CS 241: Systems Programming
Lecture 5. Version Control/Git

Fall 2023

Prof. Stephen Checkoway

Version control system (VCS)

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A way to track changes to your files

- What you changed
- Why you changed it

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A way to keep track of different versions (branches) of a project

- Development
- Release

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- What you changed
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- Development
- Release

A way to organize and collaborate on a project

VCS history (abridged)

SCCS → RCS → CVS → SVN → {Git, Mercurial, …}

1972 — Source Code Control System (SCCS)
1985 — Revision Control System (RCS)
- All users on the same system, each with their own checkout of the files

1986 — Concurrent Versioning System (CVS)
- Client/server model

2000 — Subversion (SVN)
- Essentially a better CVS

2005 — Git and Mercurial
- Distributed model: each user has their own copy of the whole repository

VCS history (abridged)

SCCS → RCS → CVS → SVN → {Git, Mercurial, …}

SCCS/RCS

- Master repository with all history stored somewhere, e.g., `/source/program`
- Individual users checkout the current version somewhere else, e.g., `~/program`
- Modifications can be checked in to the master repo
- Other users' modifications can be checked out again
- The history of files and their differences can be shown

VCS history (abridged)

SCCS → RCS → CVS → SVN → {Git, Mercurial, …}

CVS/SVN

- Master repo stored on some server, e.g., `vcs.oberlin.edu:/vcs/program`
- Users on many different machines can checkout copies, e.g., `clyde.cs.oberlin.edu:~/program`
- Changes to files are committed to the server which maintains the authoritative copy of the repository history
- Local copies can be updated with other users' changes from the server
- Multiple branches, but each with a linear commit history (r1, r2, r3, …)

VCS history (abridged)

SCCS → RCS → CVS → SVN → {Git, Mercurial, …}

Git/Mercurial

- Decentralized
  - Each user has a full copy of the repo
  - No authoritative version
- Users can push changes to other users or pull changes from others
- Multiple, lightweight branches
- History is not linear, it's a DAG (we'll see what this means shortly)
- Decentralization is hard to deal with: use Github (or similar)

Git

Git

A distributed version control system

- Everyone can act as a “server”
- Everyone mirrors the entire repository

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- Quick to add files, commit, create new branches, etc.
- Can have local changes w/o pushing to others

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Collaborate with other developers

- “Push” and “pull” code from hosted repositories such as Github

Initial setup

```
$ git config --global user.name 'Stephen Checkoway'
$ git config --global user.email \
    'stephen.checkoway@oberlin.edu'
$ git config --global core.editor vim
```

Global config values are stored in `~/.gitconfig`

Can also have local config settings in `${repo}/.git/config`

Creating a repository

```
$ mkdir project
$ cd project
$ git init
```

Creates a `.git` folder in `project`

No files are currently being tracked or managed

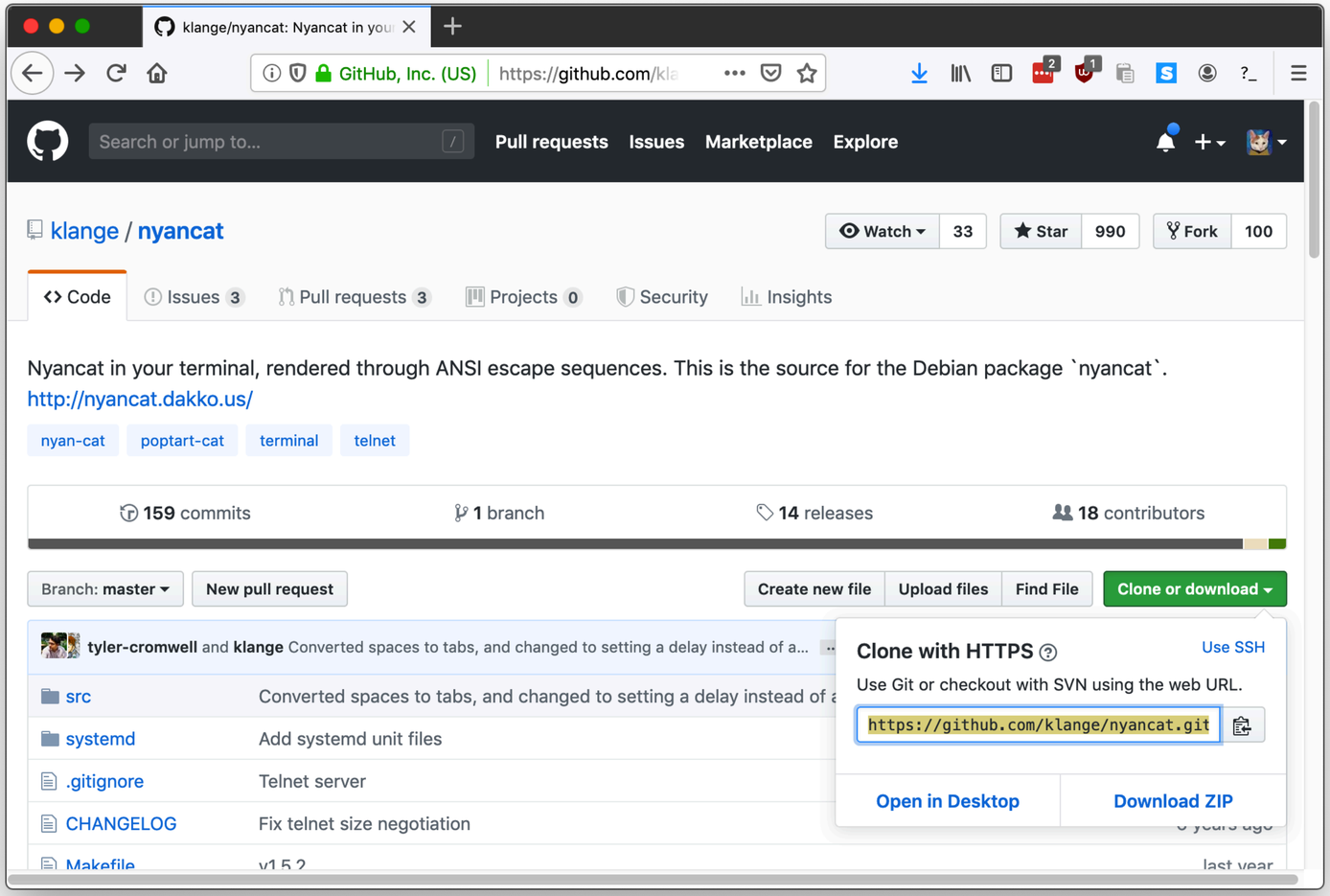
No remote server

Cloning a (remote) repository

```
$ git clone https://github.com/klange/nyancat.git
```

