Version control systems

Version control systems

Assume you have a project:

```
myproject.py
```

You would like to try a modification, but do not know if it will work.

```
mkdir versions/
mkdir versions/v1/
cp myproject.py versions/v1/
```

Result:

```
myproject.py
versions/
    v1/
        myproject.py
```

You proceed to modify `myproject.py`:

```
myproject.py                <-- modified
versions/
    v1/
        myproject.py
```

If you like the modification and want to commit to it:

```
mkdir versions/v2/
cp myproject.py versions/v2/
```

Otherwise, you revert to the old version:

```
cp versions/v1/myproject.py myproject.py
```

If we committed to the modification:

```
myproject.py          <-- same as "versions/v2/myproject.py"
versions/
    v1/
        myproject.py
    v2/
        myproject.py
```

Use cases

- try things
- determine when a bug was introduced
- multiple people working on a project

Version control systems (VCS) / source code management (SCM)

- Revision control system (RCS), 1982
- Concurrent versions system (CVS), 1986
- Apache Subversion (“SVN”), 2000
- Mercurial (“Hg”), 2005
  - Used internally at Facebook/Meta
- Piper (not public)
  - Used for internal monorepo at Google
- Git, 2005
  - Spawned large hosting industry

    (GitHub USD 7.5bn 2018, GitLab market cap around USD 8bn)
  - Used internally by all software shops (incl. Microsoft, Apple, Amazon…)

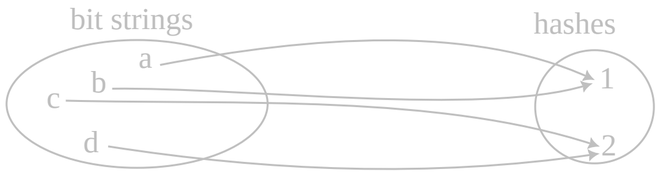
Git

Git fundamentals

- a repository stores the complete history of a project
  - ~~`versions/`~~ → `.git/`
- a commit is a unit of change; it captures:
  - a snapshot of all the project files
  - an author, a date, …
  - an indication of the “parent commit” (the one it is based on)
- commits are designated by ~~`v1/`~~ a hash

Hashes

- A hash maps any sequence of bits to a fixed-length bit string
- The map is not injective



- “SHA-1”: 160 bits / 20 bytes / 40 hex digits

  Example: `1e6cac37c5c8c5ee99ec104954d09b07e96116ba`

- Git assumes SHA-1 is injective
- … and is currently migrating to SHA-256 (256 bits / 32 bytes / 64 hex digits)

Hashes in Git

- Git commits are designated by SHA-1 hashes

  Example: `1e6cac37c5c8c5ee99ec104954d09b07e96116ba`

- When referring to a commit, a hash prefix can be used if unambiguous

  Example: `1e6cac`

Git command-line interface

- General usage:
  - `git <command> [<arguments...>]`
    - Example: `git status`
- Getting help:
  - `git help <command>`
    - Example: `git help status`
  - `man git-<command>`
    - Example: `man git-status`

Creating a repository

- Creating a new project:

```
mkdir my_new_project/
cd my_new_project/
git init
```

```
my_new_project/
    .git/
        ...
```

- “Cloning” an existing project:

```
git clone
        https://github.com/ggerganov/llama.cpp.git
cd llama.cpp/
```

```
llama.cpp/
    .git/
        ...
    ggml-alloc.c
    ggml-alloc.h
    ...
```

Building a commit

Working tree, staging, commit

- We never access the content of `.git/` directly

- Instead, we modify files in the working tree (everything not in `.git/`)
  - We can ask `git` to "check out" any past commit into the working tree
    (i.e., make the working tree reflect that commit)

- In order to prepare a new commit, we "stage" the relevant modifications
  (i.e., we tell git which files we want part of the new commit)

- Once ready, we create the new commit, along with a commit message

Staging and committing example

- We create
  - `new_file_A.py`
  - `new_file_B.py`
  - `new_file_C.py`
- We stage `new_file_A.py` and `new_file_B.py`:

```
git add new_file_A.py new_file_B.py
```

