

# Working with Git

## Understanding the Most Important Features

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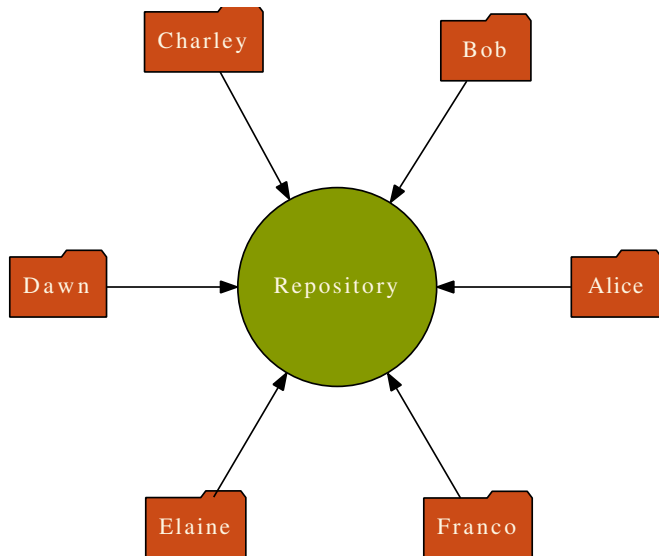
# What's In Store

Before Lunch	After Lunch
Introduction / History	Branching
Git Internals	Tagging
Daily Workflow	Merging
Undoing Things	Remotes

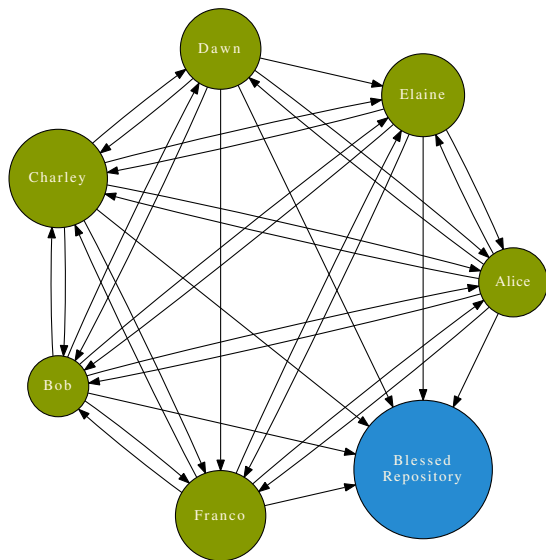
# Why Use a Source Code Control System?

- It's a time machine for code and assets
- Coordinate work among project contributors
- Track what changes went into which releases
- Record *why* something changed and who made the change

## Centralized Systems: Subversion, Perforce, etc.



# Distributed Systems: Git, Mercurial, etc.



# Centralized vs. Distributed

Feature	Centralized	Distributed
Checkout	Partial	Full Clone
Committing	Done on Remote	Local Only
Push/Pull	Automatic Push	Manual

# Patches vs. Snapshots

- Most version control systems use a set of patches (difference between a file before and after it was changed) and each set of patches is assigned an incremented ID.
- When a commit is made in Git it creates a new snapshot of the repository and assigns it a SHA1 hash
- The SHA1 hash is cryptographically secure and is used to verify the integrity of the repository
- Since the commit IDs do not follow one another numerically you have to use the `git log` command to see the commit order

# Working Directory, Index, and Repository

The three “trees”:

**Working Directory** The project's files as you and your tools see them.

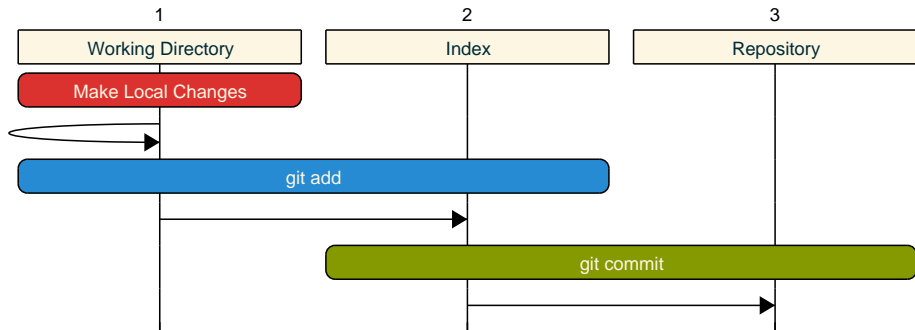
**The Index** Changes that will be included in the next commit.

