
git add analysis.py             # 4. stage the changes you want to save
git commit -m "Count exons per gene"   # 5. save a snapshot with a message
git push                        # 6. send it to GitHub
```

Write commit messages that say **what and why** ("Fix off-by-one error in exon lengths"), not "update" or "stuff". Commit small, related changes often - it makes it easy to find and undo mistakes.

Recipes

Recipe A: get your homework repository (GitHub Classroom)

1. Click the assignment link from Canvas and **Accept** it. GitHub Classroom creates a repository for you, e.g. `biodataprog/2026-hw1-YOURGITHUBID`. The first time, Classroom asks you to pick your name from the class roster - this links your GitHub account to your UCR identity so the instructor knows whose homework is whose. Pick carefully, and ask the instructor if your name is missing.
2. On that repository's page click the green **Code** button and copy the URL (SSH tab if you set up a key, otherwise HTTPS).
3. Clone it where you want to work:

```
cd ~/bigdata/gen220         # on the cluster, for example
git clone git@github.com:biodataprog/2026-hw1-YOURGITHUBID.git
cd 2026-hw1-YOURGITHUBID
ls
```

4. Work, then add, commit and push. **Your last push before the deadline is what gets graded**, so check the repository page on GitHub to be sure your files are there.

```
git add filesize.sh
git commit -m "Homework 1: file size script"
git push
```

With `gh` you can clone by name: `gh repo clone biodataprog/2026-hw1-YOURGITHUBID`.

Recipe B: turn a folder on your computer into a GitHub repository

You already have (or are starting) a project folder, and want it on GitHub.

```
mkdir gen220-practice && cd gen220-practice     # or cd into your existing folder
git init
```

```
Initialized empty Git repository in /home/you/gen220-practice/.git/
```

Add some files and make the first commit:

```
echo "# GEN220 practice" > README.md
printf '#!/usr/bin/env bash\necho "hello"\n' > hello.sh
git status
```

```
On branch main

No commits yet

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

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

```
git add README.md hello.sh
git commit -m "First commit: README and hello script"
```

```
[main (root-commit) 85a91c8] First commit: README and hello script
 2 files changed, 3 insertions(+)
 create mode 100644 README.md
 create mode 100644 hello.sh
```

Now create the GitHub copy and connect the two. **The easy way, with `gh`** (one command creates the repository on GitHub, adds it as the `origin` remote, and pushes):

```
gh repo create gen220-practice --private --source=. --remote=origin --push
```

Or on the website: click + (top right) -> **New repository**, name it `gen220-practice`, and **don't** tick "Add a README" (you already have commits). GitHub then shows the commands to connect it:

```
git remote add origin git@github.com:YOURGITHUBID/gen220-practice.git
git push -u origin main      # -u: remember origin/main, so later just "git push"
```

Recipe C: start on GitHub, then clone

Create the repository first (with a README, a `.gitignore` template, and a license), then clone it:

```
gh repo create gen220-project --public --add-readme --gitignore Python --license mit --clone
cd gen220-project
```

Or make it on the website with **Add a README file** ticked, then `git clone` its URL.

Recipe D: work on the same repository from your laptop and the cluster

Clone it once on each computer. Then follow one rule: **pull before you start, push when you stop.**

```
# on the cluster, start of a session
cd ~/bigdata/gen220/gen220-project
git pull
# ... work ...
git add -A          # stage everything that changed (check git status first!)
git commit -m "Run BLAST on all samples"
git push

# later, on your laptop
git pull            # now you have the cluster's changes
```

If you forget and both copies have new commits, `git push` is refused:

```
 ! [rejected]        main -> main (fetch first)
hint: Updates were rejected because the remote contains work that you do not
hint: have locally. This is usually caused by another repository pushing to
hint: the same ref. If you want to integrate the remote changes, use
hint: 'git pull' before pushing again.
```

Run `git pull`, then `git push` again. If you edited the same lines in both places, see merge conflicts.

Seeing what is going on

`git status` is the command to run whenever you are unsure. It tells you which branch you are on and which files are changed, staged, or untracked, and usually suggests what to do next. `git status --short` is a compact version:

```
 M hello.sh
?? notes.txt
```

(`M` = modified, `??` = untracked, `A` = newly added.)