- We commit them to the repository

```
git commit -m "My first commit."
```

Listing past commits

```
git log
```

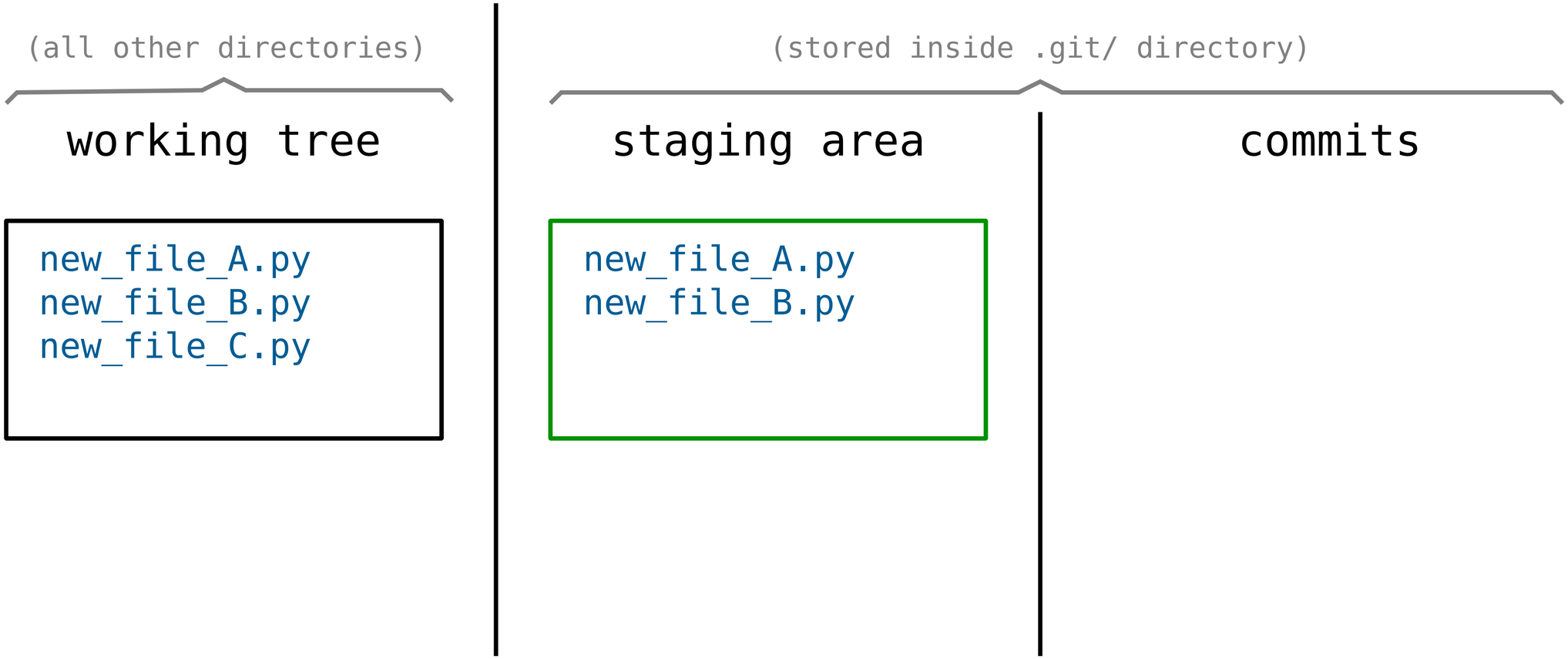
```
commit 6ea8433cf989c7c8580194035c7871b7de3c7c08 (HEAD -> main)
Author: Laurent Poirrier <poirrier@dev>
Date:   Fri Sep 29 02:04:18 2023 +0200

    My first commit.
```

```
#
```

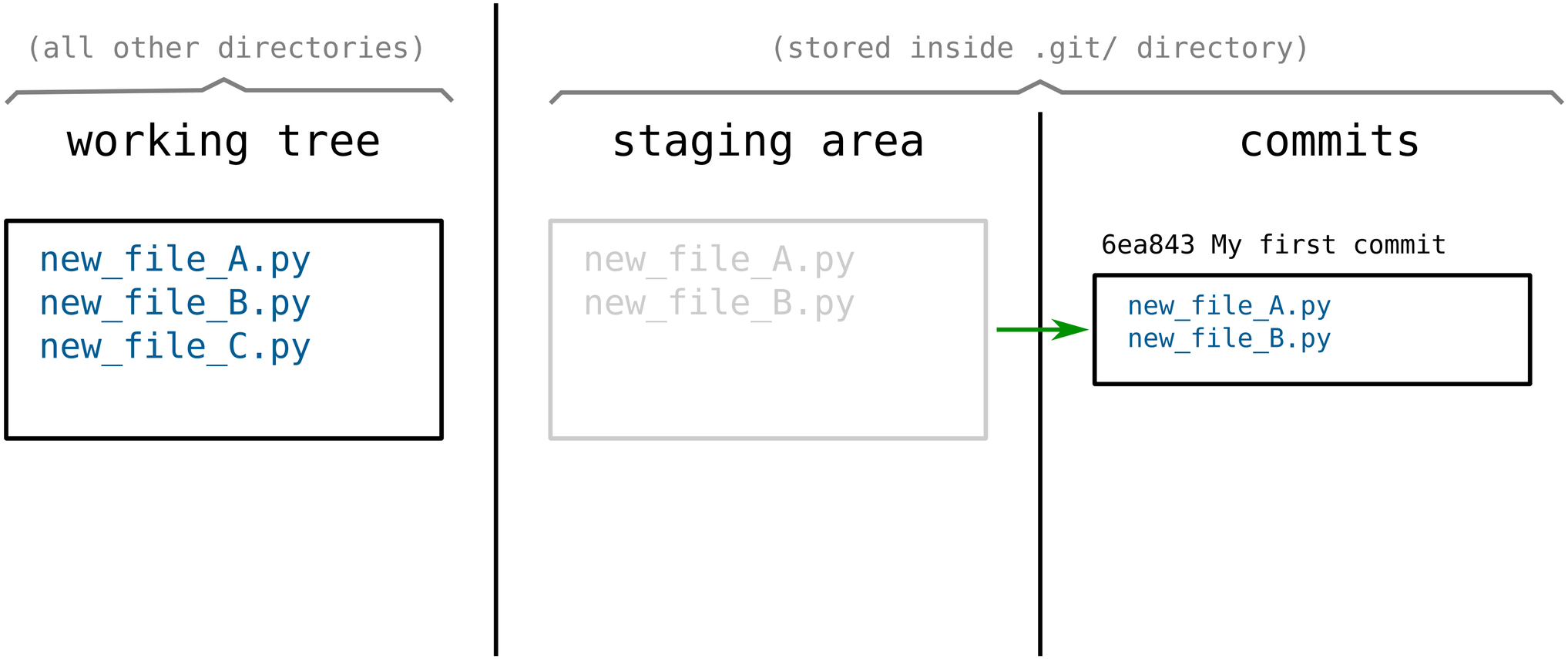
(all other directories)
(stored inside .git/ directory)
working tree
staging area
commits

```
# (creating new_file_A, new_file_B, new_file_C)
```

```
git add new_file_A.py new_file_B.py
```



```
git commit -m "My first commit."
```



```
#
```

(all other directories)

