2.4 Git Basics - Undoing Things

Undoing Things

At any stage, you may want to undo something. Here, we'll review a few basic tools for undoing changes that you've made. Be careful, because you can't always undo some of these undos. This is one of the few areas in Git where you may lose some work if you do it wrong.

One of the common undos takes place when you commit too early and possibly forget to add some files, or you mess up your commit message. If you want to try that commit again, you can run commit with the `--amend` option:

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

This command takes your staging area and uses it for the commit. If you've made no changes since your last commit (for instance, you run this command immediately after your previous commit), then your snapshot will look exactly the same, and all you'll change is your commit message.

The same commit-message editor fires up, but it already contains the message of your previous commit. You can edit the message the same as always, but it overwrites your previous commit.

As an example, if you commit and then realize you forgot to stage the changes in a file you wanted to add to this commit, you can do something like this:

```
$ git commit -m 'initial commit'
$ git add forgotten_file
$ git commit --amend
```

You end up with a single commit – the second commit replaces the results of the first.

Unstaging a Staged File

The next two sections demonstrate how to wrangle your staging area and working directory changes. The nice part is that the command you use to determine the state of those two areas also reminds you how to undo changes to them. For example, let's say you've changed two files and want to commit them as two separate changes, but you accidentally type `git add *` and stage them both. How can you unstage one of the two? The `git status` command reminds you:

```
$ git add *
$ git status
On branch master
Changes to be committed:
  (use "git reset HEAD &lt;file&gt;..." to unstage)

    renamed:    README.md -&gt; README
```

```
    modified:   CONTRIBUTING.md
```

Right below the “Changes to be committed” text, it says use `git reset HEAD <file>...` to unstage. So, let’s use that advice to unstage the `CONTRIBUTING.md` file:

```
$ git reset HEAD CONTRIBUTING.md
Unstaged changes after reset:
M       CONTRIBUTING.md
$ git status
On branch master
Changes to be committed:
  (use "git reset HEAD &lt;file&gt;..." to unstage)

    renamed:    README.md -&gt; README

Changes not staged for commit:
  (use "git add &lt;file&gt;..." to update what will be committed)
  (use "git checkout -- &lt;file&gt;..." to discard changes in working directory)

    modified:   CONTRIBUTING.md
```

The command is a bit strange, but it works. The `CONTRIBUTING.md` file is modified but once again unstaged.

NOTE

While `git reset` *can* be a dangerous command if you call it with `--hard`, in this instance the file in your working directory is not touched. Calling `git reset` without an option is not dangerous - it only touches your staging area.

For now this magic invocation is all you need to know about the `git reset` command. We’ll go into much more detail about what `reset` does and how to master it to do really interesting things in Reset Demystified.

Unmodifying a Modified File

What if you realize that you don’t want to keep your changes to the `CONTRIBUTING.md` file? How can you easily unmodify it – revert it back to what it looked like when you last committed (or initially cloned, or however you got it into your working directory)? Luckily, `git status` tells you how to do that, too. In the last example output, the unstaged area looks like this:

```
Changes not staged for commit:
  (use "git add &lt;file&gt;..." to update what will be committed)
  (use "git checkout -- &lt;file&gt;..." to discard changes in working directory)

    modified:   CONTRIBUTING.md
```

It tells you pretty explicitly how to discard the changes you’ve made. Let’s do what it says:

```
$ git checkout -- CONTRIBUTING.md
$ git status
On branch master
```

```
Changes to be committed:
  (use "git reset HEAD &lt;file&gt;..." to unstage)

    renamed:    README.md -&gt; README
```

You can see that the changes have been reverted.

IMPORTANT
It's important to understand that `git checkout -- [file]` is a dangerous command. Any changes you made to that file are gone – you just copied another file over it. Don't ever use this command unless you absolutely know that you don't want the file.
If you would like to keep the changes you've made to that file but still need to get it out of the way for now, we'll go over stashing and branching in Git Branching; these are generally better ways to go. Remember, anything that is *committed* in Git can almost always be recovered. Even commits that were on branches that were deleted or commits that were overwritten with an `--amend` commit can be recovered (see Data Recovery for data recovery). However, anything you lose that was never committed is likely never to be seen again.

2.5 Git Basics - Working with Remotes

Working with Remotes

To be able to collaborate on any Git project, you need to know how to manage your remote repositories. Remote repositories are versions of your project that are hosted on the Internet or network somewhere. You can have several of them, each of which generally is either read-only or read/write for you. Collaborating with others involves managing these remote repositories and pushing and pulling data to and from them when you need to share work. Managing remote repositories includes knowing how to add remote repositories, remove remotes that are no longer valid, manage various remote branches and define them as being tracked or not, and more. In this section, we'll cover some of these remote-management skills.

Showing Your Remotes

To see which remote servers you have configured, you can run the `git remote` command. It lists the shortnames of each remote handle you've specified. If you've cloned your repository, you should at least see origin – that is the default name Git gives to the server you cloned from:

```
$ git clone https://github.com/schacon/ticgit
Cloning into 'ticgit'...
remote: Reusing existing pack: 1857, done.
remote: Total 1857 (delta 0), reused 0 (delta 0)
Receiving objects: 100% (1857/1857), 374.35 KiB | 268.00 KiB/s, done.
Resolving deltas: 100% (772/772), done.
Checking connectivity... done.
```

```
$ cd ticgit
$ git remote
origin
```

You can also specify `-v`, which shows you the URLs that Git has stored for the shortname to be used when reading and writing to that remote:

```
$ git remote -v
origin  https://github.com/schacon/ticgit (fetch)
origin  https://github.com/schacon/ticgit (push)
```

If you have more than one remote, the command lists them all. For example, a repository with multiple remotes for working with several collaborators might look something like this.

```
$ cd grit
$ git remote -v
bakkdoor  https://github.com/bakkdoor/grit (fetch)
bakkdoor  https://github.com/bakkdoor/grit (push)
cho45     https://github.com/cho45/grit (fetch)
cho45     https://github.com/cho45/grit (push)
defunkt   https://github.com/defunkt/grit (fetch)
defunkt   https://github.com/defunkt/grit (push)
koke      git://github.com/koke/grit.git (fetch)
koke      git://github.com/koke/grit.git (push)
origin    git@github.com:mojombo/grit.git (fetch)
origin    git@github.com:mojombo/grit.git (push)
```

This means we can pull contributions from any of these users pretty easily. We may additionally have permission to push to one or more of these, though we can't tell that here.

Notice that these remotes use a variety of protocols; we'll cover more about this in Getting Git on a Server.

Adding Remote Repositories

We've mentioned and given some demonstrations of adding remote repositories in previous sections, but here is how to do it explicitly. To add a new remote Git repository as a shortname you can reference easily, run `git remote add [shortname] [url]`:

```
$ git remote
origin
$ git remote add pb https://github.com/paulboone/ticgit
$ git remote -v
origin  https://github.com/schacon/ticgit (fetch)
origin  https://github.com/schacon/ticgit (push)
pb      https://github.com/paulboone/ticgit (fetch)
pb      https://github.com/paulboone/ticgit (push)
```

Now you can use the string `pb` on the command line in lieu of the whole URL. For example, if you want to fetch all the information that Paul has but that you don't yet have in your repository, you can run `git fetch pb`:

```
$ git fetch pb
remote: Counting objects: 43, done.
remote: Compressing objects: 100% (36/36), done.
remote: Total 43 (delta 10), reused 31 (delta 5)
Unpacking objects: 100% (43/43), done.
From https://github.com/paulboone/ticgit
 * [new branch]      master     -&gt; pb/master
 * [new branch]      ticgit     -&gt; pb/ticgit
```

Paul's master branch is now accessible locally as `pb/master` – you can merge it into one of your branches, or you can check out a local branch at that point if you want to inspect it. (We'll go over what branches are and how to use them in much more detail in Git Branching.)

Fetching and Pulling from Your Remotes

As you just saw, to get data from your remote projects, you can run:

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

The command goes out to that remote project and pulls down all the data from that remote project that you don't have yet. After you do this, you should have references to all the branches from that remote, which you can merge in or inspect at any time.

If you clone a repository, the command automatically adds that remote repository under the name "origin". So, `git fetch origin` fetches any new work that has been pushed to that server since you cloned (or last fetched from) it. It's important to note that the `git fetch` command pulls the data to your local repository – it doesn't automatically merge it with any of your work or modify what you're currently working on. You have to merge it manually into your work when you're ready.
If you have a branch set up to track a remote branch (see the next section and Git Branching for more information), you can use the `git pull` command to automatically fetch and then merge a remote branch into your current branch. This may be an easier or more comfortable workflow for you; and by default, the `git clone` command automatically sets up your local master branch to track the remote master branch (or whatever the default branch is called) on the server you cloned from. Running `git pull` generally fetches data from the server you originally cloned from and automatically tries to merge it into the code you're currently working on.

Pushing to Your Remotes

When you have your project at a point that you want to share, you have to push it upstream. The command for this is simple: `git push [remote-name] [branch-name]`. If you want to push your master branch to your `origin` server (again, cloning generally sets up both of those names for you automatically), then you can run this to push any commits you've done back up to the server:

```
$ git push origin master
```

This command works only if you cloned from a server to which you have write access and if nobody has pushed in the meantime. If you and someone else clone at the same time and they push upstream and then you push upstream, your push will rightly be rejected. You'll have to pull down their work first and incorporate it into yours before you'll be allowed to push. See Git Branching for more detailed information on how to push to remote servers.

Inspecting a Remote

If you want to see more information about a particular remote, you can use the `git remote show [remote-name]` command. If you run this command with a particular shortname, such as `origin`, you get something like this:

```
$ git remote show origin
* remote origin
  Fetch URL: https://github.com/schacon/ticgit
  Push  URL: https://github.com/schacon/ticgit
  HEAD branch: master
  Remote branches:
    master                               tracked
    dev-branch                           tracked
  Local branch configured for 'git pull':
    master merges with remote master
  Local ref configured for 'git push':
    master pushes to master (up to date)
```

It lists the URL for the remote repository as well as the tracking branch information. The command helpfully tells you that if you're on the master branch and you run `git pull`, it will automatically merge in the master branch on the remote after it fetches all the remote references. It also lists all the remote references it has pulled down.

That is a simple example you're likely to encounter. When you're using Git more heavily, however, you may see much more information from `git remote show`:

```
$ git remote show origin
* remote origin
  URL: https://github.com/my-org/complex-project
  Fetch URL: https://github.com/my-org/complex-project
  Push  URL: https://github.com/my-org/complex-project
  HEAD branch: master
  Remote branches:
    master                           tracked
    dev-branch                       tracked
    markdown-strip                   tracked
    issue-43                         new (next fetch will store in remotes/origin)
    issue-45                         new (next fetch will store in remotes/origin)
    refs/remotes/origin/issue-11     stale (use 'git remote prune' to remove)
  Local branches configured for 'git pull':
    dev-branch merges with remote dev-branch
    master     merges with remote master
  Local refs configured for 'git push':
    dev-branch                     pushes to dev-branch                     (up to
date)
```

```
    markdown-strip                pushes to markdown-strip                (up to
date)
    master                        pushes to master                        (up to
date)
```

This command shows which branch is automatically pushed to when you run `git push` while on certain branches. It also shows you which remote branches on the server you don't yet have, which remote branches you have that have been removed from the server, and multiple branches that are automatically merged when you run `git pull`.

Removing and Renaming Remotes

If you want to rename a reference you can run `git remote rename` to change a remote's shortname.For instance, if you want to rename `pb` to `paul`, you can do so with `git remote rename`:

```
$ git remote rename pb paul
$ git remote
origin
paul
```

It's worth mentioning that this changes your remote branch names, too. What used to be referenced at `pb/master` is now at `paul/master`.

If you want to remove a remote for some reason – you've moved the server or are no longer using a particular mirror, or perhaps a contributor isn't contributing anymore – you can use `git remote rm`:

```
$ git remote rm paul
$ git remote
origin
```

2.6 Git Basics - Tagging

Tagging

Like most VCSs, Git has the ability to tag specific points in history as being important. Typically people use this functionality to mark release points (v1.0, and so on). In this section, you'll learn how to list the available tags, how to create new tags, and what the different types of tags are.

Listing Your Tags

Listing the available tags in Git is straightforward. Just type `git tag`:

```
$ git tag
v0.1
v1.3
```

This command lists the tags in alphabetical order; the order in which they appear has no real importance.

You can also search for tags with a particular pattern. The Git source repo, for instance, contains more than 500 tags. If you're only interested in looking at the 1.8.5 series, you can run this:

```
$ git tag -l 'v1.8.5*'
v1.8.5
v1.8.5-rc0
v1.8.5-rc1
v1.8.5-rc2
v1.8.5-rc3
v1.8.5.1
v1.8.5.2
v1.8.5.3
v1.8.5.4
v1.8.5.5
```

Creating Tags

Git uses two main types of tags: lightweight and annotated.

A lightweight tag is very much like a branch that doesn't change – it's just a pointer to a specific commit.

Annotated tags, however, are stored as full objects in the Git database. They're checksummed; contain the tagger name, email, and date; have a tagging message; and can be signed and verified with GNU Privacy Guard (GPG). It's generally recommended that you create annotated tags so you can have all this information; but if you want a temporary tag or for some reason don't want to keep the other information, lightweight tags are available too.

Annotated Tags

Creating an annotated tag in Git is simple. The easiest way is to specify `-a` when you run the `tag` command:

```
$ git tag -a v1.4 -m 'my version 1.4'
$ git tag
v0.1
v1.3
v1.4
```

The `-m` specifies a tagging message, which is stored with the tag. If you don't specify a message for an annotated tag, Git launches your editor so you can type it in.
You can see the tag data along with the commit that was tagged by using the `git show` command:

```
$ git show v1.4
tag v1.4
Tagger: Ben Straub &lt;ben@straub.cc&gt;
```

```
Date:   Sat May 3 20:19:12 2014 -0700

my version 1.4

commit ca82a6dff817ec66f44342007202690a93763949
Author: Scott Chacon &lt;schacon@gee-mail.com&gt;
Date:   Mon Mar 17 21:52:11 2008 -0700

    changed the version number
```

That shows the tagger information, the date the commit was tagged, and the annotation message before showing the commit information.

Lightweight Tags

Another way to tag commits is with a lightweight tag. This is basically the commit checksum stored in a file – no other information is kept. To create a lightweight tag, don't supply the `-a`, `-s`, or `-m` option:

```
$ git tag v1.4-lw
$ git tag
v0.1
v1.3
v1.4
v1.4-lw
v1.5
```

This time, if you run `git show` on the tag, you don't see the extra tag information. The command just shows the commit:

```
$ git show v1.4-lw
commit ca82a6dff817ec66f44342007202690a93763949
Author: Scott Chacon &lt;schacon@gee-mail.com&gt;
Date:   Mon Mar 17 21:52:11 2008 -0700

    changed the version number
```

Tagging Later

You can also tag commits after you've moved past them. Suppose your commit history looks like this:

```
$ git log --pretty=oneline
15027957951b64cf874c3557a0f3547bd83b3ff6 Merge branch 'experiment'
a6b4c97498bd301d84096da251c98a07c7723e65 beginning write support
0d52aaab4479697da7686c15f77a3d64d9165190 one more thing
6d52a271eda8725415634dd79daabbc4d9b6008e Merge branch 'experiment'
0b7434d86859cc7b8c3d5e1dddfed66ff742fcbc added a commit function
4682c3261057305bdd616e23b64b0857d832627b added a todo file
166ae0c4d3f420721acbb115cc33848dfcc2121a started write support
9fceb02d0ae598e95dc970b74767f19372d61af8 updated rakefile
```

```
964f16d36dfccde844893cac5b347e7b3d44abbc commit the todo
8a5cbc430f1a9c3d00faaeffd07798508422908a updated readme
```

Now, suppose you forgot to tag the project at v1.2, which was at the “updated rakefile” commit. You can add it after the fact. To tag that commit, you specify the commit checksum (or part of it) at the end of the command:

```
$ git tag -a v1.2 9fceb02
```

You can see that you’ve tagged the commit:

```
$ git tag
v0.1
v1.2
v1.3
v1.4
v1.4-lw
v1.5

$ git show v1.2
tag v1.2
Tagger: Scott Chacon &lt;schacon@gee-mail.com&gt;
Date:   Mon Feb 9 15:32:16 2009 -0800

version 1.2
commit 9fceb02d0ae598e95dc970b74767f19372d61af8
Author: Magnus Chacon &lt;mchacon@gee-mail.com&gt;
Date:   Sun Apr 27 20:43:35 2008 -0700

    updated rakefile
...
```

Sharing Tags

By default, the `git push` command doesn’t transfer tags to remote servers. You will have to explicitly push tags to a shared server after you have created them. This process is just like sharing remote branches – you can run `git push origin [tagname]`.

```
$ git push origin v1.5
Counting objects: 14, done.
Delta compression using up to 8 threads.
Compressing objects: 100% (12/12), done.
Writing objects: 100% (14/14), 2.05 KiB | 0 bytes/s, done.
Total 14 (delta 3), reused 0 (delta 0)
To git@github.com:schacon/simplegit.git
 * [new tag]         v1.5 -&gt; v1.5
```

If you have a lot of tags that you want to push up at once, you can also use the `--tags` option to the `git push` command. This will transfer all of your tags to the remote server that are not already there.

```
$ git push origin --tags
Counting objects: 1, done.
Writing objects: 100% (1/1), 160 bytes | 0 bytes/s, done.
Total 1 (delta 0), reused 0 (delta 0)
To git@github.com:schacon/simplegit.git
 * [new tag]         v1.4 -&gt; v1.4
 * [new tag]         v1.4-lw -&gt; v1.4-lw
```

Now, when someone else clones or pulls from your repository, they will get all your tags as well.

Checking out Tags

You can't really check out a tag in Git, since they can't be moved around. If you want to put a version of your repository in your working directory that looks like a specific tag, you can create a new branch at a specific tag with `git checkout -b [branchname] [tagname]`:

```
$ git checkout -b version2 v2.0.0
Switched to a new branch 'version2'
```

Of course if you do this and do a commit, your `version2` branch will be slightly different than your `v2.0.0` tag since it will move forward with your new changes, so do be careful.

2.7 Git Basics - Git Aliases

Git Aliases

Before we finish this chapter on basic Git, there's just one little tip that can make your Git experience simpler, easier, and more familiar: aliases. We won't refer to them or assume you've used them later in the book, but you should probably know how to use them.

Git doesn't automatically infer your command if you type it in partially. If you don't want to type the entire text of each of the Git commands, you can easily set up an alias for each command using `git config`. Here are a couple of examples you may want to set up:

```
$ git config --global alias.co checkout
$ git config --global alias.br branch
$ git config --global alias.ci commit
$ git config --global alias.st status
```

This means that, for example, instead of typing `git commit`, you just need to type `git ci`. As you go on using Git, you'll probably use other commands frequently as well; don't hesitate to create new aliases.

This technique can also be very useful in creating commands that you think should exist. For example, to correct the usability problem you encountered with unstaging a file, you can add your own unstage alias to Git:

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

This makes the following two commands equivalent:

```
$ git unstage fileA
$ git reset HEAD -- fileA
```

This seems a bit clearer. It's also common to add a `last` command, like this:

```
$ git config --global alias.last 'log -1 HEAD'
```

This way, you can see the last commit easily:

```
$ git last
commit 66938dae3329c7aebe598c2246a8e6af90d04646
Author: Josh Goebel &lt;dreamer3@example.com&gt;
Date:   Tue Aug 26 19:48:51 2008 +0800

    test for current head

    Signed-off-by: Scott Chacon &lt;schacon@example.com&gt;
```

As you can tell, Git simply replaces the new command with whatever you alias it for. However, maybe you want to run an external command, rather than a Git subcommand. In that case, you start the command with a `!` character. This is useful if you write your own tools that work with a Git repository. We can demonstrate by aliasing `git visual` to run `gitk`:

```
$ git config --global alias.visual '!gitk'
```

2.8 Git Basics - Summary

Summary

At this point, you can do all the basic local Git operations – creating or cloning a repository, making changes, staging and committing those changes, and viewing the history of all the changes the repository has been through. Next, we'll cover Git's killer feature: its branching model.

3.1 Git Branching - Branches in a Nutshell

Nearly every VCS has some form of branching support. Branching means you diverge from the main line of development and continue to do work without messing with that main line. In many VCS tools, this is a somewhat expensive process, often requiring you to create a new copy of your source code directory, which can take a long time for large projects.

Branches in a Nutshell

To really understand the way Git does branching, we need to take a step back and examine how Git stores its data.

As you may remember from Getting Started, Git doesn't store data as a series of changesets or differences, but instead as a series of snapshots.
When you make a commit, Git stores a commit object that contains a pointer to the snapshot of the content you staged. This object also contains the author's name and email, the message that you typed, and pointers to the commit or commits that directly came before this commit (its parent or parents): zero parents for the initial commit, one parent for a normal commit, and multiple parents for a commit that results from a merge of two or more branches.

To visualize this, let's assume that you have a directory containing three files, and you stage them all and commit. Staging the files checksums each one (the SHA-1 hash we mentioned in Getting Started), stores that version of the file in the Git repository (Git refers to them as blobs), and adds that checksum to the staging area:

```
$ git add README test.rb LICENSE
$ git commit -m 'The initial commit of my project'
```

When you create the commit by running `git commit`, Git checksums each subdirectory (in this case, just the root project directory) and stores those tree objects in the Git repository. Git then

creates a commit object that has the metadata and a pointer to the root project tree so it can re-create that snapshot when needed.
Your Git repository now contains five objects: one blob for the contents of each of your three files, one tree that lists the contents of the directory and specifies which file names are stored as which blobs, and one commit with the pointer to that root tree and all the commit metadata.