`git diff` shows exactly what changed (lines starting with `+` were added, `-` removed). Use `git diff --staged` to see what you've already staged.

```
git diff
```

```
diff --git a/hello.sh b/hello.sh
index c0d7ba9..b05df65 100644
--- a/hello.sh
+++ b/hello.sh
@@ -1,2 +1,3 @@
 #!/usr/bin/env bash
 echo "hello"
+echo "goodbye"
```

`git log` lists the commits, newest first:

```
git log --oneline
```

```
9ac88eb Say goodbye too
85a91c8 First commit: README and hello script
```

The short codes (`9ac88eb`) identify commits; you can use them in other commands, e.g. `git show 85a91c8`. On GitHub, the **History** or **commits** link on a repository shows the same thing.

What not to commit: .gitignore

Git is for **code, documentation, and small files**. Don't commit:

- large data (FASTQ, BAM, genomes, big tables) - GitHub refuses files over 100 MB and repositories should stay small. Keep data in `~/bigdata`, and commit the script that downloads or makes it.
- results that your scripts can regenerate
- passwords, tokens, or private keys
- system clutter (`.DS_Store`, `__pycache__/`)

List patterns to ignore in a file called `.gitignore` in the top folder of the repository:

```
# data and large outputs
data/
*.fastq.gz
*.bam
# clutter
.DS_Store
__pycache__/
```

Ignored files no longer show up in `git status`, and `git add -A` skips them. Commit the `.gitignore` file itself. GitHub has ready-made templates (e.g. for Python and R).

If you committed a big file by accident and haven't pushed yet, `git rm --cached bigfile.bam` stops tracking it (the file stays on disk), then add it to `.gitignore` and commit.

Undoing things

I want to…	Command
throw away my edits to a file since the last commit	`git restore file.py` (careful: the edits are gone)
un-stage a file I `git add`-ed (keep the edits)	`git restore --staged file.py`
fix the message of, or add a forgotten file to, my last commit **before pushing**	`git add forgotten.py` then `git commit --amend`
undo a commit that is **already pushed**	`git revert COMMITID` (makes a new commit that reverses it)

I want to…	Command
see an old version of a file	`git show COMMITID:file.py`
get an old version of a file back	`git restore --source COMMITID file.py`

`git revert` is safe for shared repositories because it adds to the history rather than rewriting it:

```
git revert --no-edit HEAD~1      # HEAD = latest commit; HEAD~1 = the one before it
git log --oneline
```

```
d8a5c5e Revert "Say goodbye too"
0a1cc48 Ignore data files
9ac88eb Say goodbye too
```

Avoid commands you find online that "rewrite history" (`git reset --hard`, `git push --force`) until you understand them; they can permanently delete work.

Branches and pull requests

A **branch** is a separate line of development. You can try an idea on a branch without disturbing the working version on `main`, then **merge** it in when it works.

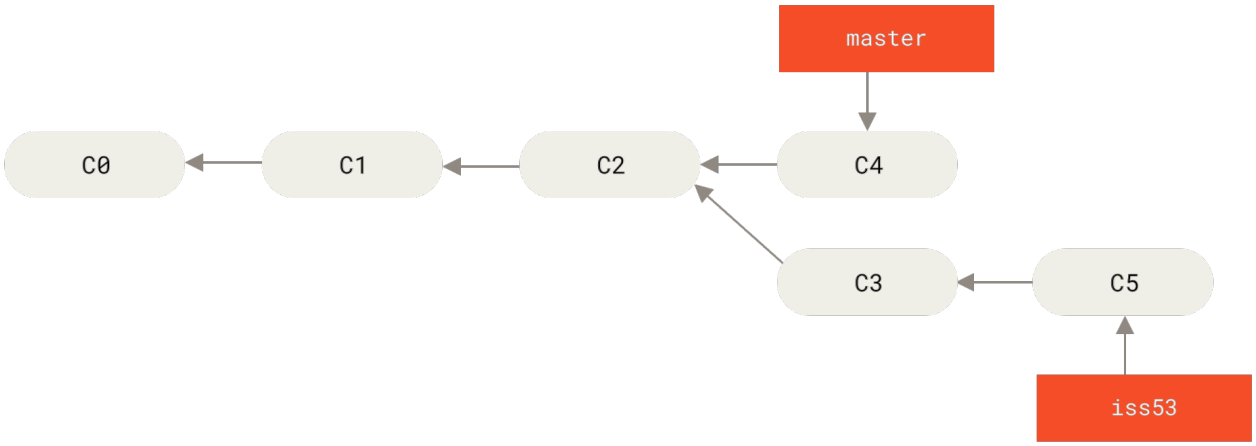


Figure 3: Two branches that have diverged

Commits C3 and C5 were made on a branch (`iss53`) while C4 was added to the main line (called `master` in older repositories, `main` today). Figure from Pro Git, CC BY-NC-SA 3.0.

```
git switch -c add-analysis        # create a new branch and switch to it
# ... edit, add, commit as usual ...
git switch main                   # go back to main
git merge add-analysis            # bring the branch's commits into main
git branch -d add-analysis        # delete the branch once merged
```

```
Updating d8a5c5e..ba625c3
Fast-forward
 count.sh | 1 +
Deleted branch add-analysis (was ba625c3).
```

