Lecture 03
version control with git

Dodecatheon meadia
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Course: Practical Bioinformatics (BIOL 4220)
Instructor: Michael Landis
Email: michael.landis@wustl.edu

Lecture 03 outline

Last time: modify filesystem
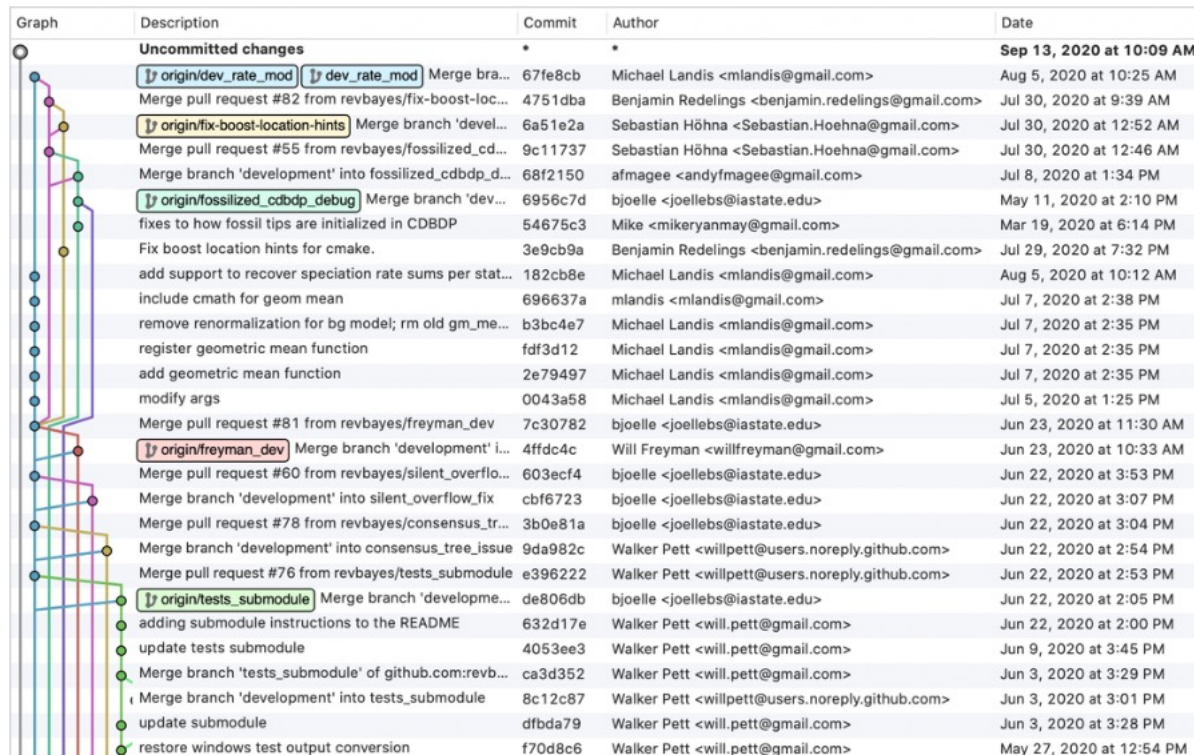
This time: version control

git basics
- repository anatomy
- stage (add) and commit
- branch and merge
- local and remote

Version control by filename

```
Viburnum Biogeography - MD - Sep 4 2019.docx
Viburnum Biogeography - MJD - Aug 21 2019.docx
Viburnum Biogeography - MJD - PWS.docx
Viburnum Biogeography - MJD new.docx
Viburnum Biogeography - MJL - Aug 24 2019.docx
Viburnum Biogeography - MJL - Oct 17 2019.docx
Viburnum Biogeography - MJL - Oct 9 2019.docx
Viburnum Biogeography - MJL - Sep 25 2019.docx
Viburnum Biogeography - MJL edits - Aug 16 2019.docx
Viburnum Biogeography - MJL&MD edits 190731.docx
Viburnum Biogeography - MJL&MD edits 190812.docx
Viburnum Biogeography - MJL&MD edits 190812.orig.docx
Viburnum Biogeography - MJL&MD edits_ELS.docx
Viburnum Biogeography - manuscript  - MJL edits 190731.docx
Viburnum Biogeography - supplement - MJL edits 190731.docx
ViburnumBiogeography_MJDnew_eje.docx .docx
Viburnum_phylogeny_manuscript_191018.docx
Viburnum_phylogeny_manuscript_191021.docx
Viburnum_phylogeny_manuscript_submitted_SystBiol_191020.pdf
Viburnum_phylogeny_supplement_191018.docx
Viburnum_phylogeny_supplement_191018_bioRxiv.pdf
Viburnum_phylogeny_manuscript_191021 copy.docx
Viburnum_phylogeny_manuscript_191021.docx
Viburnum_phylogeny_manuscript_191027_MD_fresh.docx
Viburnum_phylogeny_manuscript_191027_MD_orig.docx
Viburnum_phylogeny_manuscript_200306_MJL copy.docx
Viburnum_phylogeny_manuscript_200307_MJL.docx
Viburnum_phylogeny_manuscript_200310_MJL.docx
Viburnum_phylogeny_supplement_191018 copy.docx
Viburnum_phylogeny_supplement_191018.docx
Viburnum_phylogeny_supplement_191018_original.docx
Viburnum_phylogeny_supplement_191027_MD_orig.docx
Viburnum_phylogeny_supplement_200306_MJL.docx
Viburnum_phylogeny_supplement_200307_MD2 .docx
Viburnum_phylogeny_supplement_200307_MJL.docx
Viburnum_phylogeny_supplement_200310_MJL.docx
```