(stored inside .git/ directory)

working tree

```
new_file_A.py
new_file_B.py
new_file_C.py
```

staging area

```
new_file_A.py
new_file_B.py
```

commits

```
6ea843 My first commit
```

```
new_file_A.py
new_file_B.py
```

Automatic adding

- Add multiple files at once using a pattern (including in subdirectories):

```
git add '*.py'
```

- Add all the files in the working tree:

```
git add -A
```

- Exclude some files from “`git add -A`”:
  Put corresponding patterns in “`.gitignore`”:

```
*.o
/build/
/my_executable
```

Observing the state of the working tree and staging area

```
git status
```

```
On branch main
Untracked files:
  (use "git add <file>..." to include in what will be committed)
        new_file_C.py

nothing added to commit but untracked files present (use "git add" to track)
```

Let us modify `new_file_A.py`:

```
git status
```

```
On branch 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:   new_file_A.py

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

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

Showing differences

```
git diff
```

```
diff --git a/new_file_A.py b/new_file_A.py
index e69de29..ec7780c 100644
--- a/new_file_A.py
+++ b/new_file_A.py
@@ -0,0 +1 @@
+print('Hello, world!')
```

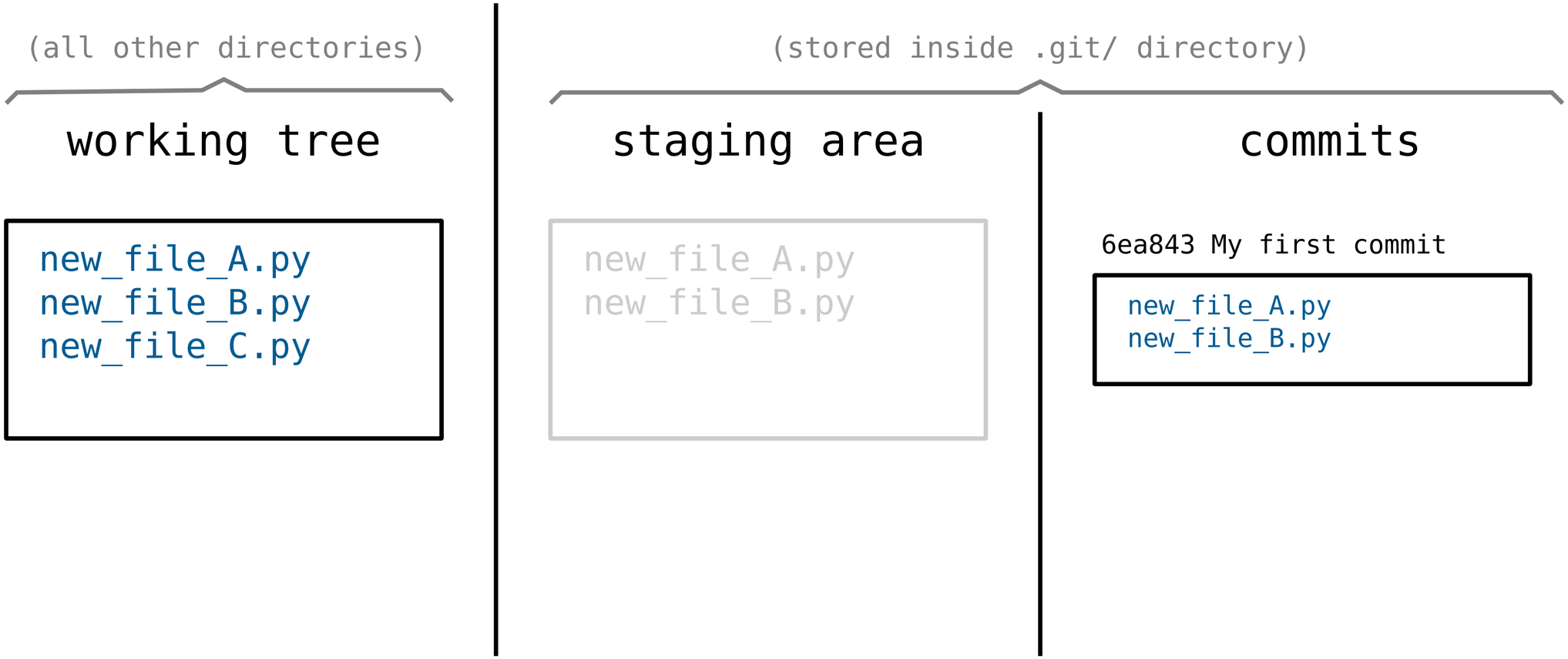
Staging again