On GitHub, teams usually merge through a **pull request (PR)**: push the branch, open a PR, let a partner review it, then merge it on the website. This is a good way to work on your class **project** with your team:

```
git switch -c add-plots
# ... edit, add, commit ...
git push -u origin add-plots
gh pr create --fill               # open a pull request using the commit message(s)
gh pr list                        # see open pull requests
gh pr merge                       # merge it (or click "Merge" on the website)
```

When two changes collide: merge conflicts

If two commits change the **same lines** of a file, git can't decide which to keep. `git pull` (or `git merge`) stops and marks the file:

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

```
# GEN220 practice
<<<<<<< HEAD
line from first copy
=======
line from clone2
>>>>>>> a7febb6c410e8b07c05c45117003978328dcb5af
```

The part between `<<<<<<<` and `=======` is your version; between `=======` and `>>>>>>>` is the incoming one. To fix it:

1. Open the file, keep what you want (one side, the other, or a combination), and **delete the marker lines**.
2. Save, then mark it resolved and finish the merge:

```
git add README.md
git commit -m "Merge changes from the cluster"
git push
```

Conflicts are normal and not dangerous. Pulling often and committing small changes makes them rare. `git merge --abort` gives up and returns to how things were before the merge.

Beyond storing code: what else GitHub offers

A GitHub repository is more than a backup. The tabs along the top of every repository page give you:

Feature	What it does	Where you'll see it in this class
Issues	a to-do list and discussion thread for a repository: bug reports, questions, tasks, with labels and assignees	keep track of tasks for your team project
Pull requests	propose, review, and discuss changes before merging them (see above)	team projects

Feature	What it does	Where you'll see it in this class
Actions	run scripts automatically on GitHub's computers when something happens (a push, a pull request, a schedule)	this course website is built and published by an Action
Pages	free web hosting for a website stored in a repository	Homework 5
Projects	a planning board (columns like To do / Doing / Done) built from issues	optional, for team projects
Releases	a named, downloadable snapshot of the code (e.g. "v1.0" for a paper)	archive your project; connect to Zenodo to get a DOI you can cite
Codespaces	a full VS Code editor and Linux terminal in your web browser, for any repository	work from a tablet or a computer without software installed
Wiki / Discussions	documentation pages and a forum attached to a repository	used by many bioinformatics tools for help

As a student, apply for the free GitHub Student Developer Pack (GitHub Education). It includes GitHub Pro, more free Codespaces and Actions time, and GitHub Copilot.

GitHub Actions: workflows and continuous integration

A **workflow** is a YAML text file in the folder `.github/workflows/` of a repository. It lists *when* to run (`on:`) and *what* to run (`jobs:` made of `steps:`). GitHub starts a fresh virtual computer, runs the steps, and shows the result (a green check or a red X) next to each commit, on pull requests, and under the repository's **Actions** tab.

Continuous integration (CI) means automatically running your tests every time code changes, so you find out right away when something breaks - even when a teammate made the change. Here is a complete example. The repository has a small function and a test file:

```
gc-tools/
|-- gc_content.py
|-- tests/
|   `-- test_gc_content.py
`-- .github/
    `-- workflows/
        `-- tests.yml
```

`gc_content.py`:

```python
def gc_content(seq):
    """Return the fraction of G and C bases in a DNA sequence."""
    seq = seq.upper()
    if len(seq) == 0:
        return 0.0
    return (seq.count("G") + seq.count("C")) / len(seq)
```

`tests/test_gc_content.py` - pytest runs every function whose name starts with `test_`, and each `assert` must be true:

```python
from gc_content import gc_content

def test_all_gc():
    assert gc_content("GCGC") == 1.0

def test_half():
    assert gc_content("atgc") == 0.5

def test_empty():
    assert gc_content("") == 0.0
```

Run the tests yourself first (`pip install pytest`):

```
python -m pytest
```

```
...                                                                      [100%]
3 passed in 0.01s
```

`.github/workflows/tests.yml` - run the same tests on GitHub on every push and pull request:

```yaml
name: Run tests

on: [push, pull_request]

jobs:
  test:
    runs-on: ubuntu-latest
    steps:
      - uses: actions/checkout@v7          # get a copy of the repository
      - uses: actions/setup-python@v7      # install Python
        with:
          python-version: "3.13"
      - run: pip install pytest
      - run: python -m pytest
```

Commit and push the workflow file, then open the **Actions** tab to watch it run. `uses:` lines run ready-made actions shared by others (browse the Actions Marketplace); `run:` lines are ordinary shell commands. Other common uses: check code style, build documentation or a website, rebuild a figure from data, or run a small test version of a pipeline.