Word contributions from 5 co-authors
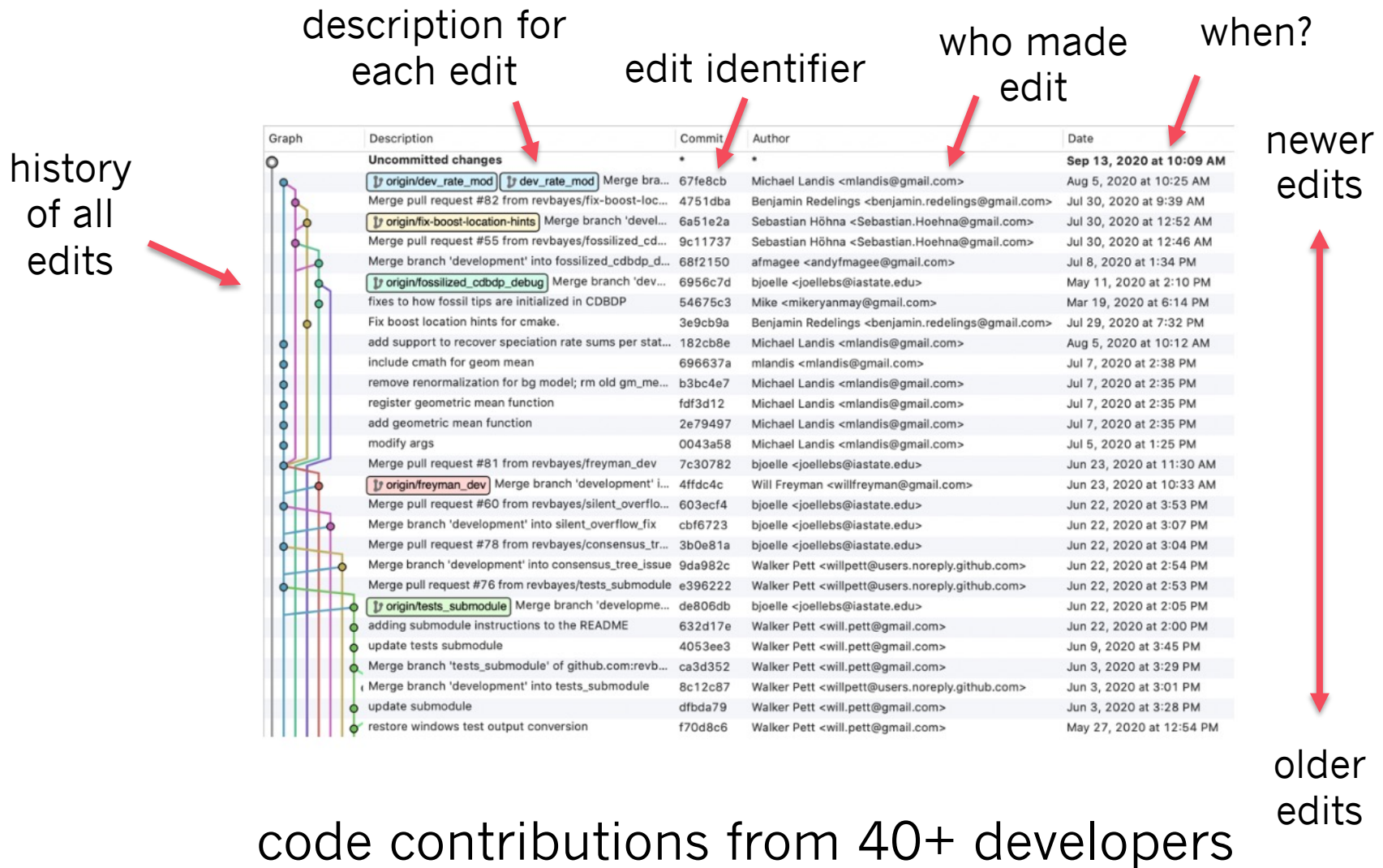
Version control by software (git)

Graph	Description	Commit	Author	Date
○	**Uncommitted changes**	•	•	**Sep 13, 2020 at 10:09 AM**
	⑂ origin/dev_rate_mod ⑂ dev_rate_mod Merge bra...	67fe8cb	Michael Landis <mlandis@gmail.com>	Aug 5, 2020 at 10:25 AM
	Merge pull request #82 from revbayes/fix-boost-loc...	4751dba	Benjamin Redelings <benjamin.redelings@gmail.com>	Jul 30, 2020 at 9:39 AM
	⑂ origin/fix-boost-location-hints Merge branch 'devel...	6a51e2a	Sebastian Höhna <Sebastian.Hoehna@gmail.com>	Jul 30, 2020 at 12:52 AM
	Merge pull request #55 from revbayes/fossilized_cd...	9c11737	Sebastian Höhna <Sebastian.Hoehna@gmail.com>	Jul 30, 2020 at 12:46 AM
	Merge branch 'development' into fossilized_cdbdp_d...	68f2150	afmagee <andyfmagee@gmail.com>	Jul 8, 2020 at 1:34 PM
	⑂ origin/fossilized_cdbdp_debug Merge branch 'dev...	6956c7d	bjoelle <joellebs@iastate.edu>	May 11, 2020 at 2:10 PM
	fixes to how fossil tips are initialized in CDBDP	54675c3	Mike <mikeryanmay@gmail.com>	Mar 19, 2020 at 6:14 PM
	Fix boost location hints for cmake.	3e9cb9a	Benjamin Redelings <benjamin.redelings@gmail.com>	Jul 29, 2020 at 7:32 PM
	add support to recover speciation rate sums per stat...	182cb8e	Michael Landis <mlandis@gmail.com>	Aug 5, 2020 at 10:12 AM
	include cmath for geom mean	696637a	mlandis <mlandis@gmail.com>	Jul 7, 2020 at 2:38 PM
	remove renormalization for bg model; rm old gm_me...	b3bc4e7	Michael Landis <mlandis@gmail.com>	Jul 7, 2020 at 2:35 PM
	register geometric mean function	fdf3d12	Michael Landis <mlandis@gmail.com>	Jul 7, 2020 at 2:35 PM
	add geometric mean function	2e79497	Michael Landis <mlandis@gmail.com>	Jul 7, 2020 at 2:35 PM
	modify args	0043a58	Michael Landis <mlandis@gmail.com>	Jul 5, 2020 at 1:25 PM
	Merge pull request #81 from revbayes/freyman_dev	7c30782	bjoelle <joellebs@iastate.edu>	Jun 23, 2020 at 11:30 AM
	⑂ origin/freyman_dev Merge branch 'development' i...	4ffdc4c	Will Freyman <willfreyman@gmail.com>	Jun 23, 2020 at 10:33 AM
	Merge pull request #60 from revbayes/silent_overflo...	603ecf4	bjoelle <joellebs@iastate.edu>	Jun 22, 2020 at 3:53 PM
	Merge branch 'development' into silent_overflow_fix	cbf6723	bjoelle <joellebs@iastate.edu>	Jun 22, 2020 at 3:07 PM
	Merge pull request #78 from revbayes/consensus_tr...	3b0e81a	bjoelle <joellebs@iastate.edu>	Jun 22, 2020 at 3:04 PM
	Merge branch 'development' into consensus_tree_issue	9da982c	Walker Pett <willpett@users.noreply.github.com>	Jun 22, 2020 at 2:54 PM
	Merge pull request #76 from revbayes/tests_submodule	e396222	Walker Pett <willpett@users.noreply.github.com>	Jun 22, 2020 at 2:53 PM
	⑂ origin/tests_submodule Merge branch 'developme...	de806db	bjoelle <joellebs@iastate.edu>	Jun 22, 2020 at 2:05 PM
	adding submodule instructions to the README	632d17e	Walker Pett <will.pett@gmail.com>	Jun 22, 2020 at 2:00 PM
	update tests submodule	4053ee3	Walker Pett <will.pett@gmail.com>	Jun 9, 2020 at 3:45 PM
	Merge branch 'tests_submodule' of github.com:revb...	ca3d352	Walker Pett <will.pett@gmail.com>	Jun 3, 2020 at 3:29 PM
	Merge branch 'development' into tests_submodule	8c12c87	Walker Pett <willpett@users.noreply.github.com>	Jun 3, 2020 at 3:01 PM
	update submodule	dfbda79	Walker Pett <will.pett@gmail.com>	Jun 3, 2020 at 3:28 PM
	restore windows test output conversion	f70d8c6	Walker Pett <will.pett@gmail.com>	May 27, 2020 at 12:54 PM

code contributions from 40+ developers

Version control by software (git)

description for each edit

edit identifier

who made edit

when?