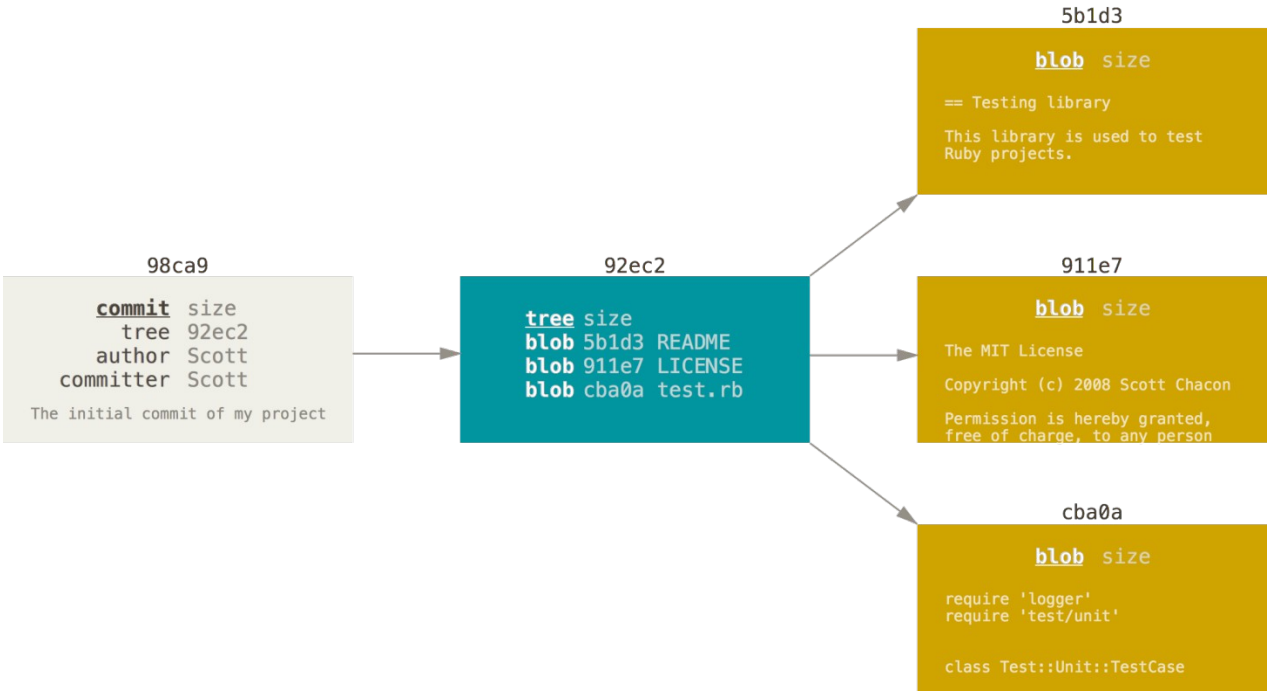


Figure 3-1. A commit and its tree

If you make some changes and commit again, the next commit stores a pointer to the commit that came immediately before it.

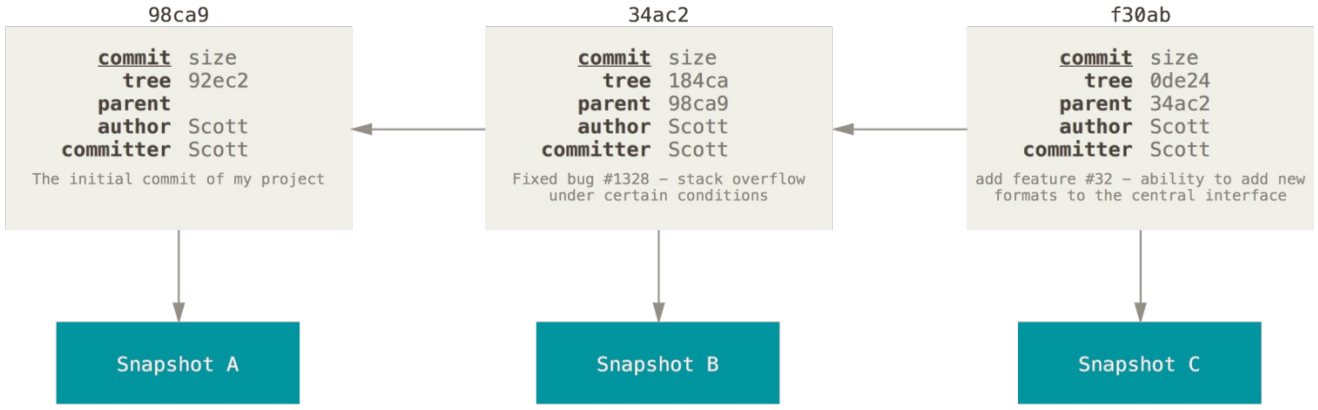


Figure 3-2. Commits and their parents

A branch in Git is simply a lightweight movable pointer to one of these commits. The default branch name in Git is `master`. As you start making commits, you're given a `master` branch that points to the last commit you made. Every time you commit, it moves forward automatically.

NOTE
The "master" branch in Git is not a special branch. It is exactly like any other branch. The only reason nearly every repository has one is that the `git init` command creates it by default and most people don't bother to change it.

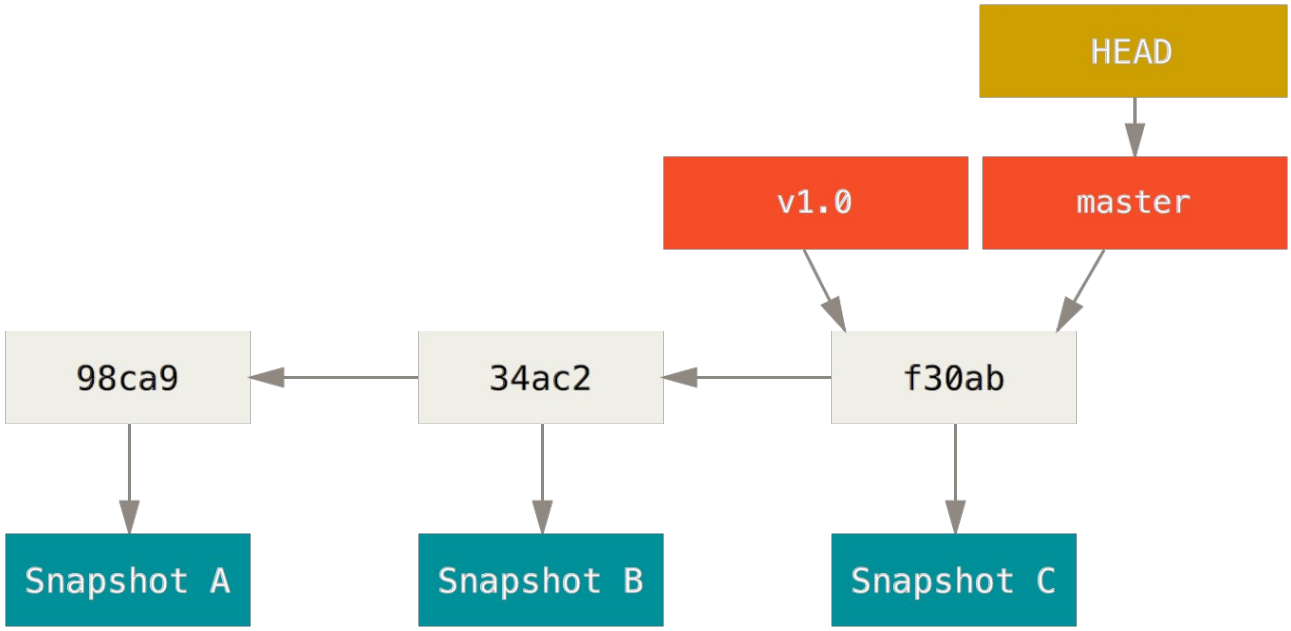


Figure 3-3. A branch and its commit history

Creating a New Branch

What happens if you create a new branch? Well, doing so creates a new pointer for you to move around. Let's say you create a new branch called testing. You do this with the `git branch` command:

```
$ git branch testing
```

This creates a new pointer at the same commit you're currently on.

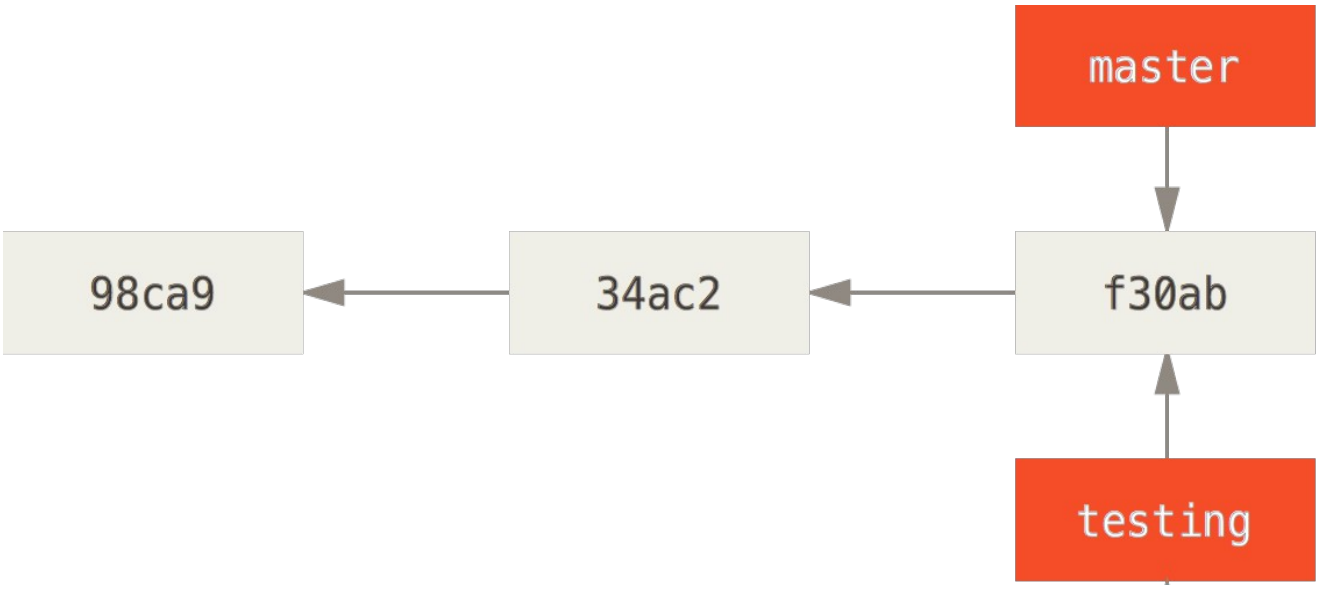


Figure 3-4. Two branches pointing into the same series of commits

How does Git know what branch you're currently on? It keeps a special pointer called `HEAD`. Note that this is a lot different than the concept of `HEAD` in other VCSs you may be used to, such as Subversion or CVS. In Git, this is a pointer to the local branch you're currently on. In this case, you're still on `master`. The `git branch` command only *created* a new branch – it didn't switch to that branch.

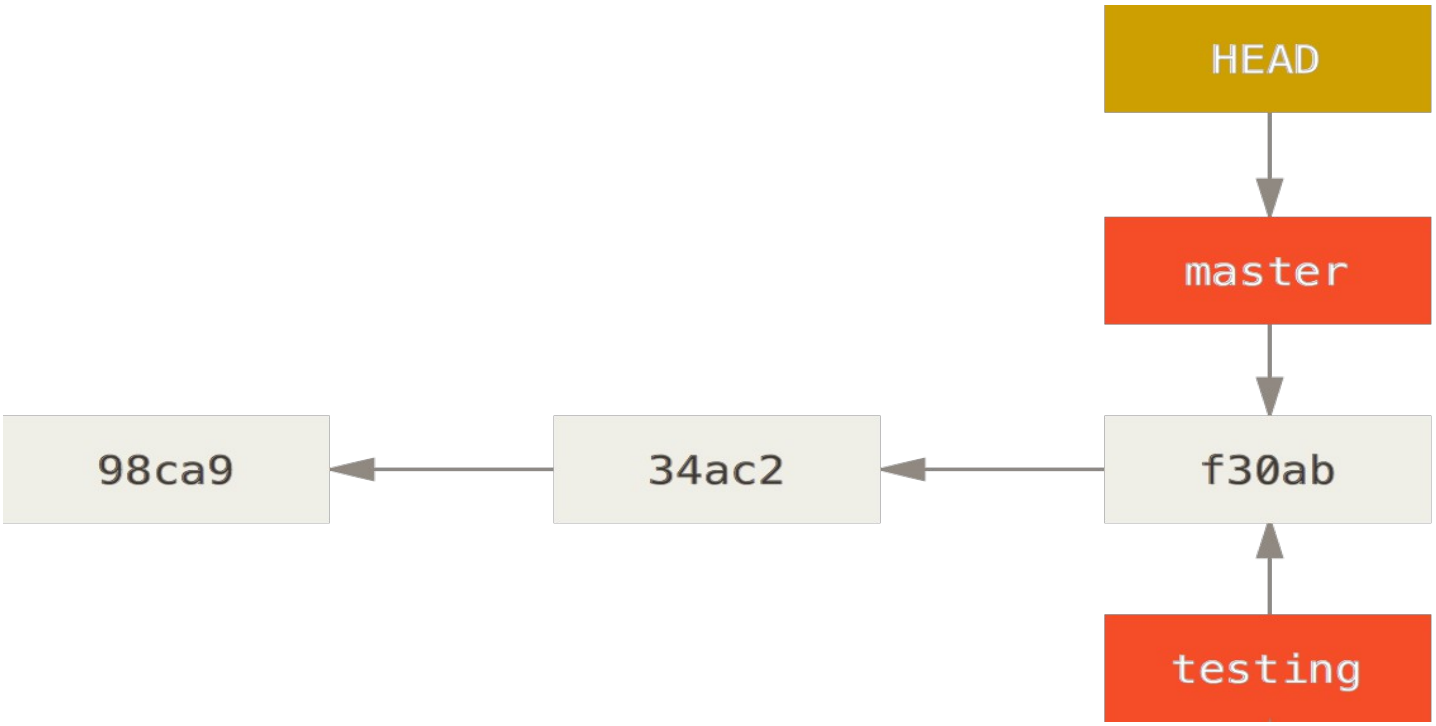


Figure 3-5. HEAD pointing to a branch

You can easily see this by running a simple `git log` command that shows you where the branch pointers are pointing. This option is called `--decorate`.

```
$ git log --oneline --decorate
f30ab (HEAD, master, testing) add feature #32 - ability to add new
34ac2 fixed bug #1328 - stack overflow under certain conditions
98ca9 initial commit of my project
```

You can see the “master” and “testing” branches that are right there next to the `f30ab` commit.

Switching Branches

To switch to an existing branch, you run the `git checkout` command. Let’s switch to the new `testing` branch:

```
$ git checkout testing
```

This moves `HEAD` to point to the `testing` branch.

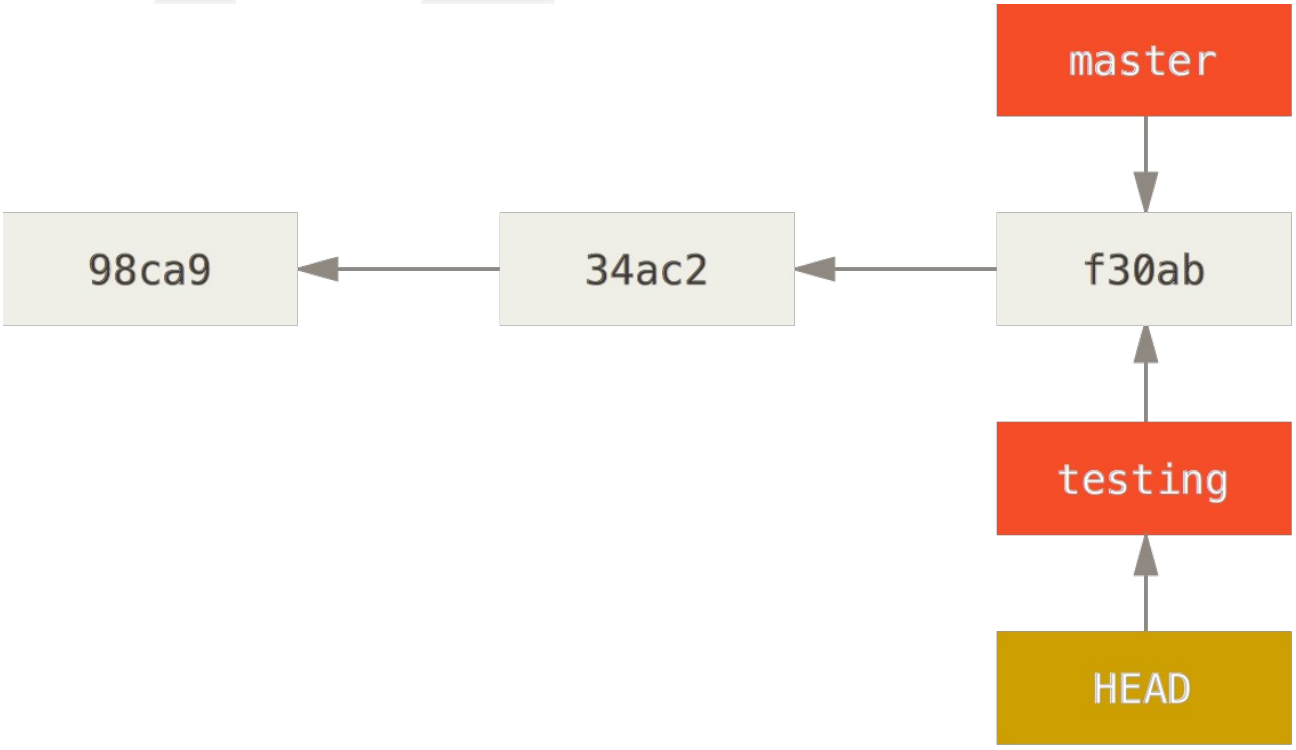


Figure 3-6. HEAD points to the current branch

What is the significance of that? Well, let’s do another commit:

```
$ vim test.rb
$ git commit -a -m 'made a change'
```

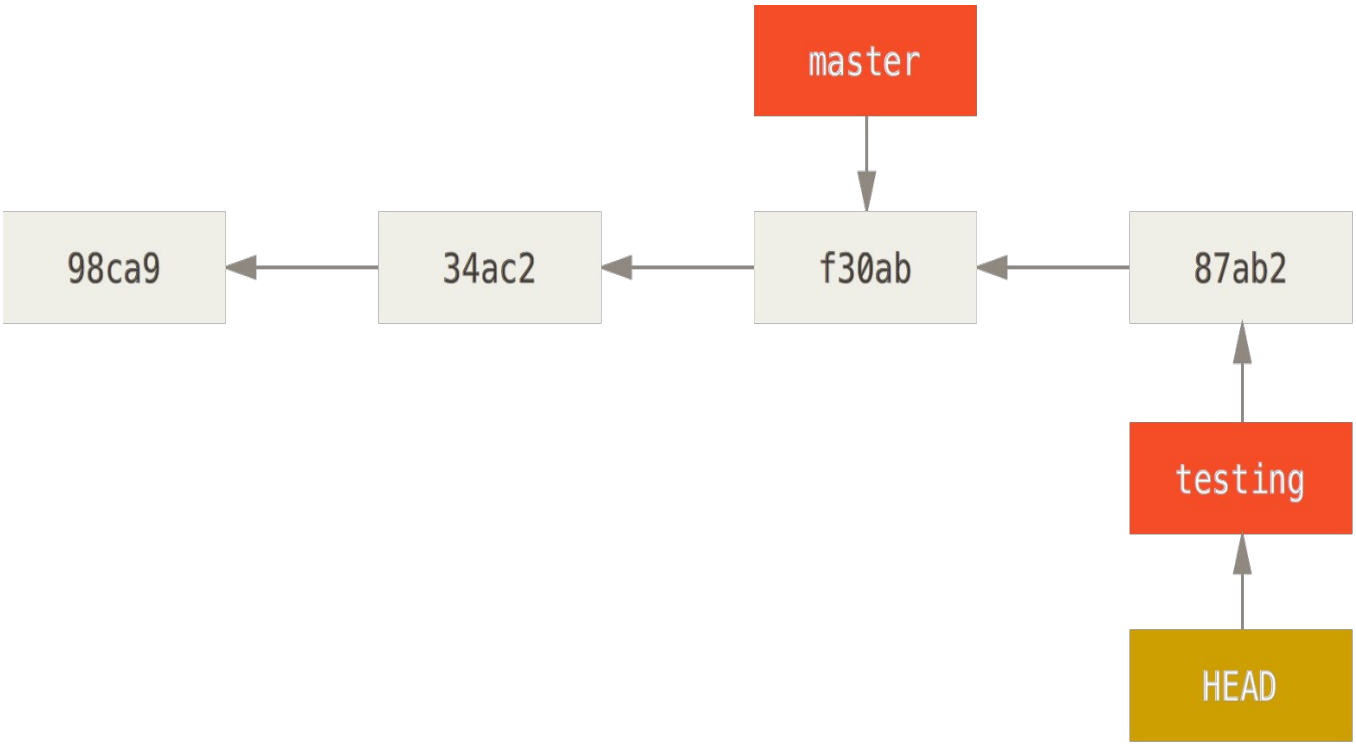


Figure 3-7. The HEAD branch moves forward when a commit is made

This is interesting, because now your `testing` branch has moved forward, but your `master` branch still points to the commit you were on when you ran `git checkout` to switch branches. Let's switch back to the `master` branch:

```
$ git checkout master
```

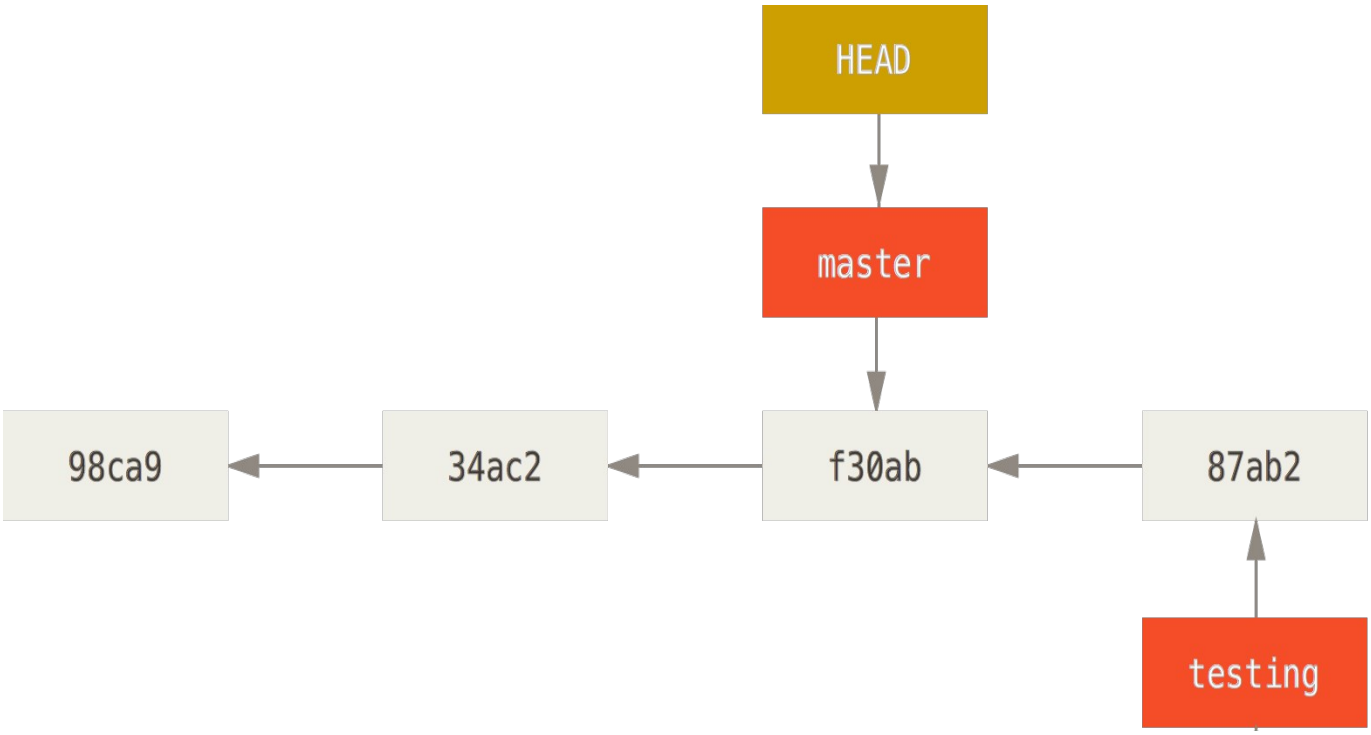


Figure 3-8. HEAD moves when you checkout

That command did two things. It moved the HEAD pointer back to point to the `master` branch, and it reverted the files in your working directory back to the snapshot that `master` points to. This also means the changes you make from this point forward will diverge from an older version of the project. It essentially rewinds the work you've done in your `testing` branch so you can go in a different direction.

