UMD DATA605 - Big Data Systems

Lesson 2.1: Git

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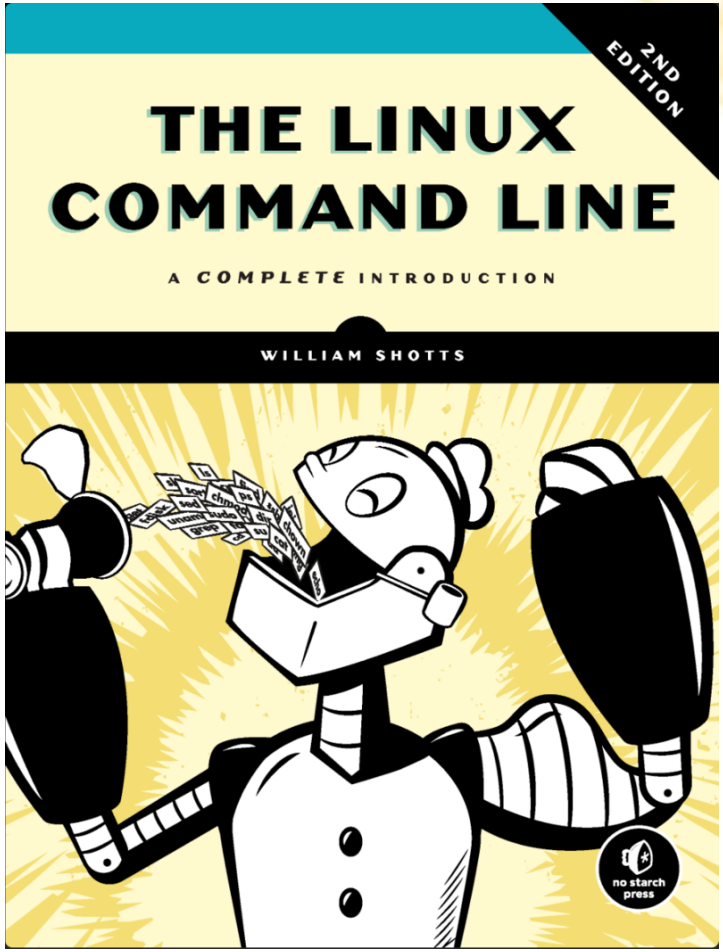
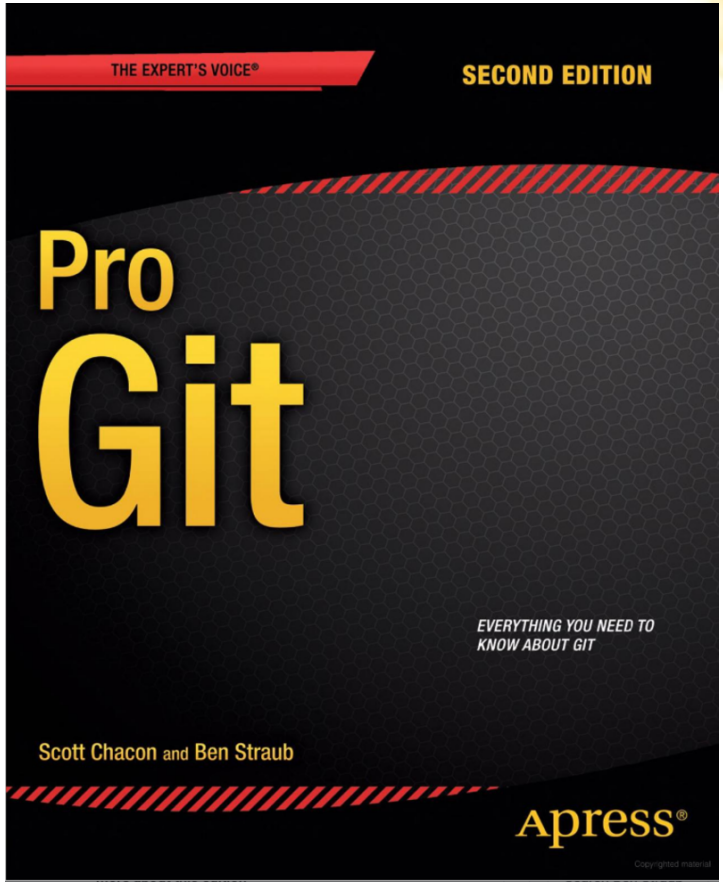
Bash / Linux: Resources

- **How Linux works**
  - Processes
  - File ownership and permissions
  - Virtual memory
  - How to administer a Linux box as root
- **Easy**
  - Command-Line for Beginners
  - E.g., `find`, `xargs`, `chmod`, `chown`, symbolic, and hard links
- **Mastery**
  - The Linux Command Line