Creates a local copy of the repo including the whole history

Associated with a remote server



Cloning a (remote) repository

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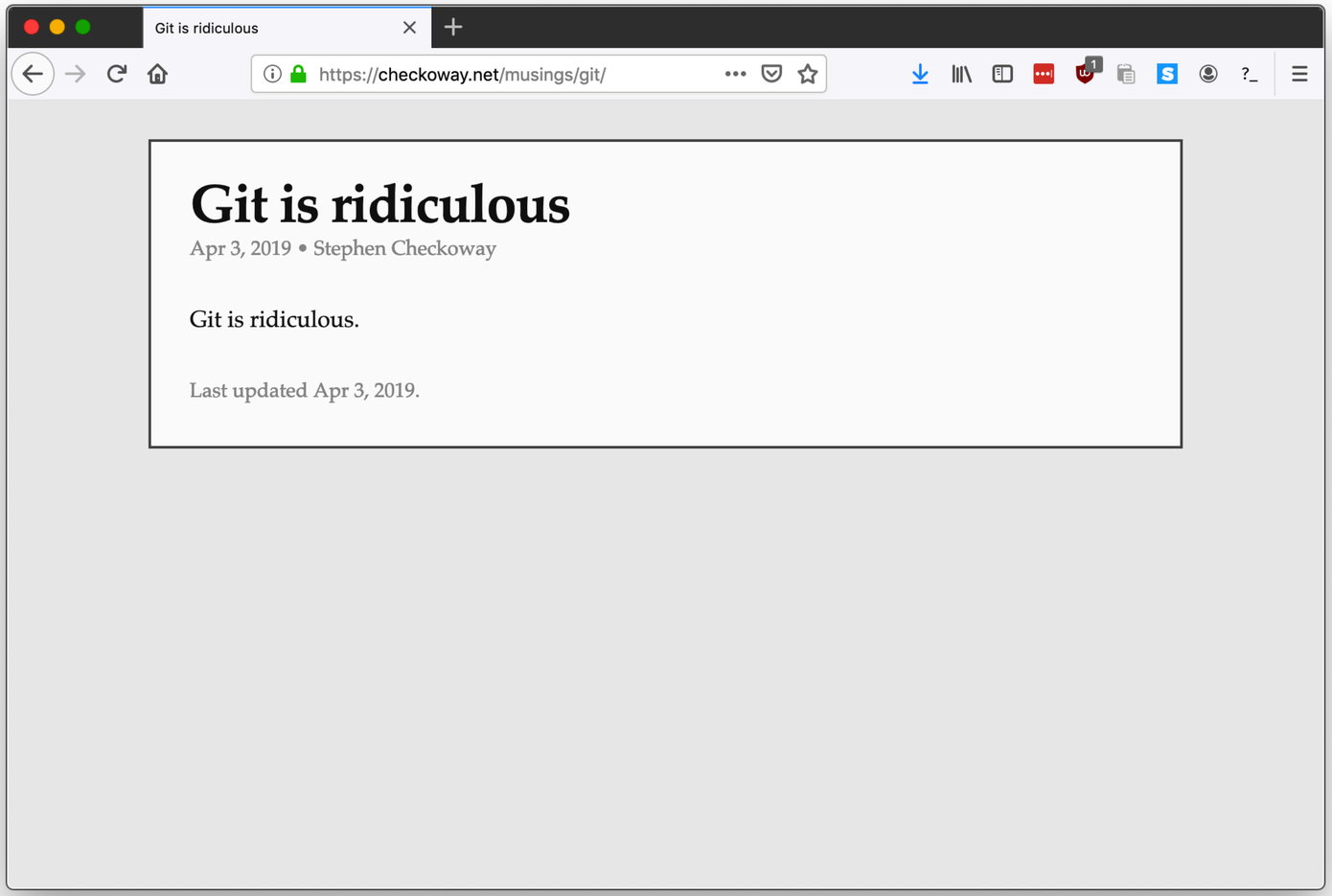
Warning: Git is ridiculous



Working dir vs staging vs .git

After `git init` or `git clone`, you have a working directory on the file system

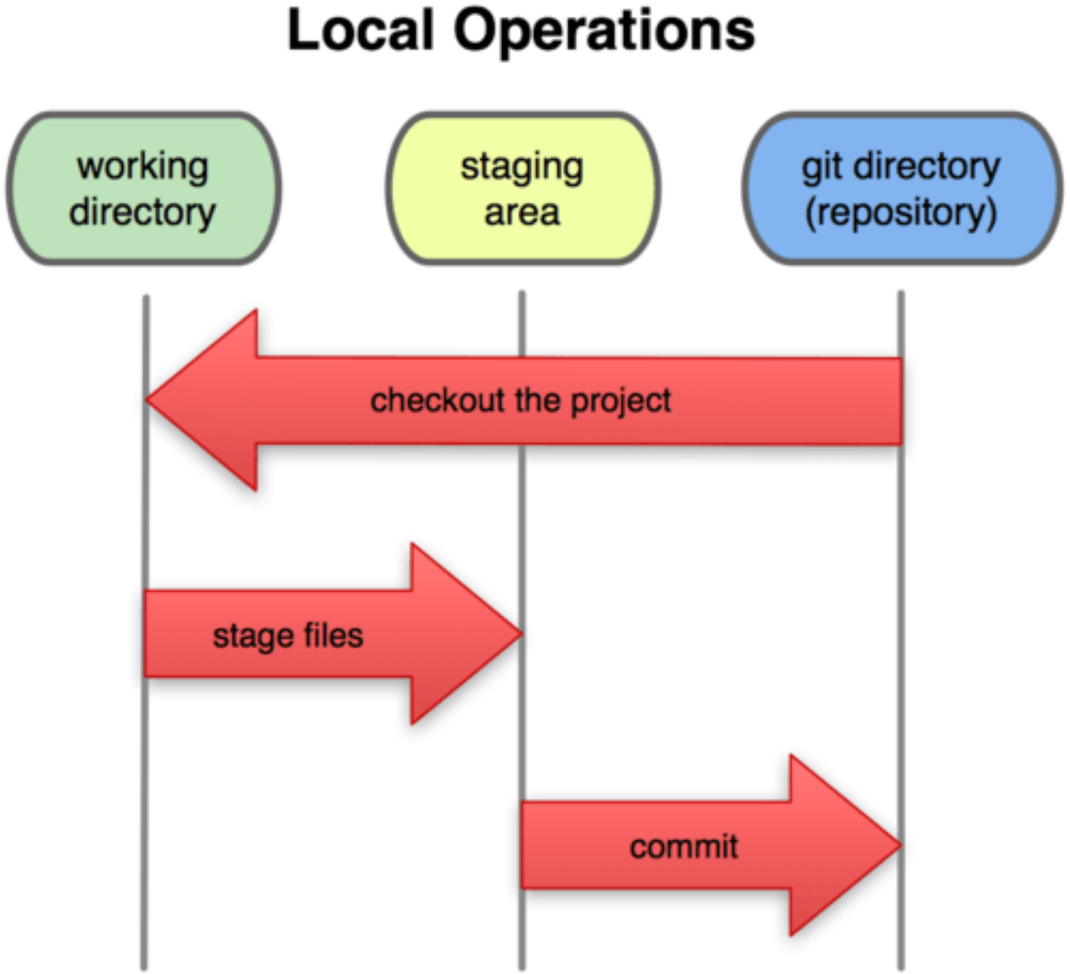
- Holds one version of the files in the repo

Inside it (usually) is a `.git` directory with

- The whole history of the repo (all commits)
- config options, branches, etc.

Conceptional staging area

- Holds files to be committed



Adding and committing

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$ vim README          # Create a readme describing the project
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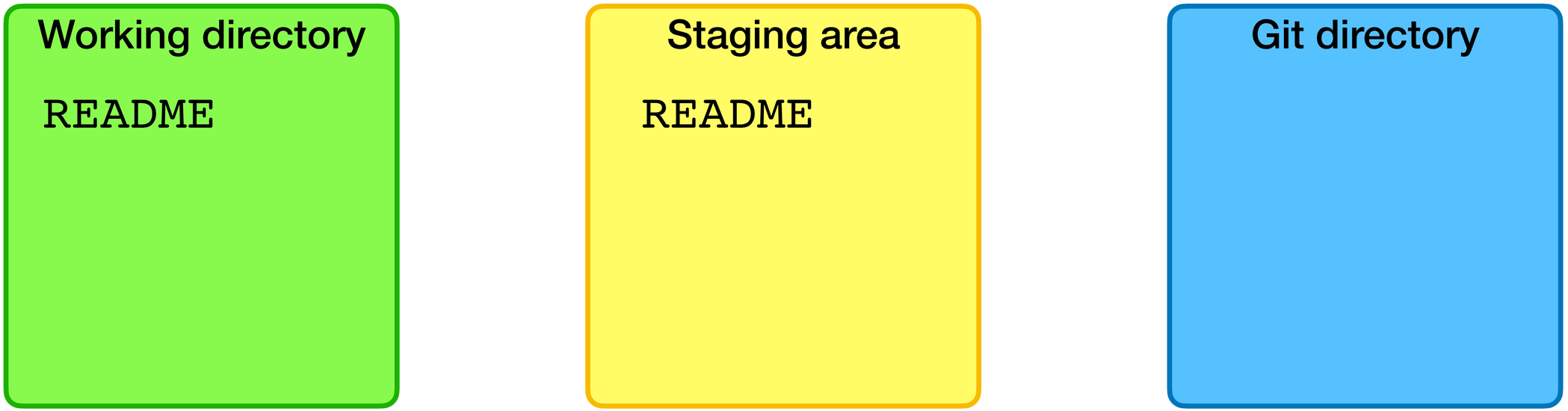