```
git add -A
```

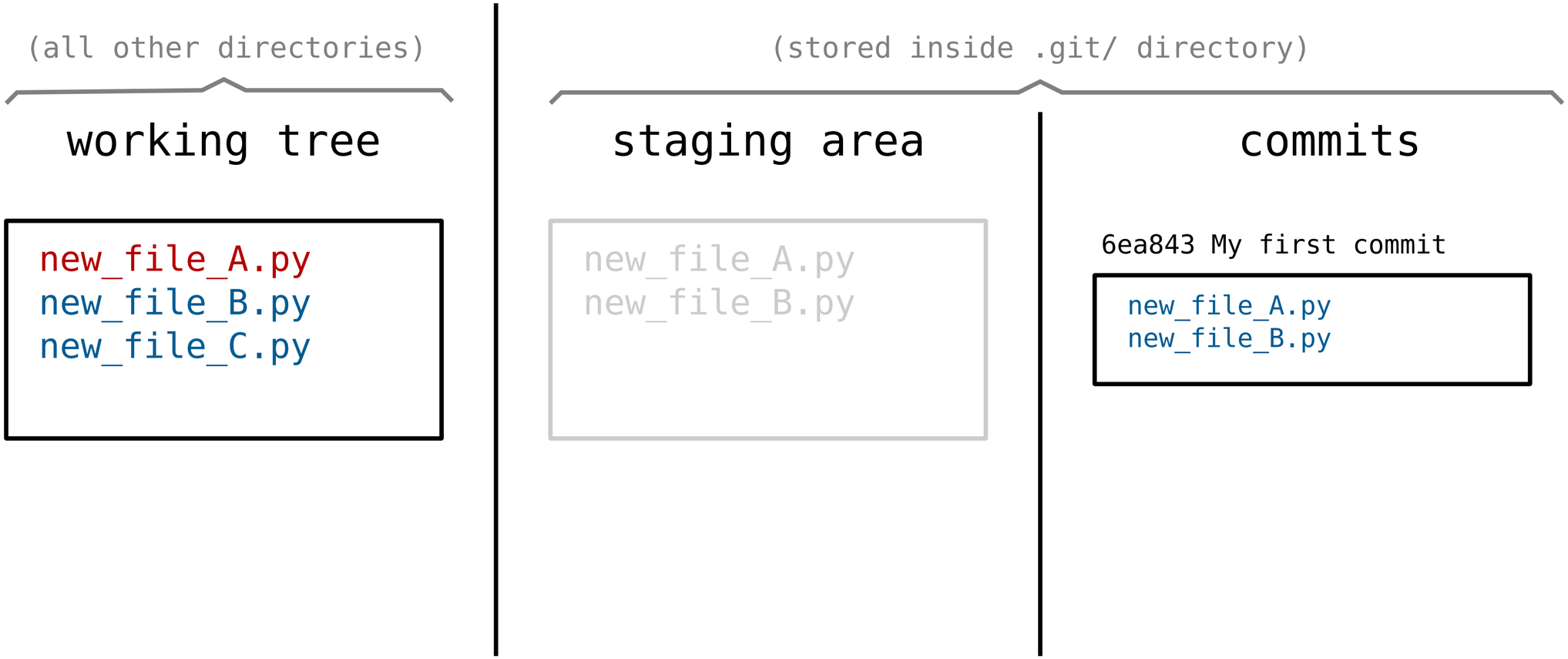
```
git status
```

```
On branch main
Changes to be committed:
  (use "git restore --staged <file>..." to unstage)
        modified:   new_file_A.py
        new file:   new_file_C.py
```

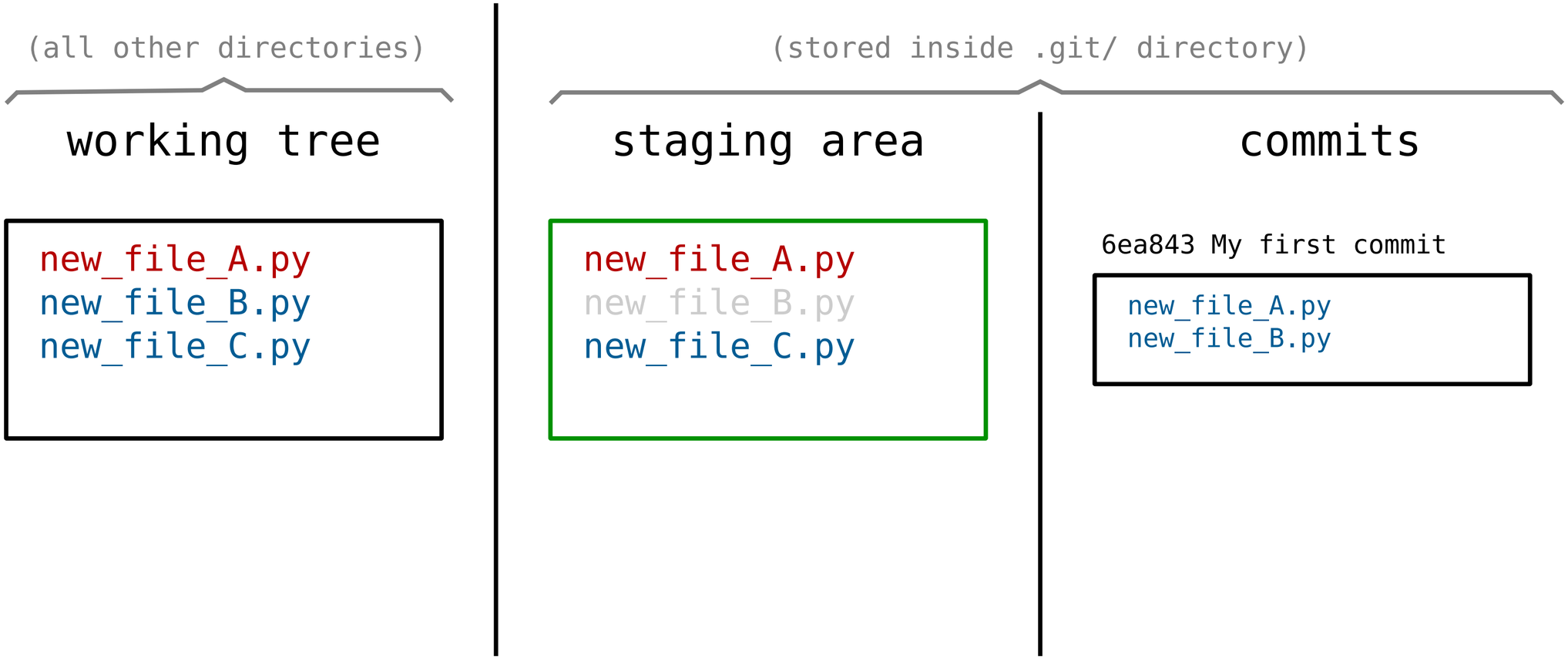
```
# (previous state after first commit)
```



```
# (modifying new_file_A)
```



```
git add -A
```


(all other directories)
(stored inside .git/ directory)
working tree
staging area
commits
new_file_A.py
new_file_B.py
new_file_C.py
new_file_A.py
new_file_B.py
new_file_C.py
6ea843 My first commit
new_file_A.py
new_file_B.py

Showing differences again