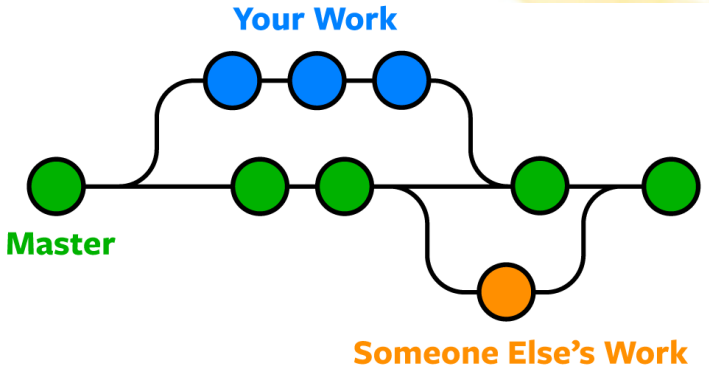
Git Resources

- Concepts in the slides
- Tutorial: Tutorial Git
- We will use Git during the project
- Mastery: Pro Git (free)
- Web resources:
  - https://githowto.com
  - dangitgit.com (without swearing)
  - Oh Sh*t, Git!?! (with swearing)
- Playgrounds
  - https://learngitbranching.js.org



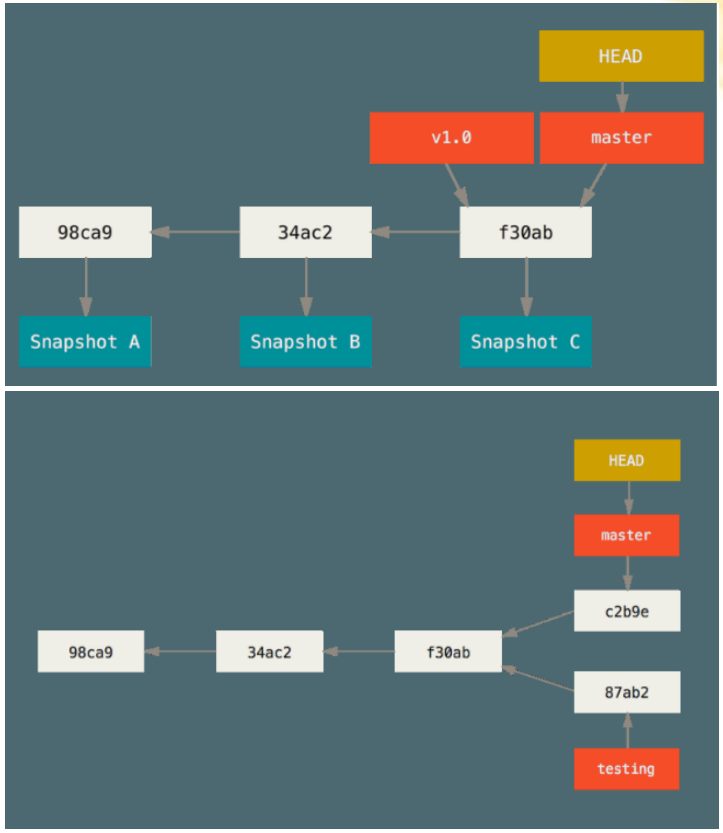
Git Branching

- **Branching**
  - Diverge from the main development line
- **Why branch?**
  - Work without affecting the main code
  - Avoid changes in the main branch
  - Merge code downstream for updates
  - Merge code upstream after completion
- **Git branching is lightweight**
  - Instantaneous
  - A branch is a pointer to a commit
  - Git stores data as snapshots, not file differences
- **Git workflows branch and merge often**
  - Multiple times a day
  - Surprising for users of centralized VCS
    - E.g., branch before lunch
  - Branches are cheap
    - Use them to isolate and organize work