history of all edits

newer edits

older edits

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code contributions from 40+ developers

Basics of git

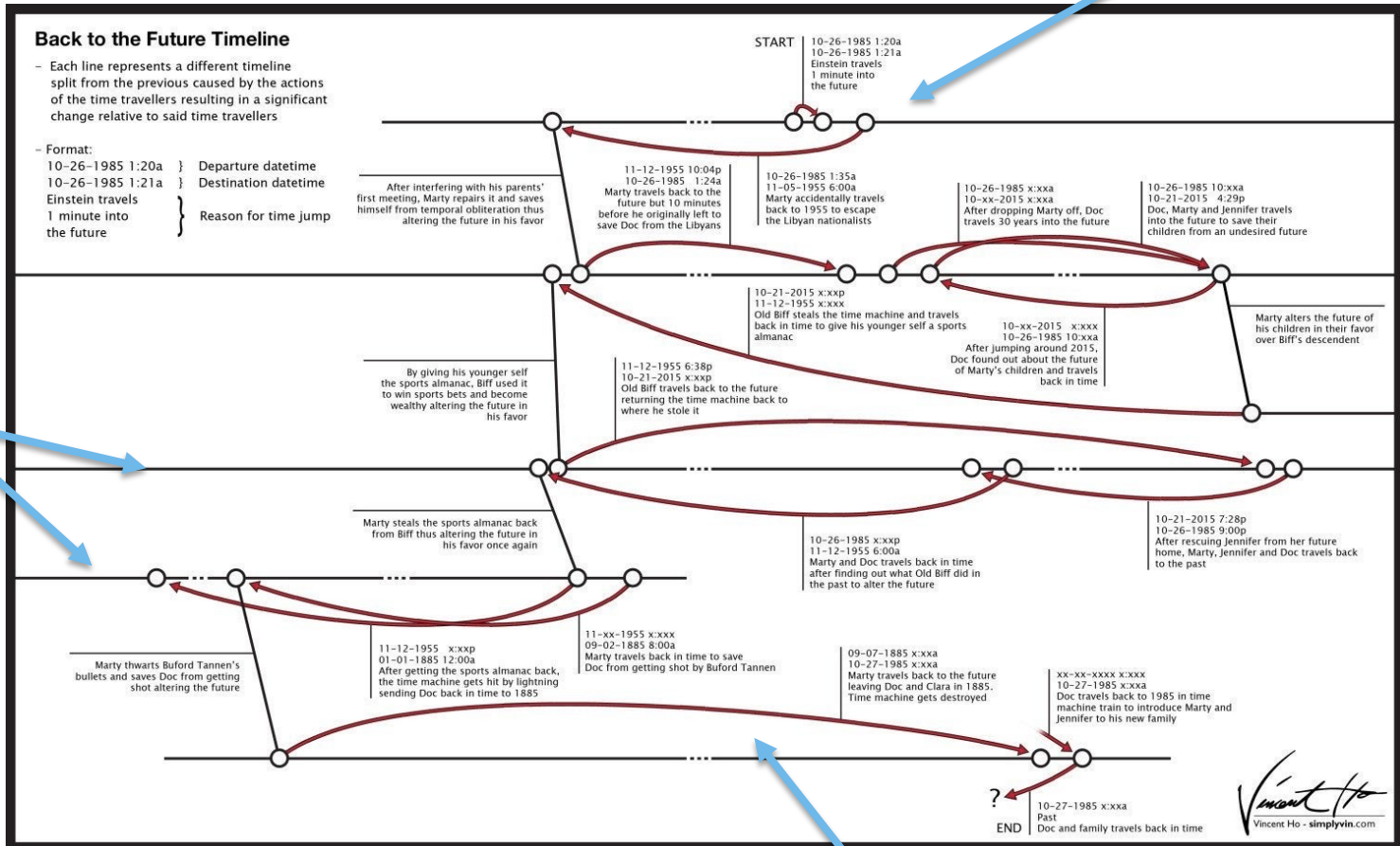git allows you to manage alternate histories and futures for a filesystem

- **add** files to monitor
- **commit** changed files to history
- **branch** to create alternate history
- **merge** to re-unify branched histories
- **checkout** commits/branches to recover past/alternate changes
- **push** histories to trusted collaborators
- **pull** histories from trusted collaborators

...using git

saved versions (*commit*)

alternate histories (*branch*, *merge*)

Back to the Future Timeline

- Each line represents a different timeline split from the previous caused by the actions of the time travellers resulting in a significant change relative to said time travellers

- Format:
  10-26-1985 1:20a } Departure datetime
  10-26-1985 1:21a } Destination datetime
  Einstein travels
  1 minute into } Reason for time jump
  the future

START
10-26-1985 1:20a
10-26-1985 1:21a
Einstein travels
1 minute into
the future

After interfering with his parents' first meeting, Marty repairs it and saves himself from temporal obliteration thus altering the future in his favor

11-12-1955 10:04p
11-05-1955 6:00a
Marty travels back to the future but 10 minutes before he originally left to save Doc from the Libyans

10-26-1985 1:35a
11-05-1955 6:00a
Marty accidentally travels back to 1955 to escape the Libyan nationalists

10-26-1985 x:xxa
10-xx-2015 x:xxa
After dropping Marty off, Doc travels 30 years into the future

10-26-1985 10:xxa
10-21-2015 4:29p
Doc, Marty and Jennifer travels into the future to save their children from an undesired future

10-21-2015 x:xxp
11-12-1955 x:xxx
Old Biff steals the time machine and travels back in time to give his younger self a sports almanac

10-xx-2015 x:xxx
After jumping around 2015, Doc found out about the future of Marty's children and travels back in time

Marty alters the future of his children in their favor over Biff's descendent

By giving his younger self the sports almanac, Biff used it to win sports bets and become wealthy altering the future in his favor