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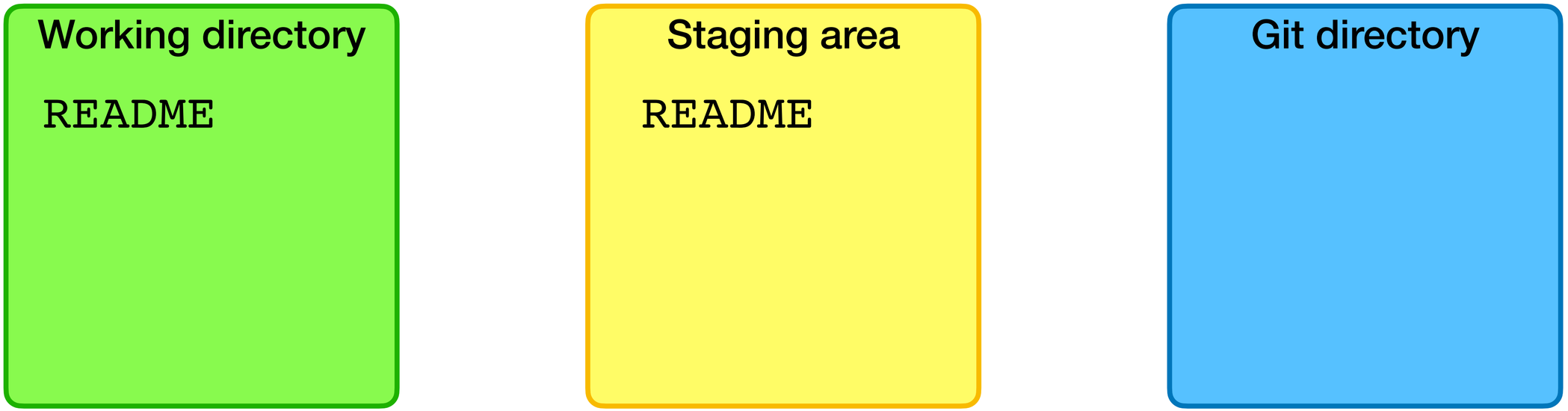

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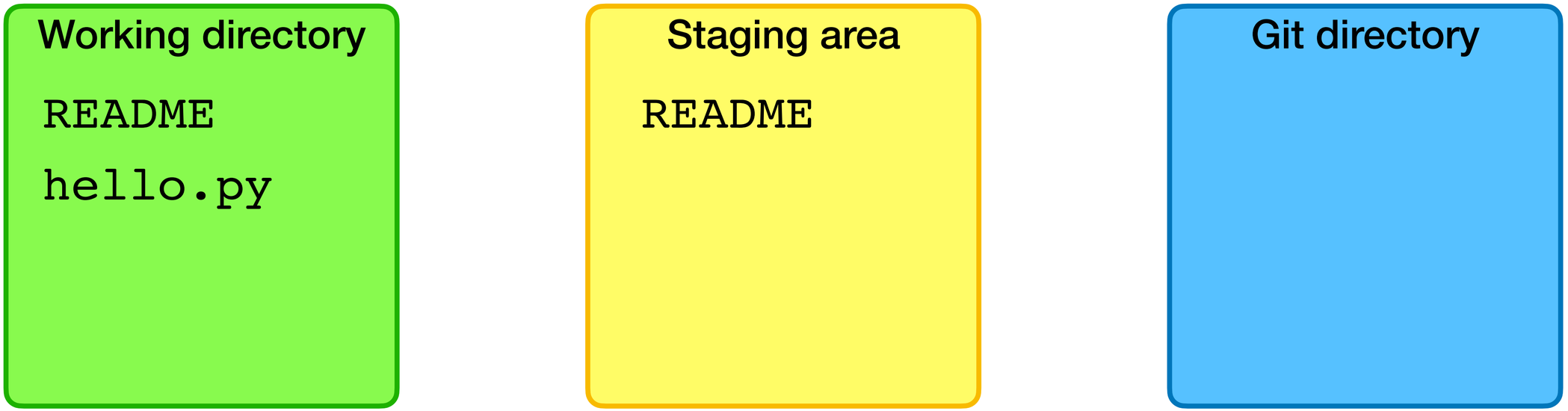

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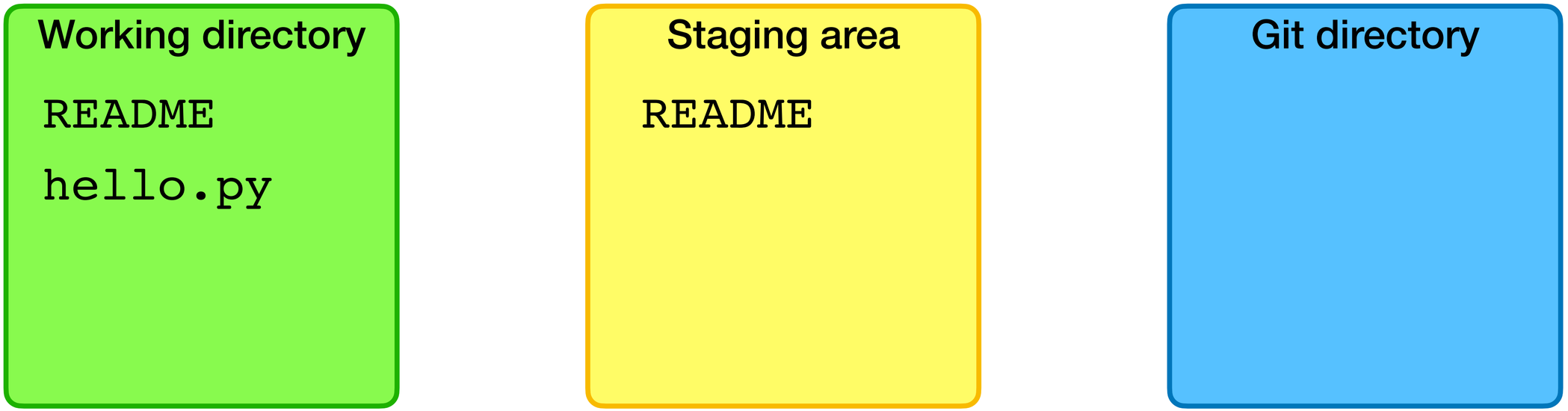

