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Version Control Systems (VCS): Introduction to Git

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SIT211 – – 2025-2026

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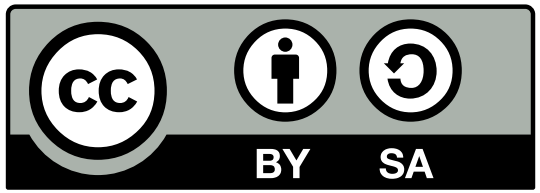

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Important notes

- If you do not understand something, please ask your questions.
  We cannot answer the questions you do not ask
- If you disagree with us, please say it (politely)
- People don't learn computer science by only reading few academic slides: practicing is fundamental

Progress

Sentences one would have preferred not to hear

- *Aaaaah! Three months of work lost!*
- *Oops Was this file really important?*
- *Great, everyone has finished! Who integrates all the parts?*
- *Why did I wrote this piece of code?*
- *Great functionality, but I think the last week version was better. Uh which one?*
- *I cannot find the version we have made 6 years ago for BigCustomer Inc., I need it immediately for a new contract!*
- *I have already done this bugfix on my laptop I left at home.*
- *It doesn't work anymore! Who messed up my code?*

Motivations

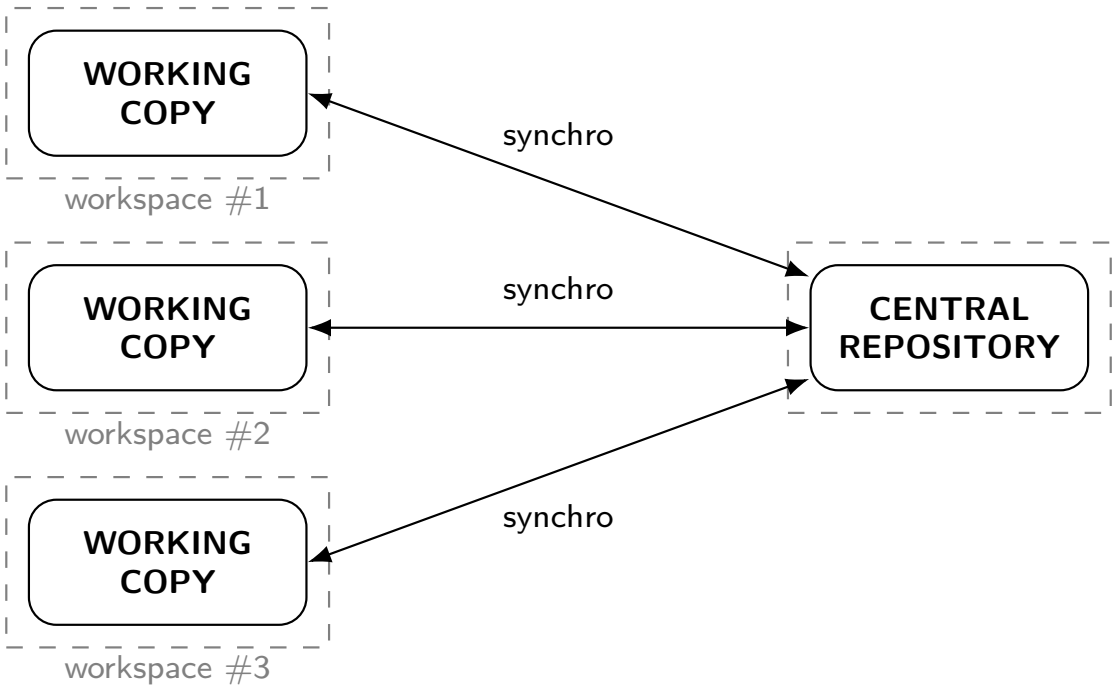
- Software traceability: tracking and documenting changes, retrieving former versions
- Flexibility: feature trials, quick rollbacks
- Parallelism and team work: multi-sites, multi-computers, multi-developers and multi-activities
- Safety: “backup” with history
  - though VCS are not (space) efficient backup systems

  $\Rightarrow$ One needs tools to solve these problems

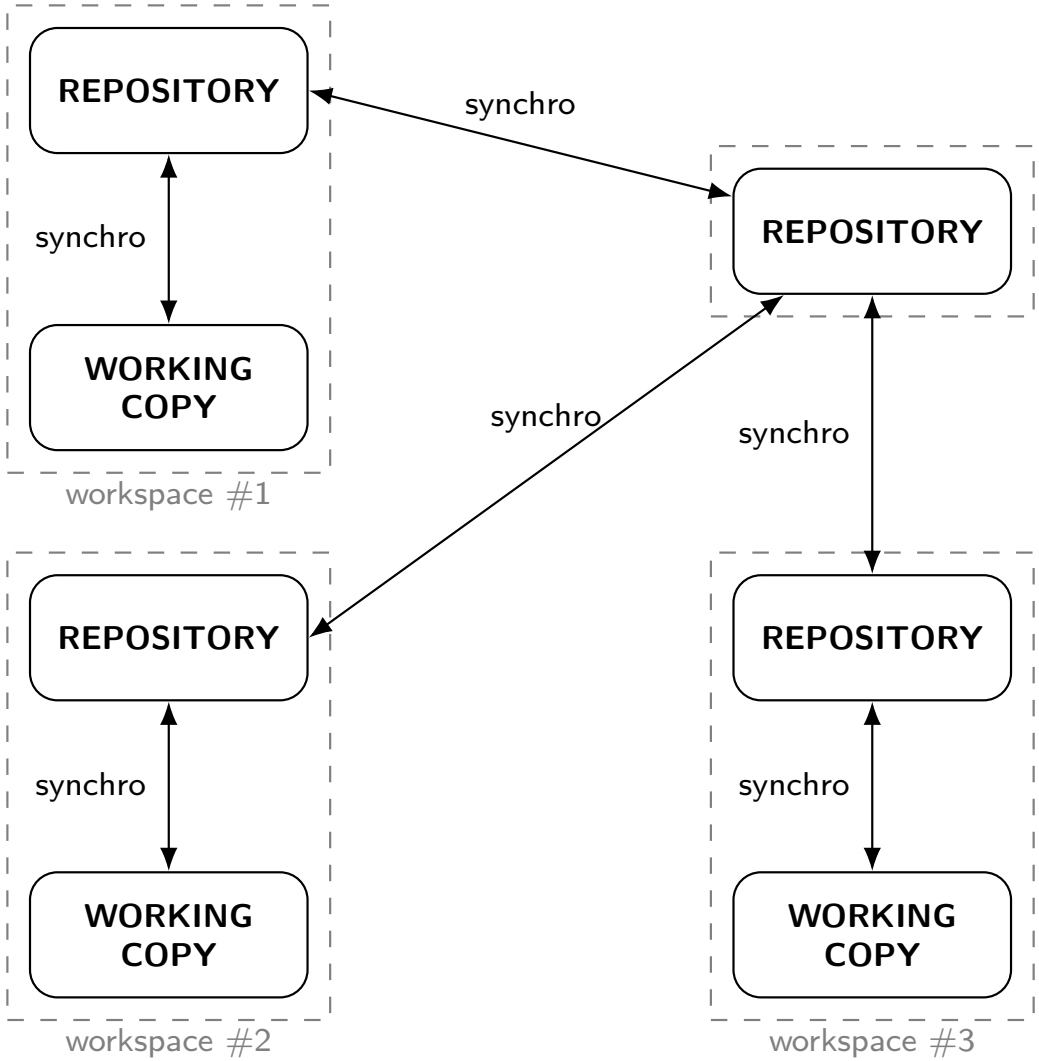
Version Control Systems (VCS)