11-12-1955 6:38p
10-21-2015 x:xxp
Old Biff travels back to the future returning the time machine back to where he stole it

Marty steals the sports almanac back from Biff thus altering the future in his favor once again

10-26-1985 x:xxp
11-12-1955 6:00a
Marty and Doc travels back in time after finding out what Old Biff did in the past to alter the future

10-21-2015 7:28p
10-26-1985 9:00p
After rescuing Jennifer from her future home, Marty, Jennifer and Doc travels back to the past

Marty thwarts Buford Tannen's bullets and saves Doc from getting shot altering the future

11-12-1955 x:xxp
01-01-1885 12:00a
After getting the sports almanac back, the time machine gets hit by lightning sending Doc back in time to 1885

11-xx-1955 x:xxx
09-02-1885 8:00a
Marty travels back in time to save Doc from getting shot by Buford Tannen

09-07-1885 x:xxa
10-27-1985 x:xxa
Marty travels back to the future leaving Doc and Clara in 1885. Time machine gets destroyed

xx-xx-xxxx x:xxx
10-27-1985 x:xxa
Doc travels back to 1985 in time machine train to introduce Marty and Jennifer to his new family

?
END
10-27-1985 x:xxa
Past
Doc and family travels back in time

Vincent Ho - simplyvin.com

visit other history (*checkout*)

xkcd.com

99% of git usage is saving local changes to your history

1. **modify** files in <u>working directory</u>
2. **add** modified files to <u>staging area</u>
3. **commit** staged files to <u>repository history</u>
4. 1% of the time, do something else
5. repeat

Local repository
(*e.g.* on your VM)

Working directory
*monitored files
that you edit*

git add

Staging area
*where files can be
committed to history*

git commit

Repository
*maintains
commit history*

Visualizing
git spaces

- working directory
- staging area
- repository

Controls which files
are saved, and how

Visualizing commit history
as a graph

gray box presents your current position in the commit history, called the **HEAD** state

main

commit: be726a1
initial commit

commit: 1014cca
add first file

commit: 032af31
add second file

commit: d091a77
edit first file
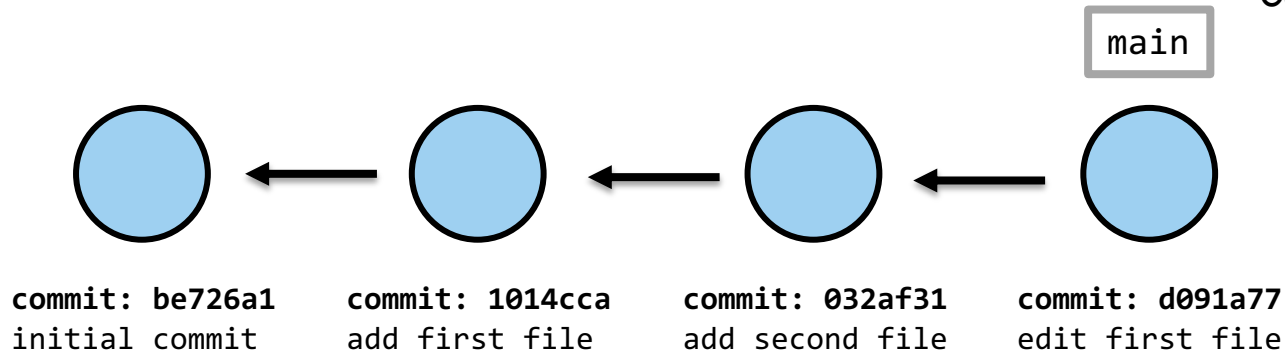
each *node* represents filesystem changes that have been committed to history

each *arrow* points toward the previous moment in history for that commit

git status

provides general info about commit
and staged status for all files in repo

```
$ # inspect status of local git repo
$ git status
On branch main
Your branch is ahead of 'origin/main' by 2 commits.
  (use "git push" to publish your local commits)

Changes to be committed:
  (use "git restore --staged <file>..." to unstage)
        new file: run.sh

Changes not staged for commit:
  (use "git add <file>..." to update what will be committed)
  (use "git restore <file>..." to discard changes in working directory)
        modified: output.txt

Untracked files:
  (use "git add <file>..." to include in what will be committed)
        data.txt
```

| *run.sh* is in staging area, ready to be committed | add tracked file *output.txt* to staging area for commit | add untracked file *data.txt* to monitor changes |

git add

move file(s) from working directory into staging area

```
$ # status shows output.txt was modified
$ git status
On branch main
Your branch is up to date with 'origin/main'.

Changes not staged for commit:
  (use "git add <file>..." to update what will be committed)
  (use "git restore <file>..." to discard changes in working directory)
        modified:   output.txt          ⬅

no changes added to commit (use "git add" and/or "git commit -a")
$ # add output.txt to staging area
$ git add output.txt          ⬅
$ # status shows output.txt ready to be committed
$ git status
On branch main
Your branch is up to date with 'origin/main'.

Changes to be committed:
  (use "git restore --staged <file>..." to unstage)
        modified:   output.txt          ⬅
```

before *commit*

main

commit: be726a1
initial commit

commit: 1014cca
add first file

commit: 032af31
add second file

after *commit*

main

commit: be726a1
initial commit

commit: 1014cca
add first file

commit: 032af31
add second file

commit: d091a77
edit first file
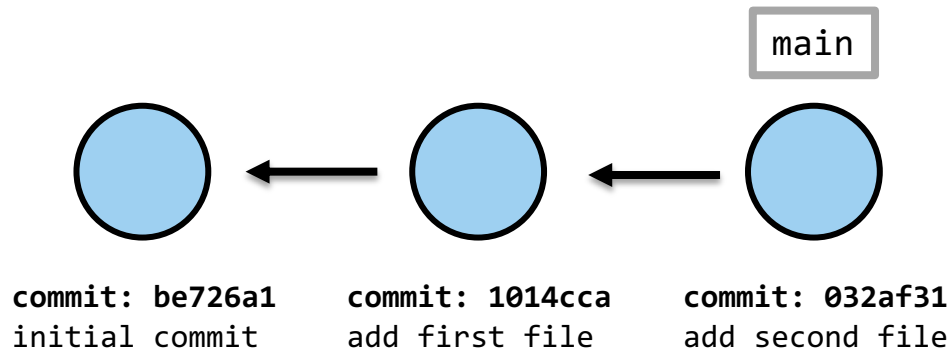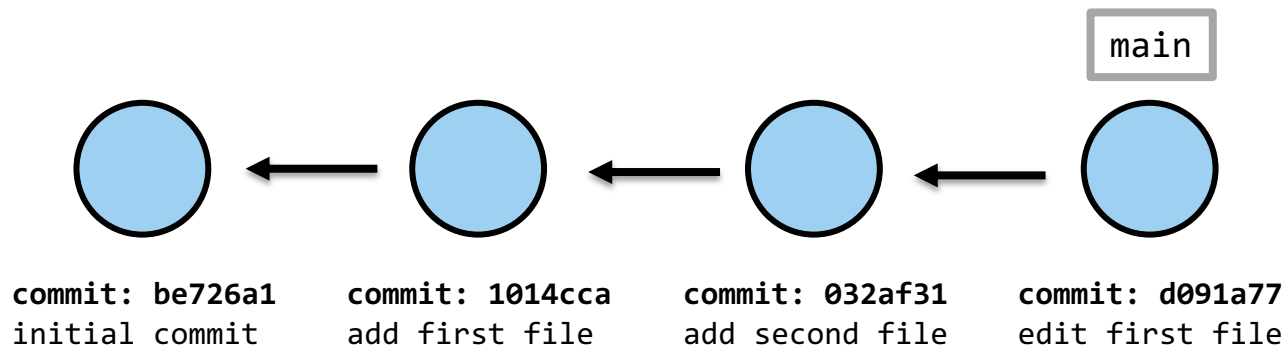
git commit