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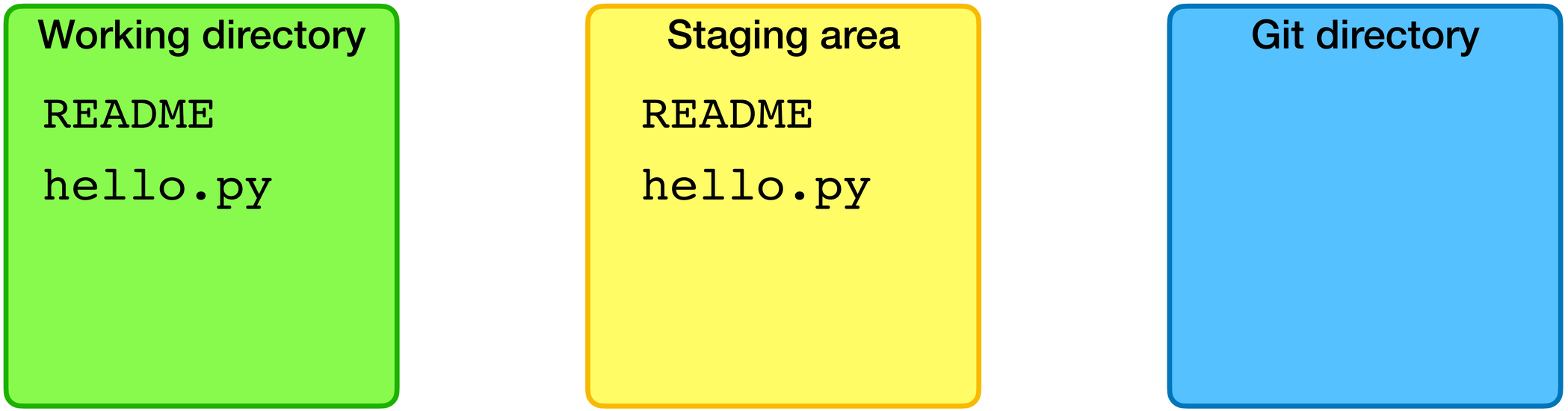

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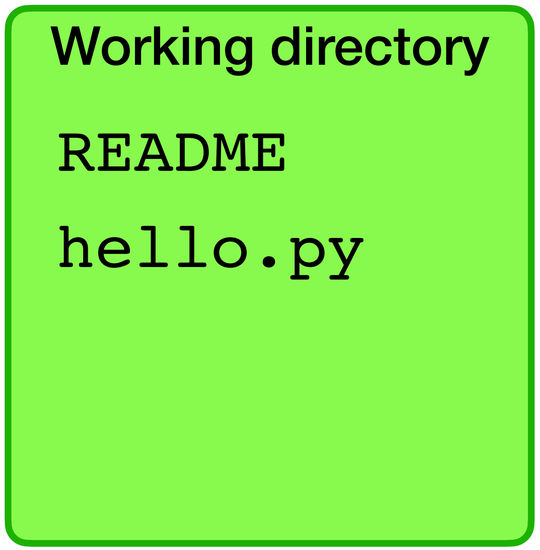

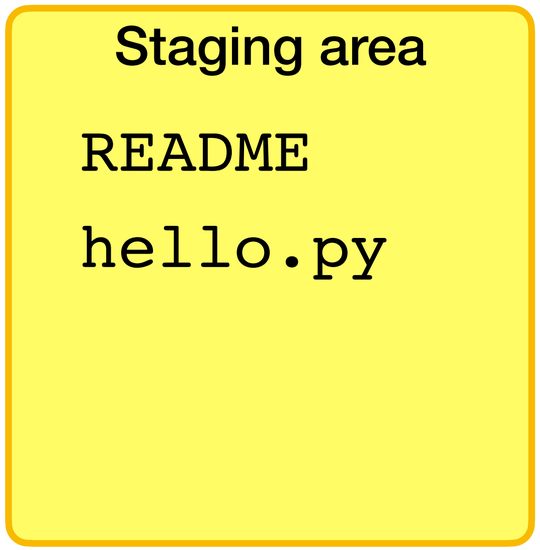

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```

Commits

Each commit is (in essence) a snapshot of the repository

Commits are named by a hash of their contents, e.g.,
`c37ce054c766b79a3577aba898b296d3557c3d24`,
often just the first 7 digits: `c37ce05`

Each commit links to its parent commit(s)

Adding and committing

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```
$ vim hello.py          # Modify the code
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Adding and committing

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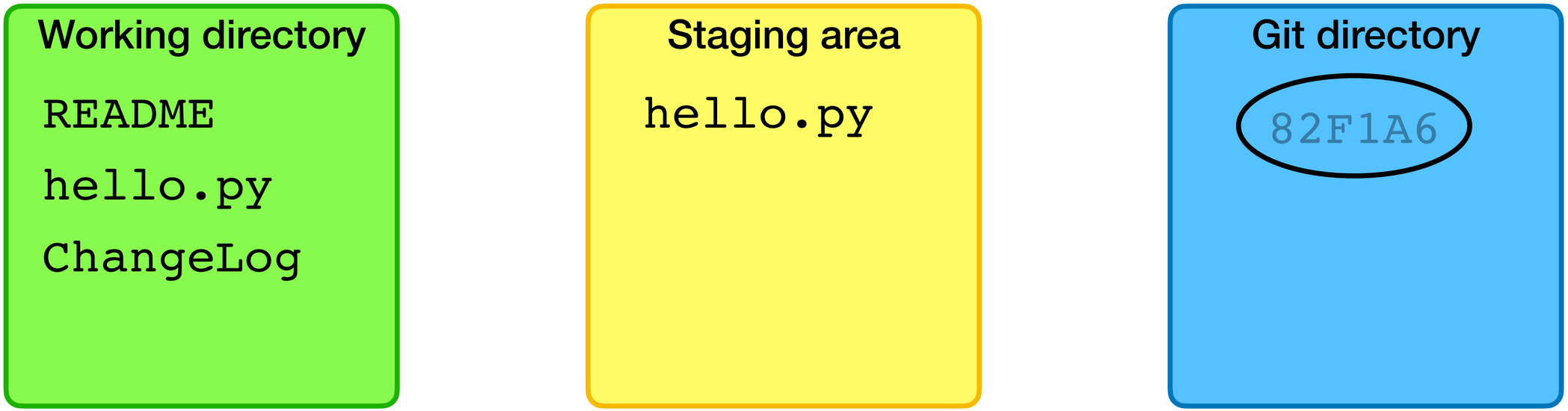

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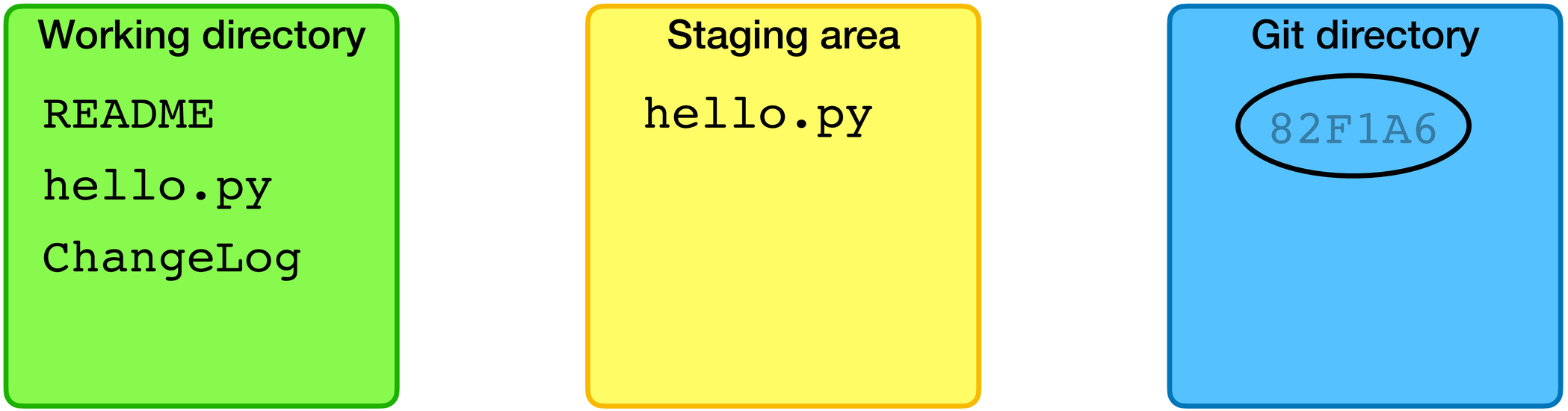