- Used for
  - storing files
  - keeping track of changes on those tracked files
  - sharing
- Each collaborator works on a local copy
- Synchronization with one (or several) remote server(s)
- 2 families of VCS
  - centralised (Subversion, CVS,)
  - distributed (Git, Mercurial, Darcs,)

Architecture of a centralised VCS



Architecture of a distributed VCS



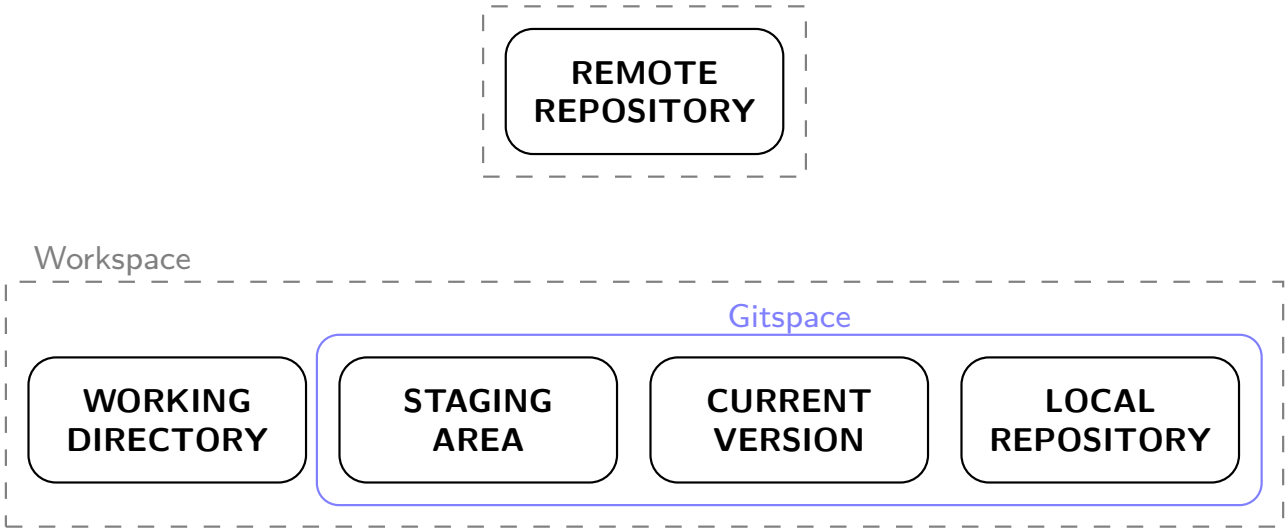
Focus on a specific VCS: Git

Why Git?

- very popular
- many platforms provide Git-based services (Bitbucket, Codeberg, Gitlab, Gitea, GitHub, SourceHut, ...)
- a bit less intuitive than other VCS for beginners, therefore if you are able to use Git, you will be able to use other VCS
- and because we had to choose a tool

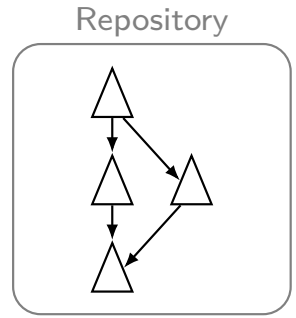
Progress

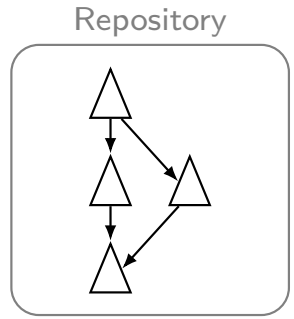
Git architecture and vocabulary



- working directory = files where changes are made
- staging area = current selected changes
- current version = current reference version
- (remote/local) repository = a database of changes