save file(s) in staging area
to the local repository

```
$ # status shows output.txt is staged for commit
$ git status
On branch main
Your branch is up to date with 'origin/main'.

Changes to be committed:
(use "git restore --staged <file>..." to unstage)
      modified:   output.txt        ⬅

$ # commit change (with a message, using -m)
$ git commit -m 'fix misspelled name'   ⬅
[main c4cd574] fix mispelled name
 1 file changed, 1 insertion(+), 1 deletion(-)
$ # no modified files to stage/commit
$ git status
On branch main
Your branch is ahead of 'origin/main' by 1 commit.
  (use "git push" to publish your local commits)

nothing to commit, working tree clean   ⬅
```

git show

provides detailed info about commit/file
(targets current commit, by default)

```
$ git show
commit c4cd574d803b56a0060e26238d43eed362bbe34c (HEAD -> main)
Author: Michael Landis <mlandis@gmail.com>
Date:   Wed Sep 7 20:11:24 2022 -0500

    fix misspelled name

diff --git a/output.txt b/output.txt
index 83b5301..2b4063a 100644
--- a/output.txt
+++ b/output.txt
@@ -1,2 +1,2 @@
-Muchael
+Michael
 :
(END)
```

shows differences between
current (a) and previous (b)
committed files

1% of git usage is managing and sharing commits

- *clone* repo from online server
- *checkout* other committed versions
- *revert* an unwanted commit
- *pull* commits from another repo
- *push* commits to another repo
- make a new *branch* of commits
- *merge* commits between two branches

git clone

copies remote repo to local directory

```
$ ls
lect_01 lect_02
$ git clone git@github.com:mlandis/lect-03-mlandis.git
Cloning into 'lect-03-mlandis'...        ⟵
remote: Enumerating objects: 6, done.
remote: Counting objects: 100% (6/6), done.
remote: Compressing objects: 100% (3/3), done.
remote: Total 6 (delta 0), reused 3 (delta 0), pack-reused 0
Receiving objects: 100% (6/6), done.
$ ls
lect_01 lect_02 lect_03
$ ls lect-03-mlandis        ⟵
data.txt output.txt
```

before *checkout*

main

commit: be726a1
initial commit

commit: 1014cca
add first file

commit: 032af31
add second file

commit: d091a77
edit first file

after *checkout*

main

commit: be726a1
initial commit

commit: 1014cca
add first file

commit: 032af31
add second file

commit: d091a77
edit first file
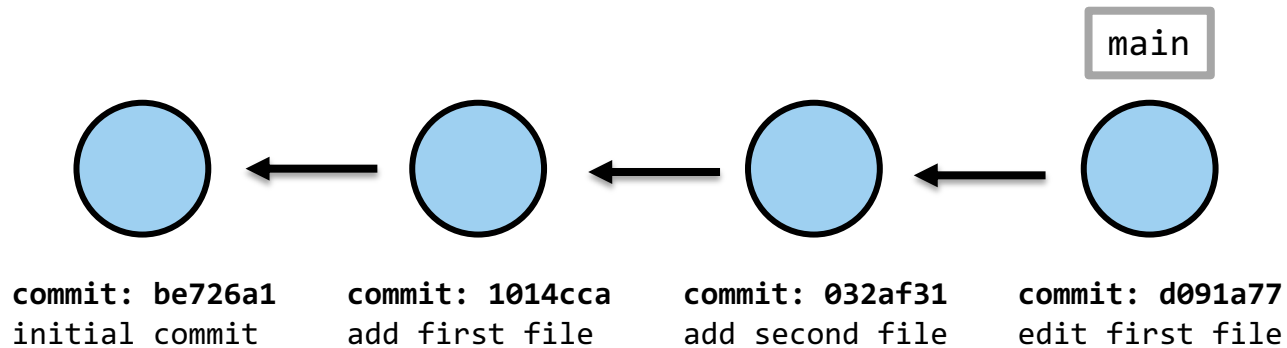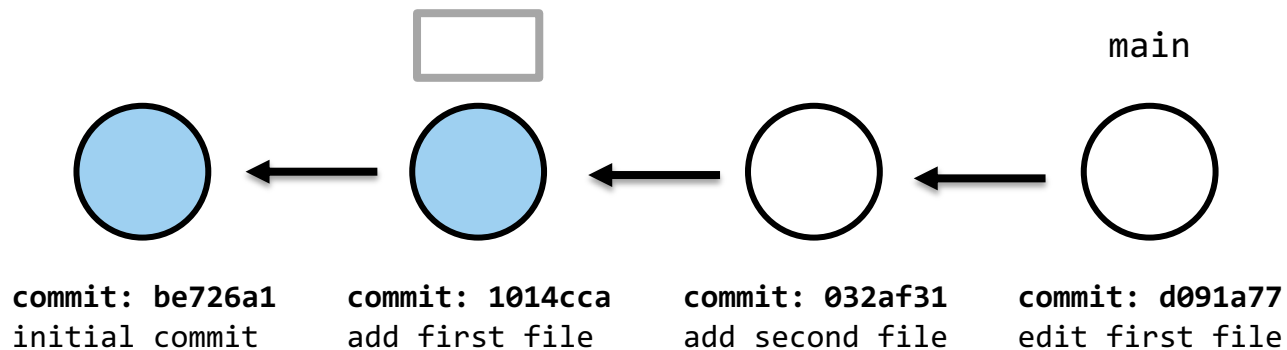
git checkout