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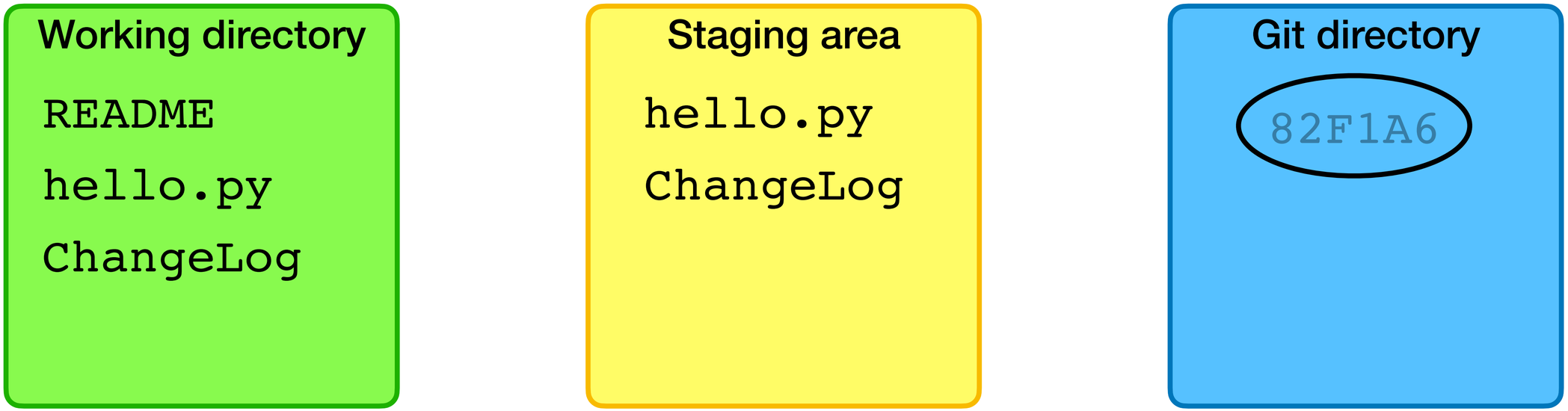

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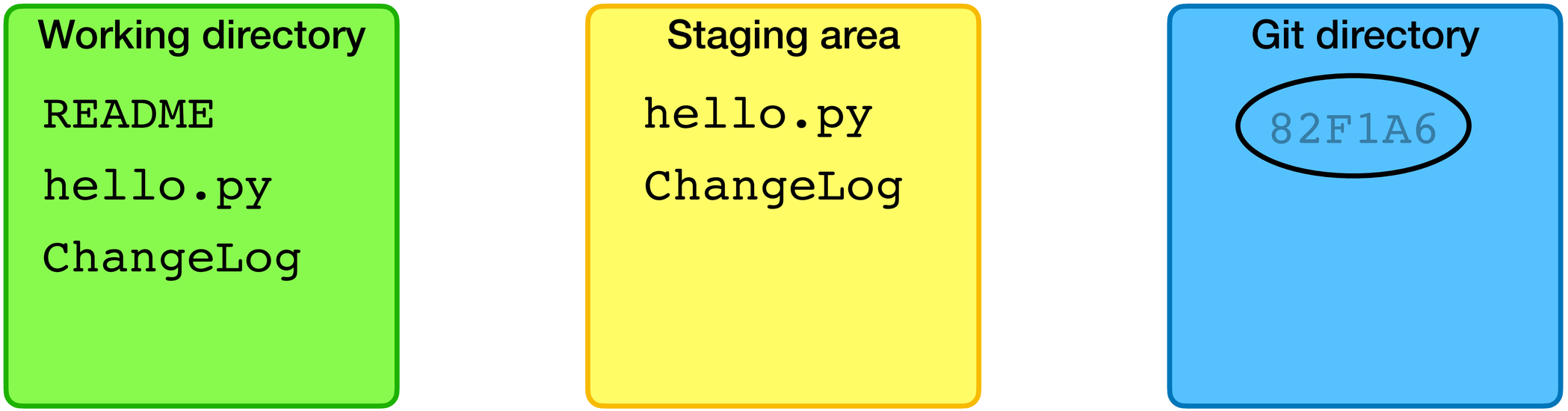

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$ git commit            # Commit the files to the repo
```

You've just cloned a repository from github, cd'd into the repo's directory, and created a new file.