```
git diff
```

```
```

```
git diff --staged
```

```
diff --git a/new_file_A.py b/new_file_A.py
index e69de29..ec7780c 100644
--- a/new_file_A.py
+++ b/new_file_A.py
@@ -0,0 +1 @@
+print('Hello, world!')
diff --git a/new_file_C.py b/new_file_C.py
new file mode 100644
index 0000000..e69de29
```

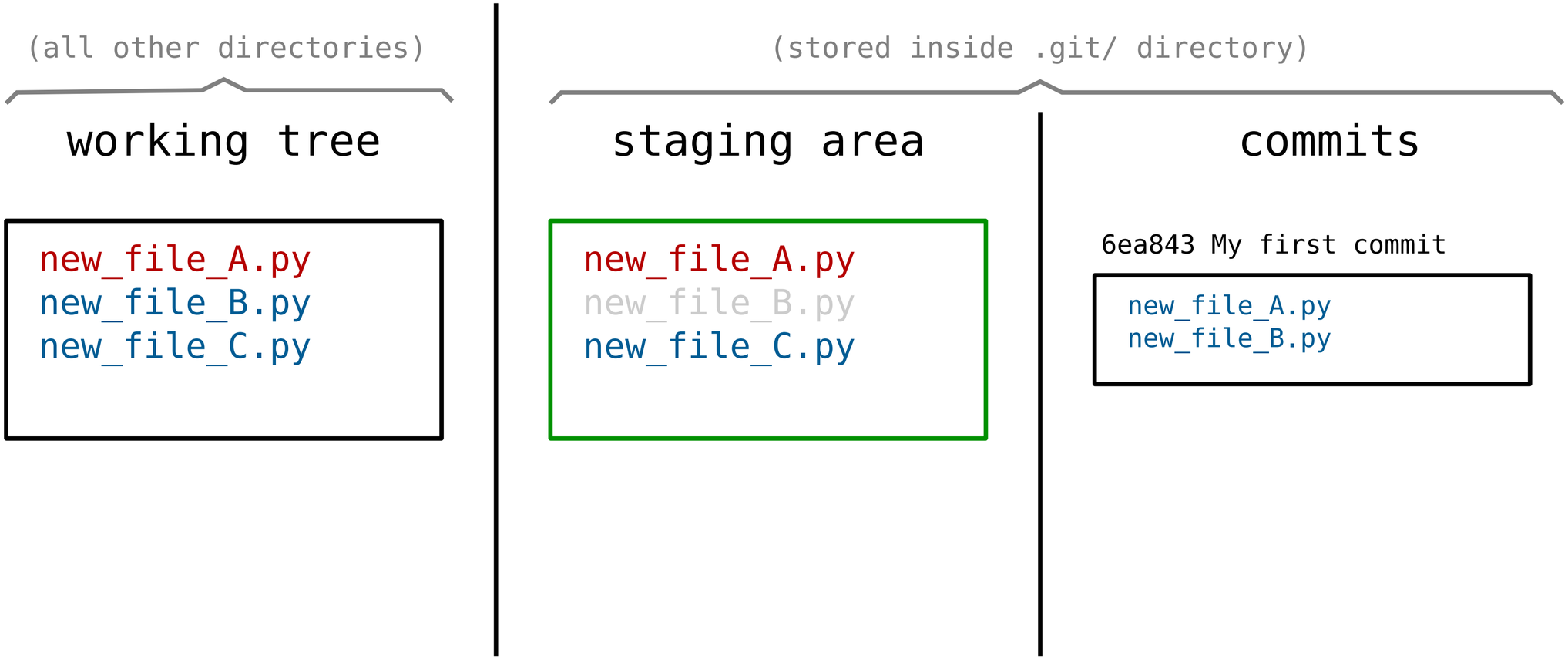
Committing again

```
git commit -m "My second commit."
```

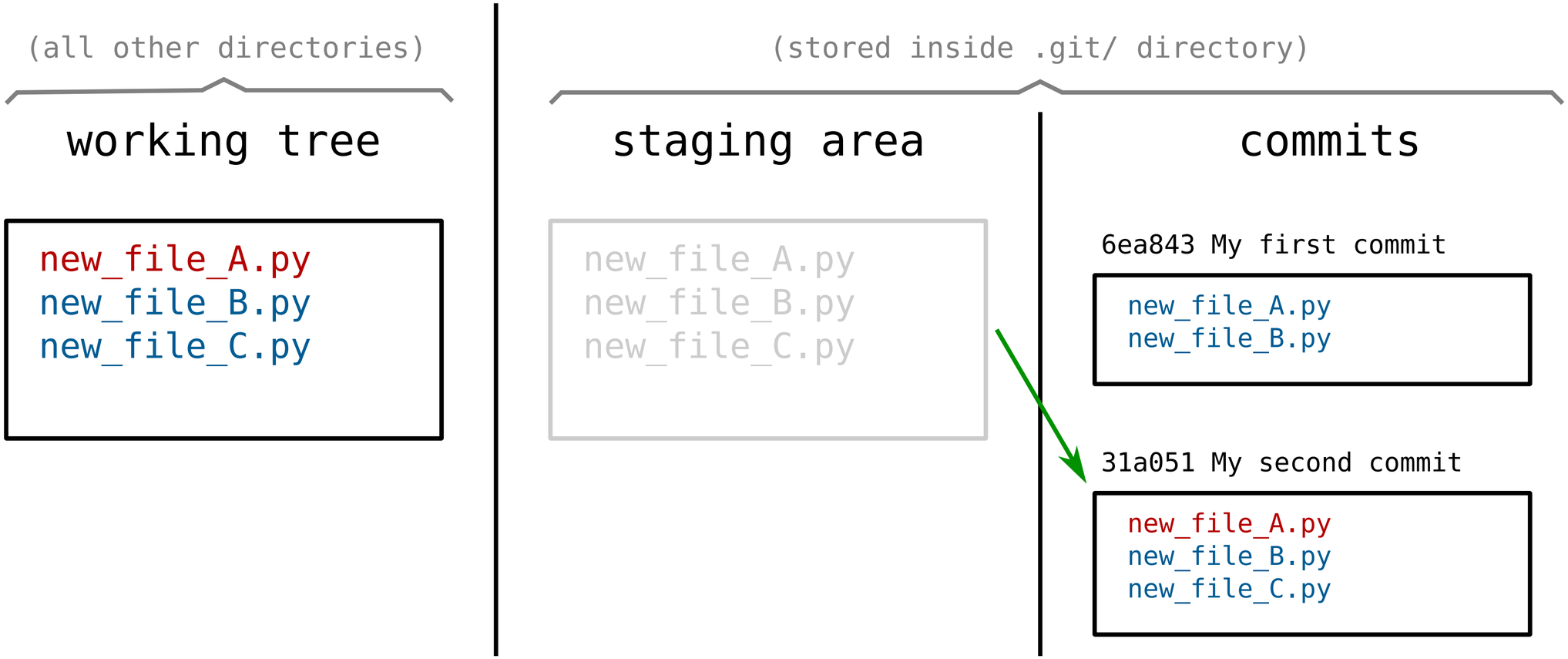
```
git log
```