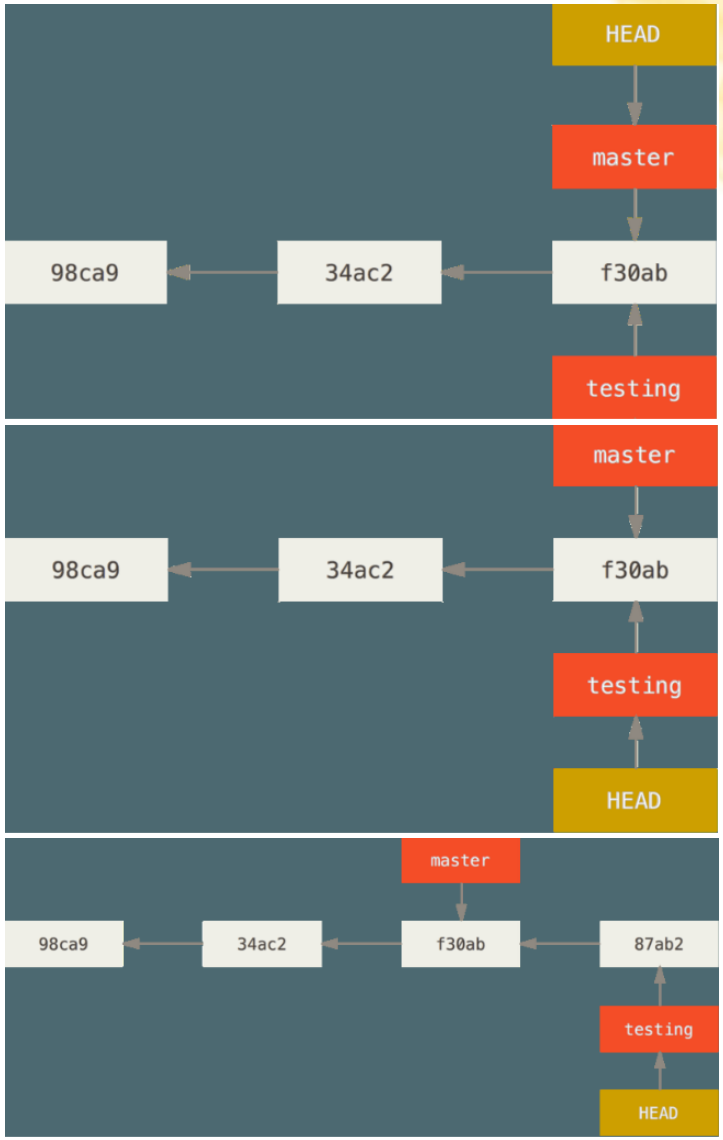
Git Branching

- `master` (or `main`) is a normal branch
  - Pointer to the last commit
  - Moves forward with each commit
- `HEAD`
  - Pointer to the current branch
  - E.g., `master`, `testing`
  - `git checkout <BRANCH>` moves across branches
- `git branch testing`
  - Creates a new pointer `testing`
  - Points to the current commit
  - Pointer is movable
- Divergent history
  - Work progresses in two "split" branches



Git Checkout

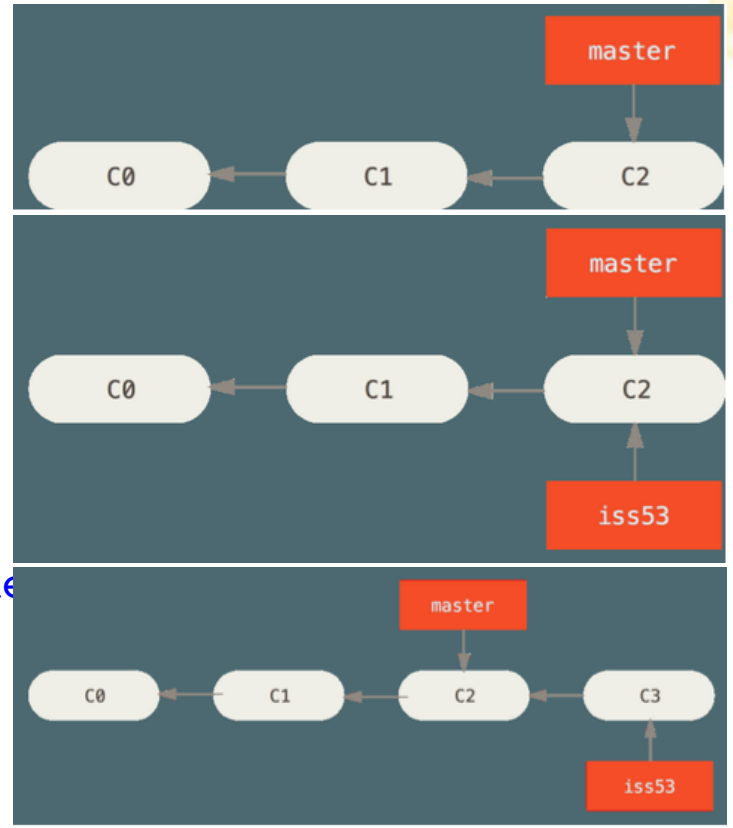
- `git checkout` switches branches
  - Moves `HEAD` pointer to the new branch
  - Changes files in the working directory to match the branch pointer
- E.g., two branches, `master` and `testing`
  - You are on `master`
  - `git checkout testing`
  - Pointer moves, working directory changes
  - Keep working and commit on `testing`
  - Pointer to `testing` moves forward



Git Branching and Merging

- Tutorials
  - Work on main
  - Hot fix
- Start from a project with some commits
- Branch to work on a new feature "Issue 53"

```
> git checkout -b iss53
work ... work ... work
> git commit -m "Add feature for Issue
```