NOTE

Switching branches changes files in your working directory

It's important to note that when you switch branches in Git, files in your working directory will change. If you switch to an older branch, your working directory will be reverted to look like it did the last time you committed on that branch. If Git cannot do it cleanly, it will not let you switch at all.

Let's make a few changes and commit again:

```
$ vim test.rb
$ git commit -a -m 'made other changes'
```

Now your project history has diverged (see Figure 3-9). You created and switched to a branch, did some work on it, and then switched back to your main branch and did other work. Both of those changes are isolated in separate branches: you can switch back and forth between the branches and merge them together when you're ready. And you did all that with simple `branch`, `checkout`, and `commit` commands.

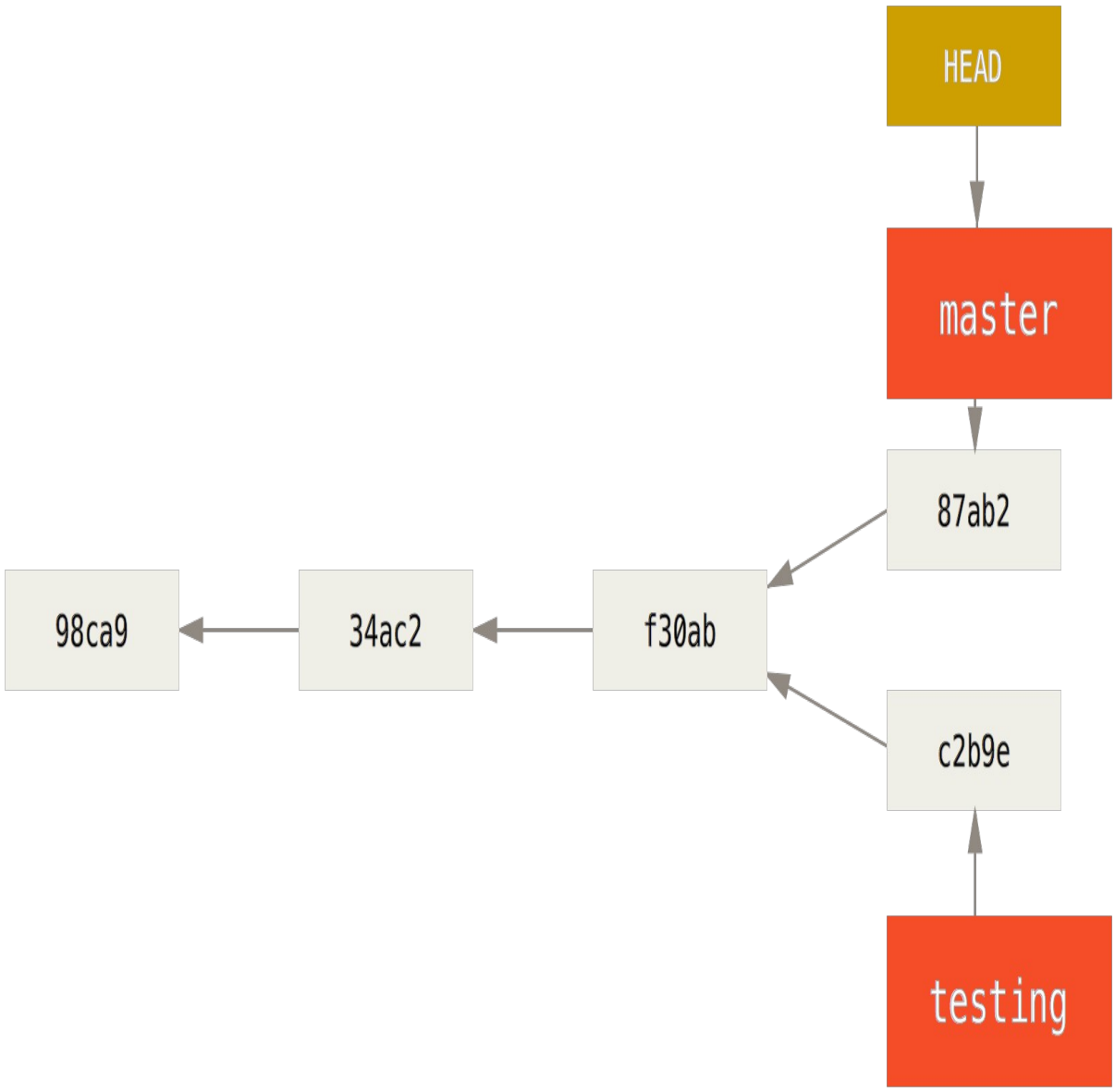


Figure 3-9. Divergent history

You can also see this easily with the `git log` command. If you run `git log --oneline --decorate --graph --all` it will print out the history of your commits, showing where your branch pointers are and how your history has diverged.

```
$ git log --oneline --decorate --graph --all
* c2b9e (HEAD, master) made other changes
| * 87ab2 (testing) made a change
|/
* f30ab add feature #32 - ability to add new formats to the
* 34ac2 fixed bug #1328 - stack overflow under certain conditions
* 98ca9 initial commit of my project
```

Because a branch in Git is in actuality a simple file that contains the 40 character SHA-1 checksum of the commit it points to, branches are cheap to create and destroy. Creating a new branch is as quick and simple as writing 41 bytes to a file (40 characters and a newline).

This is in sharp contrast to the way most older VCS tools branch, which involves copying all of the project's files into a second directory. This can take several seconds or even minutes, depending on the size of the project, whereas in Git the process is always instantaneous. Also, because we're recording the parents when we commit, finding a proper merge base for merging is automatically done for us and is generally very easy to do. These features help encourage developers to create and use branches often.

Let's see why you should do so.

3.2 Git Branching - Basic Branching and Merging

Basic Branching and Merging

Let's go through a simple example of branching and merging with a workflow that you might use in the real world. You'll follow these steps:

1. Do work on a web site.
2. Create a branch for a new story you're working on.
3. Do some work in that branch.

At this stage, you'll receive a call that another issue is critical and you need a hotfix. You'll do the following:

1. Switch to your production branch.
2. Create a branch to add the hotfix.

3. After it's tested, merge the hotfix branch, and push to production.
4. Switch back to your original story and continue working.

Basic Branching

First, let's say you're working on your project and have a couple of commits already.

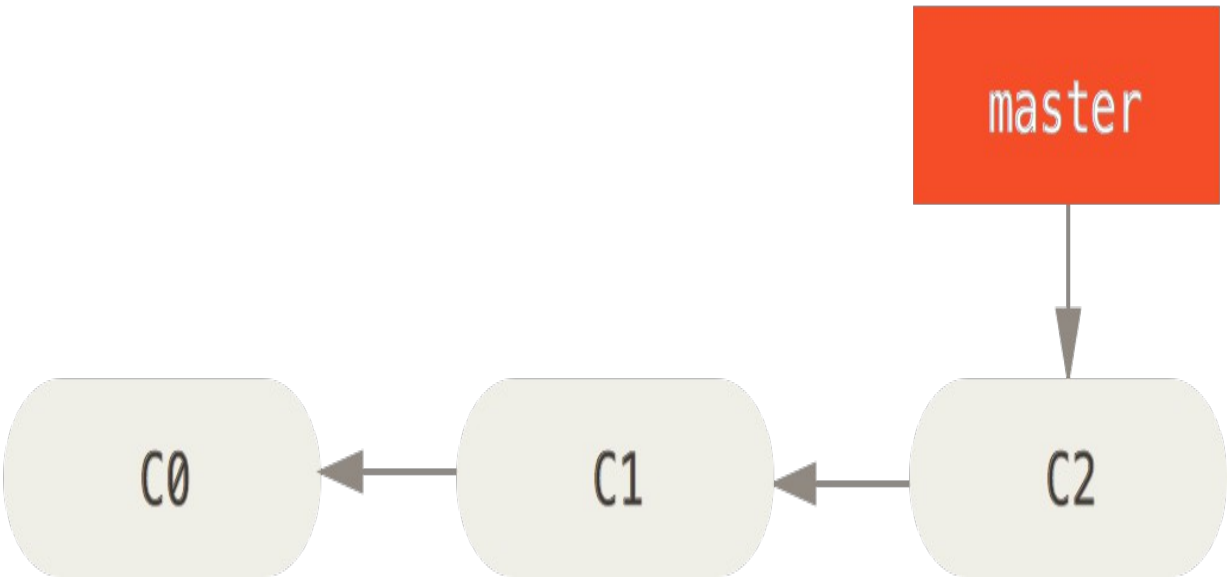


Figure 3-10. A simple commit history

You've decided that you're going to work on issue #53 in whatever issue-tracking system your company uses. To create a branch and switch to it at the same time, you can run the `git checkout` command with the `-b` switch:

```
$ git checkout -b iss53
Switched to a new branch "iss53"
```

This is shorthand for:

```
$ git branch iss53
$ git checkout iss53
```

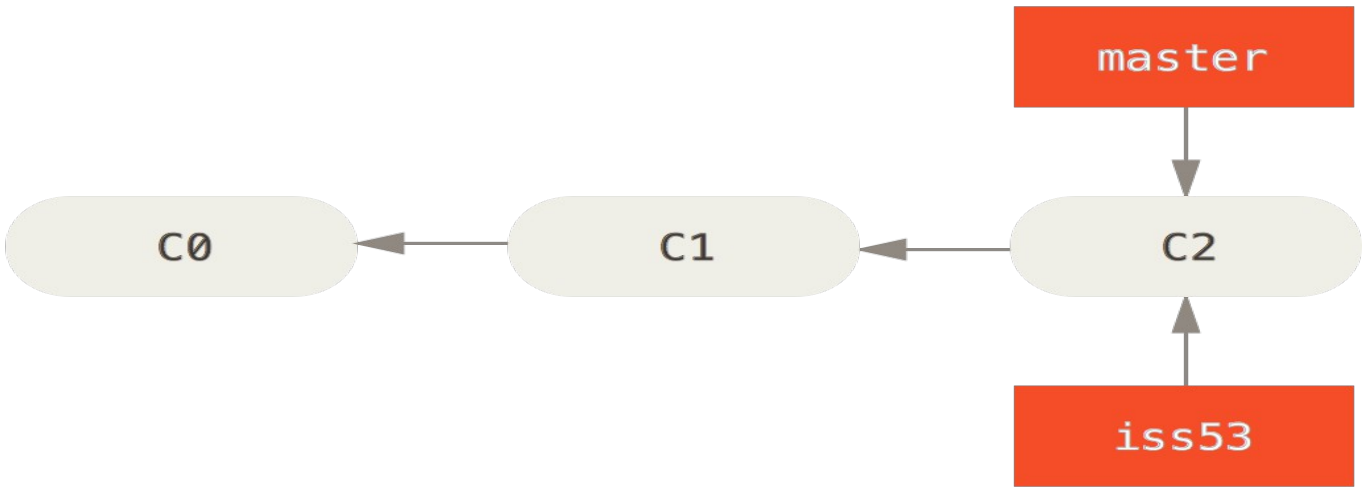


Figure 3-11. Creating a new branch pointer

You work on your web site and do some commits. Doing so moves the `iss53` branch forward, because you have it checked out (that is, your `HEAD` is pointing to it):

```
$ vim index.html
$ git commit -a -m 'added a new footer [issue 53]'
```

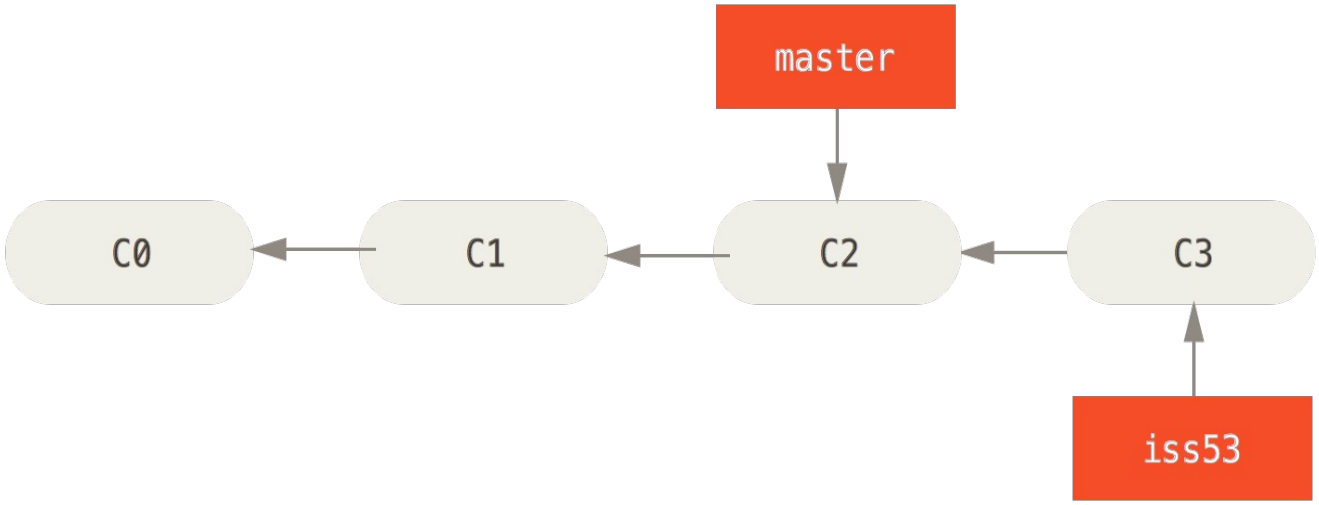


Figure 3-12. The iss53 branch has moved forward with your work

Now you get the call that there is an issue with the web site, and you need to fix it immediately. With Git, you don't have to deploy your fix along with the `iss53` changes you've made, and you don't have to put a lot of effort into reverting those changes before you can work on applying your fix to what is in production. All you have to do is switch back to your `master` branch.

However, before you do that, note that if your working directory or staging area has uncommitted changes that conflict with the branch you're checking out, Git won't let you switch branches. It's best

to have a clean working state when you switch branches. There are ways to get around this (namely, stashing and commit amending) that we'll cover later on, in Stashing and Cleaning. For now, let's assume you've committed all your changes, so you can switch back to your `master` branch:

```
$ git checkout master
Switched to branch 'master'
```

At this point, your project working directory is exactly the way it was before you started working on issue #53, and you can concentrate on your hotfix. This is an important point to remember: when you switch branches, Git resets your working directory to look like it did the last time you committed on that branch. It adds, removes, and modifies files automatically to make sure your working copy is what the branch looked like on your last commit to it.

Next, you have a hotfix to make. Let's create a hotfix branch on which to work until it's completed:

```
$ git checkout -b hotfix
Switched to a new branch 'hotfix'
$ vim index.html
$ git commit -a -m 'fixed the broken email address'
[hotfix 1fb7853] fixed the broken email address
 1 file changed, 2 insertions(+)
```

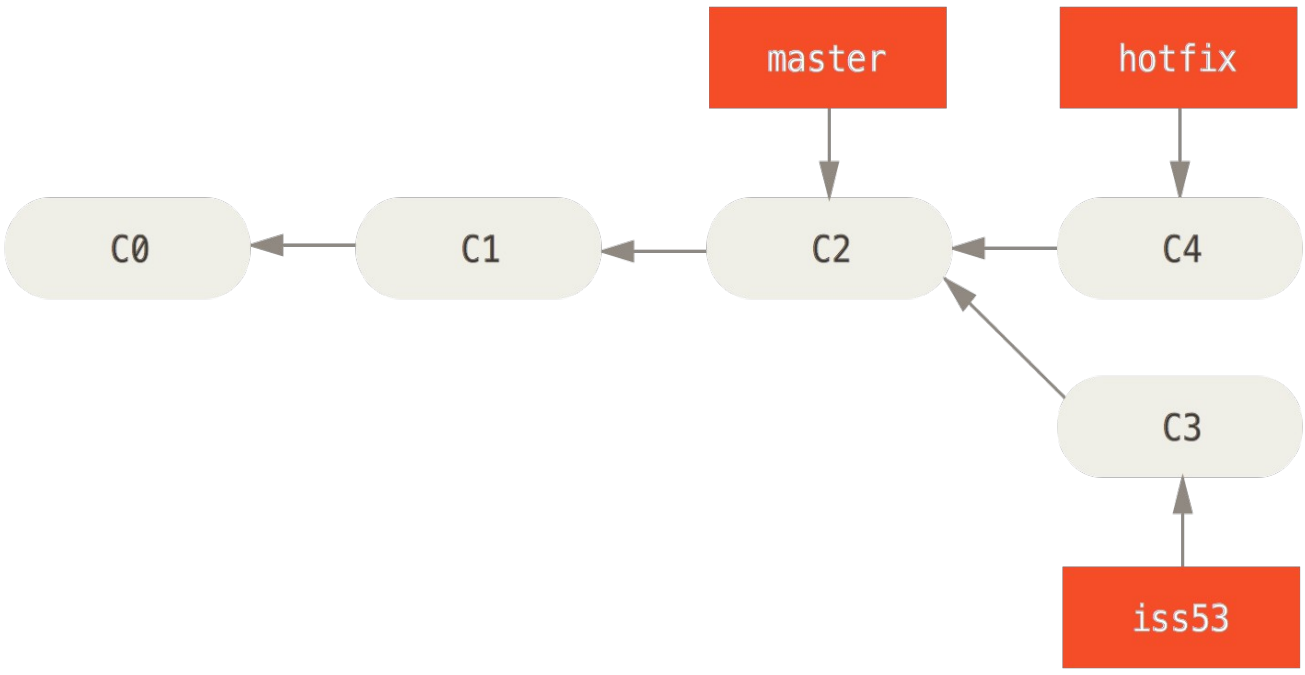


Figure 3-13. Hotfix branch based on `master`

You can run your tests, make sure the hotfix is what you want, and merge it back into your `master` branch to deploy to production. You do this with the `git merge` command:

```
$ git checkout master
$ git merge hotfix
Updating f42c576..3a0874c
Fast-forward
 index.html | 2 ++
 1 file changed, 2 insertions(+)
```

You'll notice the phrase "fast-forward" in that merge. Because the commit pointed to by the branch you merged in was directly upstream of the commit you're on, Git simply moves the pointer forward. To phrase that another way, when you try to merge one commit with a commit that can be reached by following the first commit's history, Git simplifies things by moving the pointer forward because there is no divergent work to merge together – this is called a "fast-forward."

Your change is now in the snapshot of the commit pointed to by the `master` branch, and you can deploy the fix.