Actions are free for public repositories; private repositories get a monthly allowance of free minutes. See GitHub Actions: Quickstart and Building and testing Python.

GitHub Pages: free web hosting

GitHub Pages publishes a website straight from a repository. Write pages in Markdown (or HTML), push them, and GitHub builds the site with Jekyll and serves it at:

- `https://YOURGITHUBID.github.io/` for a repository named `YOURGITHUBID.github.io` (a personal or lab home page), or
- `https://YOURGITHUBID.github.io/REPONAME/` for any other repository (a project, tool, or course site).

You turn it on under the repository's **Settings** -> **Pages**, either publishing a branch directly or through an Actions workflow. This course site is an example: its Markdown files are in github.com/biodataprog/GEN220_2026, and a workflow builds and publishes it to biodataprog.github.io on every push. Homework 5 walks you through making your own site, and the Building Websites notes have lab website templates.

Personal accounts and organizations

There are two kinds of GitHub accounts:

- A **personal account** is you. You log in with it, and repositories you create live under your name: `github.com/YOURGITHUBID/project`. Keep one account for your whole career, and add your UCR email to it (you can have several emails on one account).
- An **organization** is a shared space for a group - a lab, a course, a project, a company. Nobody logs in *as* an organization; personal accounts are added to it as **members**, and it owns repositories: `github.com/biodataprog/GEN220_2026`, `github.com/stajichlab/...`.

	Personal account	Organization
Who is it	one person	a group of people
Log in with it	yes	no - members log in with their personal accounts
Repository URLs	`github.com/YOU/repo`	`github.com/ORGNAME/repo`
Permissions	you own everything; you can add collaborators to individual repositories	**owners** manage the organization; **members** and **teams** get read, write, or admin access per repository
Good for	your own code, homework practice, your personal website	lab code and data pipelines that should outlive any one student; courses; shared tools

Why this matters for you:

- Your **homework repositories** are created by GitHub Classroom inside the `biodataprog` course organization, not in your personal account. They are normally private: only you and the instructors can see them. Clone or fork them if you want a copy under your own name after the class.
- For your **lab's** code, ask whether your lab has an organization. Code in a lab organization stays available to the lab after you graduate; code only in your personal account leaves with you.
- **Forking** copies someone else's repository into your account so you can change it; you can then send your changes back with a pull request. This is how most people contribute to open source bioinformatics tools.
- Anyone can create a free organization, and academic labs and courses can request free upgraded plans through GitHub Education.

Cheat sheet

Task	Command
set your name and email (once)	`git config --global user.name "Your Name"` and `user.email`
copy a repository from GitHub	`git clone URL` or `gh repo clone OWNER/REPO`
start tracking a folder	`git init`
what changed?	`git status`, `git diff`
stage changes	`git add FILE` (or `git add -A` for everything)
save a snapshot	`git commit -m "message"`
send commits to GitHub	`git push` (first time: `git push -u origin main`)
get commits from GitHub	`git pull`
history	`git log --oneline`
where does this repo push to?	`git remote -v`
create a GitHub repository from this folder	`gh repo create NAME --private --source=. --push`
make and switch to a branch	`git switch -c NAME`
open a pull request	`gh pr create --fill`
check GitHub login	`ssh -T git@github.com` or `gh auth status`

GitHub also publishes a printable Git cheat sheet.

Learn more

Tutorials:

- GitHub Skills - short interactive courses that run inside GitHub (start with "Introduction to GitHub")
- GitHub Docs: Get started - including About Git and Hello World
- Software Carpentry: Version Control with Git - a full beginner lesson written for scientists
- Learn Git Branching - a visual, interactive game for branches and merging

References:

- Pro Git - the free, complete book about git (source of the figures above)
- GitHub CLI manual - every `gh` command
- GitHub Docs: Authentication - SSH keys, personal access tokens, and more
- GitHub Classroom glossary - what the terms in Classroom mean
- Chapter 5 ("Git for Scientists") of Vince Buffalo's *Bioinformatics Data Skills*, free on the UCR network via O'Reilly