**The Git Database (Repository)** All commits, files, and history information.

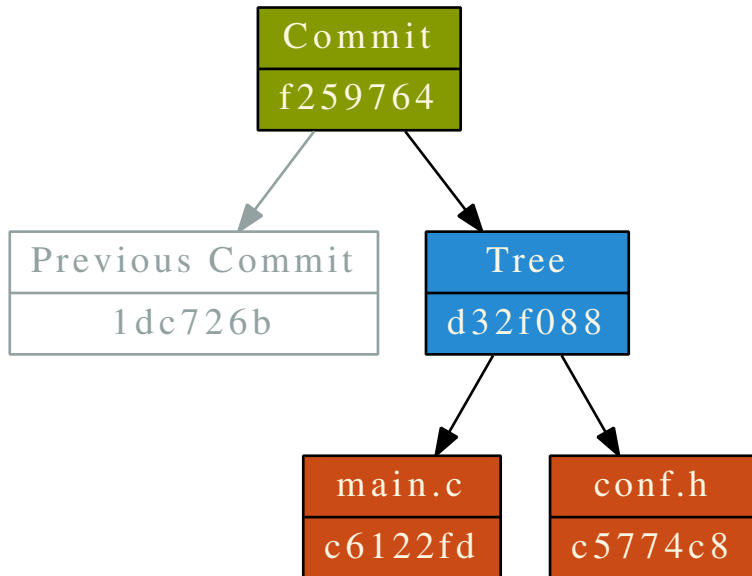
(Note: The index is sometimes referred to as the *staging area*.)



# Basic Git Workflow



# What is a Commit in Git?



# Starting Out: Cloning a Repository

To get a copy of an existing repository you *clone* it:

```
$ git clone <url>
```

## Exercise: Cloning a Repository

1. Change to the following directory:  
`repos`
2. Clone the `basic.git` repository:  
`$ git clone basic.git`
3. This should have created a `basic` directory

## Exercise: Viewing the History Log

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Use the following command to see the commit history:  
`$ git log --oneline`
3. Pick a commit and run:  
`$ git cat-file -p <commit>`
4. Also cat-file the listed tree, then the listed blob

# The `git config` Tool

All Git configuration information is stored in simple text files using the INI format. If you don't want to edit files by hand you can use the `git config` tool to do it for you.

# Setting Your Name and Email Address

Before you do anything at all with Git you should tell it your name and email address. This information is recorded with each commit you make.

```
$ git config --global user.name "Your Name Here"
```

```
$ git config --global user.email "Your Email Address Here"
```

## Exercise: Telling Git Who You Are

If you haven't done so previously:

1. Set your name and email address using `git config`
2. Verify your settings:

```
$ git config --list
```



# Exercise: Telling Git Which Editor to Use

If you haven't done so previously:

1. Tell Git which text editor to use:

```
$ git config --global core.editor <program>
```

Here are some examples for <program>:

- ▶ emacs
- ▶ vi
- ▶ "'C:/Program Files/Notepad++/notepad++.exe'"
- ▶ "code --wait"

Or search the web for instructions for your preferred editor.

# Adding Untracked Files

- When you create a new file in the working directory Git will show the file as *untracked*
- You can see what Git thinks about a file using `git status`:

```
$ git status <file>
```

- To tell Git to start tracking the file use `git add`:

```
$ git add <file>
```

- This creates a commit object to hold the file
- If you change the file you need to use `git add` again
- To record your change to the repository use `git commit`:

```
$ git commit
```

## Exercise: Adding a New File

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Create a new file called `config.h`
3. Add some content to the file (any text will do)
4. Review the output of `git status`
5. Add the file to the index
6. Check the output of `git status` again
7. Commit the change

# Modifying Existing Files

Git knows when you have changed a file that it is tracking:

- The file will show as *modified* in a `git status`
- You can use `git diff` to see what has changed
- Stage the change with `git add`
- Commit the change with `git commit`

## Exercise: Editing an Existing File

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Edit the `main.c` file
3. Add some content to the file (any text will do)
4. Review the output of `git status`
5. Review the output of `git diff`
6. Add and commit the change

# Renaming Files

Git allows you to rename files in two different ways:

1. Rename the file any way you want and let Git figure it out.
2. Use Git to rename the file:

```
$ git mv <old> <new>
```

When you rename files Git will track the rename in the repository.

(Note: If possible, using the `git mv` command is the safest way to rename a file.)