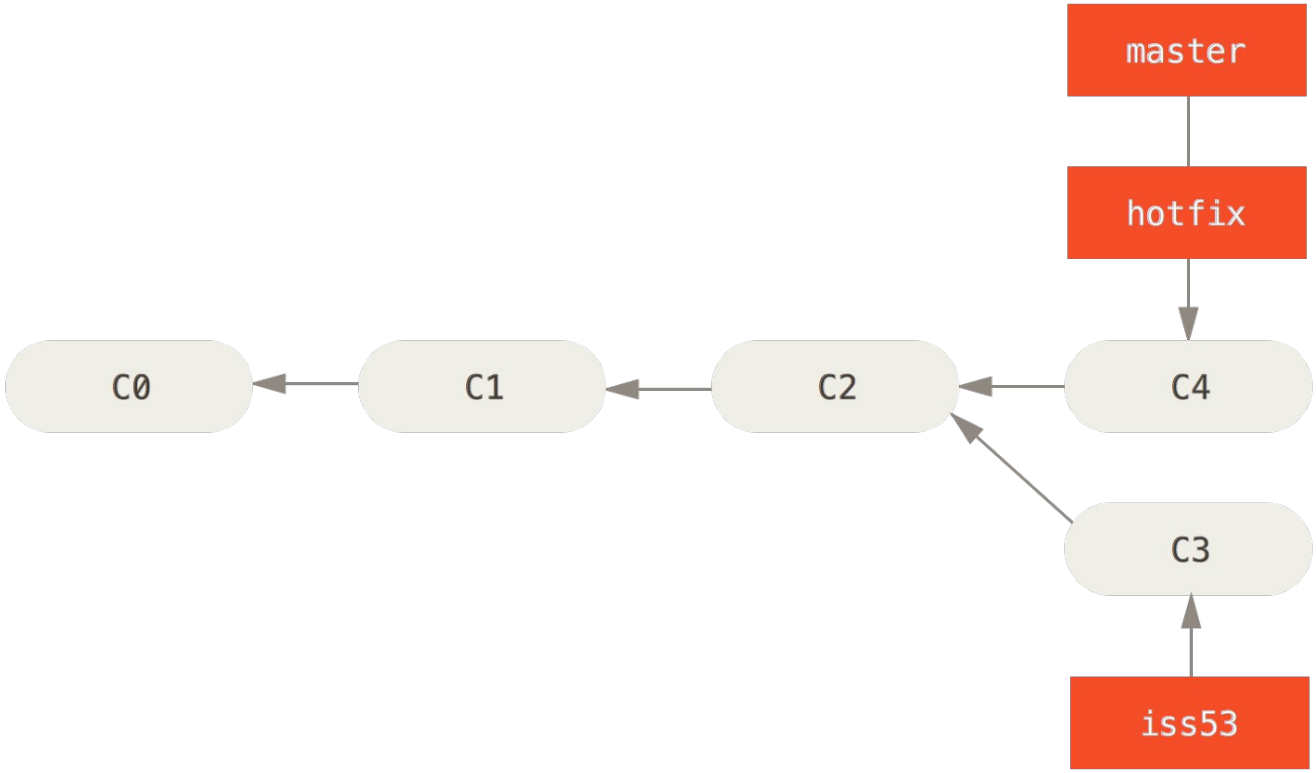


Figure 3-14. `master` is fast-forwarded to `hotfix`

After your super-important fix is deployed, you're ready to switch back to the work you were doing before you were interrupted. However, first you'll delete the `hotfix` branch, because you no longer need it – the `master` branch points at the same place. You can delete it with the `-d` option to `git branch`:

```
$ git branch -d hotfix
```

```
Deleted branch hotfix (3a0874c).
```

Now you can switch back to your work-in-progress branch on issue #53 and continue working on it.

```
$ git checkout iss53
Switched to branch "iss53"
$ vim index.html
$ git commit -a -m 'finished the new footer [issue 53]'
[iss53 ad82d7a] finished the new footer [issue 53]
1 file changed, 1 insertion(+)
```

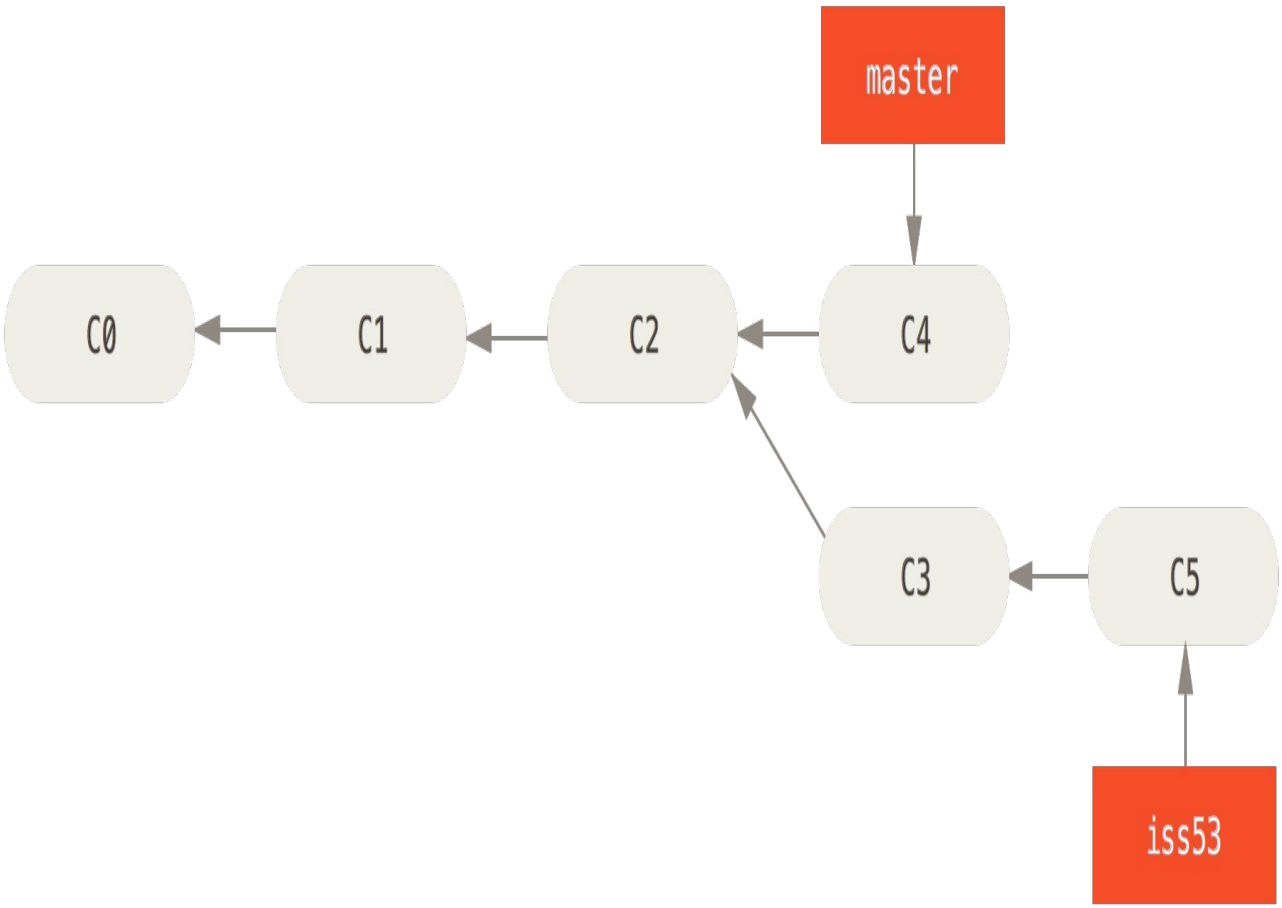


Figure 3-15. Work continues on `iss53`

It's worth noting here that the work you did in your `hotfix` branch is not contained in the files in your `iss53` branch. If you need to pull it in, you can merge your `master` branch into your `iss53` branch by running `git merge master`, or you can wait to integrate those changes until you decide to pull the `iss53` branch back into `master` later.

Basic Merging

Suppose you've decided that your issue #53 work is complete and ready to be merged into your `master` branch. In order to do that, you'll merge your `iss53` branch into `master`, much like you merged your `hotfix` branch earlier. All you have to do is check out the branch you wish to merge into and then run the `git merge` command:

```
$ git checkout master
Switched to branch 'master'
$ git merge iss53
Merge made by the 'recursive' strategy.
index.html |    1 +
1 file changed, 1 insertion(+)
```

This looks a bit different than the `hotfix` merge you did earlier. In this case, your development history has diverged from some older point. Because the commit on the branch you're on isn't a direct ancestor of the branch you're merging in, Git has to do some work. In this case, Git does a simple three-way merge, using the two snapshots pointed to by the branch tips and the common ancestor of the two.

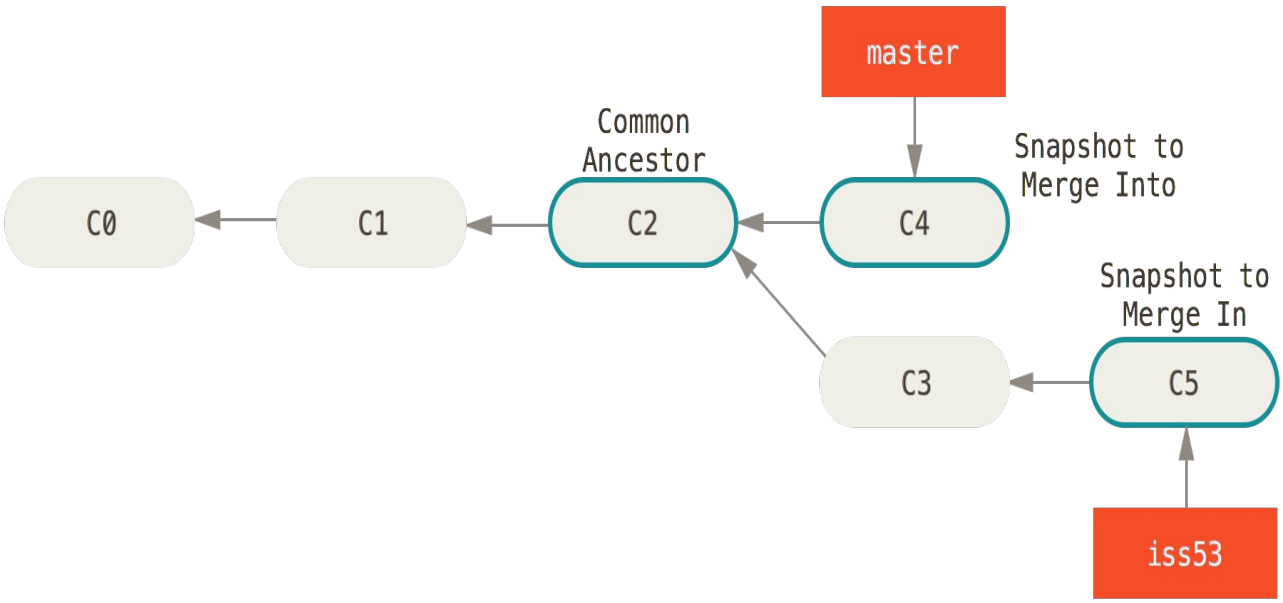


Figure 3-16. Three snapshots used in a typical merge

Instead of just moving the branch pointer forward, Git creates a new snapshot that results from this three-way merge and automatically creates a new commit that points to it. This is referred to as a merge commit, and is special in that it has more than one parent.

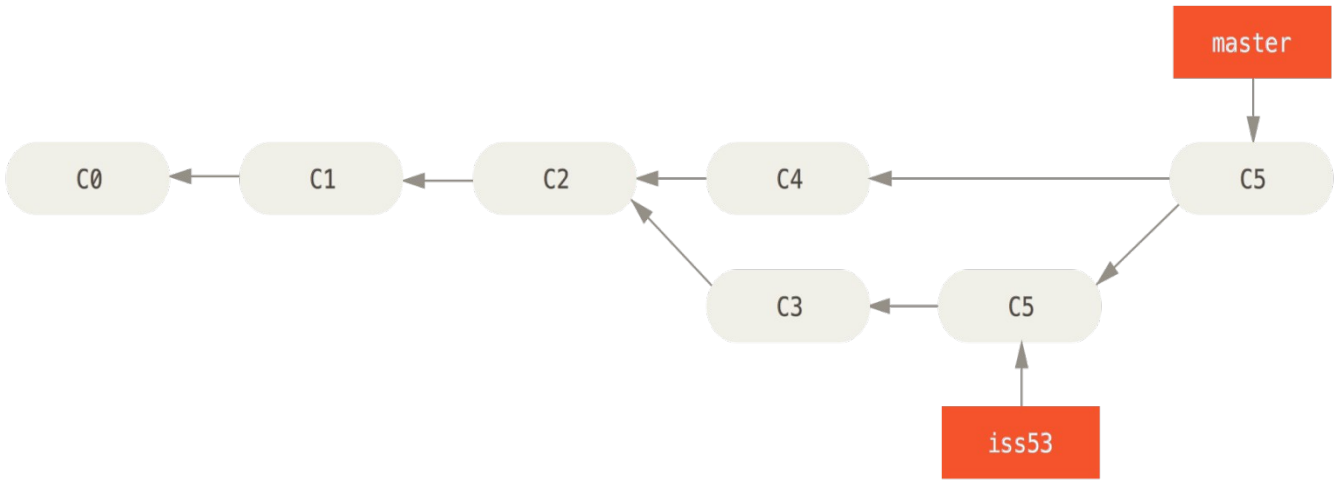


Figure 3-17. A merge commit

It's worth pointing out that Git determines the best common ancestor to use for its merge base; this is different than older tools like CVS or Subversion (before version 1.5), where the developer doing the merge had to figure out the best merge base for themselves. This makes merging a heck of a lot easier in Git than in these other systems.

Now that your work is merged in, you have no further need for the `iss53` branch. You can close the ticket in your ticket-tracking system, and delete the branch:

```
$ git branch -d iss53
```

Basic Merge Conflicts

Occasionally, this process doesn't go smoothly. If you changed the same part of the same file differently in the two branches you're merging together, Git won't be able to merge them cleanly. If your fix for issue #53 modified the same part of a file as the `hotfix`, you'll get a merge conflict that looks something like this:

```
$ 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 hasn't automatically created a new merge commit. It has paused the process while you resolve the conflict. If you want to see which files are unmerged at any point after a merge conflict, you can run `git status`:

```
$ git status
```

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

Unmerged paths:
  (use "git add &lt;file&gt;..." to mark resolution)

    both modified:      index.html

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

Anything that has merge conflicts and hasn't been resolved is listed as unmerged. Git adds standard conflict-resolution markers to the files that have conflicts, so you can open them manually and resolve those conflicts. Your file contains a section that looks something like this:

```
&lt;&lt;&lt;&lt;&lt;&lt;&lt; HEAD:index.html
&lt;div id="footer"&gt;contact : email.support@github.com&lt;/div&gt;
=======
&lt;div id="footer"&gt;
 please contact us at support@github.com
&lt;/div&gt;
&gt;&gt;&gt;&gt;&gt;&gt;&gt; iss53:index.html
```

This means the version in `HEAD` (your `master` branch, because that was what you had checked out when you ran your merge command) is the top part of that block (everything above the `=======`), while the version in your `iss53` branch looks like everything in the bottom part. In order to resolve the conflict, you have to either choose one side or the other or merge the contents yourself. For instance, you might resolve this conflict by replacing the entire block with this:

```
&lt;div id="footer"&gt;
please contact us at email.support@github.com
&lt;/div&gt;
```

This resolution has a little of each section, and the `<<<<<<<`, `=======`, and `>>>>>>>` lines have been completely removed. After you've resolved each of these sections in each conflicted file, run `git add` on each file to mark it as resolved. Staging the file marks it as resolved in Git.
If you want to use a graphical tool to resolve these issues, you can run `git mergetool`, which fires up an appropriate visual merge tool and walks you through the conflicts:

```
$ git mergetool

This message is displayed because 'merge.tool' is not configured.
See 'git mergetool --tool-help' or 'git help config' for more details.
'git mergetool' will now attempt to use one of the following tools:
opendiff kdiff3 tkdiff xxdiff meld tortoisemerge gvimdiff diffuse diffmerge
ecmerge p4merge araxis bc3 codecompare vimdiff emerge
Merging:
index.html
```

```
Normal merge conflict for 'index.html':
  {local}: modified file
  {remote}: modified file
Hit return to start merge resolution tool (opendiff):
```

If you want to use a merge tool other than the default (Git chose `opendiff` in this case because the command was run on a Mac), you can see all the supported tools listed at the top after “one of the following tools.” Just type the name of the tool you’d rather use.

NOTE
If you need more advanced tools for resolving tricky merge conflicts, we cover more on merging in Advanced Merging.

After you exit the merge tool, Git asks you if the merge was successful. If you tell the script that it was, it stages the file to mark it as resolved for you. You can run `git status` again to verify that all conflicts have been resolved:

```
$ 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
```

If you’re happy with that, and you verify that everything that had conflicts has been staged, you can type `git commit` to finalize the merge commit. The commit message by default looks something like this:

```
Merge branch 'iss53'

Conflicts:
    index.html
#
# It looks like you may be committing a merge.
# If this is not correct, please remove the file
#       .git/MERGE_HEAD
# and try again.


# Please enter the commit message for your changes. Lines starting
# with '#' will be ignored, and an empty message aborts the commit.
# On branch master
# All conflicts fixed but you are still merging.
#
# Changes to be committed:
#       modified:   index.html
#
```

You can modify that message with details about how you resolved the merge if you think it would be helpful to others looking at this merge in the future – why you did what you did, if it’s not obvious.

3.3 Git Branching - Branch Management

Branch Management

Now that you've created, merged, and deleted some branches, let's look at some branch-management tools that will come in handy when you begin using branches all the time.

The `git branch` command does more than just create and delete branches. If you run it with no arguments, you get a simple listing of your current branches:

```
$ git branch
  iss53
* master
  testing
```

Notice the `*` character that prefixes the `master` branch: it indicates the branch that you currently have checked out (i.e., the branch that `HEAD` points to). This means that if you commit at this point, the `master` branch will be moved forward with your new work. To see the last commit on each branch, you can run `git branch -v`:

```
$ git branch -v
  iss53   93b412c fix javascript issue
* master  7a98805 Merge branch 'iss53'
  testing 782fd34 add scott to the author list in the readmes
```

The useful `--merged` and `--no-merged` options can filter this list to branches that you have or have not yet merged into the branch you're currently on. To see which branches are already merged into the branch you're on, you can run `git branch --merged`:

```
$ git branch --merged
  iss53
* master
```

Because you already merged in `iss53` earlier, you see it in your list. Branches on this list without the `*` in front of them are generally fine to delete with `git branch -d`; you've already incorporated their work into another branch, so you're not going to lose anything.
To see all the branches that contain work you haven't yet merged in, you can run `git branch --no-merged`:

```
$ git branch --no-merged
  testing
```

This shows your other branch. Because it contains work that isn't merged in yet, trying to delete it with `git branch -d` will fail:

```
$ git branch -d testing
error: The branch 'testing' is not fully merged.
If you are sure you want to delete it, run 'git branch -D testing'.
```

If you really do want to delete the branch and lose that work, you can force it with `-D`, as the helpful message points out.

3.4 Git Branching - Branching Workflows

Branching Workflows

Now that you have the basics of branching and merging down, what can or should you do with them? In this section, we'll cover some common workflows that this lightweight branching makes possible, so you can decide if you would like to incorporate it into your own development cycle.

Long-Running Branches

Because Git uses a simple three-way merge, merging from one branch into another multiple times over a long period is generally easy to do. This means you can have several branches that are always open and that you use for different stages of your development cycle; you can merge regularly from some of them into others.

Many Git developers have a workflow that embraces this approach, such as having only code that is entirely stable in their `master` branch – possibly only code that has been or will be released. They have another parallel branch named `develop` or `next` that they work from or use to test stability – it isn't necessarily always stable, but whenever it gets to a stable state, it can be merged into `master`. It's used to pull in topic branches (short-lived branches, like your earlier `iss53` branch) when they're ready, to make sure they pass all the tests and don't introduce bugs.

In reality, we're talking about pointers moving up the line of commits you're making. The stable branches are farther down the line in your commit history, and the bleeding-edge branches are farther up the history.

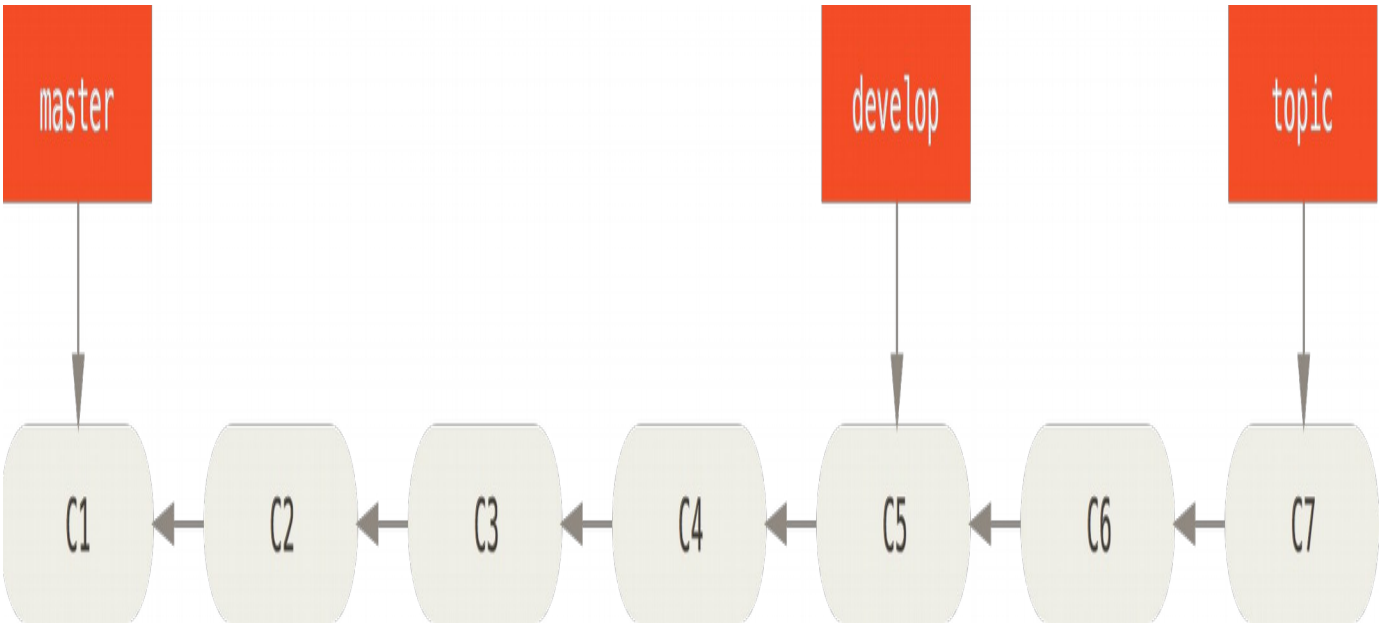


Figure 3-18. A linear view of progressive-stability branching

It's generally easier to think about them as work silos, where sets of commits graduate to a more stable silo when they're fully tested.

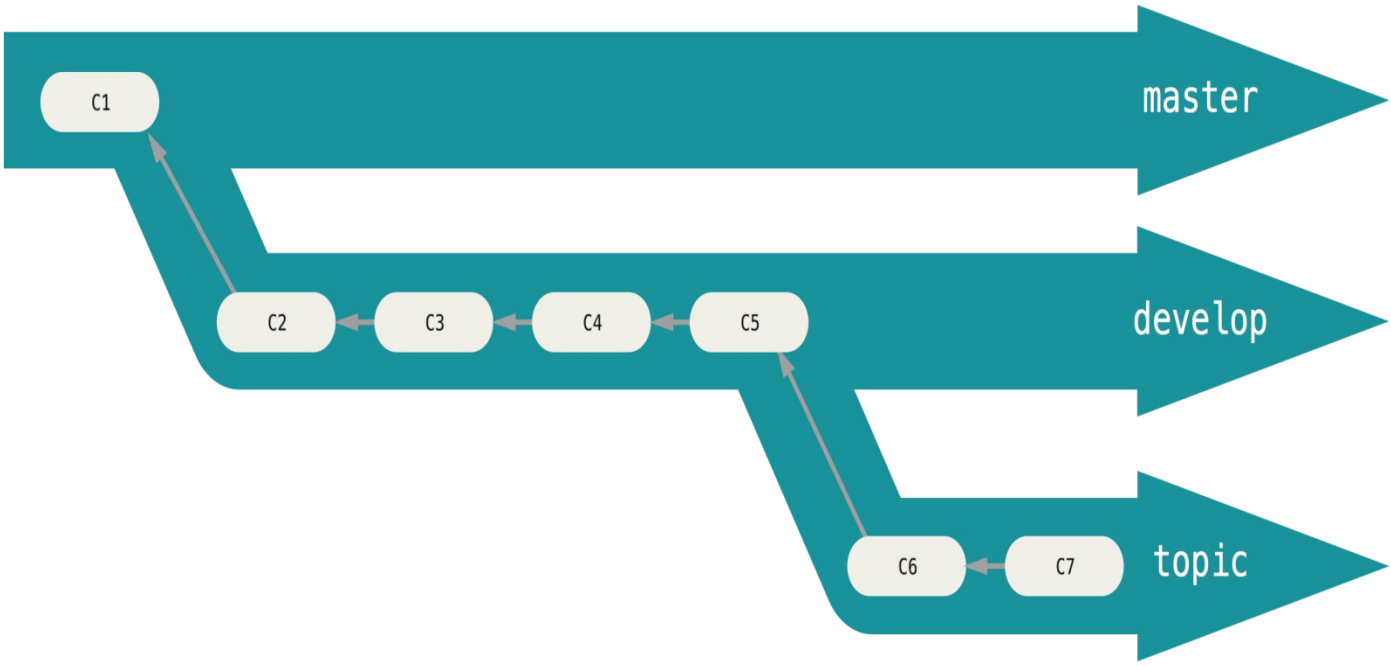


Figure 3-19. A "silo" view of progressive-stability branching

You can keep doing this for several levels of stability. Some larger projects also have a `proposed` or `pu` (proposed updates) branch that has integrated branches that may not be ready to go into the `next` or `master` branch. The idea is that your branches are at various levels of

stability; when they reach a more stable level, they're merged into the branch above them. Again, having multiple long-running branches isn't necessary, but it's often helpful, especially when you're dealing with very large or complex projects.

Topic Branches

Topic branches, however, are useful in projects of any size. A topic branch is a short-lived branch that you create and use for a single particular feature or related work. This is something you've likely never done with a VCS before because it's generally too expensive to create and merge branches. But in Git it's common to create, work on, merge, and delete branches several times a day.

You saw this in the last section with the `iss53` and `hotfix` branches you created. You did a few commits on them and deleted them directly after merging them into your main branch. This technique allows you to context-switch quickly and completely – because your work is separated into silos where all the changes in that branch have to do with that topic, it's easier to see what has happened during code review and such. You can keep the changes there for minutes, days, or months, and merge them in when they're ready, regardless of the order in which they were created or worked on.

Consider an example of doing some work (on `master`), branching off for an issue (`iss91`), working on it for a bit, branching off the second branch to try another way of handling the same thing (`iss91v2`), going back to your `master` branch and working there for a while, and then branching off there to do some work that you're not sure is a good idea (`dumbidea` branch). Your commit history will look something like this:

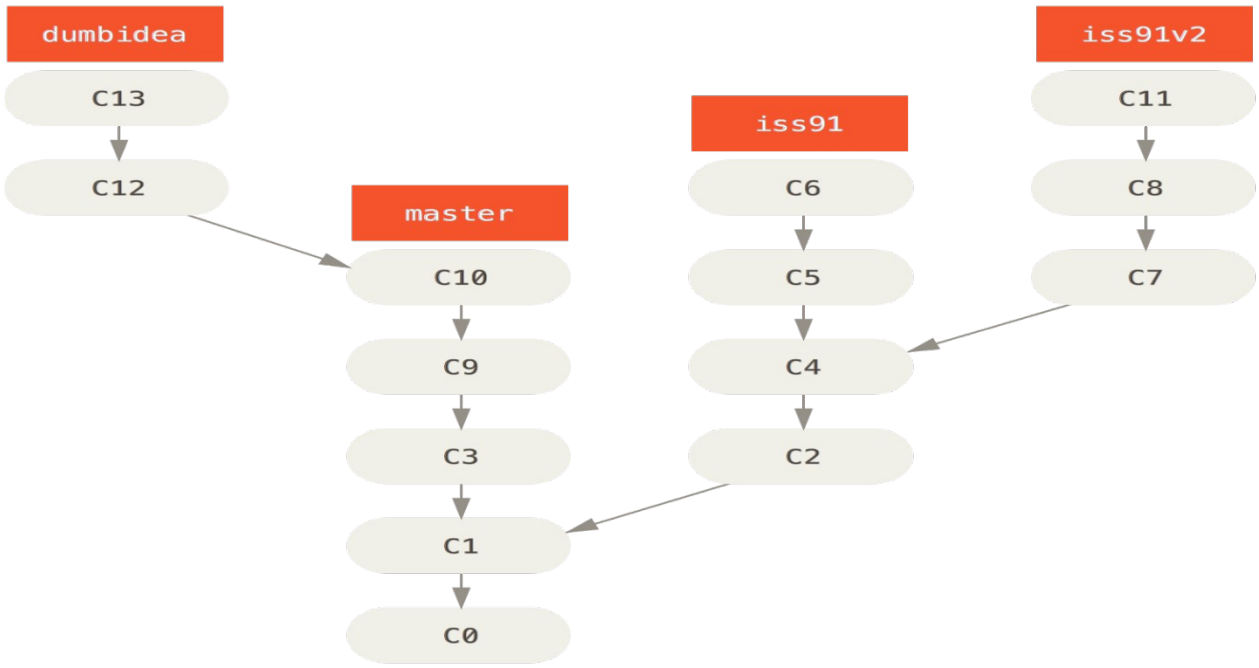


Figure 3-20. Multiple topic branches

Now, let's say you decide you like the second solution to your issue best (`iss91v2`); and you showed the `dumbidea` branch to your coworkers, and it turns out to be genius. You can throw away the original `iss91` branch (losing commits `C5` and `C6`) and merge in the other two. Your history then looks like this:

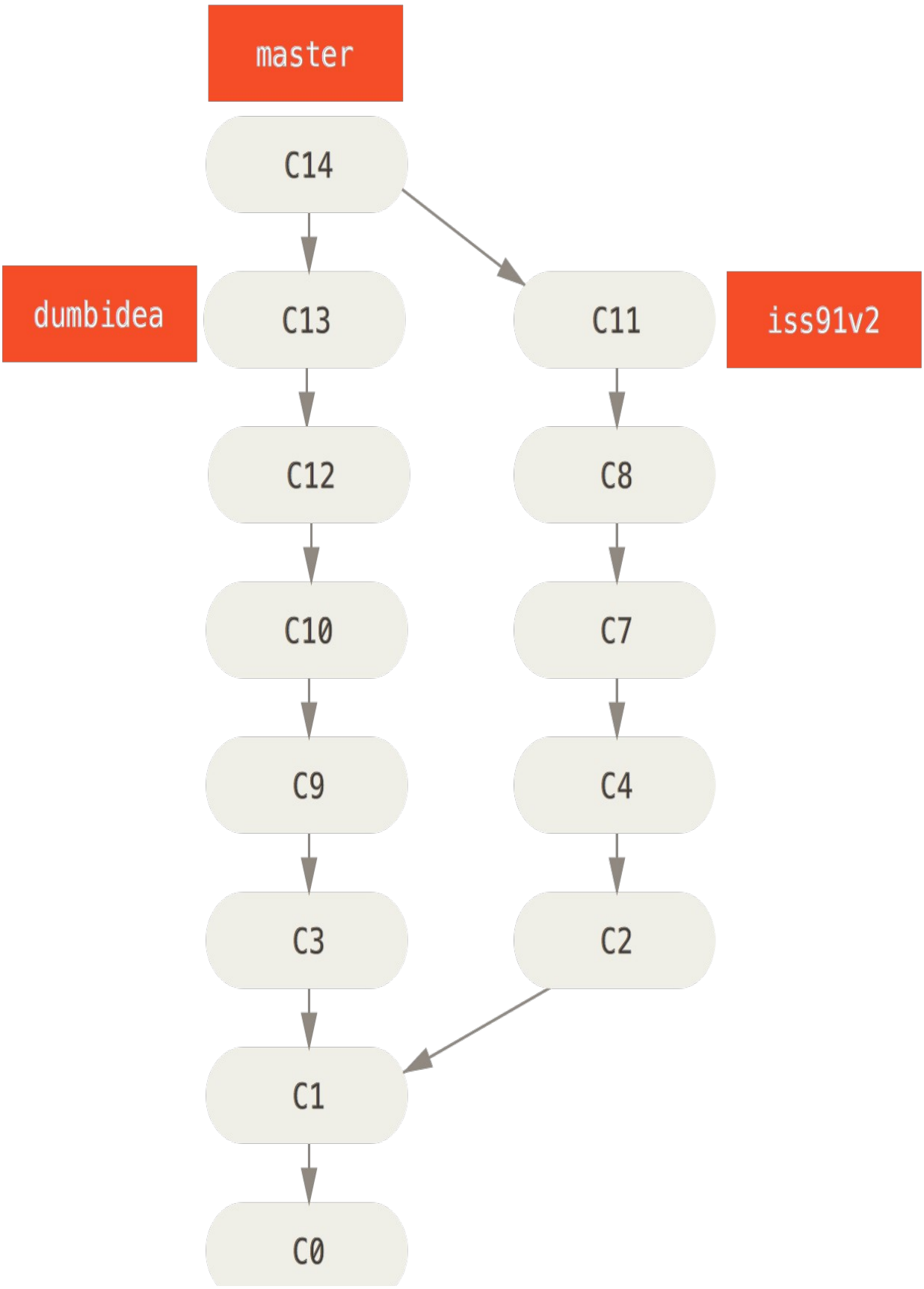

master
C14
dumbidea
C13
C11
iss91v2
C12
C8
C10
C7
C9
C4
C3
C2
C1
C0

Figure 3-21. History after merging `dumbidea` and `iss91v2`

We will go into more detail about the various possible workflows for your Git project in Distributed Git, so before you decide which branching scheme your next project will use, be sure to read that chapter.
It's important to remember when you're doing all this that these branches are completely local. When you're branching and merging, everything is being done only in your Git repository – no server communication is happening.

3.5 Git Branching - Remote Branches

Remote Branches

Remote references are references (pointers) in your remote repositories, including branches, tags, and so on. You can get a full list of remote references explicitly with `git ls-remote (remote)`, or `git remote show (remote)` for remote branches as well as more information. Nevertheless, a more common way is to take advantage of remote-tracking branches.
Remote-tracking branches are references to the state of remote branches. They're local references that you can't move; they're moved automatically for you whenever you do any network communication. Remote-tracking branches act as bookmarks to remind you where the branches in your remote repositories were the last time you connected to them.

They take the form `(remote)/(branch)`. For instance, if you wanted to see what the `master` branch on your `origin` remote looked like as of the last time you communicated with it, you would check the `origin/master` branch. If you were working on an issue with a partner and they pushed up an `iss53` branch, you might have your own local `iss53` branch; but the branch on the server would point to the commit at `origin/iss53`.

This may be a bit confusing, so let's look at an example. Let's say you have a Git server on your network at `git.ourcompany.com`. If you clone from this, Git's `clone` command automatically names it `origin` for you, pulls down all its data, creates a pointer to where its `master` branch is, and names it `origin/master` locally. Git also gives you your own local `master` branch starting at the same place as origin's `master` branch, so you have something to work from.

NOTE

"origin" is not special

Just like the branch name "master" does not have any special meaning in Git, neither does "origin". While "master" is the default name for a starting branch when you run `git init` which is the only reason it's

widely used, “origin” is the default name for a remote when you run `git clone`. If you run `git clone -o booyah` instead, then you will have `booyah/master` as your default remote branch.

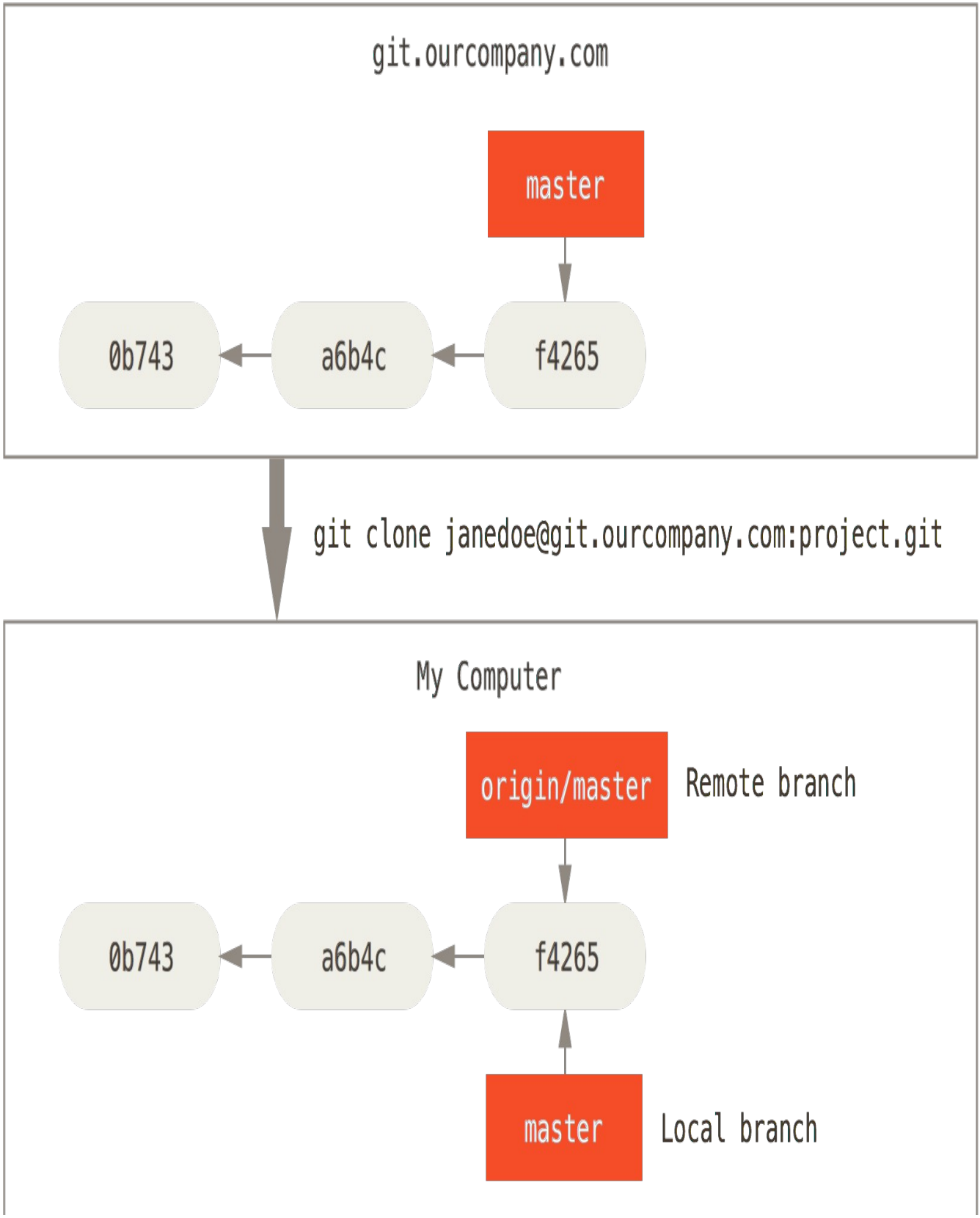

git.ourcompany.com
master
0b743
a6b4c
f4265
git clone janedoe@git.ourcompany.com:project.git
My Computer
origin/master
Remote branch
0b743
a6b4c
f4265
master
Local branch

Figure 3-22. Server and local repositories after cloning

If you do some work on your local `master` branch, and, in the meantime, someone else pushes to `git.ourcompany.com` and updates its `master` branch, then your histories move forward differently. Also, as long as you stay out of contact with your origin server, your `origin/master` pointer doesn't move.

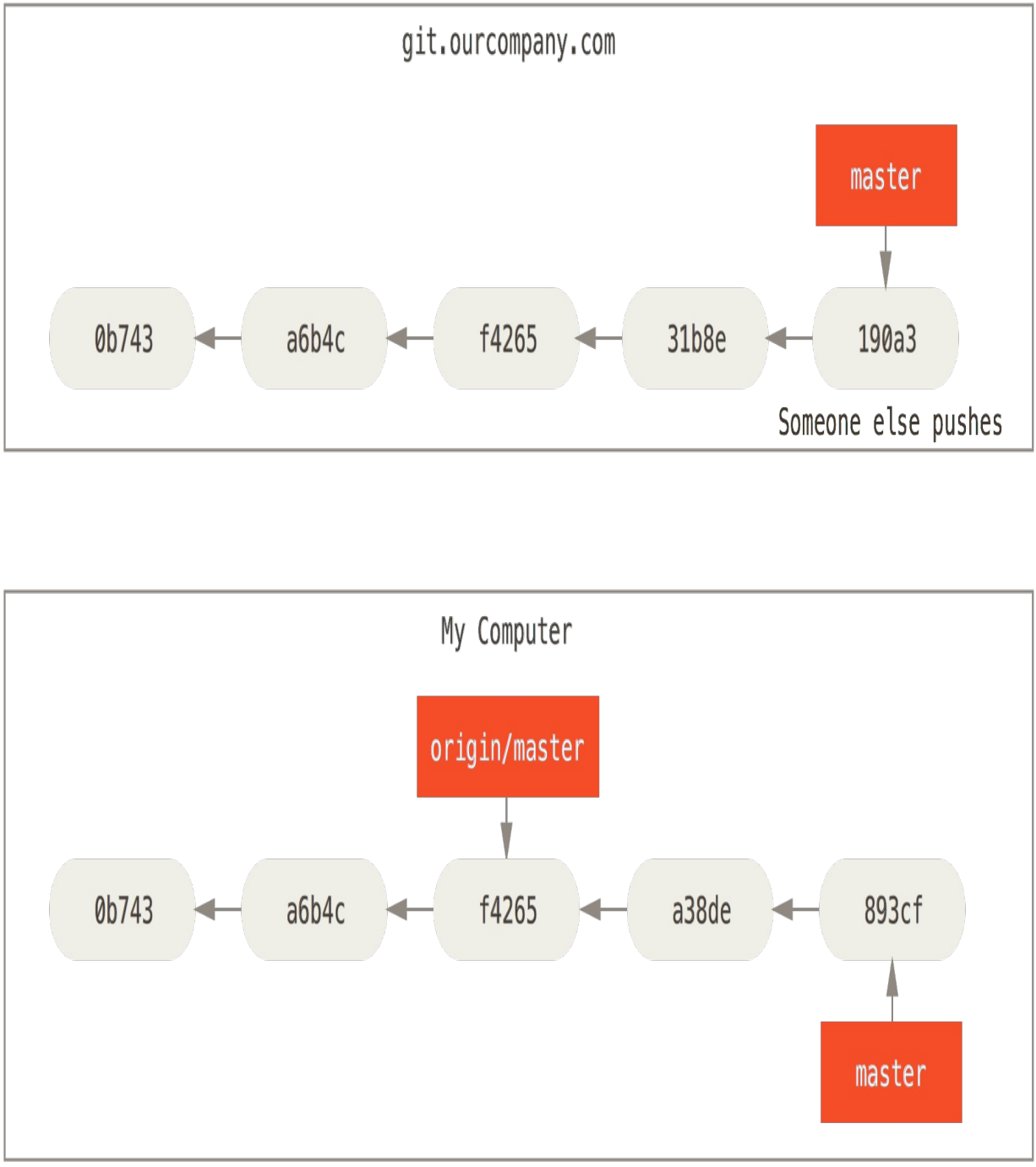


Figure 3-23. Local and remote work can diverge

To synchronize your work, you run a `git fetch origin` command. This command looks up which server "origin" is (in this case, it's `git.ourcompany.com`), fetches any data from it that you

don’t yet have, and updates your local database, moving your `origin/master` pointer to its new, more up-to-date position.

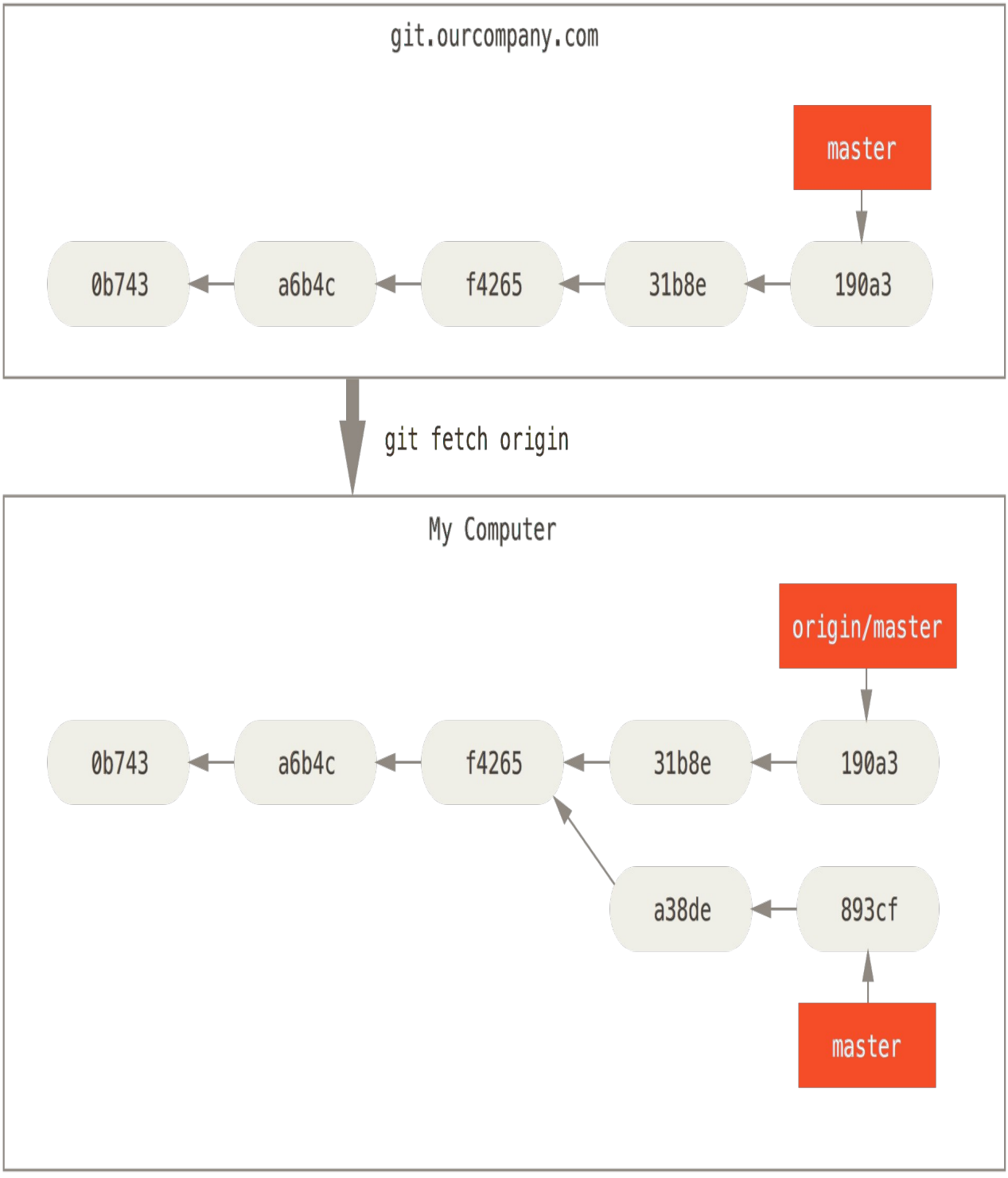


Figure 3-24. `git fetch` updates your remote references

To demonstrate having multiple remote servers and what remote branches for those remote projects look like, let's assume you have another internal Git server that is used only for development by one of your sprint teams. This server is at `git.team1.ourcompany.com`. You can add it as a new remote reference to the project you're currently working on by running the `git remote add` command as we covered in Git Basics. Name this remote `teamone`, which will be your shortname for that whole URL.

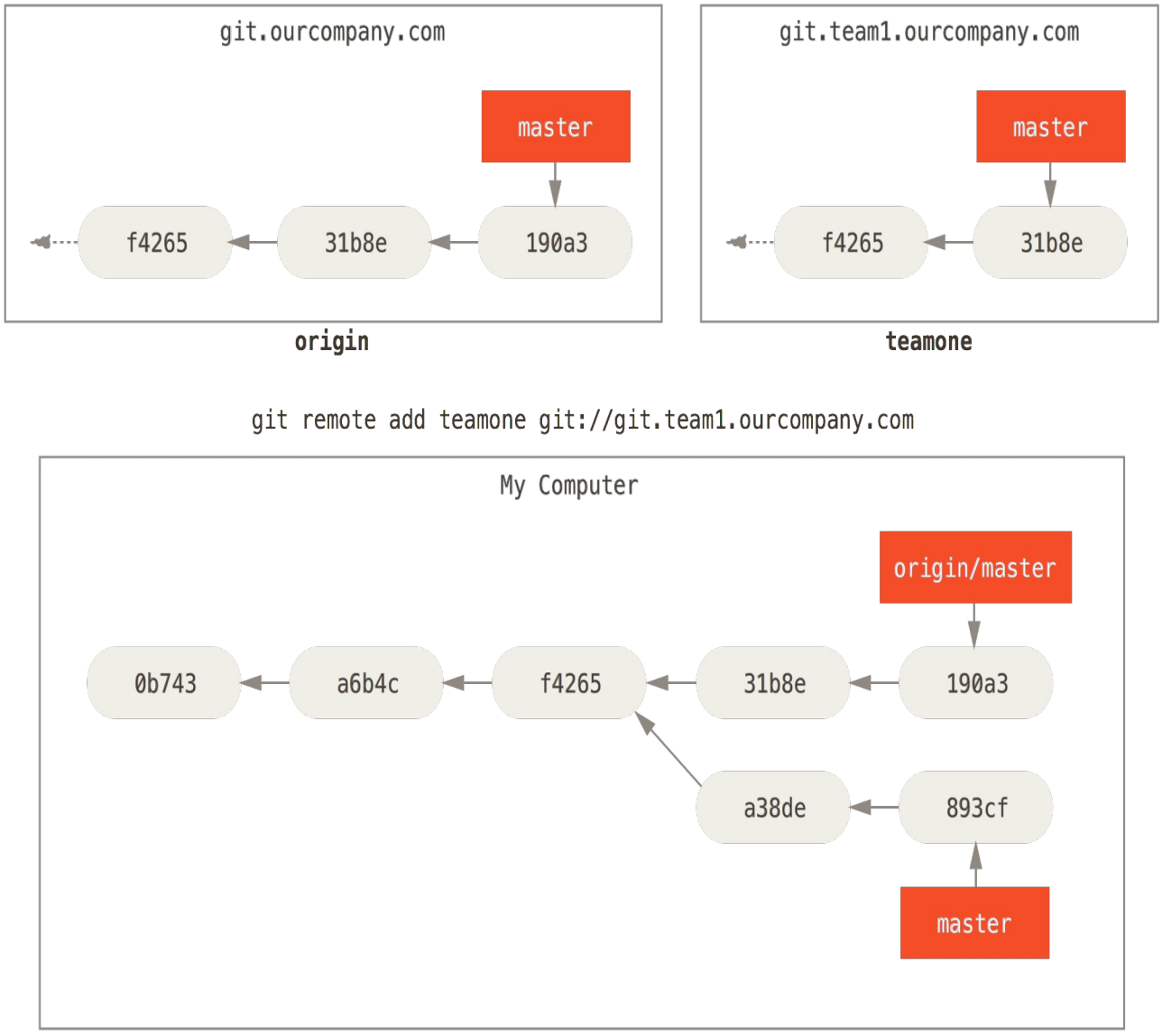


Figure 3-25. Adding another server as a remote

Now, you can run `git fetch teamone` to fetch everything the remote `teamone` server has that you don't have yet. Because that server has a subset of the data your `origin` server has right

now, Git fetches no data but sets a remote-tracking branch called `teamone/master` to point to the commit that `teamone` has as its `master` branch.

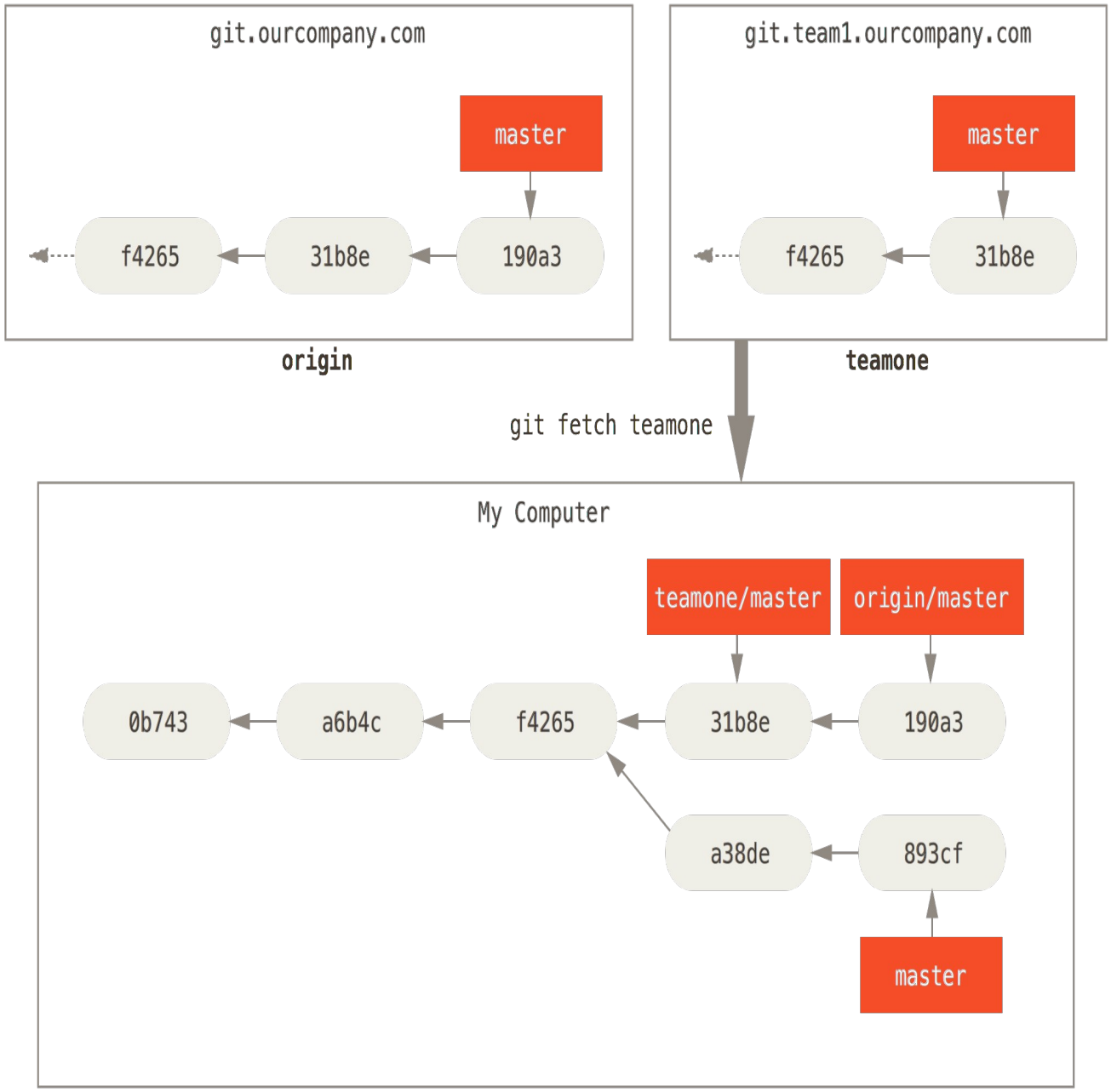


Figure 3-26. Remote tracking branch for `teamone/master`

Pushing

When you want to share a branch with the world, you need to push it up to a remote that you have write access to. Your local branches aren't automatically synchronized to the remotes you write to –

you have to explicitly push the branches you want to share. That way, you can use private branches for work you don't want to share, and push up only the topic branches you want to collaborate on.

If you have a branch named `serverfix` that you want to work on with others, you can push it up the same way you pushed your first branch. Run `git push (remote) (branch)`:

```
$ git push origin serverfix
Counting objects: 24, done.
Delta compression using up to 8 threads.
Compressing objects: 100% (15/15), done.
Writing objects: 100% (24/24), 1.91 KiB | 0 bytes/s, done.
Total 24 (delta 2), reused 0 (delta 0)
To https://github.com/schacon/simplegit
 * [new branch]      serverfix -&gt; serverfix
```

This is a bit of a shortcut. Git automatically expands the `serverfix` branchname out to `refs/heads/serverfix:refs/heads/serverfix`, which means, "Take my serverfix local branch and push it to update the remote's serverfix branch." We'll go over the `refs/heads/` part in detail in[Git Internals](), but you can generally leave it off. You can also do `git push origin serverfix:serverfix`, which does the same thing – it says, "Take my serverfix and make it the remote's serverfix." You can use this format to push a local branch into a remote branch that is named differently. If you didn't want it to be called `serverfix` on the remote, you could instead run `git push origin serverfix:awesomebranch` to push your local `serverfix` branch to the `awesomebranch` branch on the remote project.

NOTE

Don't type your password every time

If you're using an HTTPS URL to push over, the Git server will ask you for your username and password for authentication. By default it will prompt you on the terminal for this information so the server can tell if you're allowed to push.

If you don't want to type it every single time you push, you can set up a "credential cache". The simplest is just to keep it in memory for a few minutes, which you can easily set up by running `git config --global credential.helper cache`.

For more information on the various credential caching options available, see [Credential Storage]().

The next time one of your collaborators fetches from the server, they will get a reference to where the server's version of `serverfix` is under the remote branch `origin/serverfix`:

```
$ git fetch origin
remote: Counting objects: 7, done.
remote: Compressing objects: 100% (2/2), done.
remote: Total 3 (delta 0), reused 3 (delta 0)
Unpacking objects: 100% (3/3), done.
From https://github.com/schacon/simplegit
 * [new branch]      serverfix    -&gt; origin/serverfix
```

It's important to note that when you do a fetch that brings down new remote-tracking branches, you don't automatically have local, editable copies of them. In other words, in this case, you don't have a new `serverfix` branch – you only have an `origin/serverfix` pointer that you can't modify. To merge this work into your current working branch, you can run `git merge origin/serverfix`. If you want your own `serverfix` branch that you can work on, you can base it off your remote-tracking branch:

```
$ git checkout -b serverfix origin/serverfix
Branch serverfix set up to track remote branch serverfix from origin.
Switched to a new branch 'serverfix'
```

This gives you a local branch that you can work on that starts where `origin/serverfix` is.

Tracking Branches

Checking out a local branch from a remote-tracking branch automatically creates what is called a "tracking branch" (or sometimes an "upstream branch"). Tracking branches are local branches that have a direct relationship to a remote branch. If you're on a tracking branch and type `git pull`, Git automatically knows which server to fetch from and branch to merge into.
When you clone a repository, it generally automatically creates a `master` branch that tracks `origin/master`. However, you can set up other tracking branches if you wish – ones that track branches on other remotes, or don't track the `master` branch. The simple case is the example you just saw, running `git checkout -b [branch] [remotename]/[branch]`. This is a common enough operation that git provides the `--track` shorthand:

```
$ git checkout --track origin/serverfix
Branch serverfix set up to track remote branch serverfix from origin.
Switched to a new branch 'serverfix'
```

In fact, this is so common that there's even a shortcut for that shortcut. If the branch name you're trying to checkout (a) doesn't exist and (b) exactly matches a name on only one remote, Git will create a tracking branch for you:

```
$ git checkout serverfix
Branch serverfix set up to track remote branch serverfix from origin.
Switched to a new branch 'serverfix'
```

To set up a local branch with a different name than the remote branch, you can easily use the first version with a different local branch name:

```
$ git checkout -b sf origin/serverfix
Branch sf set up to track remote branch serverfix from origin.
Switched to a new branch 'sf'
```

Now, your local branch `sf` will automatically pull from `origin/serverfix`.

If you already have a local branch and want to set it to a remote branch you just pulled down, or want to change the upstream branch you're tracking, you can use the `-u` or `--set-upstream-to` option to `git branch` to explicitly set it at any time.

```
$ git branch -u origin/serverfix
Branch serverfix set up to track remote branch serverfix from origin.
```

NOTE

Upstream shorthand

When you have a tracking branch set up, you can reference it with the `@{upstream}` or `@{u}` shorthand. So if you're on the `master` branch and it's tracking `origin/master`, you can say something like `git merge @{u}` instead of `git merge origin/master` if you wish.
If you want to see what tracking branches you have set up, you can use the `-vv` option to `git branch`. This will list out your local branches with more information including what each branch is tracking and if your local branch is ahead, behind or both.

```
$ git branch -vv
  iss53     7e424c3 [origin/iss53: ahead 2] forgot the brackets
  master    1ae2a45 [origin/master] deploying index fix
* serverfix f8674d9 [teamone/server-fix-good: ahead 3, behind 1] this should do it
  testing   5ea463a trying something new
```

So here we can see that our `iss53` branch is tracking `origin/iss53` and is "ahead" by two, meaning that we have two commits locally that are not pushed to the server. We can also see that our `master` branch is tracking `origin/master` and is up to date. Next we can see that our `serverfix` branch is tracking the `server-fix-good` branch on our `teamone` server and is ahead by three and behind by one, meaning that there is one commit on the server we haven't merged in yet and three commits locally that we haven't pushed. Finally we can see that our `testing` branch is not tracking any remote branch.

It's important to note that these numbers are only since the last time you fetched from each server. This command does not reach out to the servers, it's telling you about what it has cached from these servers locally. If you want totally up to date ahead and behind numbers, you'll need to fetch from all your remotes right before running this. You could do that like this: `$ git fetch --all; git branch -vv`

Pulling

While the `git fetch` command will fetch down all the changes on the server that you don't have yet, it will not modify your working directory at all. It will simply get the data for you and let you merge it yourself. However, there is a command called `git pull` which is essentially a `git fetch` immediately followed by a `git merge` in most cases. If you have a tracking branch set up as demonstrated in the last section, either by explicitly setting it or by having it created for you by

the `clone` or `checkout` commands, `git pull` will look up what server and branch your current branch is tracking, fetch from that server and then try to merge in that remote branch.
Generally it's better to simply use the `fetch` and `merge` commands explicitly as the magic of `git pull` can often be confusing.

Deleting Remote Branches

Suppose you're done with a remote branch – say you and your collaborators are finished with a feature and have merged it into your remote's `master` branch (or whatever branch your stable codeline is in). You can delete a remote branch using the `--delete` option to `git push`. If you want to delete your `serverfix` branch from the server, you run the following:

```
$ git push origin --delete serverfix
To https://github.com/schacon/simplegit
 - [deleted]         serverfix
```

Basically all this does is remove the pointer from the server. The Git server will generally keep the data there for a while until a garbage collection runs, so if it was accidentally deleted, it's often easy to recover.

3.6 Git Branching - Rebasing

Rebasing

In Git, there are two main ways to integrate changes from one branch into another: the `merge` and the `rebase`. In this section you'll learn what rebasing is, how to do it, why it's a pretty amazing tool, and in what cases you won't want to use it.

The Basic Rebase

If you go back to an earlier example from Basic Merging, you can see that you diverged your work and made commits on two different branches.

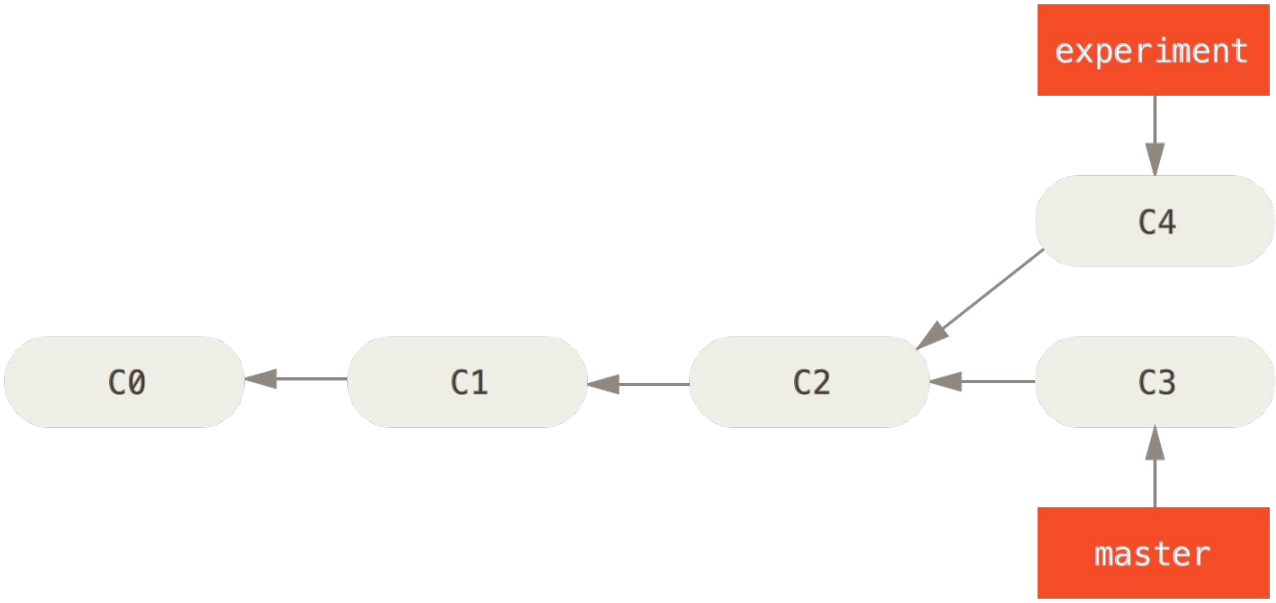


Figure 3-27. Simple divergent history

The easiest way to integrate the branches, as we've already covered, is the `merge` command. It performs a three-way merge between the two latest branch snapshots (`C3` and `C4`) and the most recent common ancestor of the two (`C2`), creating a new snapshot (and commit).

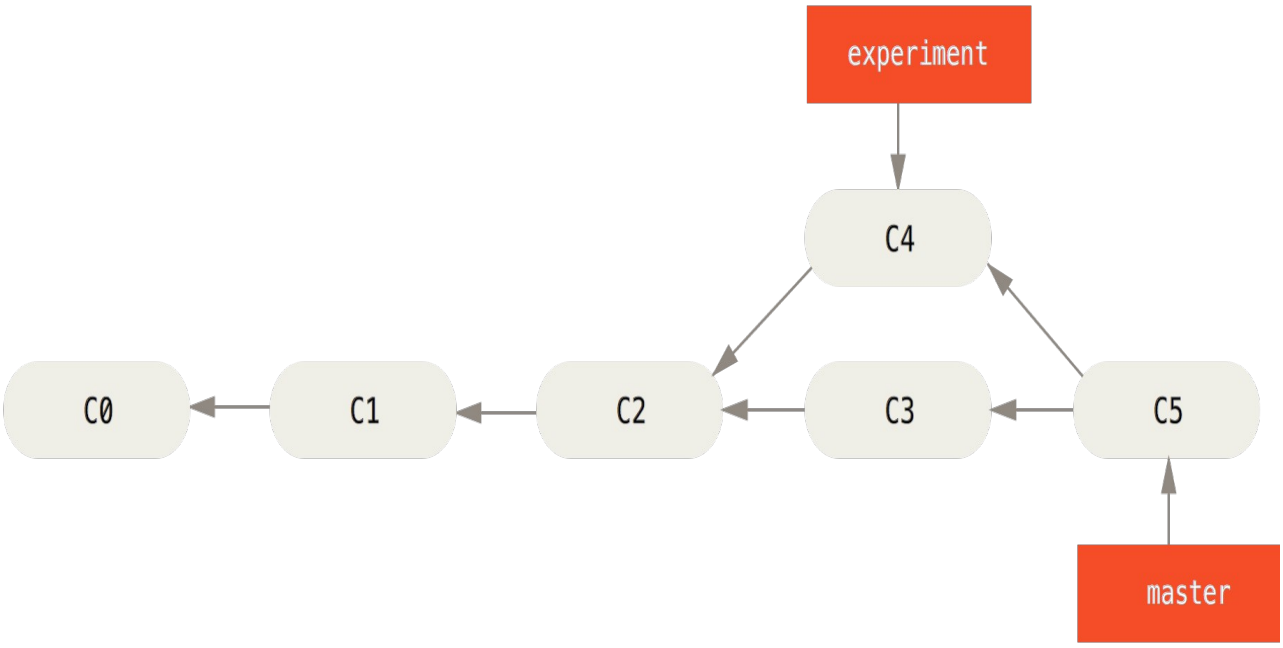


Figure 3-28. Merging to integrate diverged work history

However, there is another way: you can take the patch of the change that was introduced in `C4` and reapply it on top of `C3` . In Git, this is called *rebasing*. With the `rebase` command, you can take all the changes that were committed on one branch and replay them on another one.

In this example, you'd run the following:

```
$ git checkout experiment
$ git rebase master
First, rewinding head to replay your work on top of it...
Applying: added staged command
```

It works by going to the common ancestor of the two branches (the one you're on and the one you're rebasing onto), getting the diff introduced by each commit of the branch you're on, saving those diffs to temporary files, resetting the current branch to the same commit as the branch you are rebasing onto, and finally applying each change in turn.

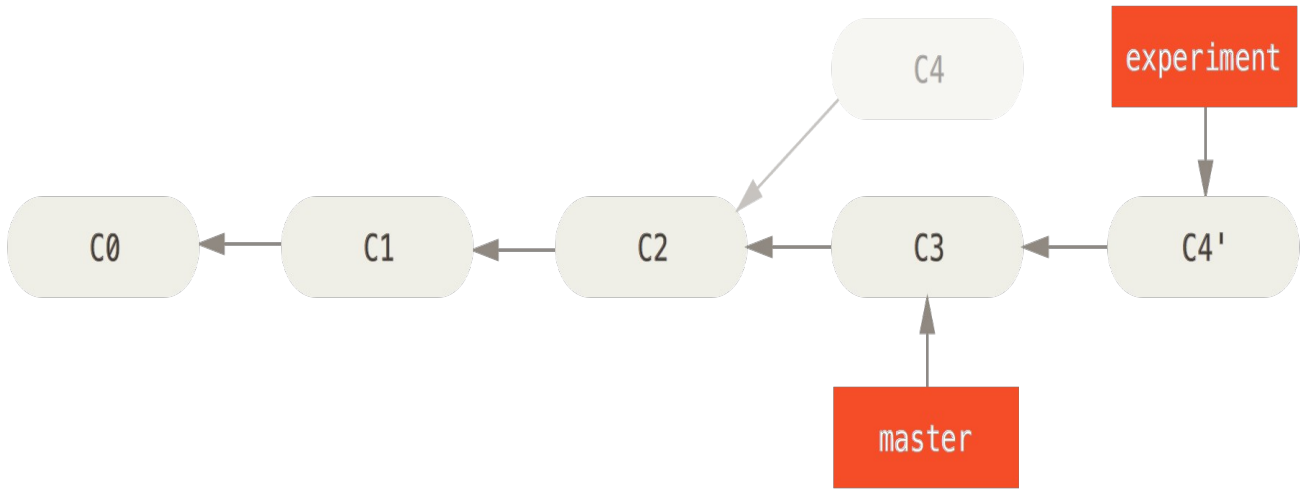


Figure 3-29. Rebasing the change introduced in `C4` onto `C3`

At this point, you can go back to the `master` branch and do a fast-forward merge.