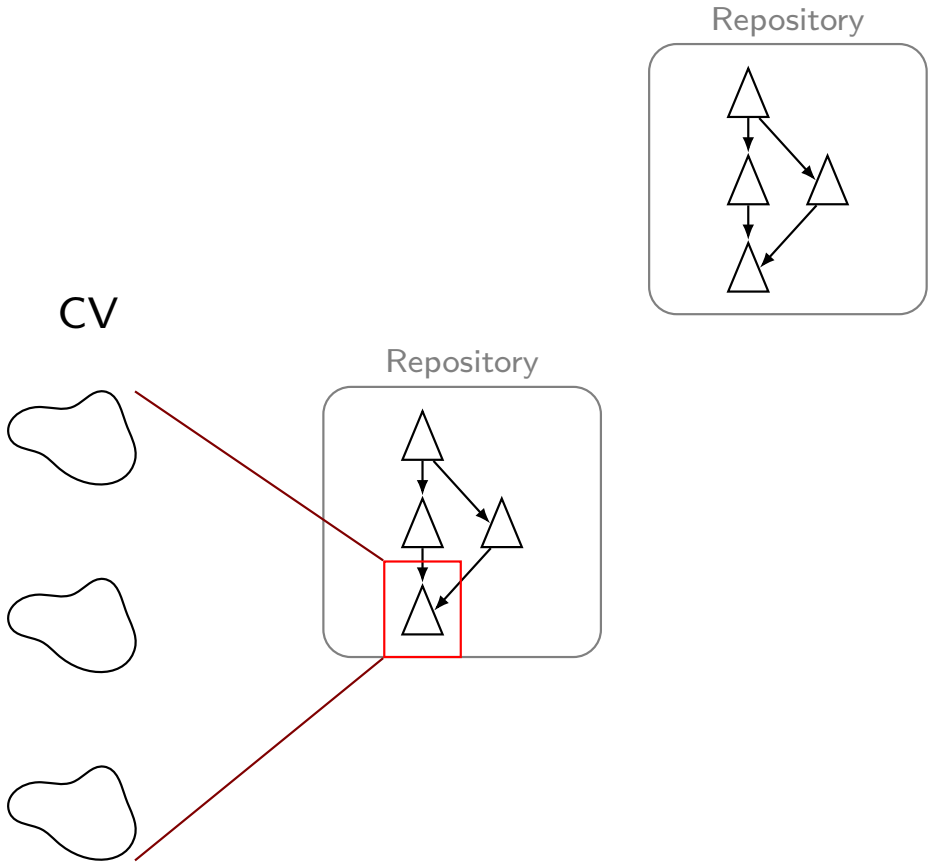
Diving into Git core





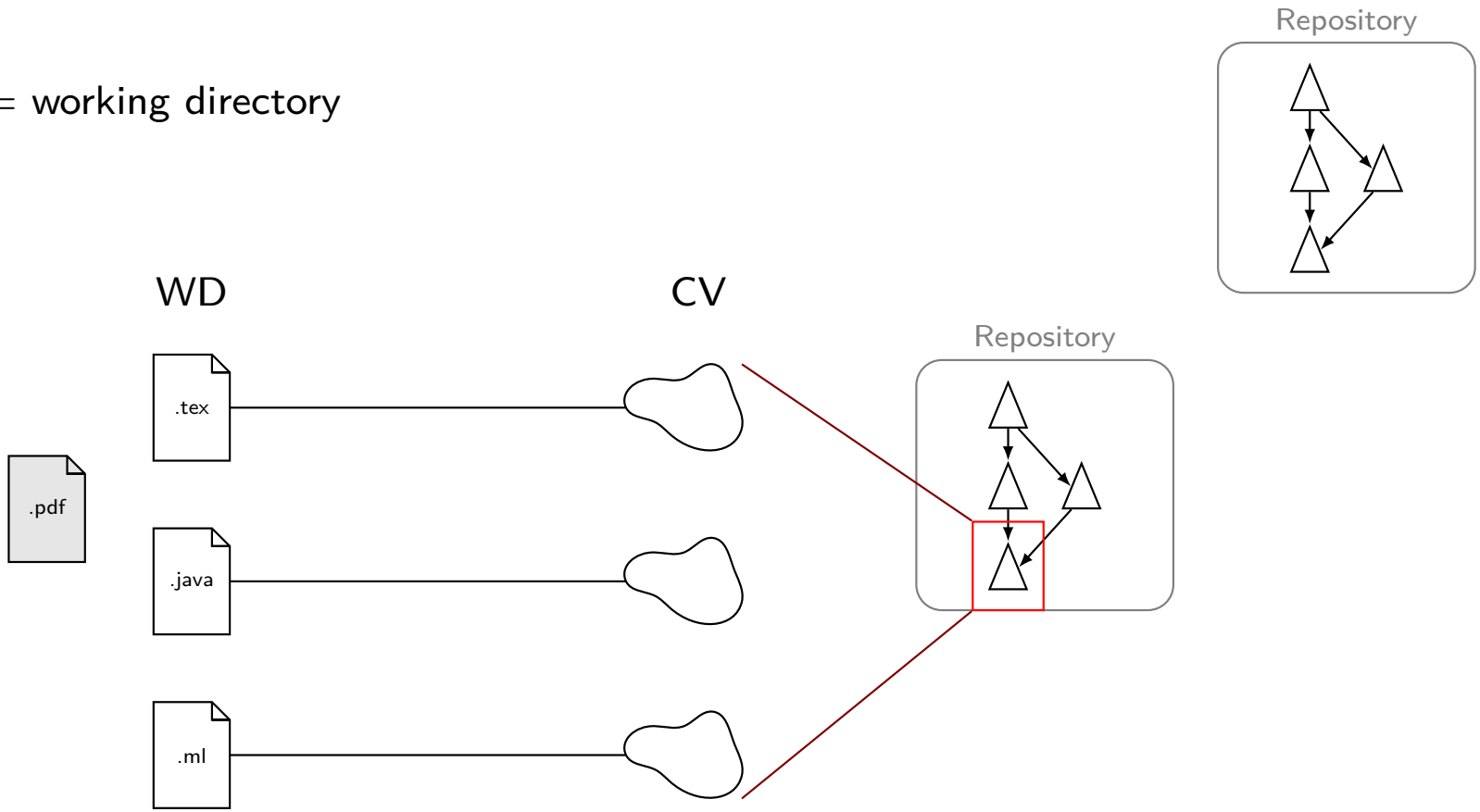
Diving into Git core

CV = current version

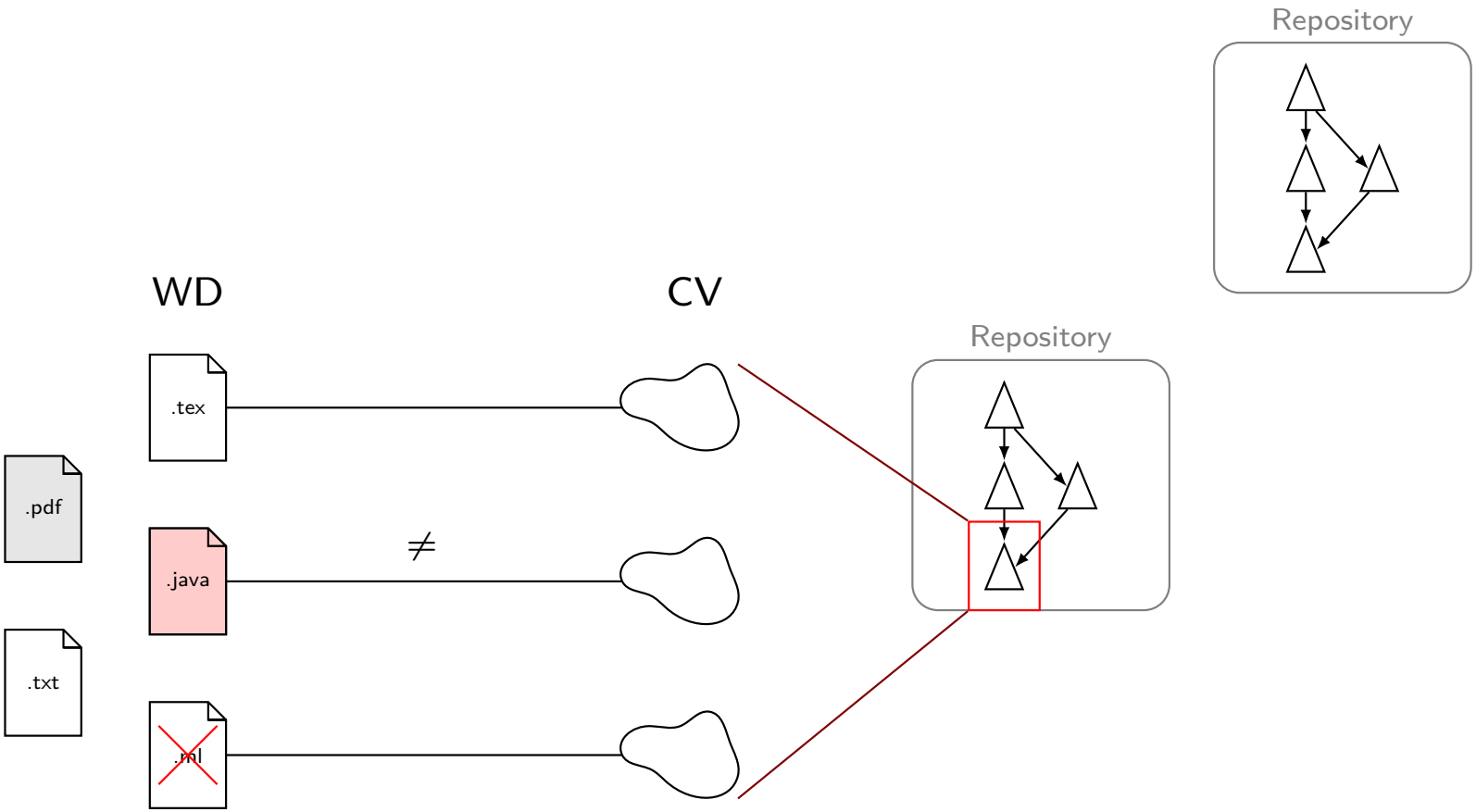


Diving into Git core

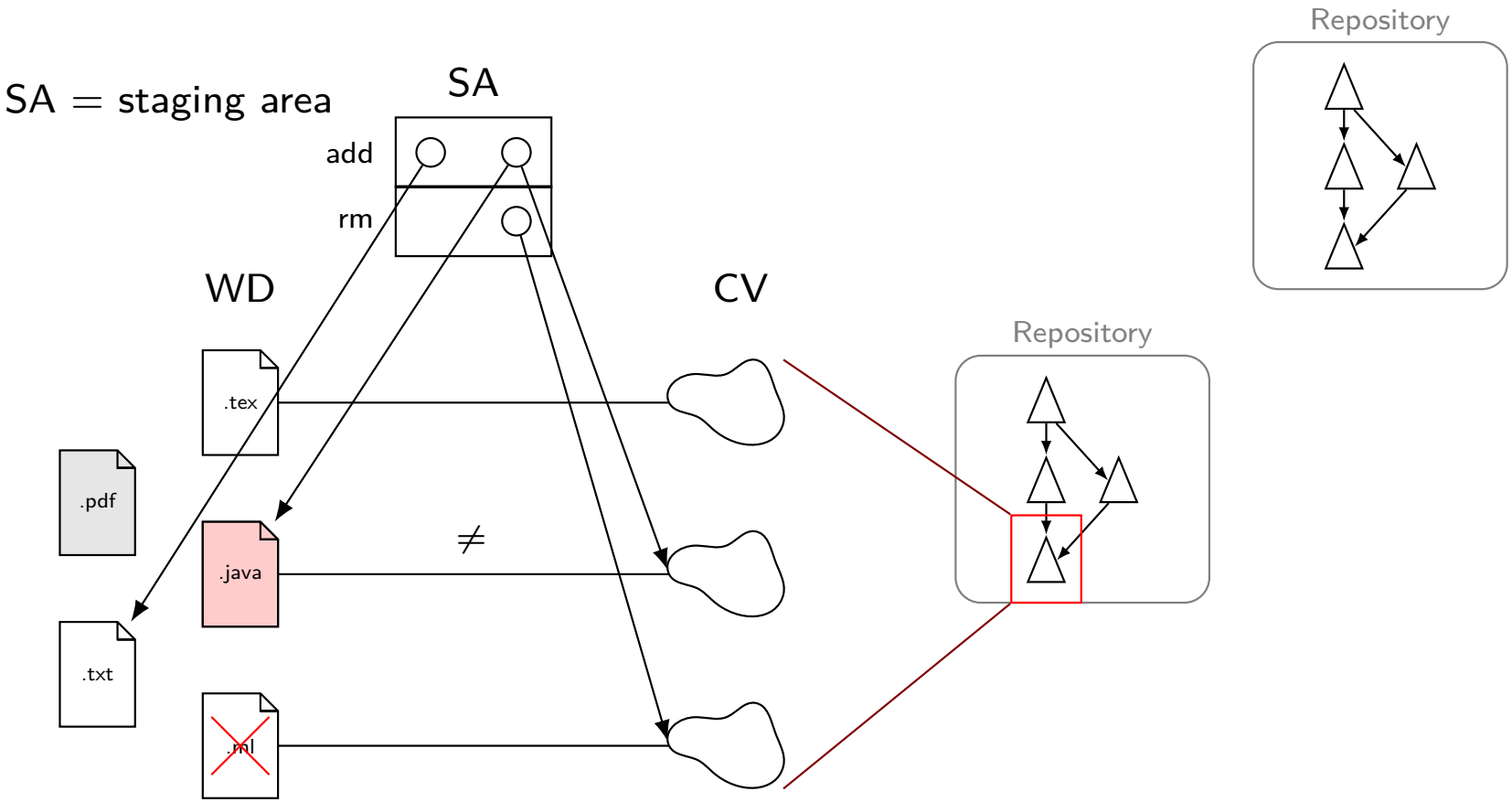
WD = working directory



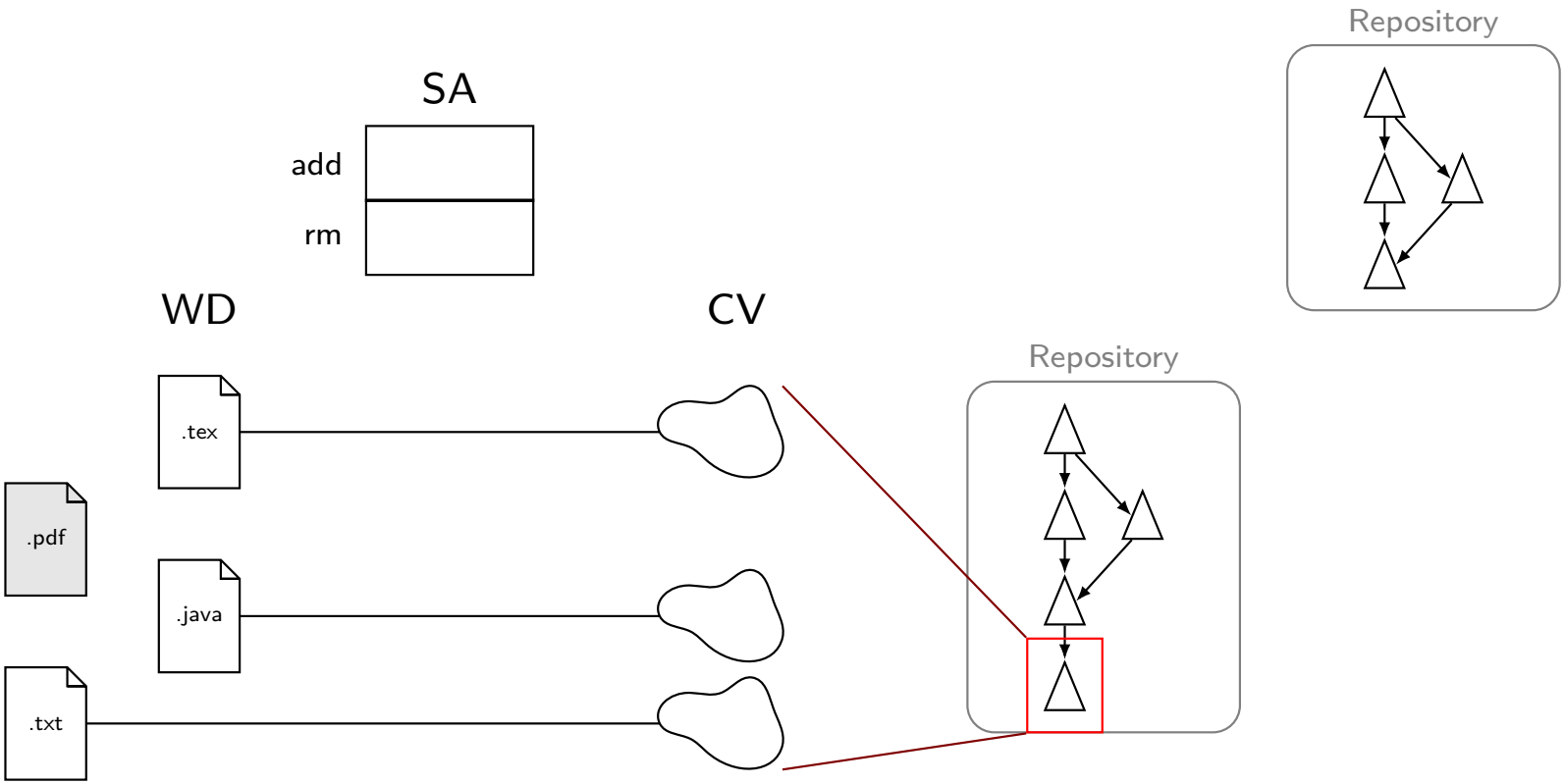
Diving into Git core



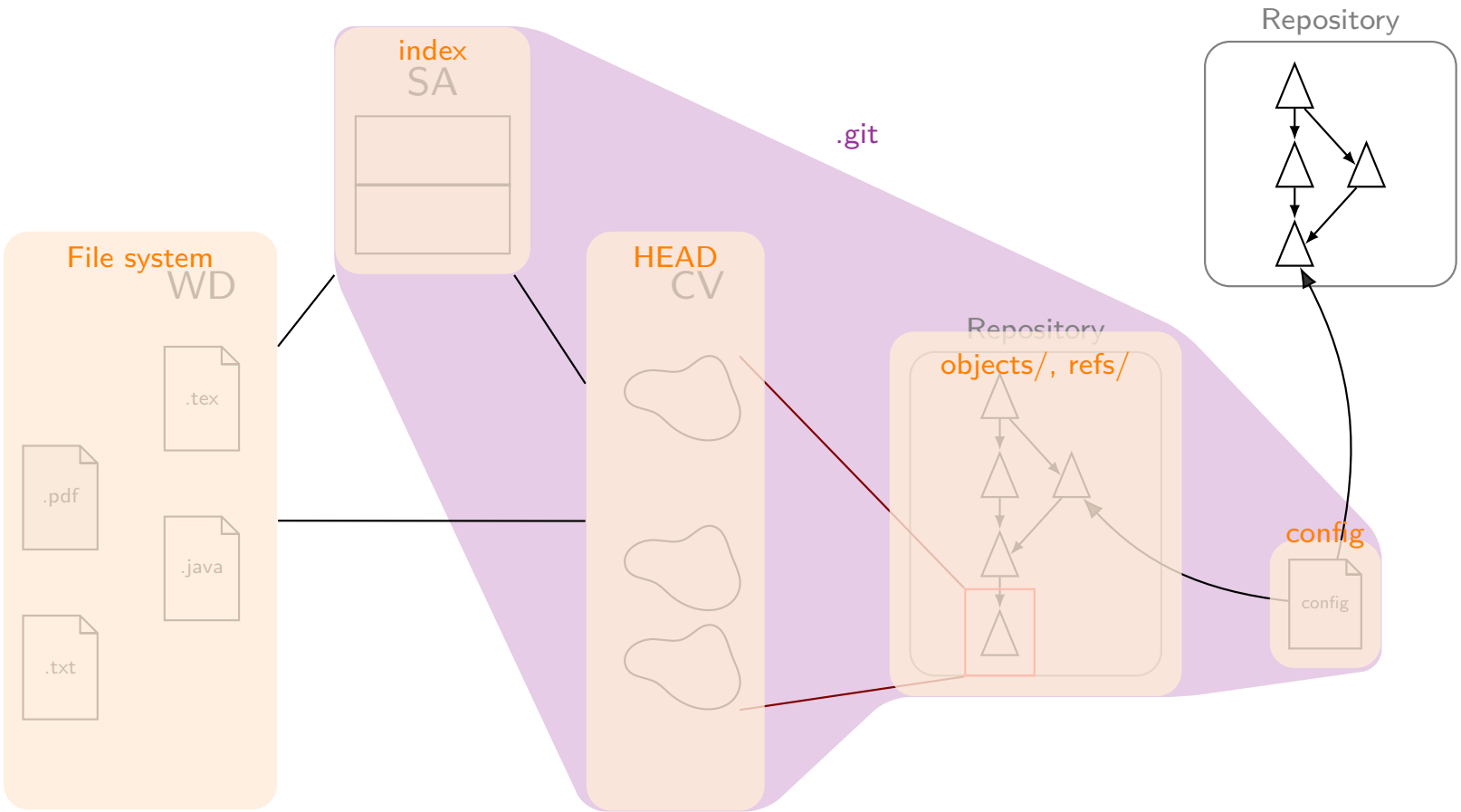