```
$ git clone git@github.com:username/example-project.git
$ cd example-project
$ vim foo
```

What command(s) should you run to commit this new file to the repo?

A.
```
$ git add foo
```

B.
```
$ git commit foo
```

C.
```
$ git add foo
$ git commit
```

D.
```
$ git add foo
$ git push
```

E.
```
$ git add --commit foo
```

After adding and committing initially, you've been working on `foo` for a while and want to commit again.

What command(s) should you run to commit your changes repo?

A.
```
$ git add foo
```

B.
```
$ git commit foo
```

C.
```
$ git add foo
$ git commit
```

D.
```
$ git commit foo
$ git push
```

E.
```
$ git add --commit foo
```

Commit Message

When doing a commit, your editor will be opened so you can enter a commit message

- Short summary line
- Blank line
- Longer description

Try to provide enough detail that you can read the message to understand what changes were made (and why)

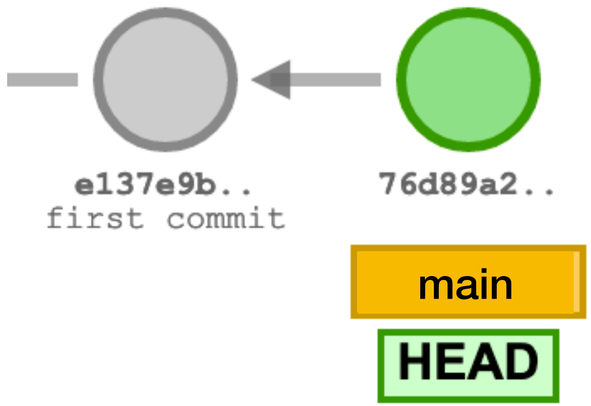
- Might be easy to remember now, but in 6 months?

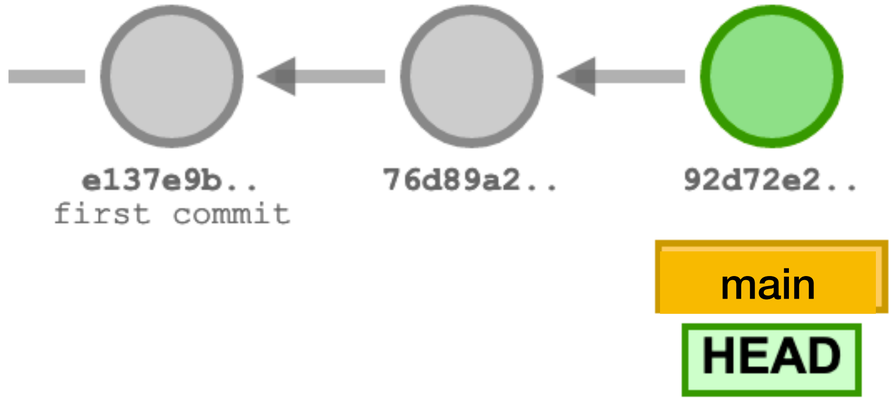
Naming commits

Individual commits can have human-readable names

- `HEAD` is the currently checked out commit
- `main` is most recent commit on the default **branch** (which is itself named `main`)
- `main` used to be named `master`, lots of documentation still refers to `master`
- tags and branches give names to commits

Example

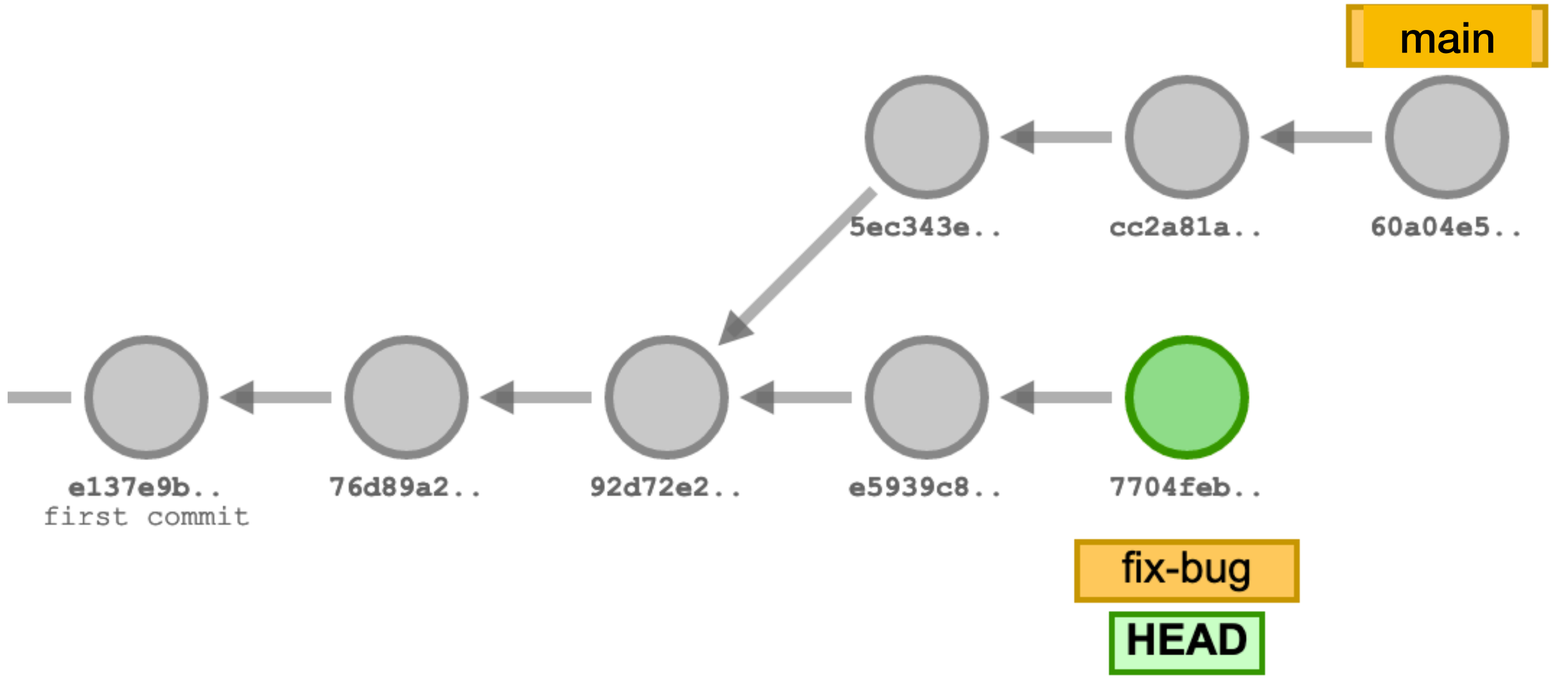




After two commits, `HEAD` and `main` point to the second commit

After a third commit, `HEAD` and `main` point to the third commit

`HEAD != main`



We can create a new branch `fix-bug` and commit to that branch

We can also keep committing to `main`

`HEAD` points to the branch we have checked out

Pushing to the remote server

```
$ git push
```

Sends to the remote server all of your committed data (it doesn't already have)

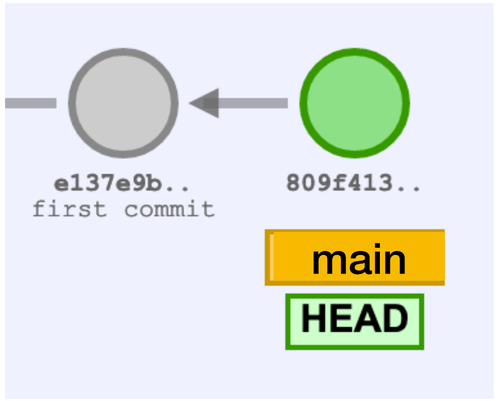
Remote servers are called remotes

- When cloning, the remote is named `origin` by default
- Remotes have their own branches `origin/main` is `origin`'s `main` branch
- It's possible to have multiple remotes (but we probably won't in this class)

Example

Local repository

Origin



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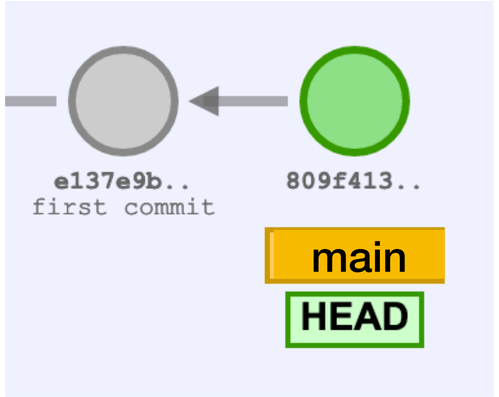


```
$ git clone …
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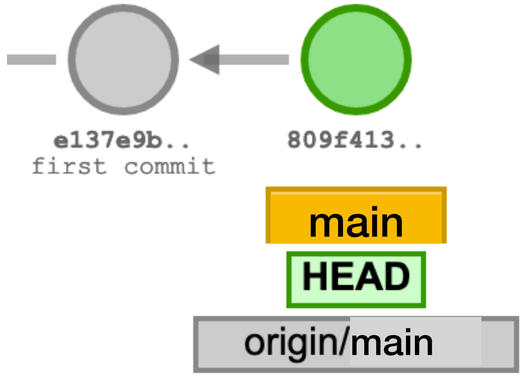
Local repository



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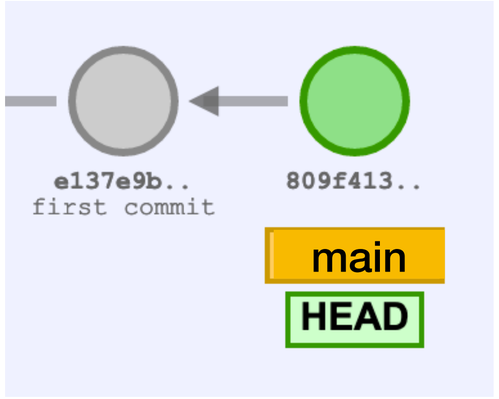

Example

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$ git clone …
```

```
$ git add …
$ git commit
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$ git commit
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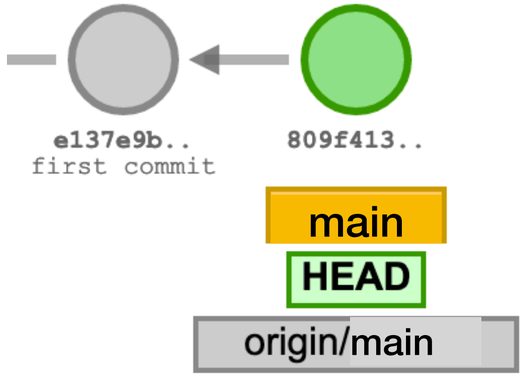
Local repository



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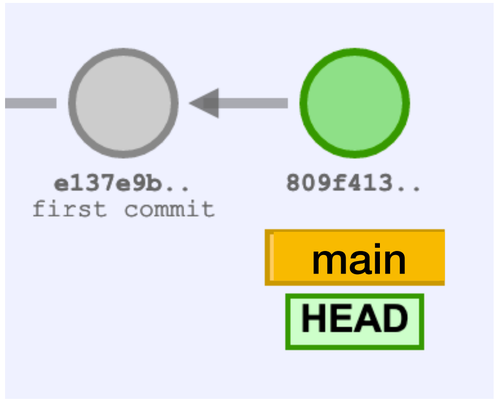