```
commit 31a05126a56b8156de47ee53092b6996d75a0c8c (HEAD -> main)
Author: Laurent Poirrier <poirrier@dev>
Date:   Fri Sep 29 02:15:19 2023 +0200

    My second commit.

commit 6ea8433cf989c7c8580194035c7871b7de3c7c08
Author: Laurent Poirrier <poirrier@dev>
Date:   Fri Sep 29 02:04:18 2023 +0200

    My first commit.
```

```
# (previous state after "git add -A")
```



```
git commit -m "My second commit."
```



```
#
```

(all other directories)

working tree

```
new_file_A.py
new_file_B.py
new_file_C.py
```

(stored inside .git/ directory)

staging area

```
new_file_A.py
new_file_B.py
new_file_C.py
```

commits

6ea843 My first commit

```
new_file_A.py
new_file_B.py
```

31a051 My second commit

```
new_file_A.py
new_file_B.py
new_file_C.py
```

Checking out specific commits

```
git checkout 6ea843
```

```
git log
```

```
commit 6ea8433cf989c7c8580194035c7871b7de3c7c08 (HEAD)
Author: Laurent Poirrier <poirrier@dev>
Date:   Fri Sep 29 02:04:18 2023 +0200

    My first commit.
```

```
git log --all
```

```
commit 31a05126a56b8156de47ee53092b6996d75a0c8c (main)
Author: Laurent Poirrier <poirrier@dev>
Date:   Fri Sep 29 02:15:19 2023 +0200

    My second commit.

commit 6ea8433cf989c7c8580194035c7871b7de3c7c08 (HEAD)
Author: Laurent Poirrier <poirrier@dev>
Date:   Fri Sep 29 02:04:18 2023 +0200

    My first commit.
```

```
#
```

(all other directories)

(stored inside .git/ directory)

working tree

```
new_file_A.py
new_file_B.py
new_file_C.py
```

staging area

```
new_file_A.py
new_file_B.py
new_file_C.py
```

commits

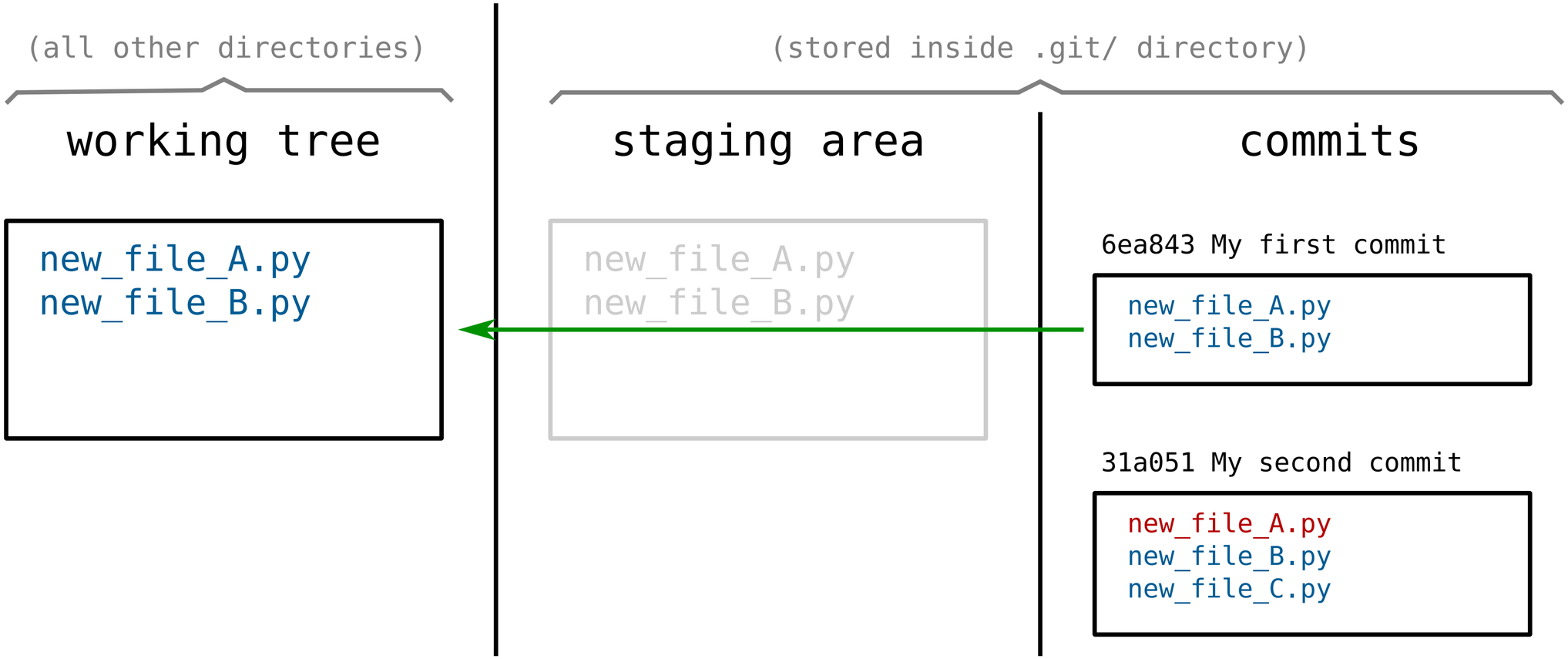
6ea843 My first commit