Diving into Git core



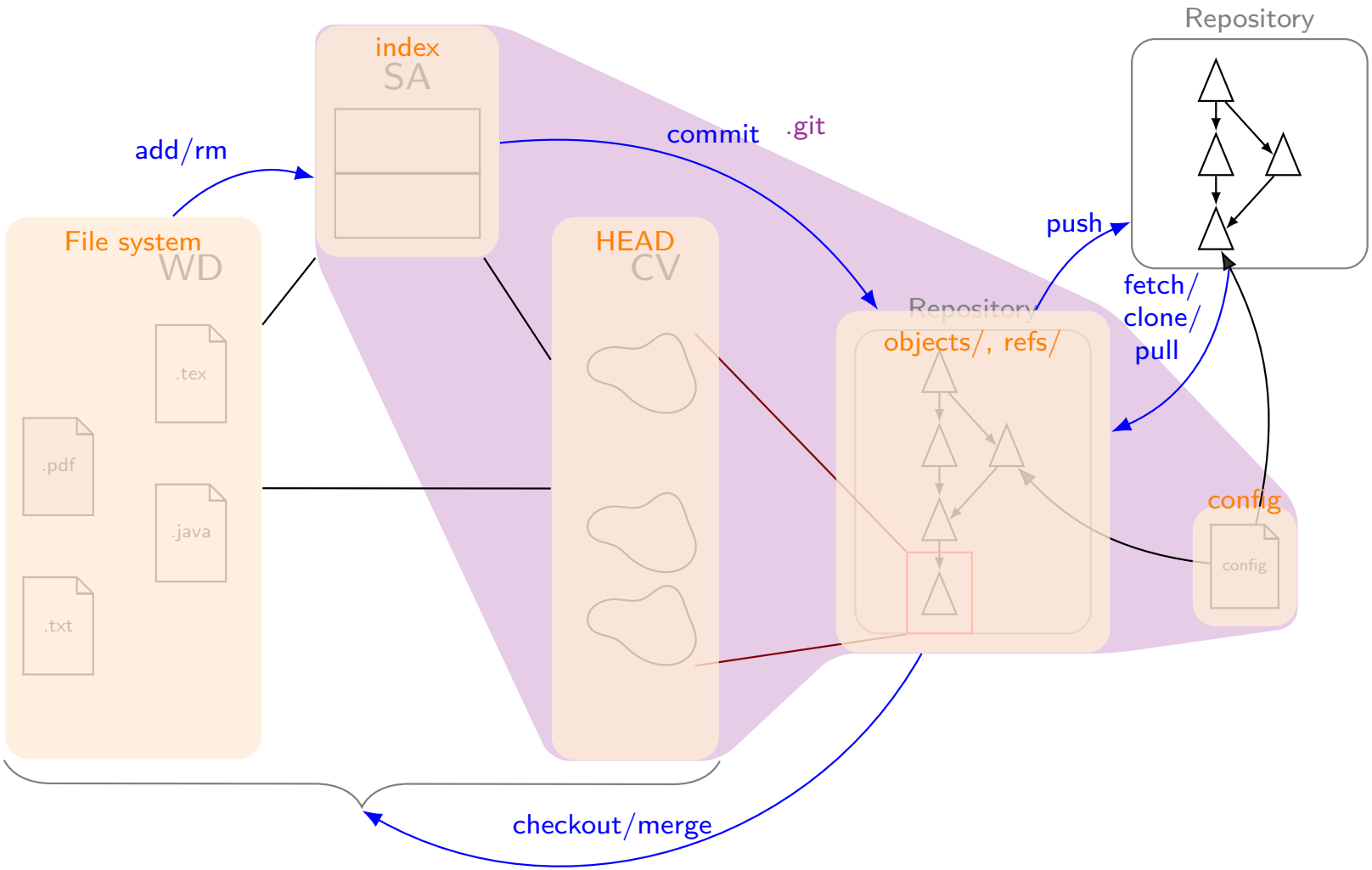
Diving into Git core



Diving into Git core



Diving into Git core



Structure of a versioned project with Git

```
jcbach@minitel2#11:32:20>taf-ilsd$ls -lah
total 72K
drwxr-xr-x  14 jcbach jcbach 4.0K Aug 12 09:58 .
drwxr-xr-x 258 jcbach jcbach  12K Aug 19 10:54 ..
drwxr-xr-x   7 jcbach jcbach 4.0K Jan 10  2025 adm
drwxr-xr-x   6 jcbach jcbach 4.0K Aug 12 09:58 contenu
drwxr-xr-x   2 jcbach jcbach 4.0K Aug 12 09:58 descriptions
drwxr-xr-x   8 jcbach jcbach 4.0K Jun 25  2019 fiches
drwxr-xr-x   2 jcbach jcbach 4.0K May  3  2024 fichesPASS
drwxr-xr-x   7 jcbach jcbach 4.0K Aug 22 10:42 .git
-rw-r--r--   1 jcbach users    50 Dec 11  2024 .gitignore
drwxr-xr-x   2 jcbach users  4.0K Aug 12 09:58 logo
drwxr-xr-x   4 jcbach users  4.0K Aug 12 09:58 poster
drwxr-xr-x   4 jcbach users  4.0K Aug 19 15:07 presentations
drwxr-xr-x   4 jcbach users  4.0K Aug 12 09:58 projets-procom
-rw-r--r--   1 jcbach users   494 Aug 12 09:58 README
drwxr-xr-x   2 jcbach jcbach 4.0K Dec  1  2020 reunions
drwxr-xr-x   6 jcbach users  4.0K Aug 13 17:52 semainerentree
```