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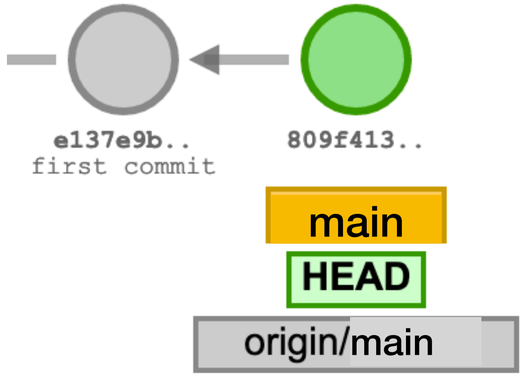

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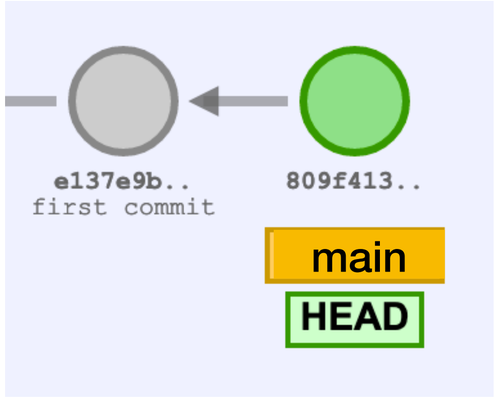


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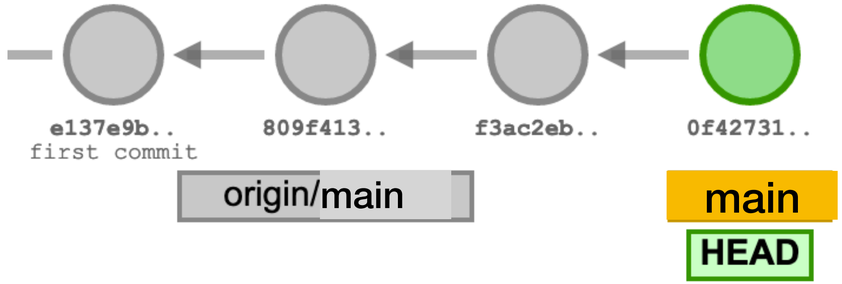

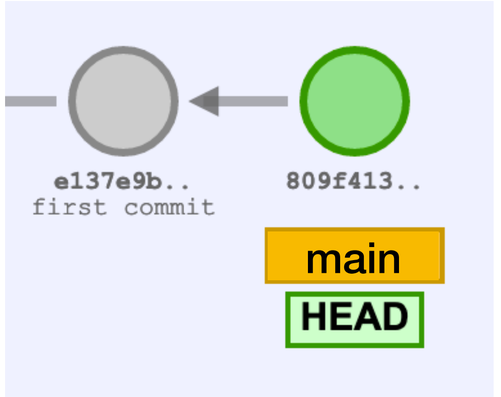

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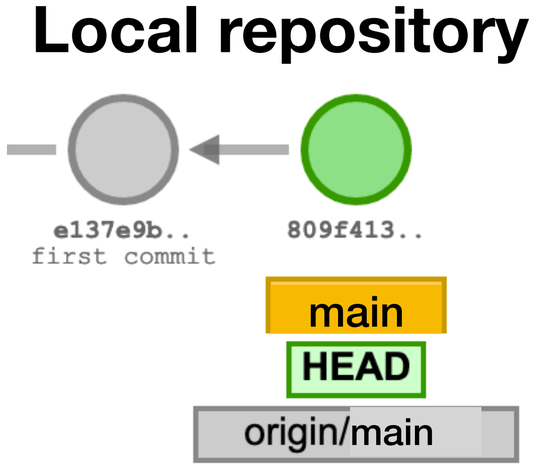

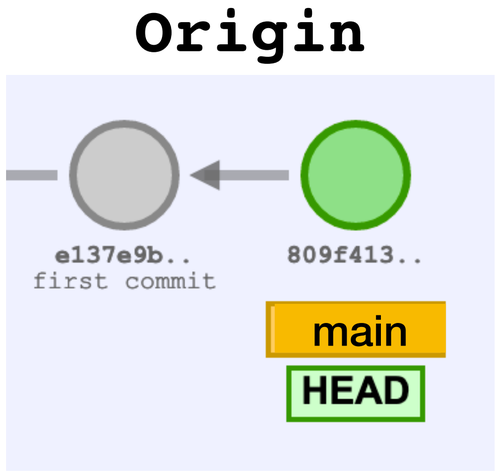


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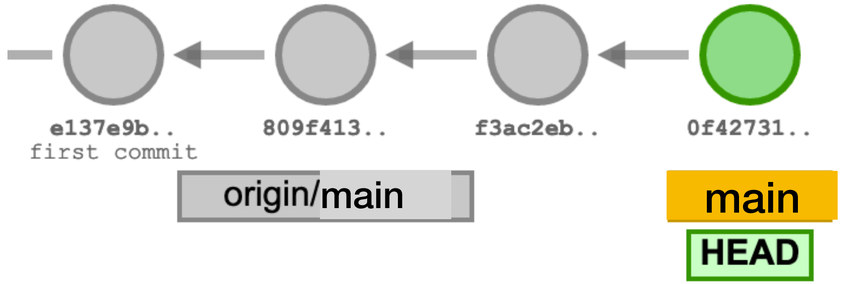

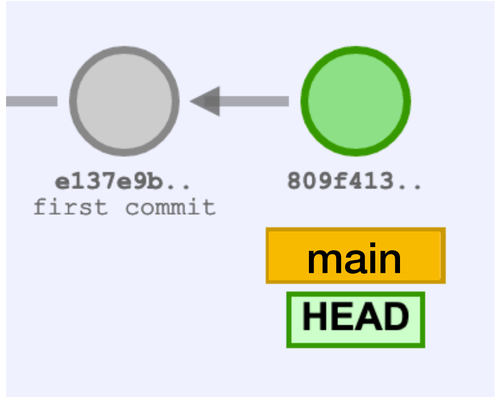


```
$ git push
```

Example

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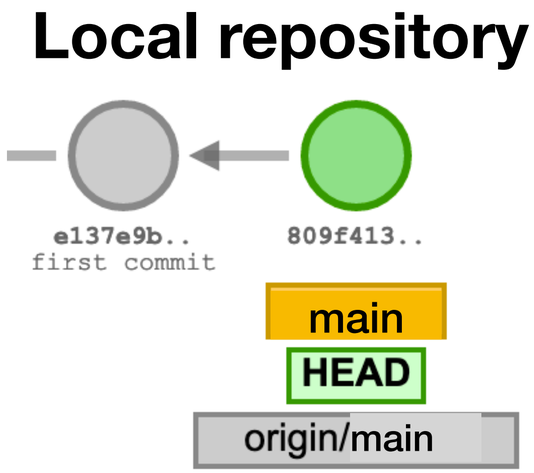