```
new_file_A.py
new_file_B.py
```

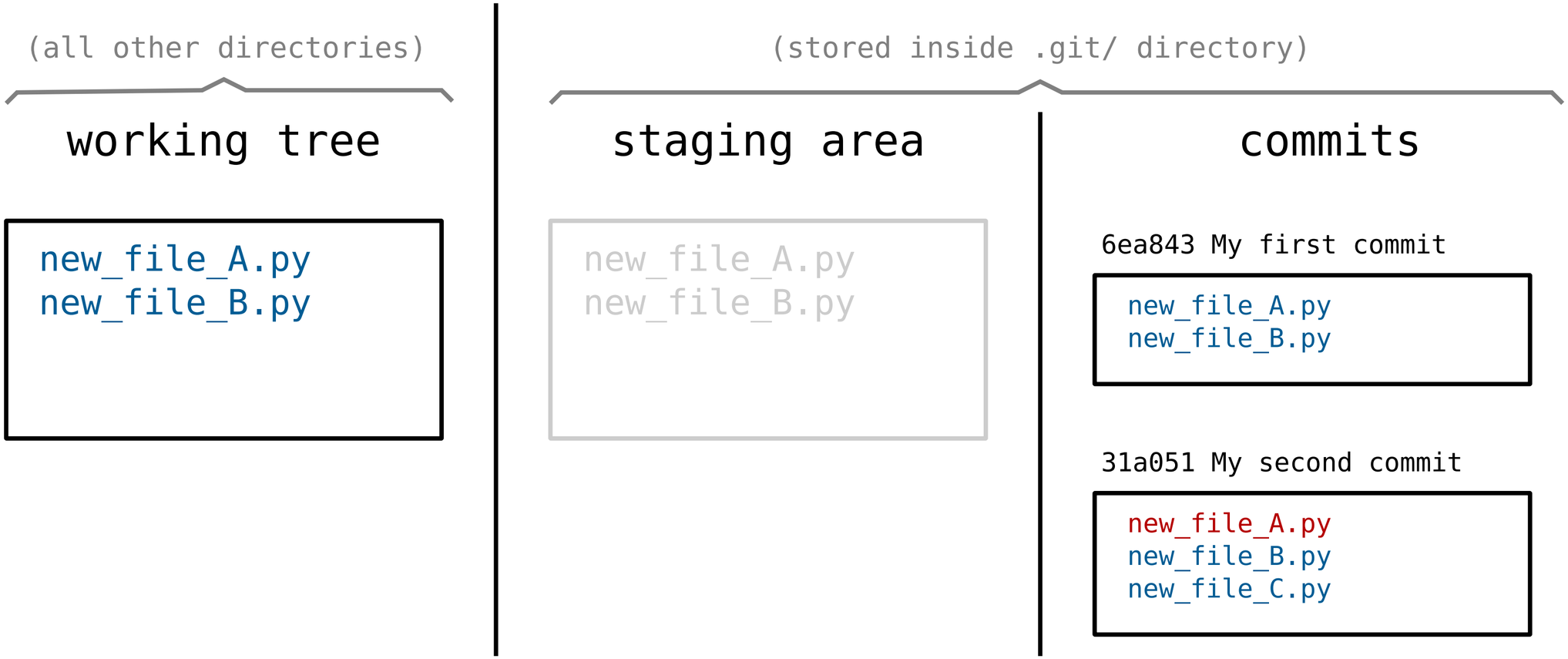
31a051 My second commit

```
new_file_A.py
new_file_B.py
new_file_C.py
```

```
git checkout 6ea843
```



```
#
```


(all other directories)
(stored inside .git/ directory)
working tree
staging area
commits
new_file_A.py
new_file_B.py
new_file_A.py
new_file_B.py
6ea843 My first commit
new_file_A.py
new_file_B.py
31a051 My second commit
new_file_A.py
new_file_B.py
new_file_C.py

Branches

Commit structure

```
31a051 ("My second commit.")
 ^
 |
6ea843 ("My first commit.")
```

```
git checkout 31a051  # "My second commit"
```

```
31a051 ("My second commit.")      <-- HEAD
 ^
 |
6ea843 ("My first commit.")
```

```
git checkout 6ea843  # "My first commit"
```

```
31a051 ("My second commit.")
 ^
 |
6ea843 ("My first commit.")       <-- HEAD
```

```
# modify some files
git add -A
git commit -m "Another commit."
```

```
31a051 ("My second commit.")              07714c ("Another commit.")       <-- HEAD
                          Λ                 Λ
                          |                 |
                        6ea843 ("My first commit.")
```