## Exercise: Renaming a File

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Rename the `config.h` file from the previous exercise to `init.h`
3. Review the output of `git status`
4. Notice that Git already staged the rename
5. Commit your change

# Removing Files

When you no longer need a file you can remove it by:

1. Remove the file with any tool, then run `git rm`.  
In this case `git status` will report that the file was deleted and `git rm` will stage the removal.
2. Use `git rm` directly.  
The `git rm` command can delete the file and then stage the removal in one step.



## Exercise: Removing a File

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Remove the `init.h` file
3. Review the output of `git status`
4. Notice that the file deletion was staged for you
5. Commit your changes
6. Restore the file

# Restoring a Removed File

You can always restore a file from a previous commit using the `git checkout` command:

```
git checkout HEAD <file> Restore <file> from the last commit  
git checkout HEAD^ <file> Restore <file> from two commits ago  
git checkout 325a910 <file> Restore <file> from commit 325a910
```

# Accessing the Commit Log

The easiest way to review the commit history is by viewing the output from the `git log` command. To get a compact commit listing use the following command:

```
$ git log --oneline
```

Try it out!

# Getting More Detail from the Log

The Log command supports many options for controlling its output. The three most common ways of calling it are:

1. Basic details with full commit message:

```
$ git log
```

2. Single line output with commit subject:

```
$ git log --oneline
```

3. Basic details with diff output:

```
$ git log --patch
```

# Customizing the Commit Log

We can also fully customize the output of the log command:

```
$ git log \  
  --pretty=format: '%Cgreen%h%Creset %Cred%cd%Creset %Cblue%ae'
```

(Note: We'll see later how we can create aliases for these complicated commands.)

# Searching for a Commit

The `log` command can be used to search the commit history for changes involving a string:

- Find commits that added or removed lines containing `printf`:

```
$ git log -G printf
```

- The same, but with regular expressions:

```
$ git log -G 's?printf'
```

- Must change the number of occurrences:

```
$ git log -S printf
```

# The Reference Log

Git also keeps a temporary history file which tracks every change you make to HEAD. It's call the *reflog*:

```
$ git reflog
```

To see the history of all branches you've worked on:

```
$ git reflog --all
```

Reference log with dates:

```
$ git log -g --pretty=format:"%h %cd %gd %gs"
```

(Entries in the reflog are automatically removed after 90 days.)

# Specifying Revisions

Examples of absolute revisions `f259764`, `feature`, `HEAD`, `@`

First parent of a commit `f259764^` or `f259764~1`

Grandparent of a commit `f259764~2`

Entries from the reflog `master@{yesterday}`, `HEAD@{5}`

Ranges (useful for generating diffs) `1cfd75c..0ee2723`



## Exercise: Using git rev-parse

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Use the following command to see the commit history:  
`$ git log --oneline`
3. Experiment with `git rev-parse`, for example:  
`$ git rev-parse HEAD`

# Fixing the Last Commit

You finish creating a commit and then realize:

- Forgot to add a file to the index
- You have typos in your commit message
- etc.

Before pushing the commit you can edit it:

```
$ git commit --amend
```

# The Process of Amending a Commit

1. Add any missing files to the index
2. Run `git commit --amend`
3. Edit the commit message if necessary
4. Exit your text editor

(Note: If you want to remove a file from a commit you will need to perform a soft reset and create a new commit.)

## Exercise: Amending the Last Commit

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Create a branch that starts at the commit named `merge-start`  
`$ git checkout -b NAME merge-start`
3. Take note of the last commit hash
4. Amend the last commit, changing the commit message
5. Notice that the most recent commit was rewritten

## Unstaging a Modification or File

Have you ever staged a file by accident and then wanted to *unstage* it?

```
$ git reset HEAD <file>
```

Or:

```
$ git reset -- <file>
```

(Or, create an *unstage* alias. We'll do this later.)

## Exercise: Unstaging a File

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Create a branch that starts at the commit named `merge-start`  
`$ git checkout -b NAME merge-start`
3. Edit the `main.c` file, making a simple change to it
4. Stage (`git add`) and unstage (`git reset`) the file

## Restoring a Modified File

Have you ever changed a file and wanted to restore it back to how it was in the last commit?

```
$ git checkout -- <file>
```

What about its state two commits ago?

```
$ git checkout HEAD~2 <file>
```

## Exercise: Restoring a File

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. In the last exercise we changed the `main.c` file, restore it back to its previous state



## Exercise: Restoring a File

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Look through the commit history and find the commit that added a version number to `main.c`
3. Restore `main.c` to its content before the version number was added