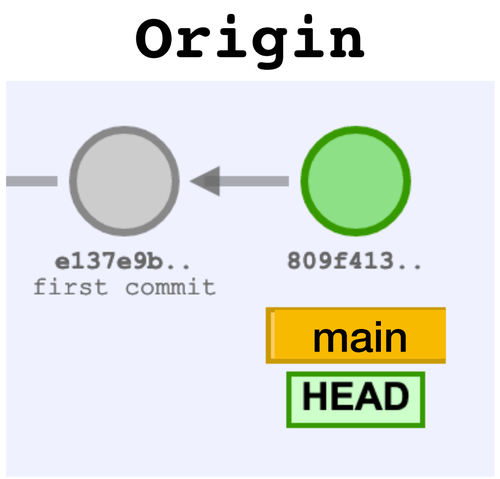


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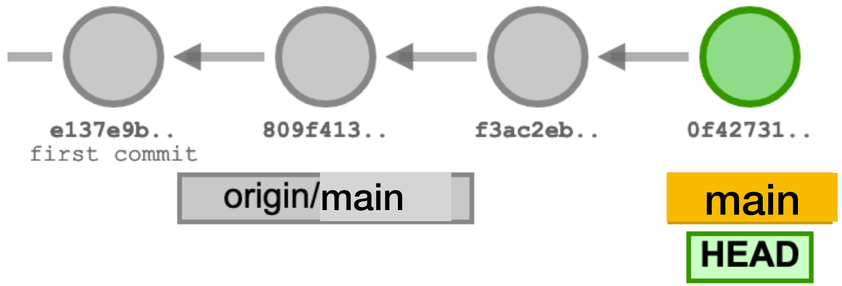

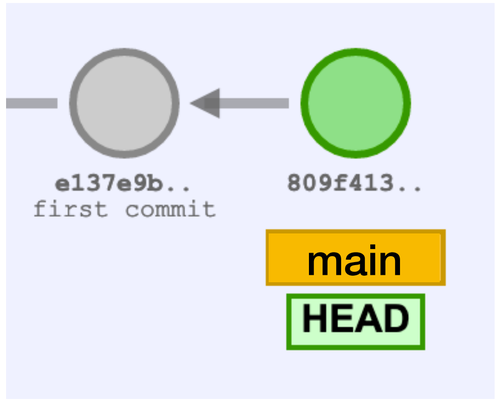


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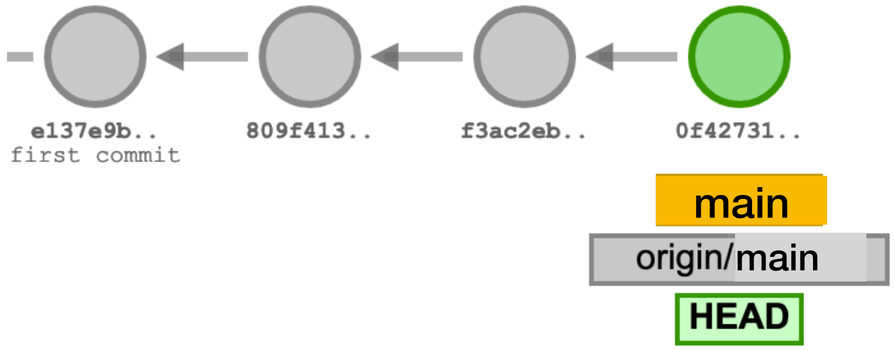
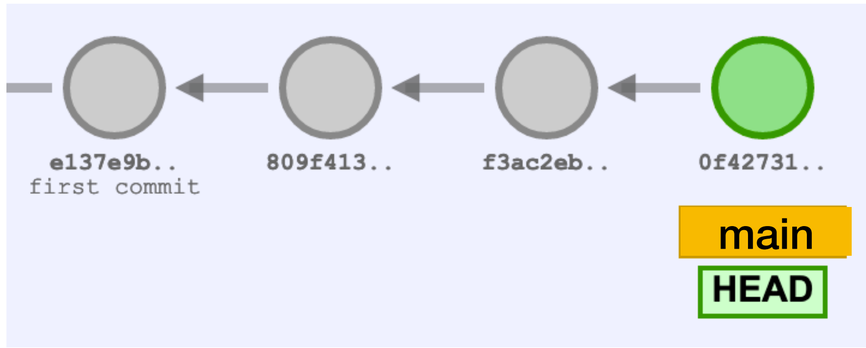
```





Pulling from the remote server

```
$ git pull
```

Pulls changes from the remote server to the local repo and merges with the local changes

```
$ git pull --rebase
```

Pulls changes from the remote server to the local repo and rebases local commits on top of remote commits

Pulling with merging

Commits from the remote will be added to the local repository
If there are local commits, git tries to merge them by creating a new commit

```
       A---B---C main on origin
      /
D---E---F---G main
     ^
     origin/main in your repository
```

```
       A---B---C origin/main
      /         \
D---E---F---G---H main
```

Pulling with rebasing

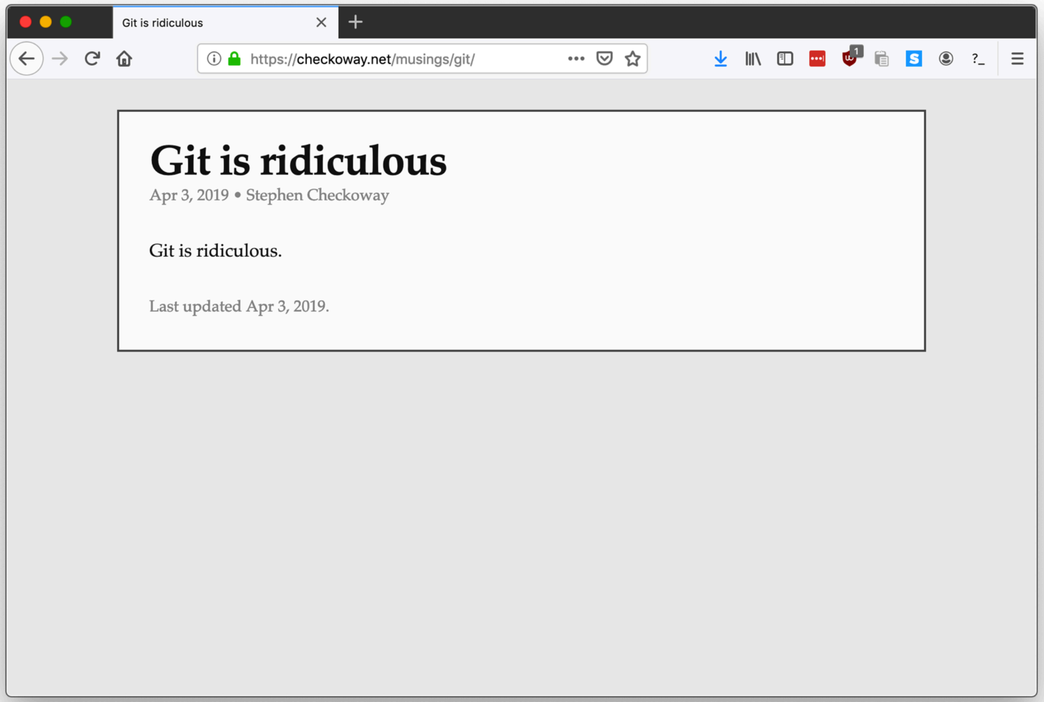
Commits from the remote will be added to the local repository
If there are local commits, git replays them on top of the new commits

```
       A---B---C main on origin
      /
D---E---F---G main
     ^
    origin/main in your repository


                  origin/main
                  v
D---E---A---B---C---F'--G' main
```

Reminder: Git is ridiculous

Warning: Git is ridiculous



Gitting help

```
$ git --help

$ git init --help

$ git clone --help

$ git add --help

$ git commit --help

$ git push --help

$ git pull --help
```

Basic Lab Workflow

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Create the repository by clicking on the link in the lab

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Clone the repository on lab machines using `$ gh repo clone ⟨url⟩`

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Push files to the server using `$ git push`

See the current state of the files using `$ git status`

Commit often

Commits are cheap, commit often

Commits can be reverted by `git revert`

- Makes a new commit that undoes the old commit
- `$ git revert ⟨commit_hash⟩`

Commits that haven't been pushed can be undone completely by `git reset`

- `$ git reset --hard ⟨commit_hash⟩`

Demo at https://jmegner.github.io/visualizing-git/