```
git log --all --graph
```

```
* commit 07714cbadc8f13939039c07ac4b063d8b9b92506 (HEAD)
| Author: Laurent Poirrier <poirrier@dev>
| Date:   Fri Sep 29 03:06:02 2023 +0200
|
|     Another commit.
|
| * commit 31a05126a56b8156de47ee53092b6996d75a0c8c (main)
|/  Author: Laurent Poirrier <poirrier@dev>
|   Date:   Fri Sep 29 02:15:19 2023 +0200
|
|       My second commit.
|
* commit 6ea8433cf989c7c8580194035c7871b7de3c7c08
  Author: Laurent Poirrier <poirrier@dev>
  Date:   Fri Sep 29 02:04:18 2023 +0200

      My first commit.
```

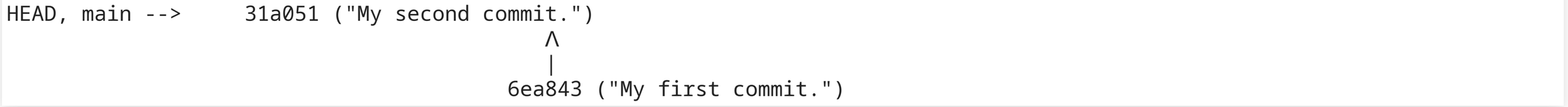
Problem: if we “`git checkout`” back to the first or second commit, we lose “Another commit.”

Solution: named branches

Creating branches

```
git branch <branch-name>
```

(initial state after two commits)



```
git checkout 6ea843
```

```
     main -->     31a051 ("My second commit.")
                                          Λ
                                          |
                           HEAD -->   6ea843 ("My first commit.")
```

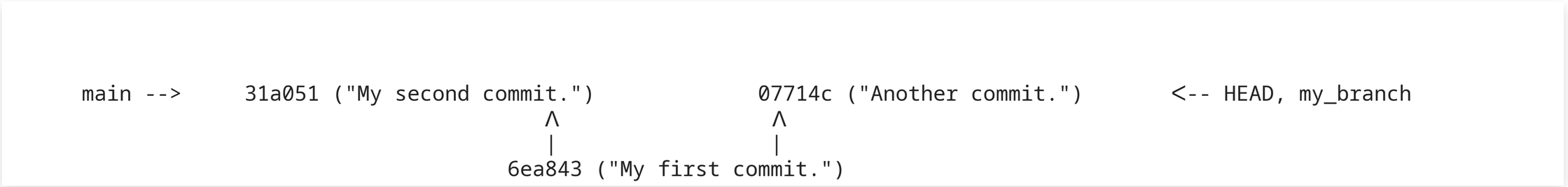
```
git branch my_branch
```

```
     main -->     31a051 ("My second commit.")
                                        Λ
                                        |
                           HEAD -->   6ea843 ("My first commit.")   <-- my_branch
```

```
git checkout my_branch
```

```
     main -->     31a051 ("My second commit.")
                                          Λ
                                          |
                                       6ea843 ("My first commit.")   <-- HEAD, my_branch
```

```
git add ...; git commit
```



Merging

```
git checkout main
```

```
HEAD, main -->     31a051 ("My second commit.")             07714c ("Another commit.")       <-- my_branch
                                          ^                  ^
                                          |                  |
                                       6ea843 ("My first commit.")
```

```
git merge my_branch
```

```
     HEAD, main -->     81db75de ("Merge remote-tracking branch")
                                         ^                  ^
                                         |                  |
                   31a051 ("My second commit.")             07714c ("Another commit.")       <-- my_branch
                                         ^                  ^
                                         |                  |
                                      6ea843 ("My first commit.")
```

Merge conflicts

```
<<<<<<< HEAD:new_file_A.py
print('Hello, world!")
=======
print('Bye, world')
>>>>>>> my_branch:new_file_A.py
```

- resolve merge conflicts by editing files
- `git add ... ; git commit`

Rebase

```
(just committed to branch my_branch)
```

```
main -->     31a051 ("My second commit.")             07714c ("Another commit.")       <-- HEAD, my_branch
                                    ^                  ^
                                    |                  |
                                  6ea843 ("My first commit.")
```

```
git rebase main
```

```
                  3c7c08 ("Another commit.")       <-- HEAD, my_branch
                                          ^
                                          |
     main -->     31a051 ("My second commit.")
                                          ^
                                          |
                                       6ea843 ("My first commit.")
```

```
git checkout main
```

```
                  3c7c08 ("Another commit.")       <-- my_branch
                                      ^
                                      |
HEAD, main -->    31a051 ("My second commit.")
                                      ^
                                      |
                                   6ea843 ("My first commit.")
```

```
git merge my_branch
```

```
HEAD, main -->     3c7c08 ("Another commit.")       <-- my_branch
                                  ^
                                  |
                   31a051 ("My second commit.")
                                  ^
                                  |
                                6ea843 ("My first commit.")
```

Remotes

Sharing repositories

Git is distributed: there is no notion of a central server.

If the repository was created using

```
git clone <URL>
```

then

```
git fetch
```

checks for new commits from the same <URL> origin

To download commits from a remote repository:

```
git fetch <URL>
```

Note: <URL> must be public, or we must have appropriate credentials

- as an alternative,

  ```
  git format-patch
  ```

  saves commits in files that can be sent by email.

Fetch and pull, remotes

- Just fetch repository data, do not affect working tree:

```
git fetch [<repository>] [remote_branch:local_branch]
```

- Fetch data and attempt merge (or rebase):

```
git pull [<repository>]
```

- Setup a remote:

```
git remote add [options] <name> <URL>
```

Configuration and more

Configuration

- For anything too long for the CLI, `git` will make you edit a temporary file:

```
git config --global core.editor "code --wait"
```

- Commits capture the author's name and email address:

```
git config --global user.name "John Doe"
git config --global user.email johndoe@example.com
```

Q: How many `git` subcommands are there?

```
man git | grep -E '^ *git-.*\(1\)$'
```

A: 156

⇒ Use `git help` / `man git`