# Reverting a Commit

Sometimes an entire commit needs to be undone.

```
$ git revert <commit>
```

...will create a new commit that reverses the changes in <commit>

## Exercise: Reverting a Commit

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Create a branch that starts at the commit named `merge-start`  
`$ git checkout -b NAME merge-start`
3. Edit the `main.c` file, making a simple change to it
4. Commit the change
5. Revert the commit you just created

# What are Aliases

- Just like with your favorite shell, Git supports aliases.
- When you run a Git command, it will first be looked up as an alias
- For example:

```
$ git unstage main.c
```

Could be an alias for:

```
$ git reset HEAD -- main.c
```

# Creating New Aliases

The easiest way to create an alias is with the `git config` command:

```
$ git config --global alias.unstage "reset HEAD --"
```

The `git config --global` command simply edits `~/.gitconfig`:

```
[alias]
```

```
unstage = reset head --
```

# Some Useful Aliases

[alias]

**b** = branch -vv

**s** = status --short

**ci** = commit

**co** = checkout

**ds** = describe --long --tags --dirty --always

**lg** = log --pretty=format:'%Cgreen%h%Creset %Cred%cd%Creset %'

**sb** = submodule

**sbu** = submodule update --init --recursive

**sbp** = submodule update --remote --checkout

**unstage** = reset head --

(Taken from the examples/aliases.ini file.)

## Exercise: Create Some Aliases

1. Take a moment and create some helpful aliases
2. Pick a repository and test your new aliases

# Why You May Want to Ignore Certain Files

There are several types of files you may want Git to ignore:

- Build artifact files (e.g., object files)
- Temporary files or directories
- Log files generated during testing



# Telling Git to Ignore Files

- When you tell Git to ignore a file it will no longer show up in the `git status` listing as modified or untracked.
- Ignore files are listed in the `.gitignore` file as a list of file patterns

# Ignoring Files Using Glob Patterns

Examples of various glob patterns you can use:

- Using a file extension glob (these match files at any directory depth):
  - ▶ `*.o`
  - ▶ `*.a`
- Anchoring a pattern to a specific directory (start with `/`):
  - ▶ `/dist/*.o`
  - ▶ `/log/*.log`
- Ignoring entire directories (end in `/`):
  - ▶ `log/`
  - ▶ `/tmp/`
- Remove a pattern from the ignore list (start with `!`):
  - ▶ `!*.*`

# What is Stashing?

Stashing is for those times when you are in the middle of working but need to switch tasks. With stashing you can:

1. Save modifications to tracked files, new files, and staged changes
2. Safely clean your working directory
3. Come back later and restore the changes from step 1

# Saving Work In Progress without Committing

The fastest way to save your work in progress and restore the three trees to HEAD:

```
$ git stash
```

This will leave you with a clean index and working directory.

(Note: You can use the `--message` option to name the new stash object. You can also use the `--all` option to capture ignored files.)

# Listing and Recovering Stashes

List stashes:

```
$ git stash list
```

Restore the first stash (`stash@{0}`) and then delete it:

```
$ git stash pop
```

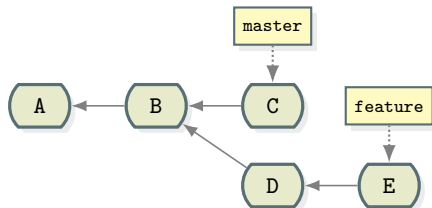
Restore the first stash without deleting it:

```
$ git stash apply
```

## Exercise: Pushing and Popping the Stash

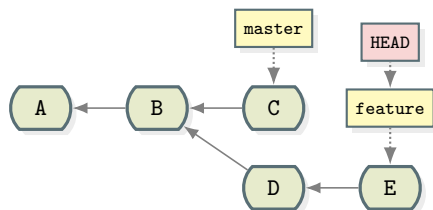
1. Change to the directory holding a clone of the following repository:  
`repos/conflicts.git`
2. Create a branch that starts off the `origin/feature` branch
3. Add a comment to the bottom of `main.c`
4. Create a new stash
5. Review the index and working directory state
6. Restore the stash that was previously created

# Separate Lines of Development



- Branches allow you to work independently of others
- The default branch in Git is called *master*
- Branches can be joined back together via *merging*

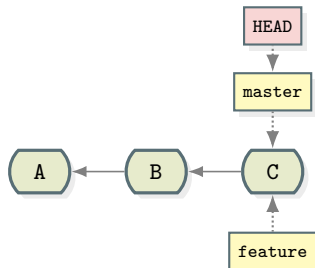
# What Branch Are You Using?