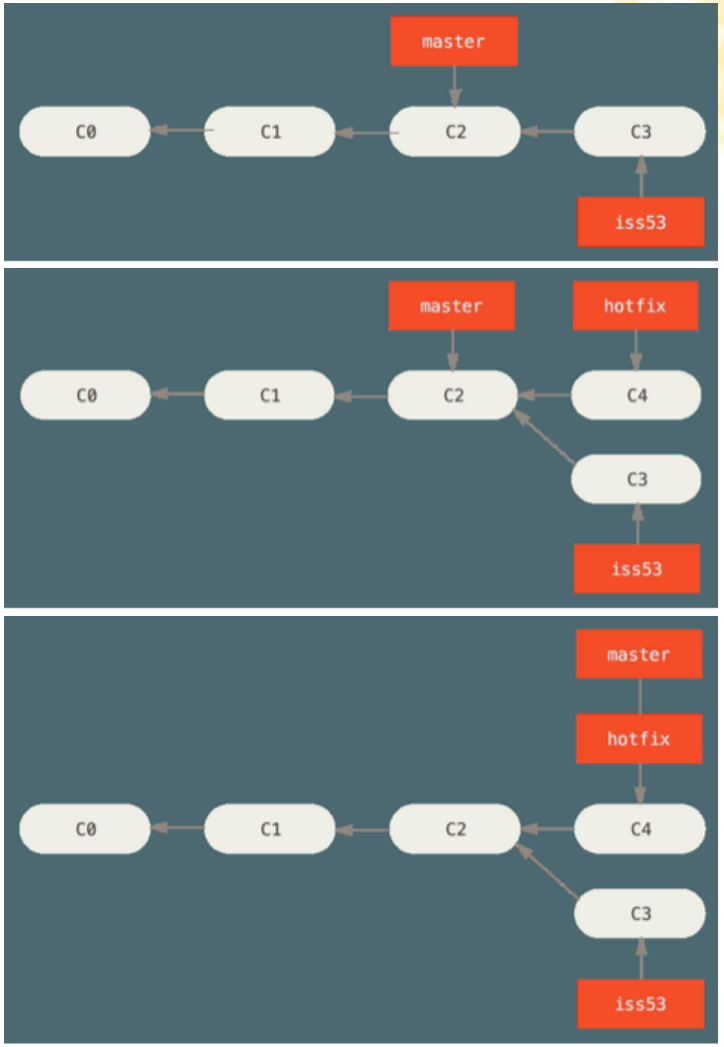


Git Branching and Merging

- **Need a hotfix** to `master`

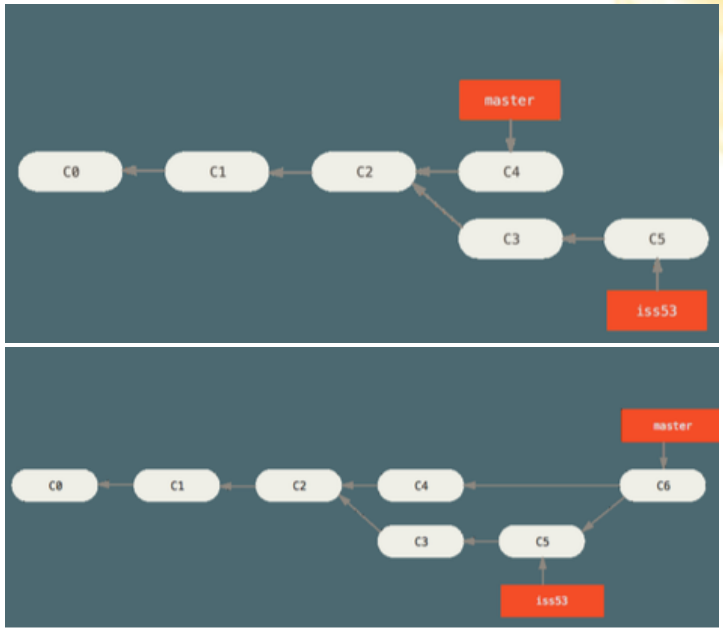
```
> git checkout master
> git checkout -b hotfix
fix ... fix ... fix
> git commit -am "Hot fix"
> git checkout master
> git merge hotfix
```

- **Fast forward**
  - Now there is no divergent history between `master` and `iss53`



Git Branching and Merging

- Keep working on `iss53`
  ```
  > git checkout iss53
  work ... work ... work
  ```
  - The branch keeps diverging
- At some point you are done with `iss53`
  - You want to merge your work back to `master`
  - Go to the target branch
    ```
    > git checkout master
    > git merge iss53
    ```



- Git can't fast forward
- Git creates a new snapshot with the 3-way "merge commit" (i.e., a commit with more than one parent)
- Delete the branch

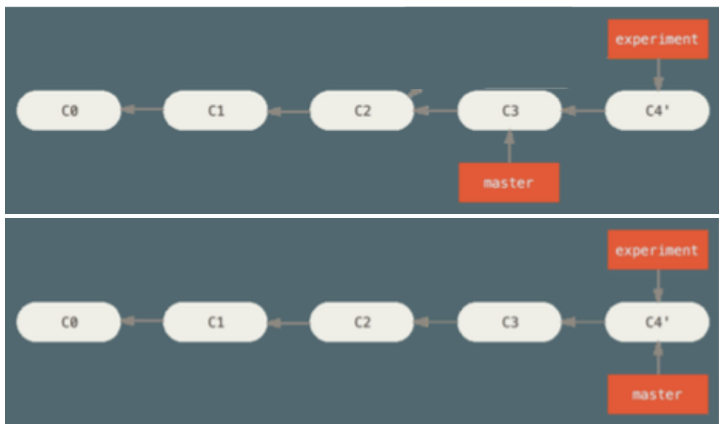
  ```
  > git branch -d iss53
  ```

Fast Forward Merge

- Merge a commit `Y` with a commit `X` that can be reached by following the history of commit `Y`
- There is no divergent history to merge
  - Git simply moves the branch pointer forward from X to Y
- **Mental model**: a branch is just a pointer that indicates where the tip of the branch is
- E.g., `C4'` is reachable from `C3`

```
> git checkout master
> git merge experiment
```