replace filesystem with files from previous or alternative histories; *extremely versatile*

```
$ # create file
$ nano README.md
$ # add/commit file
$ git add README.md
$ git commit —m 'add user documentation'
[main 1c7e159] add user documentation
 1 file changed, 1 insertion(+)
 create mode 100644 README.md
$ # modify/add/commit file
$ nano README.md
$ git add README.md; git commit —m 'fix another typo'
 [main d6e897d] fix another typo
 1 file changed, 1 insertion(+), 1 deletion(—)
$ # checkout version of file from commit 1c7e159
$ git checkout 1c7e159
Note: switching to '1c7e159'.

You are in 'detached HEAD' state. You can look around, make experimental
changes and commit them, and you can discard any commits you make in this
state without impacting any branches by switching back to a branch.

( more text for suggested actions )
```

before *revert*

main

commit: **be726a1**
initial commit

commit: **1014cca**
add first file

commit: **032af31**
add second file

after *revert*

main

commit: **be726a1**
initial commit

commit: **1014cca**
add first file

commit: **032af31**
add second file

commit: **d091a77**
revert 1014cca
add first file
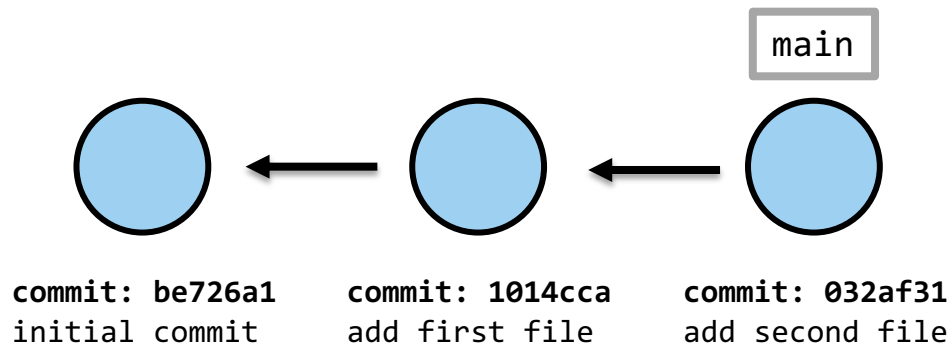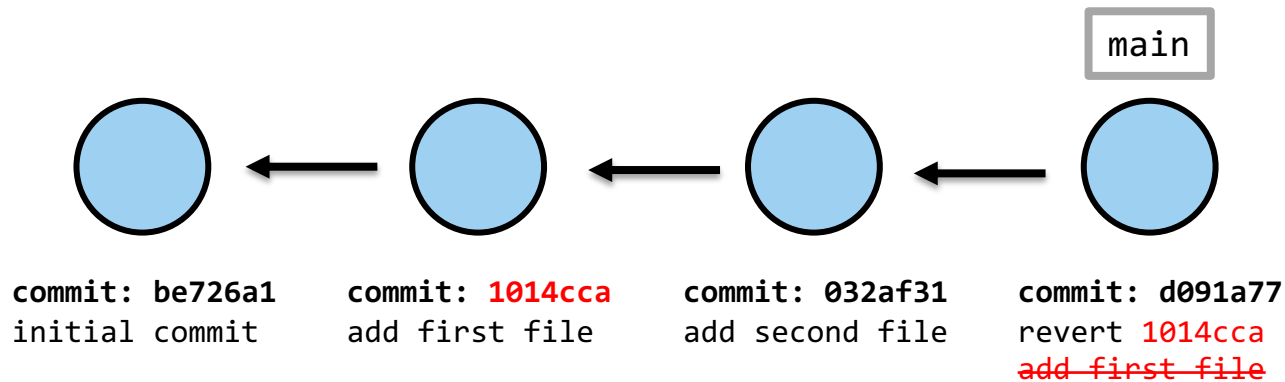
(revert 1041cca)

git revert

adds commit to history that
undoes edits from previous commit

```
$ # make a new typo in file
$ nano README.md
$ # stage/commit changes
$ git add README.md
$ git commit -m 'make typo'
[main 2d5a1f4] make typo
 1 file changed, 1 insertion(+), 1 deletion(-)
$ # undo the commit containing the typo by
$ # adding a 'revert' commit to the history
$ git revert 2d5a1f4
[main c41b09a] Revert "make typo"
 1 file changed, 1 insertion(+), 1 deletion(-)
```

git pull

retrieves committed changes from another repo (*e.g.* from GitHub)

```
$ # retrieve changes from remote repo (GitHub)
$ git pull
remote: Enumerating objects: 5, done.
remote: Counting objects: 100% (5/5), done.
remote: Compressing objects: 100% (2/2), done.
Unpacking objects: 100% (3/3), 691 bytes | 345.00 KiB/s, done.
remote: Total 3 (delta 0), reused 0 (delta 0), pack-reused 0
From github.com:mlandis/lect-03-mlandis
   c41b09a..ed8884e main -> origin/main
Updating c41b09a..ed8884e
Fast-forward
 README.md | 2 +-
 1 file changed, 1 insertion(+), 1 deletion(-)
```

Local repository
(*e.g.* on your VM)

Working directory
monitored files
that you edit

⬇ git add

Staging area
where files can be
committed to history

⬇ git commit

Repository
maintains
commit history

pull commits
from remote
repository

git
pull

Remote repository
(*e.g.* on GitHub)

Repository
maintains
commit history

git push

sends local committed changes to
another repo (*e.g.* to GitHub)

```
$ # modify/stage/commit README.md
$ nano README.md
$ git add README.md
$ git commit -m 'changed greeting message'
[main b2aec1c] changed greeting message
 1 file changed, 1 insertion(+), 1 deletion(-)
$ # send new commit to remote repo (GitHub)
$ git push
Enumerating objects: 5, done.
Counting objects: 100% (5/5), done.
Delta compression using up to 16 threads
Compressing objects: 100% (2/2), done.
Writing objects: 100% (3/3), 336 bytes | 336.00 KiB/s, done.
Total 3 (delta 0), reused 0 (delta 0), pack-reused 0
To github.com:mlandis/lect-03-mlandis.git
   ed8884e..b2aec1c main -> main
```
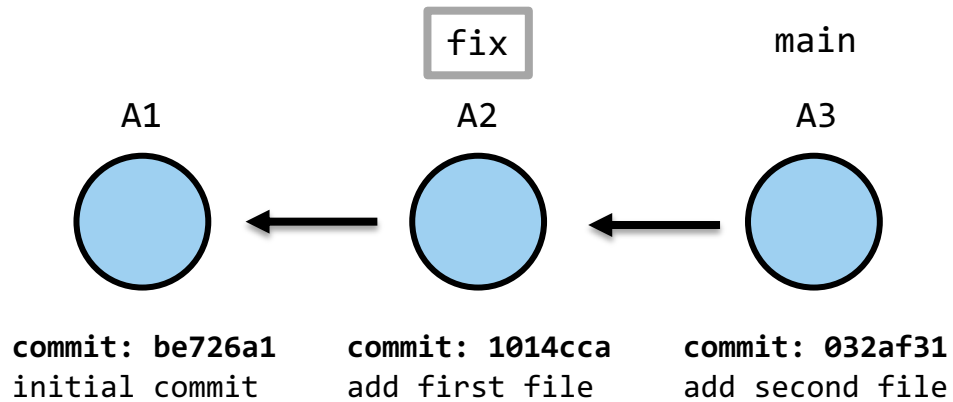
1. *branch* fix from commit A2 on main
2. *commit* B1 to fix
3. *merge* fix into main as commit A4