- Git uses a pointer called HEAD to track the current branch
- The `.git/HEAD` file references a branch's head
- A branch's head is its latest commit ID



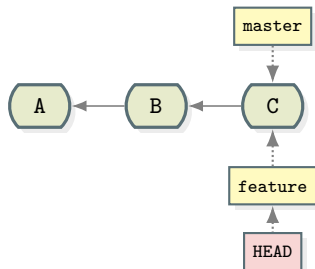
# How Do You Create a Branch?



```
$ git branch feature
```

- Creates a branch called `feature`
- `HEAD` still points at `master`

# How Do You Switch Branches?



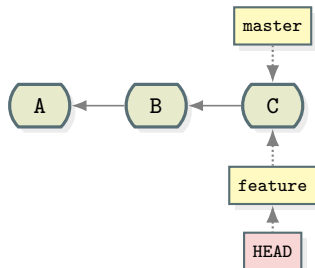
```
$ git checkout feature
```

- Changes where HEAD points
- (HEAD now points to the feature branch)

## Exercise: Moving HEAD Around

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. List the names of all branches
3. For each branch:
  1. Check out the branch
  2. Use `git log --oneline` to find the latest commit hash

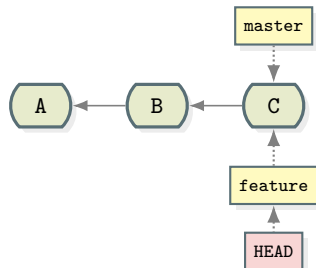
# Creating and Switching Branches



```
$ git checkout -b feature
```

- Create a feature branch
- And point HEAD at feature

# Creating a Branch from a Revision



```
$ git checkout -b feature master
```

- Create a feature branch which starts at master
- And point HEAD at feature

## Exercise: Creating Branches

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Switch to the `master` branch
3. Create a new branch called `m2`
4. Use `git log` to see the latest commit:  
  
`$ git log --oneline -1`
5. Create a branch called `f2` that starts at `merge-start`
6. Compare the latest commits on `m2` and `f2`

## Viewing Files from Other Branches

Sometimes you just want to view a complete file the way it is on another branch (or revision). You can do that with `git show`:

```
$ git show master:main.c  
# [file contents]
```

```
$ git show HEAD^:main.c  
# [file contents]
```

Note: You can use the `--no-pager` option to `git` to dump the entire file to the terminal without using a pager.

## Using `git diff` with Branch Names

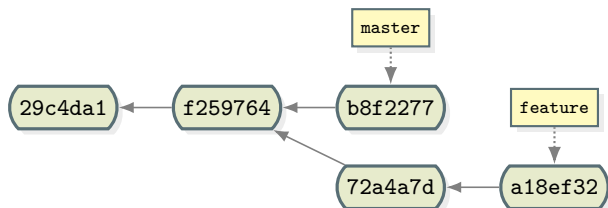
See how files changed in `feature` compared to `master`:

```
$ git diff master..feature
```

- Compares the tip of `master` with the tip of `feature`
- Note: uses two dots ("`..`")
- If `master` has diverged you need to compare specific revisions instead



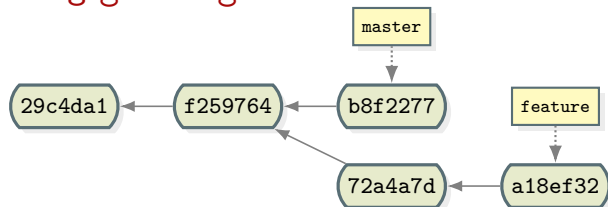
## Using git diff with a Merge Base



```
$ git merge-base feature master  
f259764e2f5a16eae7b33a96a8fb5105df99cbfb  
$ git diff f259764..feature
```

- Used when the base branch has diverged
- The merge-base subcommand locates the common ancestor
- Shortcut: `git diff master...feature` (Note: three dots)

# Using git log to Visualize Branches



```
$ git log --oneline --abbrev-commit \  
    --all --graph --decorate --color
```

```
* a18ef32 (feature) Add a missing newline character  
* 72a4a7d Add a version number  
| * b8f2277 (master) Add a proper greeting message  
|/  
* f259764 Indicate success by returning zero  
* 29c4da1 Initial import of main.c
```