- Git moves the pointer of master to `C4'`



Merging Conflicts

- Tutorial:
  - Merging conflicts
- Sometimes **Git can't merge**, e.g.,
  - The same file has been modified by both branches
  - One file was modified by one branch and deleted by another
- **Git**:
  - Does not create a merge commit
  - Pauses to let you resolve the conflict
  - Adds conflict resolution markers
- **User merges manually**
  - Edit the files using `git mergetool`
  - Use `git add` to mark as resolved
  - Use `git commit` to finalize the merge
  - Use PyCharm or VS Code for assistance

```
<<<<<<< HEAD:index.html
<div id="footer">contact : email.support@github.com</div>
=======
<div id="footer">
 please contact us at support@github.com
</div>
>>>>>>> iss53:index.html
```

```
$ git merge iss53
Auto-merging index.html
CONFLICT (content): Merge conflict in index.html
Automatic merge failed; fix conflicts and then commit the result.
```

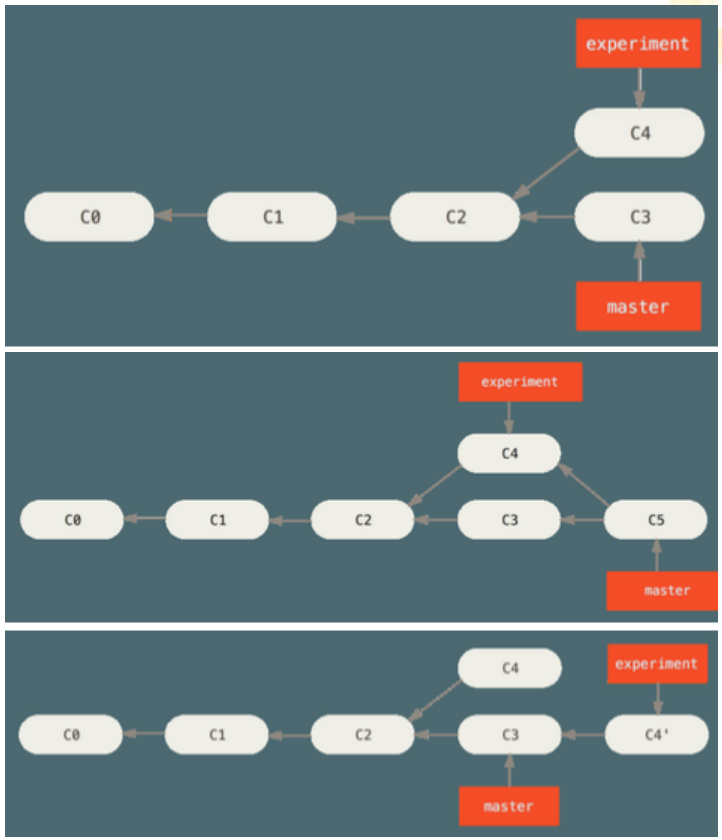
```
$ git status
On branch master
You have unmerged paths.
  (fix conflicts and run "git commit")

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

    both modified:      index.html

no changes added to commit (use "git add" and/or "git commit -a")
```

```
$ git status
On branch master
All conflicts fixed but you are still merging.
  (use "git commit" to conclude merge)

Changes to be committed:

    modified:   index.html
```

Git Rebasing

- In Git, there are **two ways of merging divergent history**
- E.g., consider `master` and `experiment` have a common ancestor `C2`

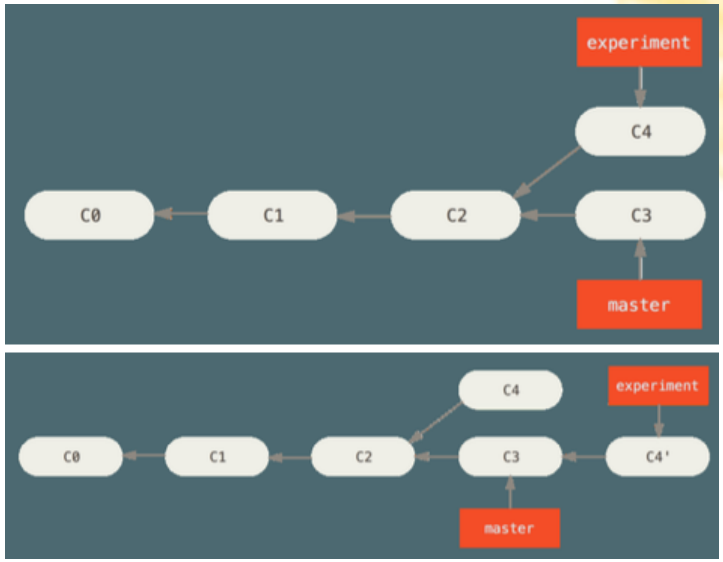
- **Merge**
  - Go to the target branch
    ```
    > git checkout master
    > git merge experiment
    ```
  - Create a new snapshot `C5` and commit
- **Rebase**
  - Go to the branch to rebase
    ```
    > git checkout experiment
    > git rebase master
    ```
  - Rebase algorithm:
    - Get all the changes committed in the branch (`C4`) where we are on (`experiment`) since the common ancestor (`C2`)
    - Sync to the branch that we are rebasing onto (`master` at `C3`)
    - Apply the changes `C4`
    - Only the current branch is affected
    - Finally, fast forward `experiment`