1. *branch* fix from commit A2 on main
2. *commit* B1 to fix
3. *merge* fix into main as commit A4

main

A1

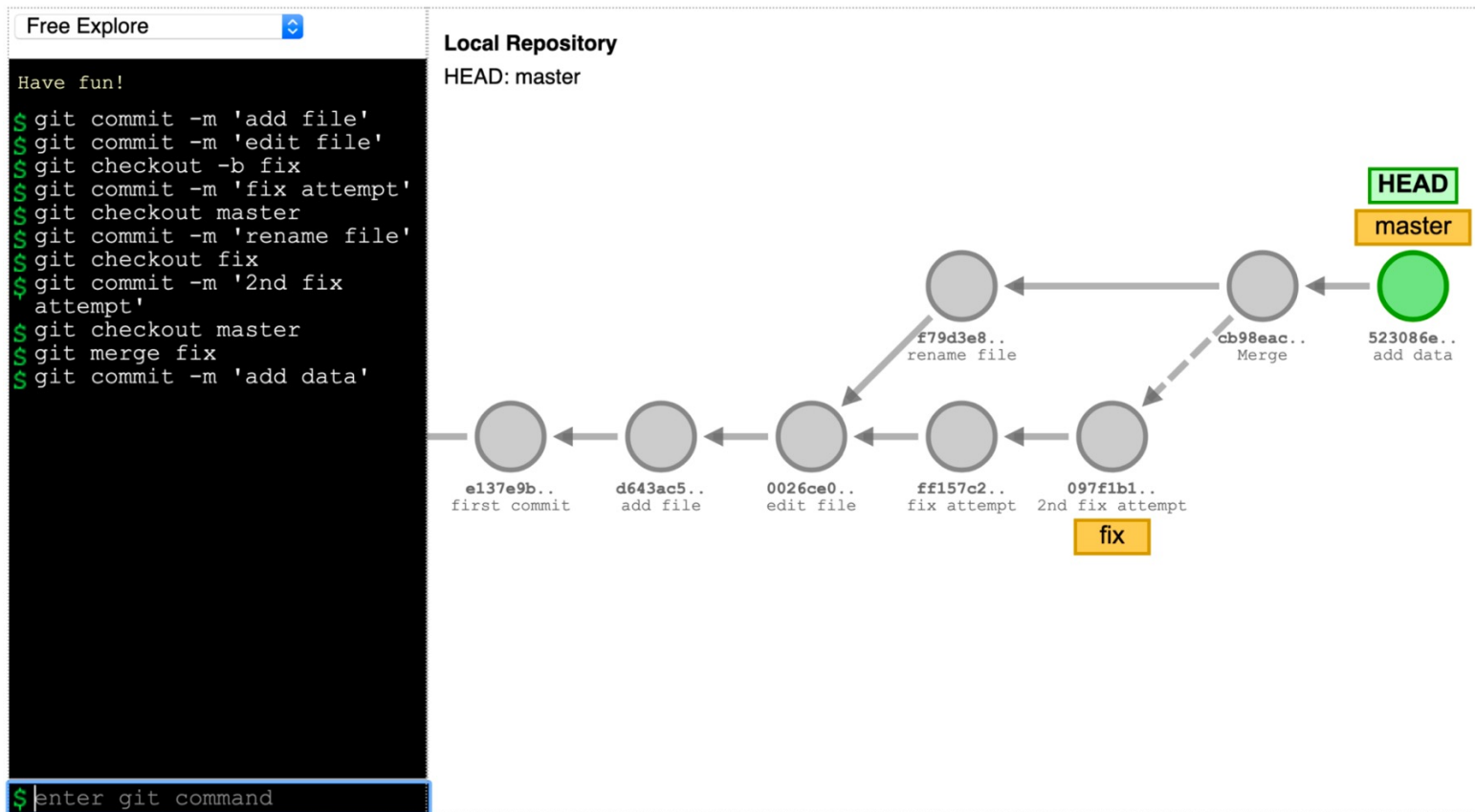commit: be726a1
initial commit

A2

commit: 1014cca
add first file

A3

commit: 032af31
add second file

fix

B1

commit: 7e817ac
fix first file
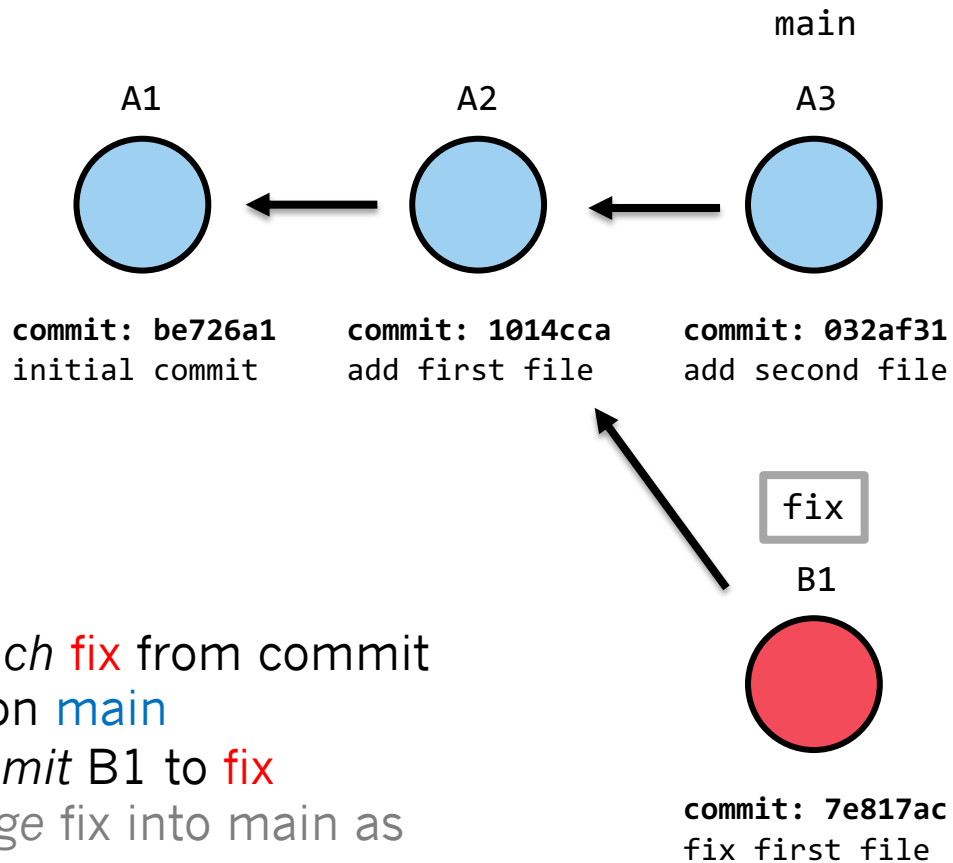
1. *branch* fix from commit A2 on main
2. *commit* B1 to fix
3. *merge* fix into main as commit A4