.git structure

```
jcbach@minitel2#11:36:28>.git$ls -lah
total 84K
drwxr-xr-x   7 jcbach jcbach 4.0K Aug 22 10:42 .
drwxr-xr-x  14 jcbach jcbach 4.0K Aug 12 09:58 ..
-rw-r--r--   1 jcbach jcbach   20 Sep 17  2024 COMMIT_EDITMSG
-rw-r--r--   1 jcbach users   276 Dec 11  2024 config
-rw-r--r--   1 jcbach jcbach   73 Jun 25  2019 description
-rw-r--r--   1 jcbach jcbach  107 Aug 19 14:59 FETCH_HEAD
-rw-r--r--   1 jcbach users    21 Dec 11  2024 HEAD
drwxr-xr-x   2 jcbach jcbach 4.0K Jun 25  2019 hooks
-rw-r--r--   1 jcbach users   27K Aug 22 10:42 index
drwxr-xr-x   2 jcbach jcbach 4.0K Jun 25  2019 info
drwxr-xr-x   3 jcbach jcbach 4.0K Jun 25  2019 logs
drwxr-xr-x 260 jcbach jcbach 4.0K Aug 19 14:59 objects
-rw-r--r--   1 jcbach users    41 Aug 19 14:59 ORIG_HEAD
-rw-r--r--   1 jcbach jcbach  114 Jun 25  2019 packed-refs
drwxr-xr-x   5 jcbach jcbach 4.0K Sep 23  2020 refs
```

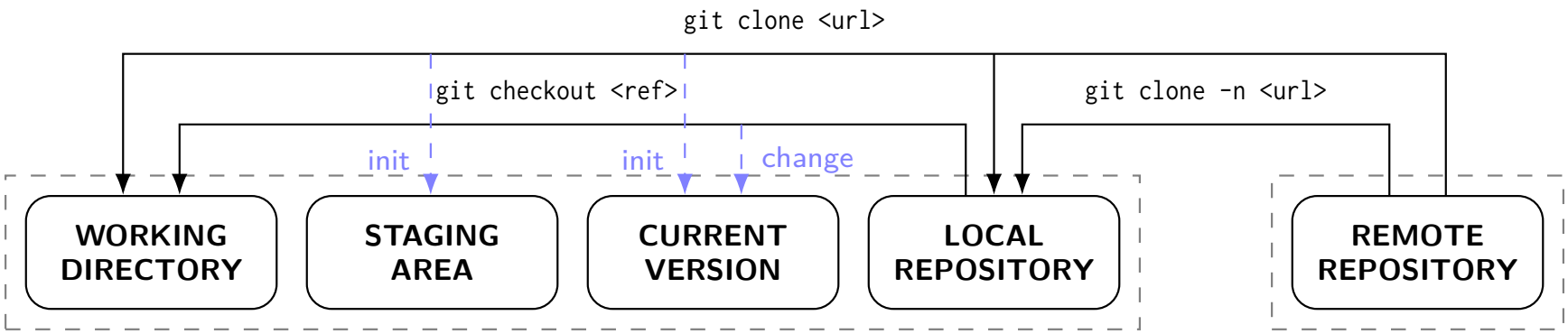
Progress

Git by the example

- Practical use cases in order to learn few commands
  - setting up a new repository (`init`, `remote url`)
  - retrieving a repository (`clone`)
  - making changes in the working repository (`status`)
  - updating the remote environment (`add`, `commit`, `push`)
  - checking differences after changes (`diff`)
  - updating dev environment (`fetch`, `pull`)
  - diverging/branching (`branch`, `merge`, `checkout`)
  - ...
- Non-exhaustive use cases
- Workflows

Let's have a look at the terminal!
(I'll probably forget the slides)

Retrieving a repository



`$> git clone -n <url>`

only creates the `.git` directory

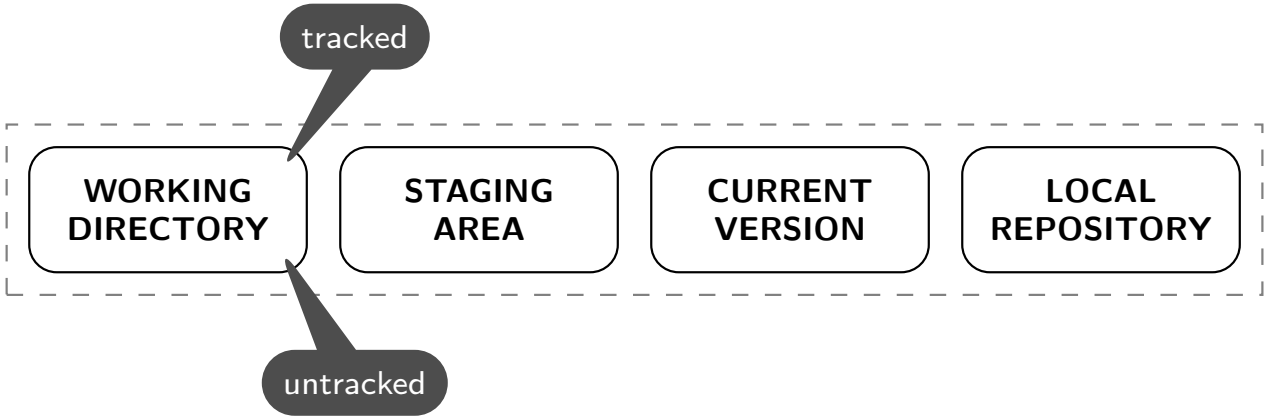
`$> git checkout <ref>`

retrieves files from local repository into the working directory

`$> git clone <url>`

creates the `.git` directory and retrieves files into the working directory; `clone = clone -n + checkout`

Making changes in the working directory

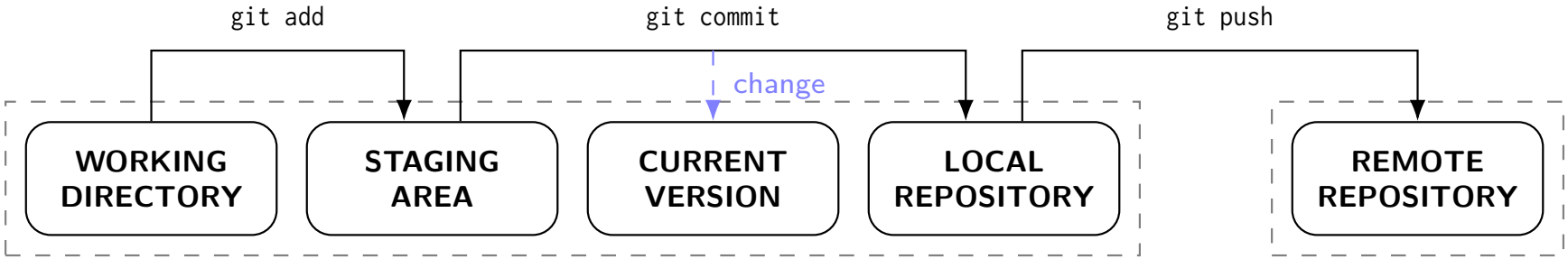


Checking the current state

```
$> 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 checkout -- <file>..." to discard changes in working directory)
        modified:   file1
        ...
Untracked files:
  (use "git add <file>..." to include in what will be committed)
        file4
        ...
no changes added to commit (use "git add" and/or "git commit -a")
```