SCIENCE ACADEMY

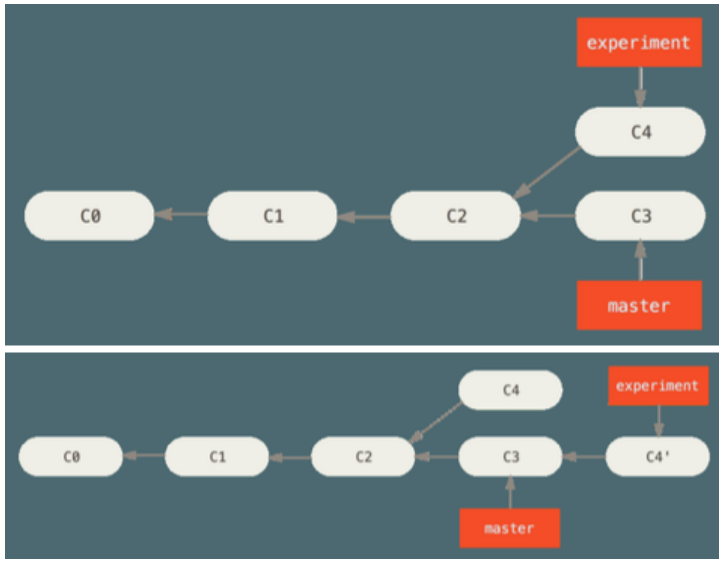
Uses of Rebase

- **Rebasing makes for a cleaner history**
  - The history looks like all the work happened in series
  - Although in reality, it happened in parallel to the development in the master branch
- **Rebasing to contribute to a project**
  - Developer
    - You are contributing to a project that you don't maintain
    - You work on your branch
    - When you are ready to integrate your work, rebase your work onto `origin/master`
  - The maintainer
    - Does not have to do any integration work
    - Does just a fast forward or a clean apply (no conflicts)



Golden Rule of Rebasing

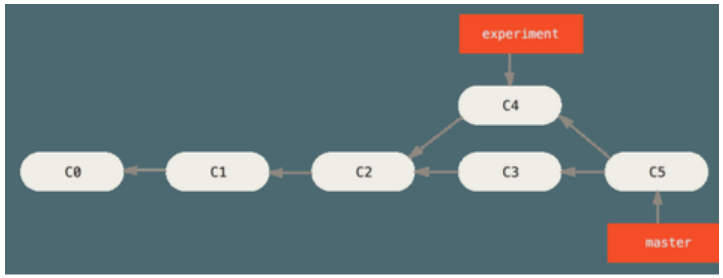
- **Remember**: rebasing means abandoning existing commits and creating new ones that are similar but different
- **Problem**
  - You push commits to a remote
  - Others pull commits and base work on them
  - You rewrite commits with `git rebase`
  - You push again with `git push --force`
  - Collaborators must re-merge work
- **Solution**
  - Strict: *"Do not ever rebase commits outside your repository"*
  - Loose: *"Rebase your branch if only you use it, even if pushed to a server"*



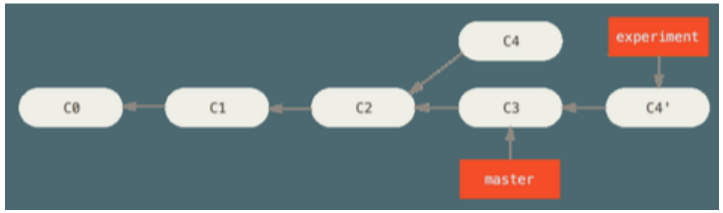
Rebase vs Merge: Philosophical Considerations

- Deciding **Rebase-vs-merge** depends on the answer to the question:
  - *What does the commit history of a repo mean?*

1. **History is the record of what actually happened**
   - *"History should not be tampered with, even if messy!"*
   - Use `git merge`



2. **History represents how a project should have been made**
   - *"You should tell the history in the way that is best for future readers"*
   - Use `git rebase` and `filter-branch`



Rebase vs Merge: Philosophical Considerations

- **Many man-centuries have been wasted** discussing rebase-vs-merge at the watercooler
  - Total waste of time! Tell people to get back to work!
- When you contribute to a project often people decide for you based on their preference
- **Best of the merge-vs-rebase approaches**
  - Rebase changes you've made in your local repo
    - Even if you have pushed but you know the branch is yours
    - Use `git pull --rebase` to clean up the history of your work
    - If the branch is shared with others then you need to definitively `git merge`
  - Only `git merge` to master to preserve the history of how something was built
- **Personally**
  - I like to squash-and-merge branches to `master`
  - Rarely are my commits "complete"; they are just checkpoints