git branch

create a new branch of commit histories;
... or switch between branches

```
$ # we are on the 'main' branch
$ git branch
* main
$ # make new branch called 'fix' from
$ # current location
$ git branch fix
$ # switch to branch 'fix'
$ git checkout fix
Switched to branch 'fix'
$ # we are now on the 'fix' branch
$ git branch
* fix
  main
```

main

A1

A2

A3

commit: be726a1
initial commit

commit: 1014cca
add first file

commit: 032af31
add second file

fix

B1

1. branch fix from commit A2 on main
2. commit B1 to fix
3. merge fix into main as commit A4

commit: 7e817ac
fix first file

main

A1
A2
A3
A4

commit: be726a1
initial commit

commit: 1014cca
add first file

commit: 032af31
add second file

commit: d091a77
edit first file

fix

B1

commit: 7e817ac
fix first file
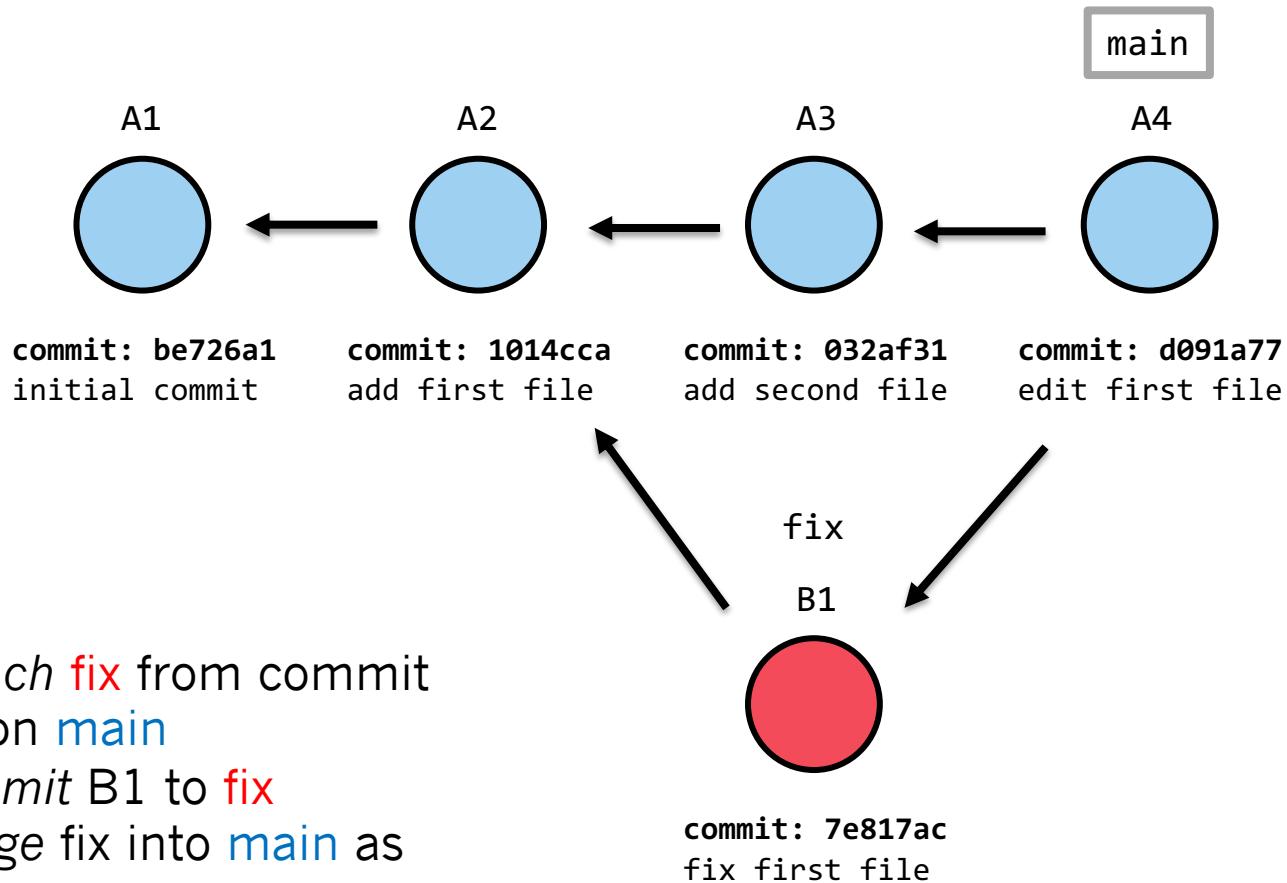
1. *branch* fix from commit A2 on main
2. *commit* B1 to fix
3. *merge* fix into main as commit A4

git merge

merge another branch into
your current branch

```
$ # start on 'fix' branch
$ # create/add/commit new file to 'fix' branch
$ touch file.txt
$ git add file.txt
$ git commit -m 'new file'
[fix 81e0dd2] new file
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 file.txt
$ # switch to 'main' branch
$ git checkout main
Switched to branch 'main'
Your branch is up to date with 'origin/main'.
$ # merge changes from 'fix' into 'main' (current branch)
$ git merge fix
Updating b2aec1c..81e0dd2
Fast-forward
 file.txt | 0
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 file.txt
$ # 'main' branch now contains new file from 'fix'
$ ls
README.md data.txt file.txt output.txt
```

More tools to visualize relationships between commands, graphs, and filesystems

https://git-school.github.io/visualizing-git

https://learngitbranching.js.org

Git Data Transport Commands

http://osteele.com

Overview for Lab 03