# Using gitk to Visualize Branches

Sometimes it's easier to use a GUI:

```
$ gitk --all
```

**File Edit View Help**

**feature** Add a missing newline character

Add a version number

**master** Add a proper greeting message

Indicate success by returning zero

Initial import of main.c

Samantha Bee < 2018-04-17 16:58:50

Samantha Bee < 2018-04-17 16:58:50

Jane Doe <jdoe@ 2018-04-17 16:58:50

Jane Doe <jdoe@ 2018-04-17 16:58:50

Jane Doe <jdoe@ 2018-04-17 16:58:50

**SHA1 ID:** a18ef32212ae8b283c11acbadc729645e70d370c

Row 1 / 5

# Safely Deleting Branches

If a branch has been pushed or merged it can be safely deleted:

```
$ git branch --delete feature
```

# or, the shortcut...

```
$ git branch -d feature
```

# Deleting Branches with Extreme Prejudice

You can delete a branch without any safety checks:

```
$ git branch --delete --force feature
```

# beware of the shortcut:

```
$ git branch -D feature
```

## Recreating a Deleted Branch

```
$ git branch -D feature  
Deleted branch feature (was a18ef32).
```

```
$ git branch feature a18ef32  
# branch is now restored
```

- As long as the deleted branch's commits have not been pruned by the garbage collector you can recover the branch.

# Deleting Remote Branches

When you are completely done with a branch you may want to delete your local copy and any remote copies. Remote copies can be deleted with `git push`:

```
$ git push --delete origin feature
```

# What is a Tag?

- In Git a tag is a pointer to a specific commit object.
- Typically they are used for recording a software release and include details about who made the release.



# Creating Tags

To create a tag that points to HEAD:

```
$ git tag <name>
```

For release you probably want to create an annotated tag:

```
$ git tag -a <name>
```

You can also:

- Sign a tag using your GPG private key
- Create a tag that points at any commit

## Listing Tags

Once you have tags in your repository you can list them:

```
$ git tag --list
```

To list tags from a remote you can:

```
$ git ls-remote --tags <remote>
```

# Deleting or Recreating Tags

Tags can be safely deleted when no longer needed:

```
$ git tag --delete <name>
```

If you absolutely must recreate an existing tag, and you understand the problems it might cause, you can:

```
$ git tag --force -a <name>
```

## Branching from a Tag

Once a tag is created you can start a new branch off it:

```
$ git checkout -b <branch-name> <tag-name>
```

This is useful for creating a branch to fix a bug in a past release.

# Pushing Tags

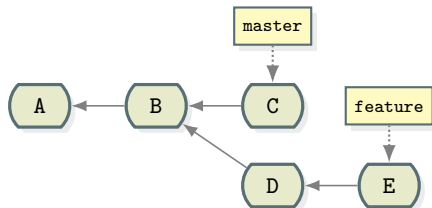
Which pushing branches to a remote Git will *not* push tags automatically.  
You must do it manually:

```
$ git push --tags
```

## Exercise: Tagging the Current Commit

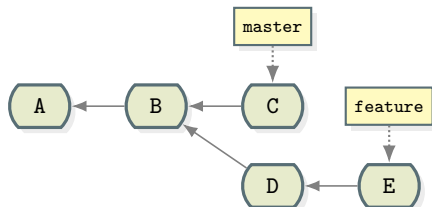
1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Create a tag called `v1.1`
3. Use `git tag --list` to list your tags
4. Try using `git rev-parse` to see how the tag name resolves
5. Create a branch starting from the tag
6. Push the tag back to the `origin` remote
7. Use `git ls-remote` to confirm the tags were pushed

# Merging Branches



- Work on the feature branch is complete
- We would like commits D and E to move to the `master` branch
- We will do this through merging

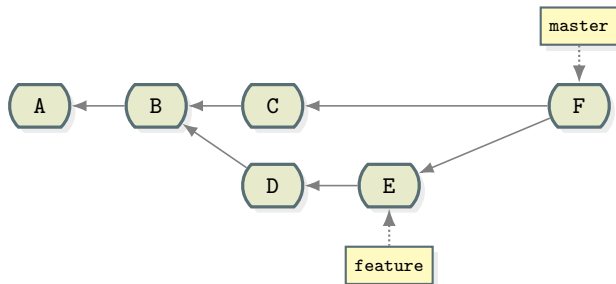
# Revisiting the Merge Base



- The feature branch and master branch share a common ancestor
- That ancestor is commit B
- Git will perform a 3-way merge with B, C, and E
- The result is a commit with two parents



# Merges Cause Multiple Parents



- A new commit is created: F
- This is called a *merge commit* and has two parents

# Performing a Merge

1. Switch to the destination branch:

```
$ git checkout master
```

2. Merge in the other branch:

```
$ git merge feature
```

3. Write a commit message in your text editor

## Exercise: Merging a Branch

1. Change to the directory holding a clone of the following repository:  
`repos/basic.git`
2. Create and switch to a new branch that starts at v1.0:  
`$ git checkout -b NAME v1.0`
3. Merge the `origin/feature` branch into your new branch

# What is a Merge Conflict?

- You are merging two branches that changed the same thing
- Git doesn't assume one change is more important than the other
- The merge process is paused and you must resolve the issue
- After resolving issues, you resume the merge process

# How Git Reports a Merge Conflict

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

## What git status Shows During a Conflict

On branch master

You have unmerged paths.