Remote Branches

- **Remote branches** are pointers to branches in remote repositories

```
> git remote -v
origin  git@github.com:gpsaggese/umd_classes.git (fetch)
origin  git@github.com:gpsaggese/umd_classes.git (push)
```

- **Tracking branches**
  - Local references representing the state of the remote repository
  - E.g., `master` tracks `origin/master`
  - You can't change the remote branch (e.g., `origin/master`)
  - You can change the tracking branch (e.g., `master`)
  - Git updates tracking branches when you do `git fetch origin` (or `git pull`)
- To share code in a local branch you need to push it to a remote

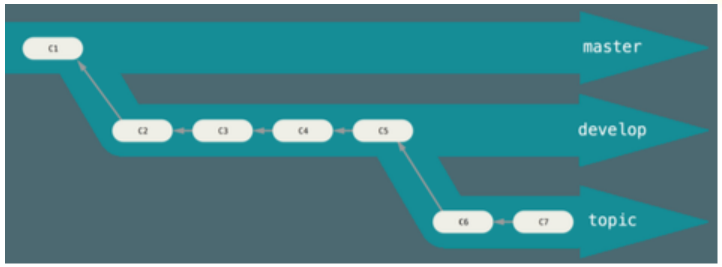
```
> git push origin serverfix
```

- To work on it

```
> git checkout -b serverfix origin/serverfix
```

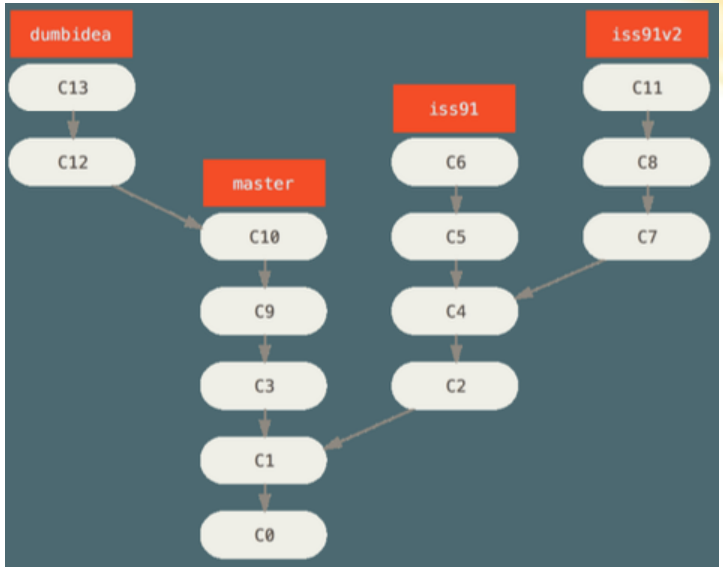
Git Workflows

- **Git workflows** = ways of working and collaborating using Git
- **Long-running branches** = branches at different levels of stability that are always open
  - `master` is always ready to be released
  - `develop` branch to develop in
  - topic/feature branches
  - When branches are "stable enough," they are merged up



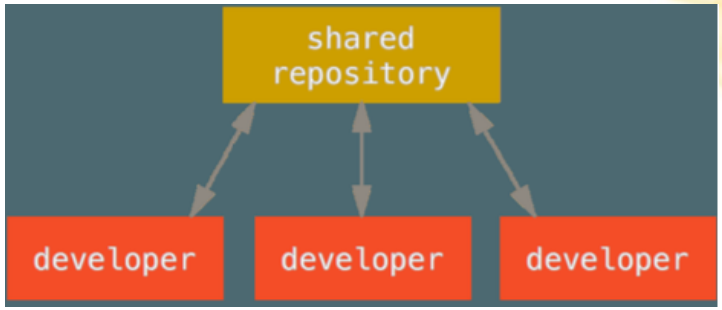
Git Workflows

- **Topic branches** = short-lived branches for a single feature
  - E.g., `hotfix`, `wip-XYZ`
  - Easy to review
  - Siloed from the rest
  - This is typical of Git since other VCS support for branches is not good enough
  - E.g.,
    - You start `iss91`, then you cancel some stuff, and go to `iss91v2`
    - Somebody starts a `dumbidea` branch and merges it to `master` (!)
    - You squash-and-merge your `iss91v2`



Centralized Workflow

- **Centralized workflow in centralized VCS**
  - Developers:
    - Check out the code from the central repo on their computer
    - Modify the code locally
    - Push it back to the central hub (assuming no conflicts with the latest copy, otherwise they need to merge)



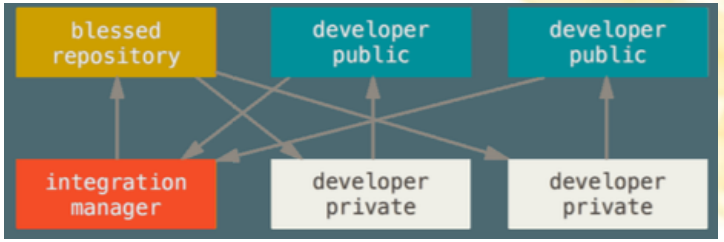
- **Centralized workflow in Git**
  - Developers:
    - Have push (i.e., write) access to the central repo
    - Need to fetch and then merge
    - Cannot push code that will overwrite each other's code (only fast-forward changes)