```
$ git checkout master
$ git merge experiment
```

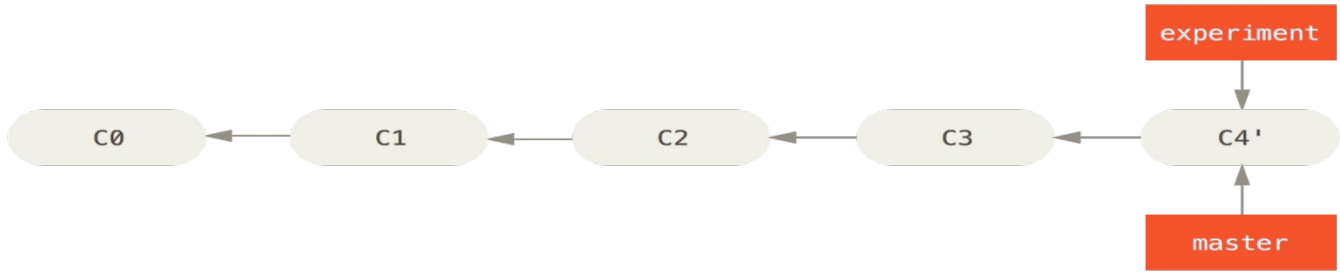


Figure 3-30. Fast-forwarding the master branch

Now, the snapshot pointed to by `C4'` is exactly the same as the one that was pointed to by `C5` in the merge example. There is no difference in the end product of the integration, but rebasing makes for a cleaner history. If you examine the log of a rebased branch, it looks like a linear history: it appears that all the work happened in series, even when it originally happened in parallel.

Often, you'll do this to make sure your commits apply cleanly on a remote branch – perhaps in a project to which you're trying to contribute but that you don't maintain. In this case, you'd do your work in a branch and then rebase your work onto `origin/master` when you were ready to submit your patches to the main project. That way, the maintainer doesn't have to do any integration work – just a fast-forward or a clean apply.

Note that the snapshot pointed to by the final commit you end up with, whether it's the last of the rebased commits for a rebase or the final merge commit after a merge, is the same snapshot – it's only the history that is different. Rebasing replays changes from one line of work onto another in the order they were introduced, whereas merging takes the endpoints and merges them together.

More Interesting Rebases

You can also have your rebase replay on something other than the rebase target branch. Take a history like Figure 3-31, for example. You branched a topic branch (`server`) to add some server-side functionality to your project, and made a commit. Then, you branched off that to make the client-side changes (`client`) and committed a few times. Finally, you went back to your server branch and did a few more commits.

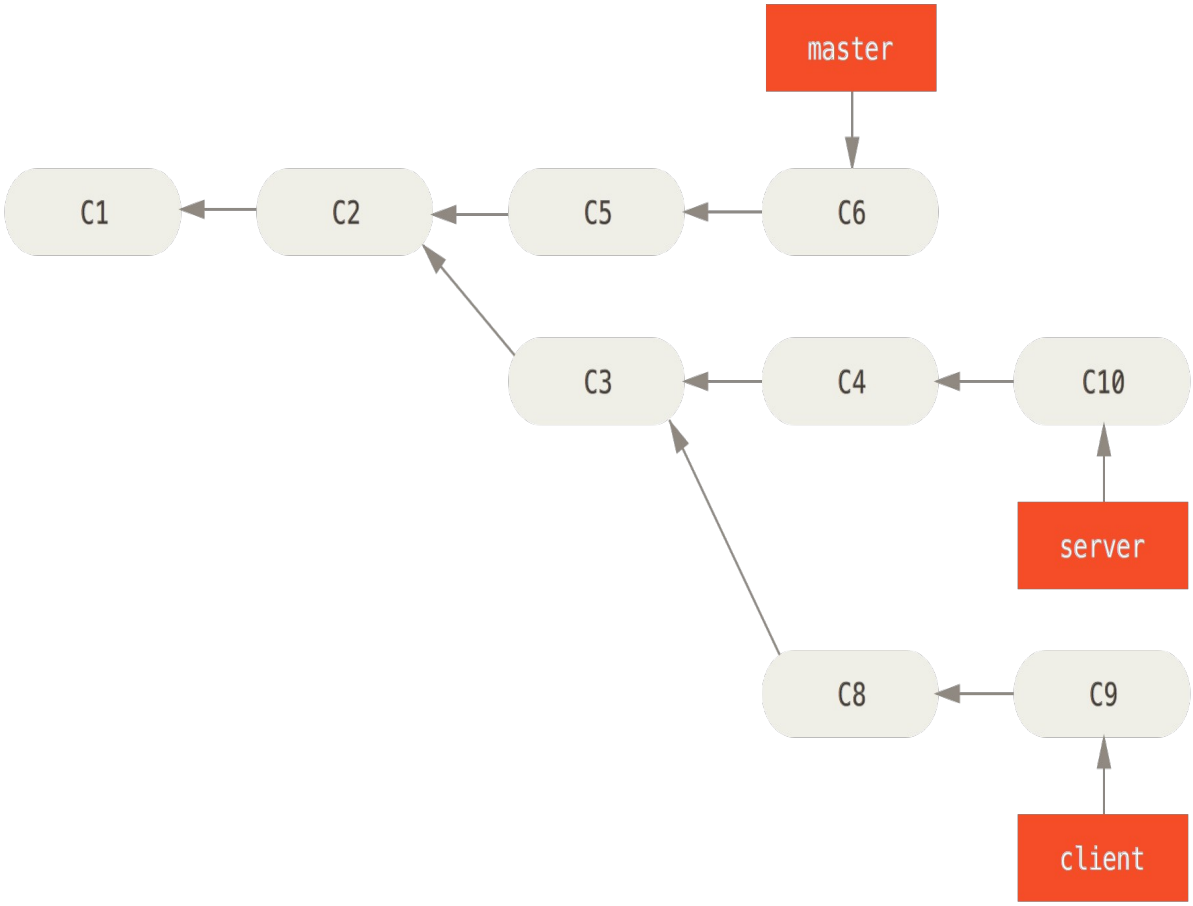


Figure 3-31. A history with a topic branch off another topic branch

Suppose you decide that you want to merge your client-side changes into your mainline for a release, but you want to hold off on the server-side changes until it's tested further. You can take the changes on client that aren't on server (`C8` and `C9`) and replay them on your `master` branch by using the `--onto` option of `git rebase` :

```
$ git rebase --onto master server client
```

This basically says, "Check out the client branch, figure out the patches from the common ancestor of the `client` and `server` branches, and then replay them onto `master` ." It's a bit complex, but the result is pretty cool.

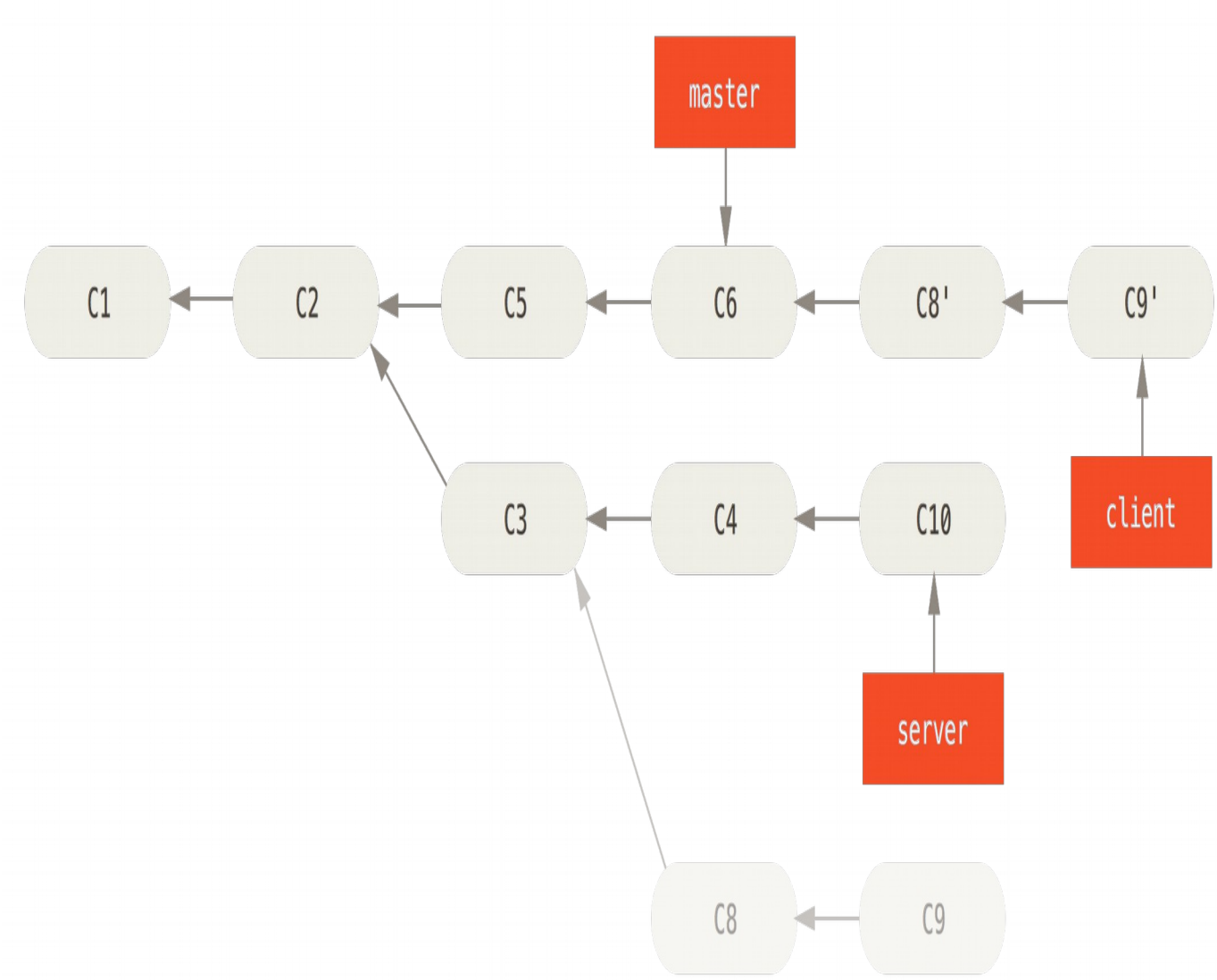


Figure 3-32. Rebasing a topic branch off another topic branch

Now you can fast-forward your `master` branch (see Figure 3-33):

```
$ git checkout master
$ git merge client
```

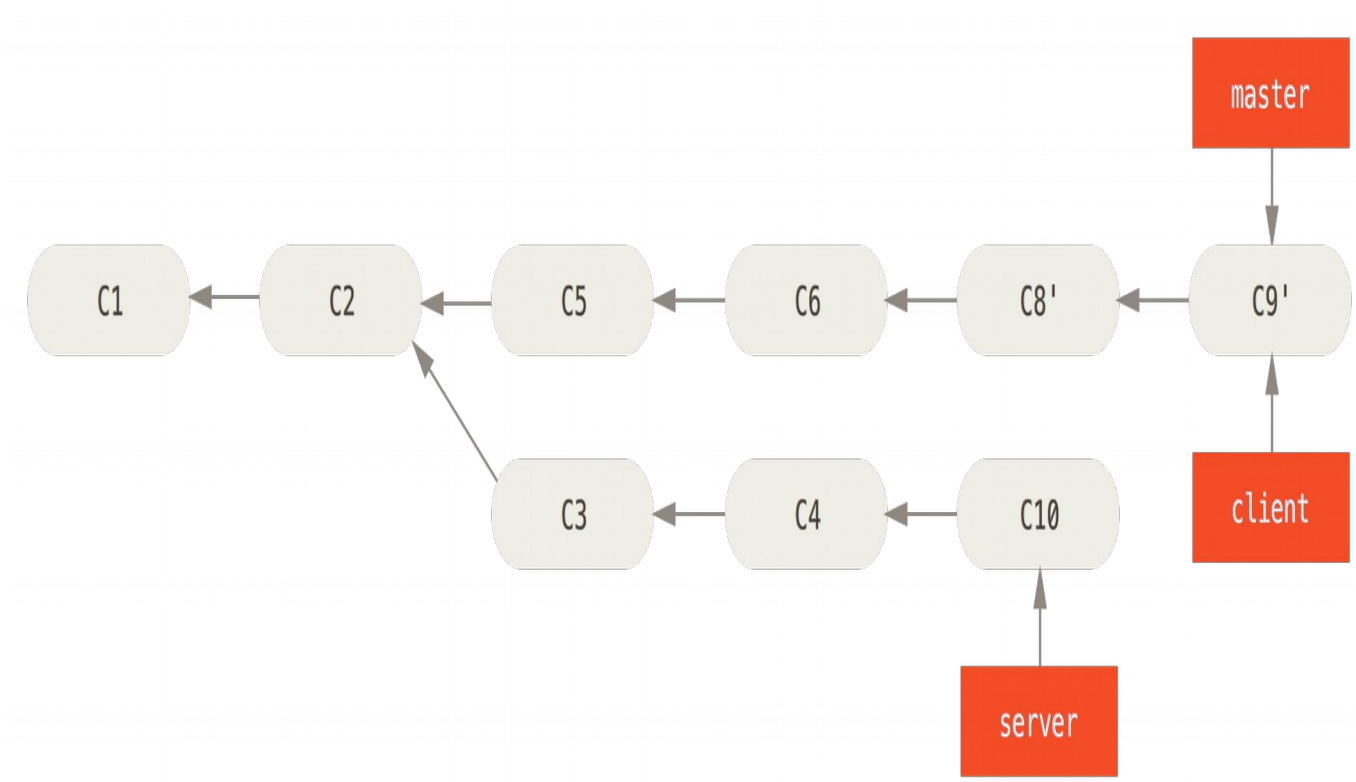


Figure 3-33. Fast-forwarding your master branch to include the client branch changes

Let's say you decide to pull in your server branch as well. You can rebase the server branch onto the `master` branch without having to check it out first by running `git rebase [basebranch] [topicbranch]` – which checks out the topic branch (in this case, `server`) for you and replays it onto the base branch (`master`):

```
$ git rebase master server
```

This replays your `server` work on top of your `master` work, as shown in Figure 3-34.

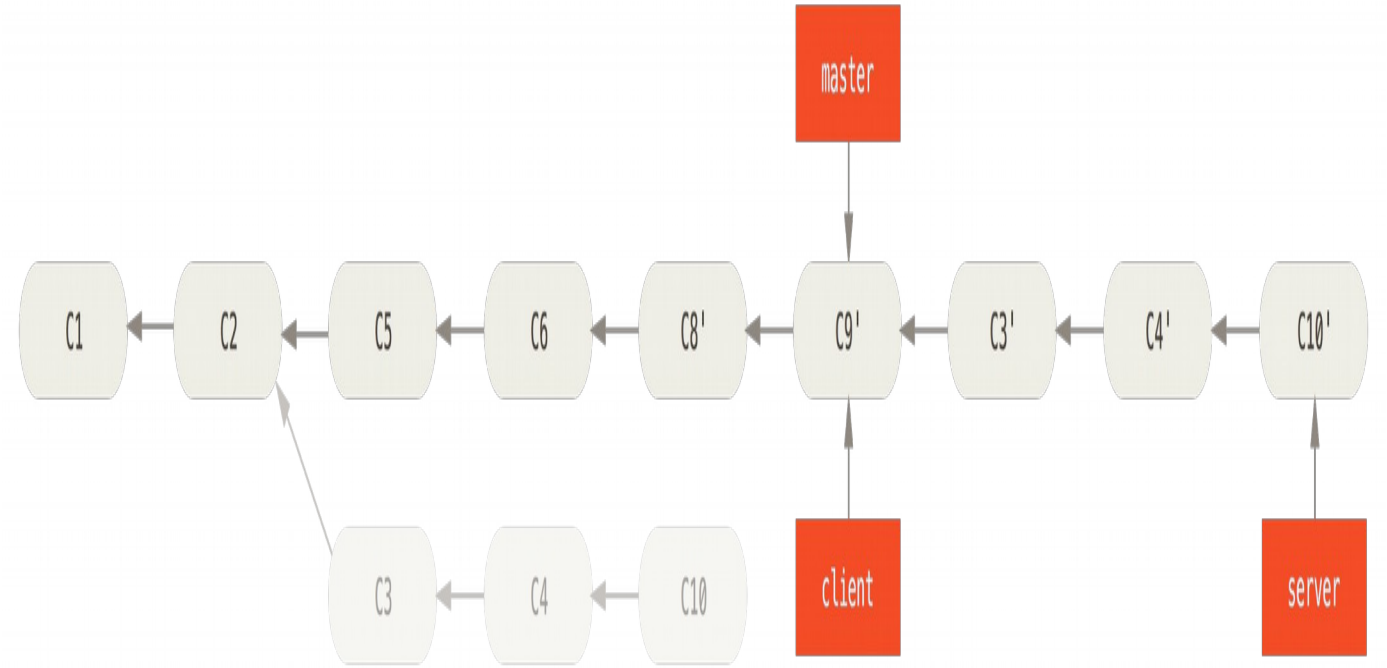


Figure 3-34. Rebasing your server branch on top of your master branch

Then, you can fast-forward the base branch (`master`):

```
$ git checkout master
$ git merge server
```

You can remove the `client` and `server` branches because all the work is integrated and you don't need them anymore, leaving your history for this entire process looking like Figure 3-35:

```
$ git branch -d client
$ git branch -d server
```

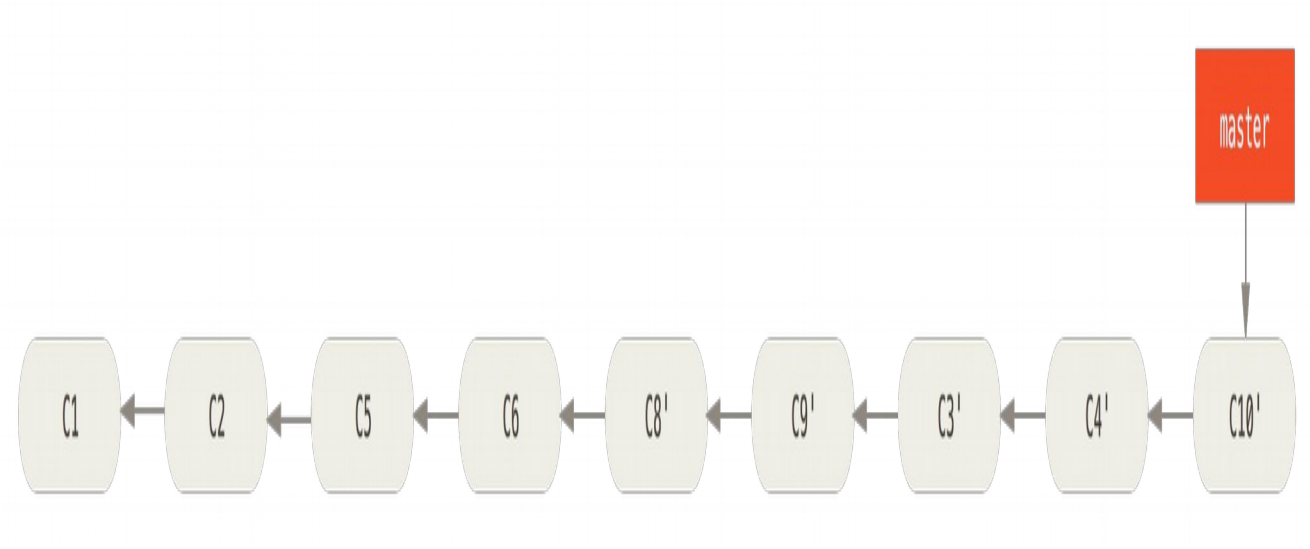


Figure 3-35. Final commit history

The Perils of Rebasing

Ahh, but the bliss of rebasing isn't without its drawbacks, which can be summed up in a single line:

Do not rebase commits that exist outside your repository.

If you follow that guideline, you'll be fine. If you don't, people will hate you, and you'll be scorned by friends and family.

When you rebase stuff, you're abandoning existing commits and creating new ones that are similar but different. If you push commits somewhere and others pull them down and base work on them, and then you rewrite those commits with `git rebase` and push them up again, your collaborators will have to re-merge their work and things will get messy when you try to pull their work back into yours.

Let's look at an example of how rebasing work that you've made public can cause problems. Suppose you clone from a central server and then do some work off that. Your commit history looks like this:

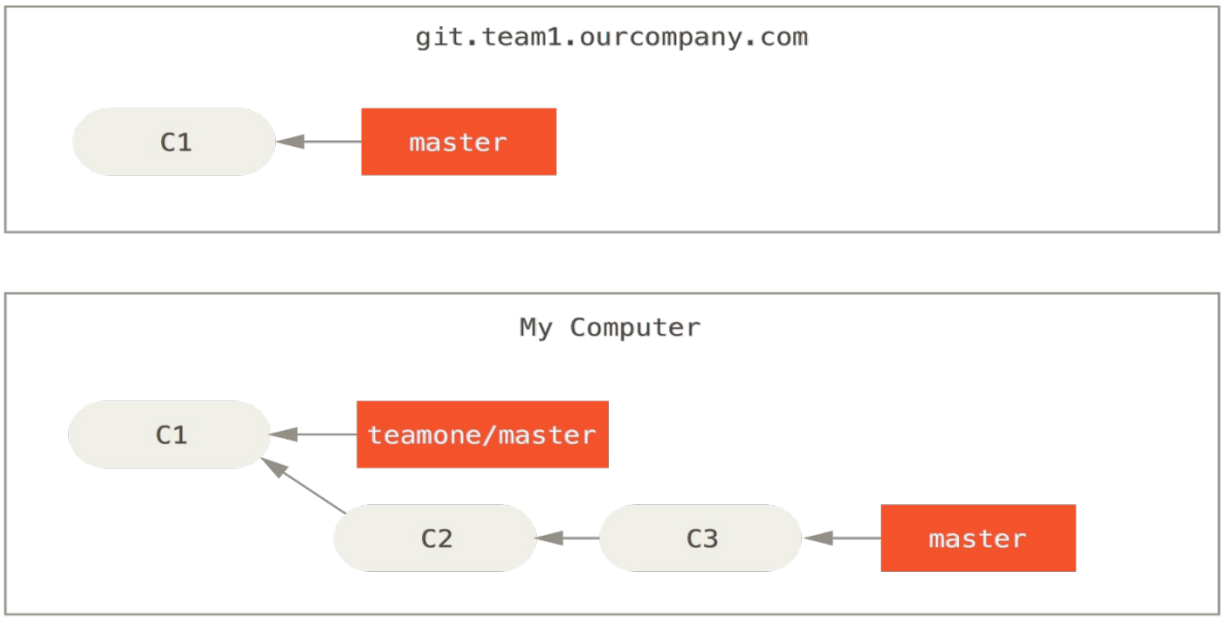
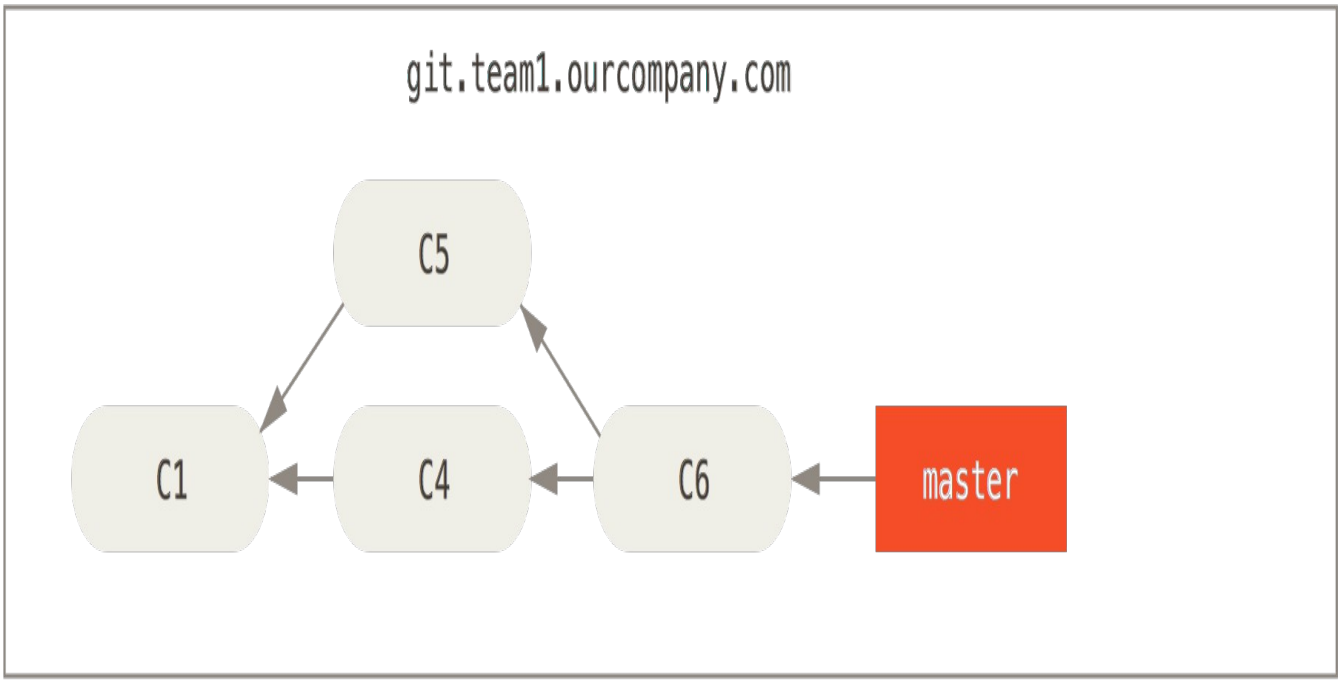


Figure 3-36. Clone a repository, and base some work on it

Now, someone else does more work that includes a merge, and pushes that work to the central server. You fetch it and merge the new remote branch into your work, making your history look something like this:


git.team1.ourcompany.com
C5
C1
C4
C6
master

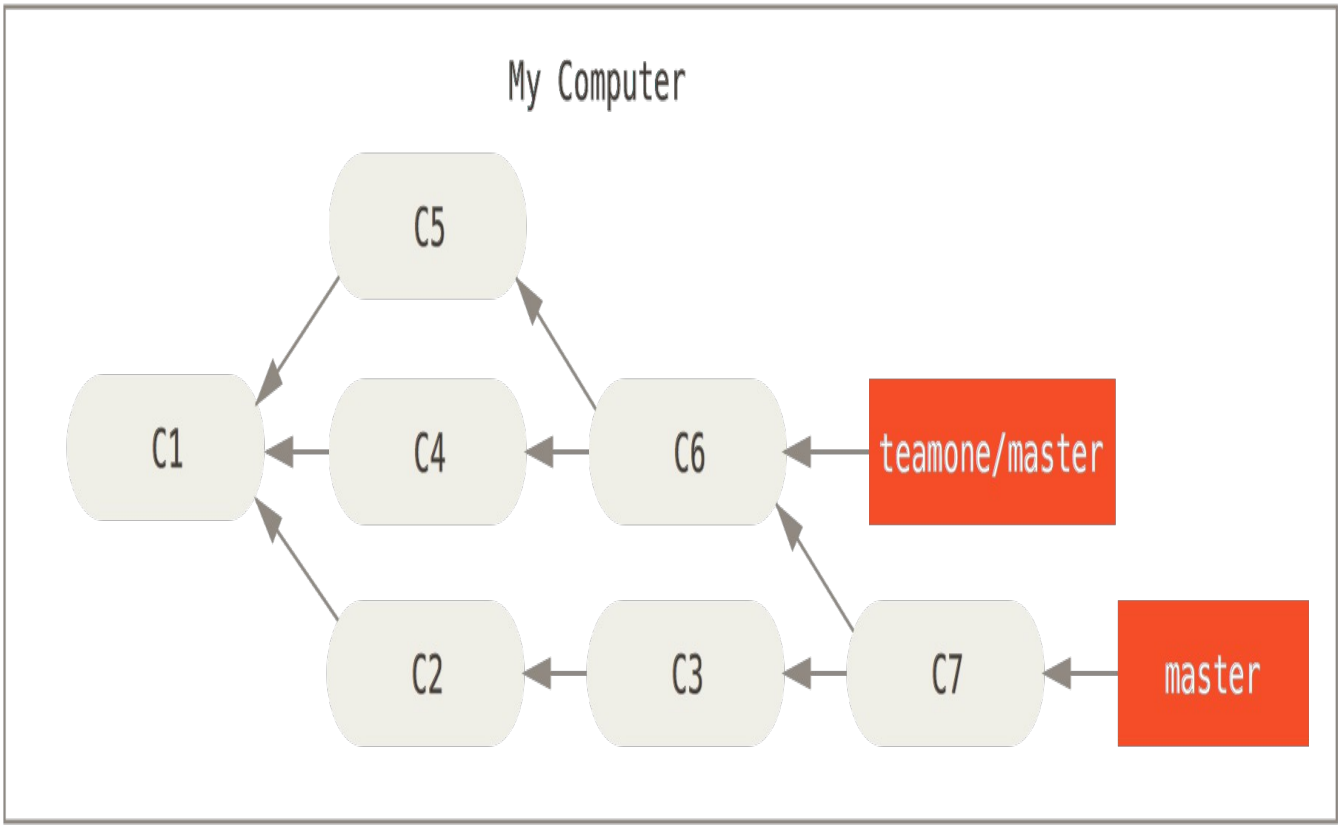

My Computer
C5
C1
C4
C6
teamone/master
C2
C3
C7
master

Figure 3-37. Fetch more commits, and merge them into your work

Next, the person who pushed the merged work decides to go back and rebase their work instead; they do a `git push --force` to overwrite the history on the server. You then fetch from that server, bringing down the new commits.

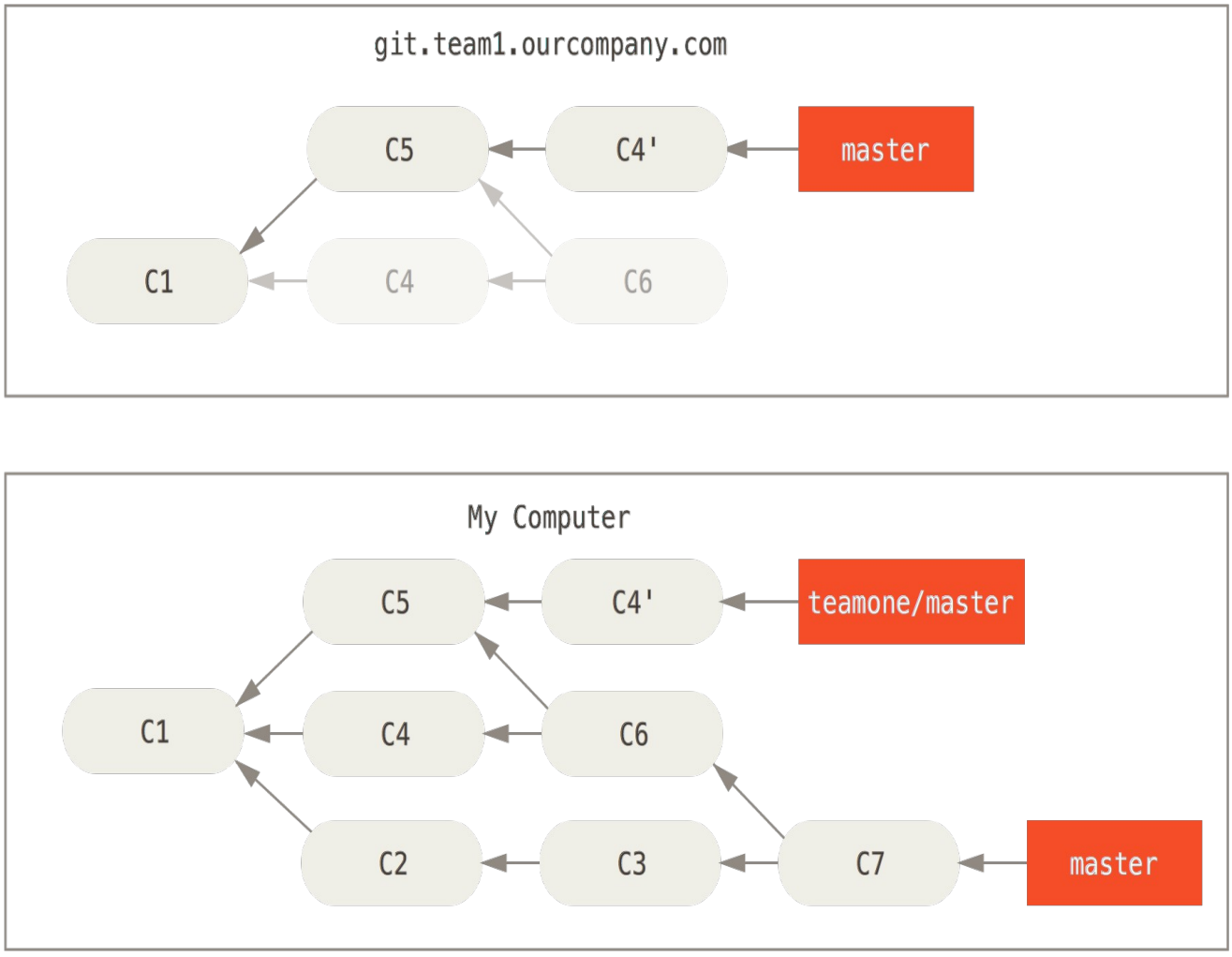


Figure 3-38. Someone pushes rebased commits, abandoning commits you've based your work on

Now you're both in a pickle. If you do a `git pull`, you'll create a merge commit which includes both lines of history, and your repository will look like this:

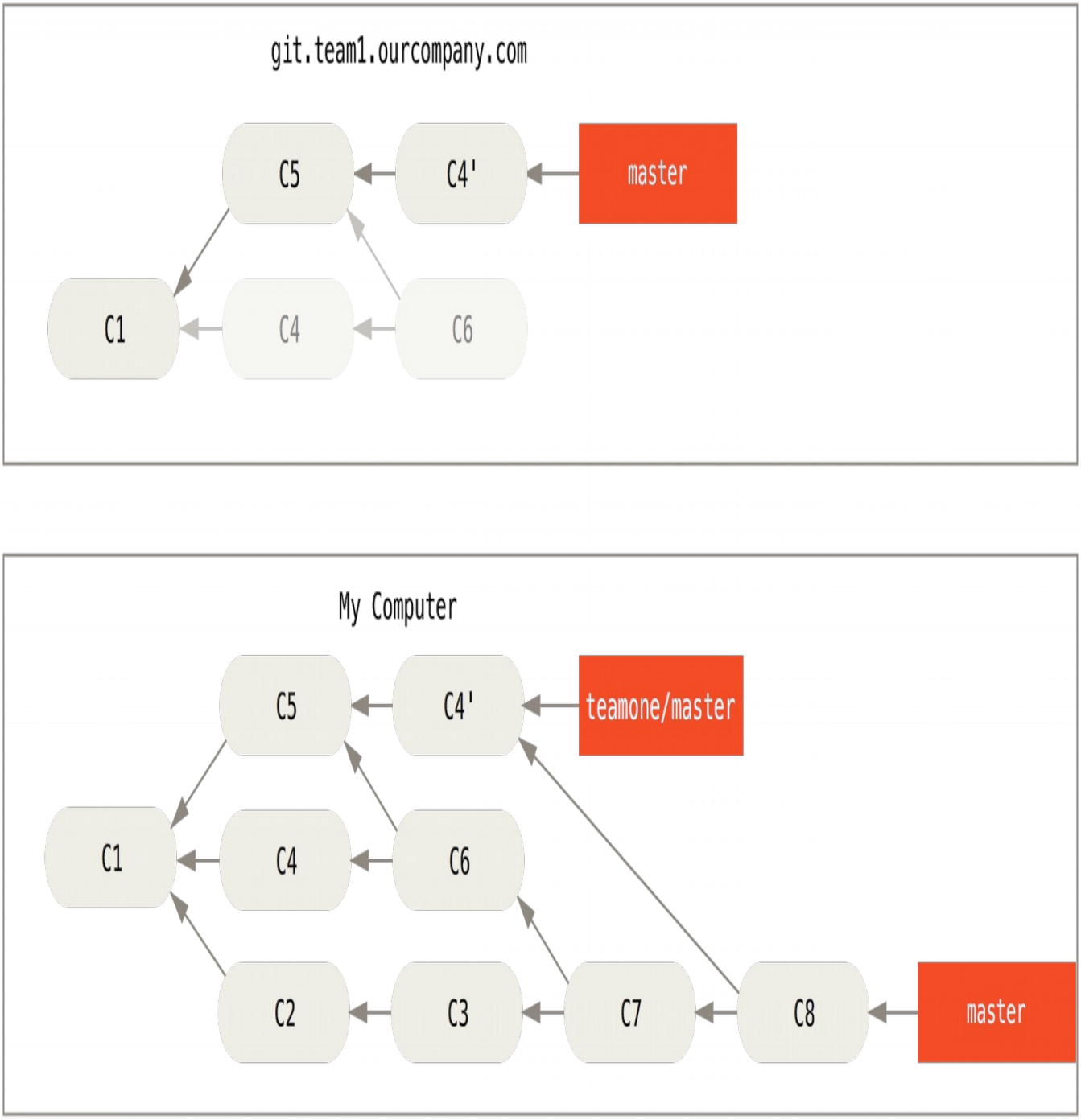


Figure 3-39. You merge in the same work again into a new merge commit

If you run a `git log` when your history looks like this, you'll see two commits that have the same author, date, and message, which will be confusing. Furthermore, if you push this history back up to the server, you'll reintroduce all those rebased commits to the central server, which can further

confuse people. It's pretty safe to assume that the other developer doesn't want `C4` and `C6` to be in the history; that's why they rebased in the first place.

Rebase When You Rebase

If you **do** find yourself in a situation like this, Git has some further magic that might help you out. If someone on your team force pushes changes that overwrite work that you've based work on, your challenge is to figure out what is yours and what they've rewritten.
It turns out that in addition to the commit SHA-1 checksum, Git also calculates a checksum that is based just on the patch introduced with the commit. This is called a "patch-id".

If you pull down work that was rewritten and rebase it on top of the new commits from your partner, Git can often successfully figure out what is uniquely yours and apply them back on top of the new branch.

For instance, in the previous scenario, if instead of doing a merge when we're at Figure 3-38 we run `git rebase teamone/master`, Git will:

- Determine what work is unique to our branch (C2, C3, C4, C6, C7)
- Determine which are not merge commits (C2, C3, C4)
- Determine which have not been rewritten into the target branch (just C2 and C3, since C4 is the same patch as C4')
- Apply those commits to the top of `teamone/master`

So instead of the result we see in Figure 3-39, we would end up with something more like Figure 3-40.

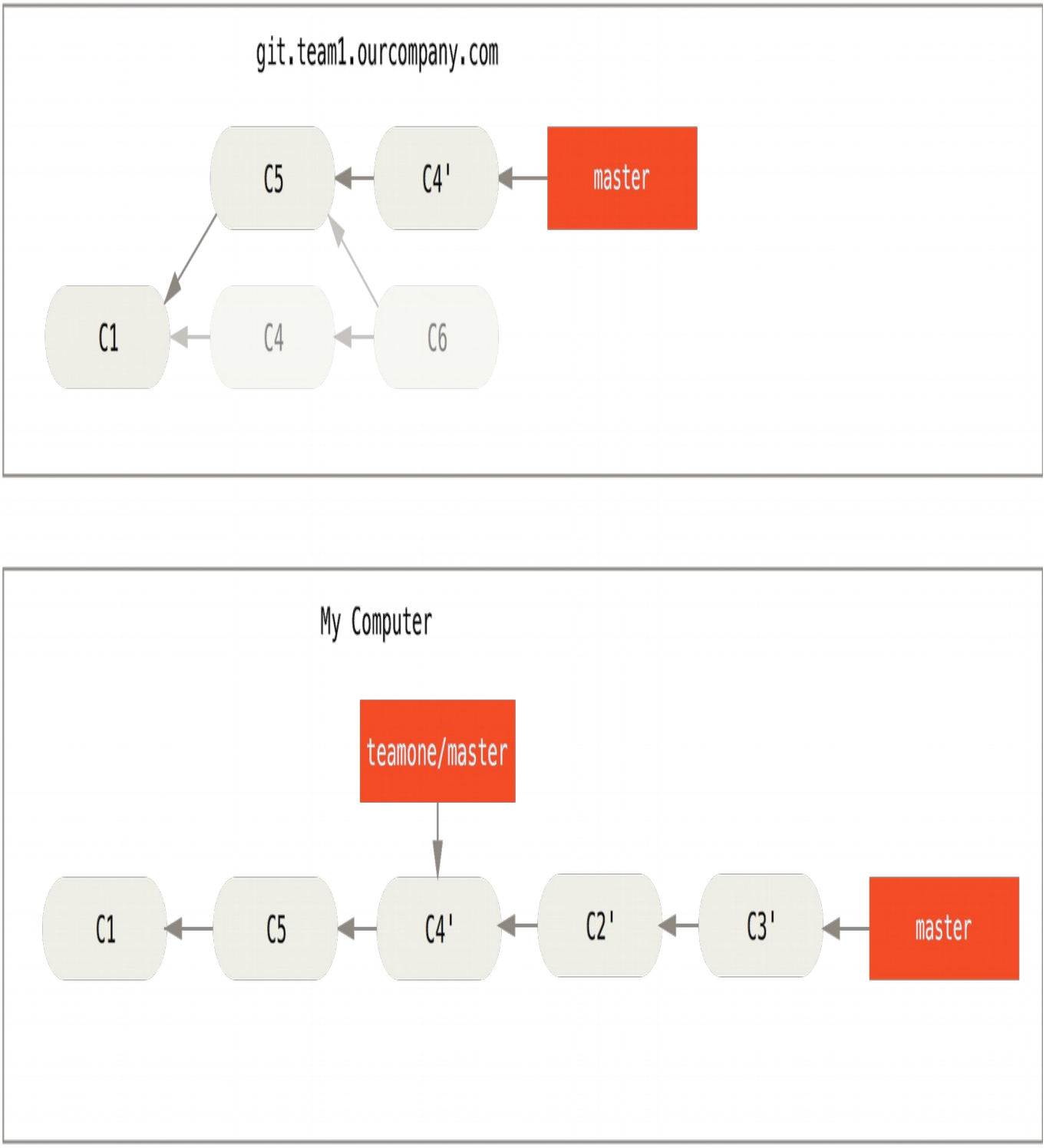


Figure 3-40. Rebase on top of force-pushed rebase work.

This only works if C4 and C4' that your partner made are almost exactly the same patch. Otherwise the rebase won't be able to tell that it's a duplicate and will add another C4-like patch (which will probably fail to apply cleanly, since the changes would already be at least somewhat there).

You can also simplify this by running a `git pull --rebase` instead of a normal `git pull`. Or you could do it manually with a `git fetch` followed by a `git rebase teamone/master` in this case.

If you are using `git pull` and want to make `--rebase` the default, you can set the `pull.rebase` config value with something like `git config --global pull.rebase true`.

If you treat rebasing as a way to clean up and work with commits before you push them, and if you only rebase commits that have never been available publicly, then you'll be fine. If you rebase commits that have already been pushed publicly, and people may have based work on those commits, then you may be in for some frustrating trouble, and the scorn of your teammates.

If you or a partner does find it necessary at some point, make sure everyone knows to run `git pull --rebase` to try to make the pain after it happens a little bit simpler.

Rebase vs. Merge

Now that you've seen rebasing and merging in action, you may be wondering which one is better. Before we can answer this, let's step back a bit and talk about what history means.

One point of view on this is that your repository's commit history is a **record of what actually happened.** It's a historical document, valuable in its own right, and shouldn't be tampered with. From this angle, changing the commit history is almost blasphemous; you're *lying* about what actually transpired. So what if there was a messy series of merge commits? That's how it happened, and the repository should preserve that for posterity.

The opposing point of view is that the commit history is the **story of how your project was made.** You wouldn't publish the first draft of a book, and the manual for how to maintain your software deserves careful editing. This is the camp that uses tools like rebase and filter-branch to tell the story in the way that's best for future readers.

Now, to the question of whether merging or rebasing is better: hopefully you'll see that it's not that simple. Git is a powerful tool, and allows you to do many things to and with your history, but every team and every project is different. Now that you know how both of these things work, it's up to you to decide which one is best for your particular situation.

In general the way to get the best of both worlds is to rebase local changes you've made but haven't shared yet before you push them in order to clean up your story, but never rebase anything you've pushed somewhere.