(fix conflicts and run "git commit")

(use "git merge --abort" to abort the merge)

Unmerged paths:

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

both modified: main.c

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

# Merge Conflict Markers

```
int main (int argc, char** argv) {  
<<<<<< HEAD  
    printf("%s\n", "Hello Everyone");  
=====  
    print_version();  
    printf("%s\n", "Hello World!");  
>>>>>> feature  
    return 0;  
}
```

# Resolving Merge Conflicts

1. Edit all files that are *unmerged*
2. Use `git add` to add them to the index
3. Finish the merge by using `git commit`



## Exercise: Merging with Conflicts

1. Change to the directory holding a clone of the following repository:  
`repos/conflicts.git`
2. Create and switch to a new branch that starts at v1.0:  
`$ git checkout -b NAME v1.0`
3. Merge the `origin/feature` branch into your new branch
4. Resolve conflicts and finish the merge

## Merging a Remote Branch into HEAD

Let's say you want to merge `origin/master` into `master`:

```
$ git pull origin master
```

Or more simply:

```
$ git pull
```

Which is a shortcut for:

```
$ git fetch origin
```

```
$ git merge origin/master
```

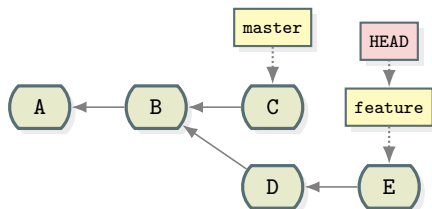
# What is Rebasing?

When rebasing a topic branch (i.e. `feature`) onto an ancestor branch (i.e. `master`):

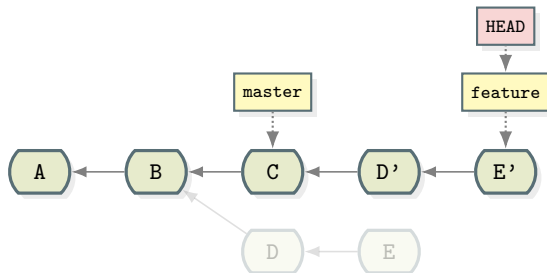
- A new commit history is created for `feature` so that it comes *after* all work on `master`
- New commits are created, old commits are abandoned
- Commits are created by *replaying* diffs on top of `master`

# Visualizing a Rebase

Before the rebase:



After the rebase:



# A Word of Caution

While rebasing is completely safe, it can make things difficult if you are not careful.

- Rebasing published branches can lead duplicated commits for other team members
- Best practice: Rebase before pushing commits to a remote branch
- Each team member should work on their own branches
- We'll talk about ways to fix things if you break these rules

# Listing Remotes

- When you clone a repository it will have one remote by default: *origin*
- The origin remote points back to the original clone URL
- You can list remotes with the following command:

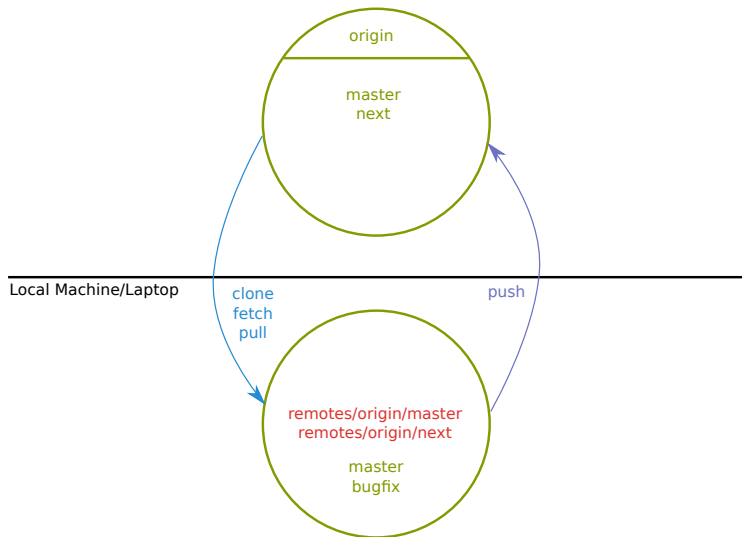
```
$ git remote -v show
```

## Exercise: Listing Remotes

1. Go into any repository that we've used today
2. List the remotes for that repository
3. What does the `-v` flag do?

# Typical Remote Setup

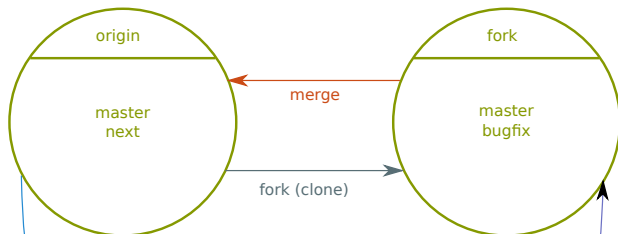
Remote Server



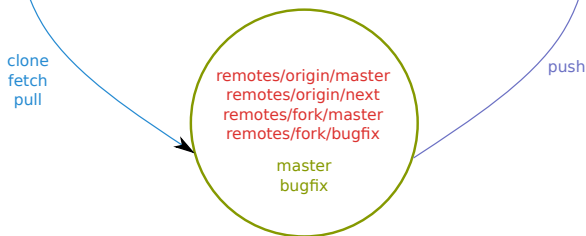


# Dual Remote Setup (Fork)

Remote Server



Local Machine/Laptop



# Adding Remotes

It's common to have more than one remote. To add another remote you:

```
$ git remote add <name> <url>
```

Reasons to have additional remotes:

- Pull from a coworker's repo
- Backup your repository without pushing to the central one
- Creating a pull request on an open source project

# Renaming and Removing Remotes

You can rename a remote:

```
$ git remote rename <old> <new>
```

or completely remove a remote from your repository:

```
$ git remote remove <name>
```

# Fetching Objects from a Remote

You can fetch all objects from a remote by:

```
$ git fetch <remote>
```

(Note: this fetches objects and places them in the repository but does not change any branches.)

# Fetching and Updating Branches

If you want to fetch objects from a remote and then update your branch to match upstream you have two choices:

1. Fetch and then merge:

```
$ git fetch <remote>  
$ git merge origin/master
```

2. Use git pull:

```
$ git pull origin master
```

(Note: if you are on a tracking branch you can use `git pull` without any arguments.)

# Pushing Objects to Remotes

To publish your changes to a remote you can:

```
$ git push origin master
```

This pushes your changes to the origin server's master branch.

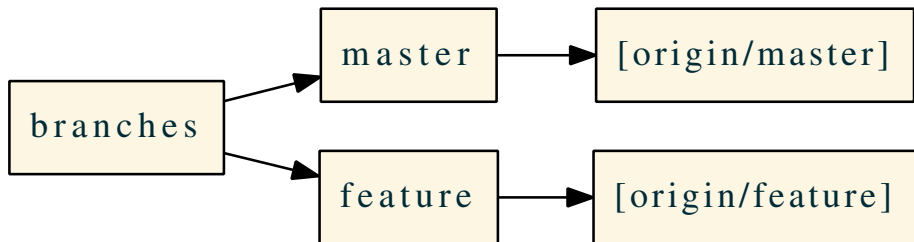
(Note: if you are on a tracking branch you can use `git push` without any arguments.)

# Pushing Tags to Remotes

Using `git push` won't send your tags to the remote by default. You have to use the `--tags` flag:

```
$ git push --tags origin
```

# What is a Tracking Branch?



A *tracking branch* is branch that is linked to a specific remote repository.



## Creating Tracking Branches

If you `git checkout` a branch that has the same name as a remote branch it will automatically track the remote branch:

```
$ git branch --all
* master
  remotes/origin/HEAD -> origin/master
  remotes/origin/feature
  remotes/origin/master
$ git checkout feature
Branch 'feature' set up to track remote branch 'feature' from
```

# Manually Creating Tracking Branches

You can manually create a branch and set its tracking information:

```
$ git checkout -b ft origin/feature
```

Branch 'ft' set up to track remote branch 'feature' from 'origin'

# Getting Tracking Information

To see tracking information for local branches:

```
$ git branch -vv
```

```
* master 7f86f19 [origin/master] Add a proper greeting message
```

# Setting Tracking Information

To change the tracking information for the current branch:

```
$ git branch -u origin/master
```

```
Branch 'master' set up to track remote branch 'master' from 'origin'
```