Forking Workflows

- Typically, developers don't have permissions to update branches directly on a project
  - Read-write permissions for core contributors
  - Read-only for everybody else
- **Solution**
  - "Forking" a repo
  - External contributors:
    - Clone the repo and create a branch with their work
    - Create a writable fork of the project
    - Push branches to the fork
    - Prepare a PR (Pull Request) with their work
  - Project maintainer:
    - Reviews PRs
    - Accepts PRs
    - Integrates PRs
  - In practice, it's the project maintainer who pulls the code when it's ready, instead of external contributors pushing the code
- **Aka "GitHub workflow"**
  - The "innovation" was forking (Fork me on GitHub!)
  - GitHub was acquired by Microsoft for 7.5 billion USD

Integration-Manager Workflow

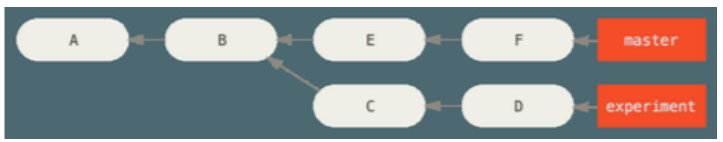
- This is the classical model for open-source development
  - E.g., Linux, GitHub (forking) workflow



1. **One repo is the official project**
   - Only the project maintainer pushes to the public repo
   - E.g., `causify-ai/csfy`
2. **Each contributor**
   - Has read access to everyone else's public repo
   - Forks the project into a private copy
     - Write access to their own public repo
     - E.g., `gpsaggese/csfy`
   - Makes changes
   - Pushes changes to their own public copy
   - Sends a pull request to the maintainer asking to merge changes
3. **The maintainer**
   - Adds the contributor's repo as a remote
   - Merges the changes into a local branch
   - Tests changes locally
   - Pushes the branch to the official repo

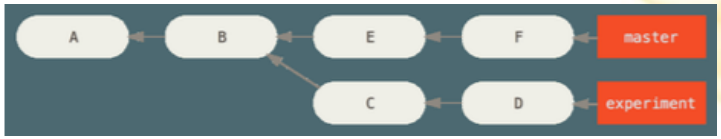
Git log

- `git log` reports info about commits
- **refs** are references to:
  - `HEAD` (commit you are working on, next commit)
  - `origin/master` (remote branch)
  - `experiment` (local branch)
  - `d921970` (commit)
- `^` after a reference resolves to the parent of that commit
  - `HEAD^` = commit before `HEAD`, i.e., last commit
  - `^2` means the second parent of a merge commit
  - A merge commit has multiple parents

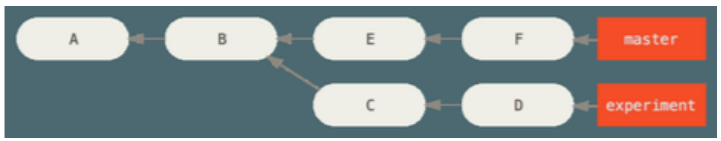


Dot notation

- **Double-dot notation**
  - `1..2` = commits that are reachable from 2 but not from 1
  - Like a "difference"
  - `git log master..experiment` → `D,C`
  - `git log experiment..master` → `F,E`



- **Triple-dot notation**
  - `1...2` = commits that are reachable from either branch but not from both
  - Like "union excluding intersection"
  - `git log master...experiment` → `F,E,D,C`



Advanced Git

- **Stashing**
  - Copy the state of your working directory (e.g., modified and staged files)
  - Save it in a stack
  - Apply it later
- **Cherry-picking**
  - Apply a single commit from one branch onto another
- **rerere**
  - = "Reuse Recorded Resolution"
  - Git caches how to solve certain conflicts
- **Submodules / subtrees**
  - Projects including other Git projects

Advanced Git

- **bisect**
  - `git bisect` helps identify the commit that introduced a bug
    - Bug appears at the top of the tree
    - Unknown revision where it started
    - Script returns 0 if good, non-zero if bad
    - `git bisect` finds the revision where the script changes from good to bad
- **filter-branch**
  - Rewrite repository history in a scriptable way
    - E.g., change email, remove sensitive file
  - Check out each version, run a command, commit the result
- **Hooks**
  - Run scripts before committing, merging, etc

GitHub

- GitHub acquired by MSFT for $7.5 billion
- **GitHub: largest host for Git repositories**
  - Git hosting (100M+ open source projects)
  - Pull Requests (PRs), forks
  - Issue tracking
  - Code review
  - Collaboration
  - Wiki
  - Actions (CI/CD)
- **"Forking a project"**
  - Open-source communities
    - Negative connotation
    - Modify and create a competing project
  - GitHub parlance
    - Copy a project to contribute without push/write access