Updating the remote environment



Example

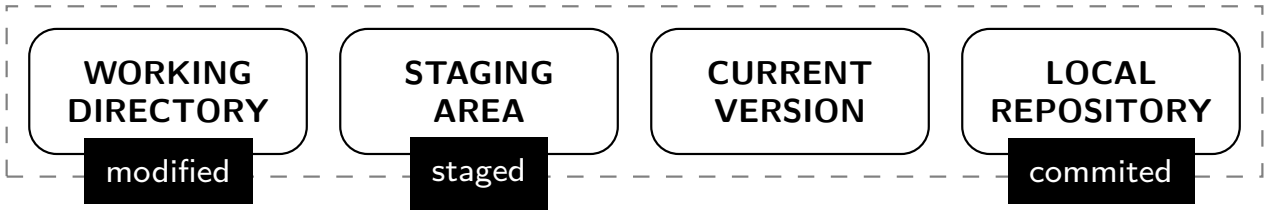
```
$> git add file1 file2 file3 ...
```
add in the index of the staging area

```
$> git commit -m ``add my super new feature''
```

```
...
```

```
$> git push
```
push into the remote repository

Checking differences after changes



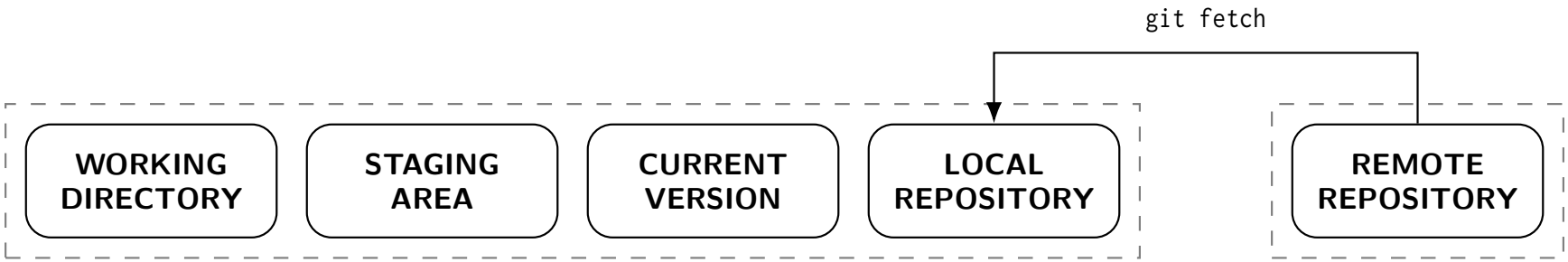
Diff commands

`$> git diff`

`$> git diff --staged`

`$> man git-diff` will help you

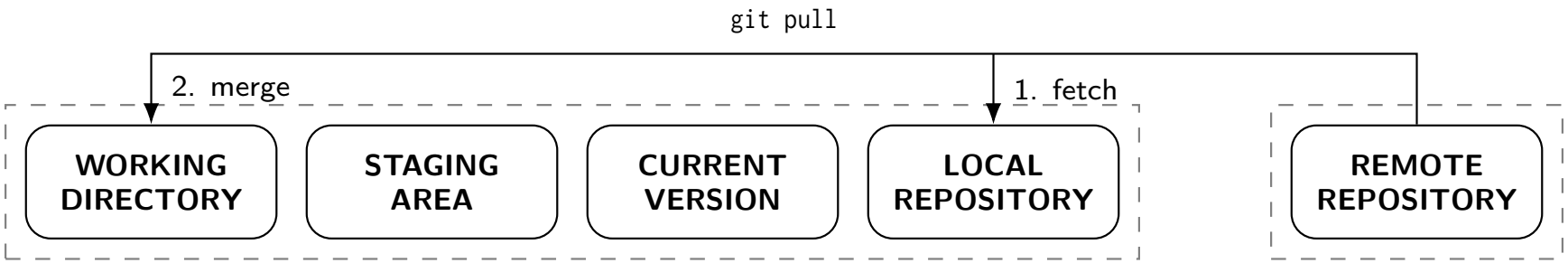
Updating dev environment (`fetch`)



`$> git fetch`

- retrieves updates from the remote repository
- is safe
  - does not affect working directory ⇒ cannot lose uncommited changes,
  - no automated merge

Updating dev environment (pull)



`$> git pull`

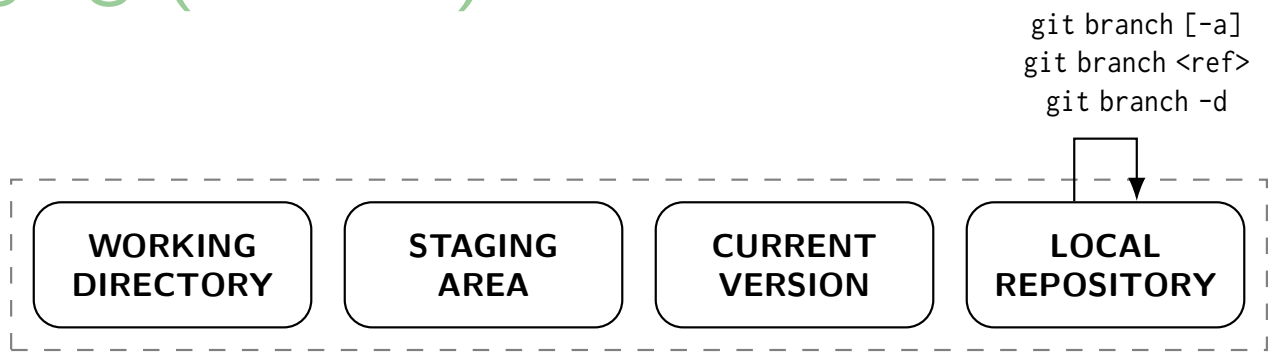
retrieves updates from the remote repository and merge them with the working directory

- `git merge`: to be seen few slides later

Diverging: vocabulary

- a branch = a reference to a version
  - can be seen as a “local checkpoint” (another says like a bookmark)
- branching
  - creating a named reference to a version
  - the common way to work without messing with the main line

Diverging (branch)



`$> git branch`

list local branches

`$> git branch -a`

list all (local and remote) branches

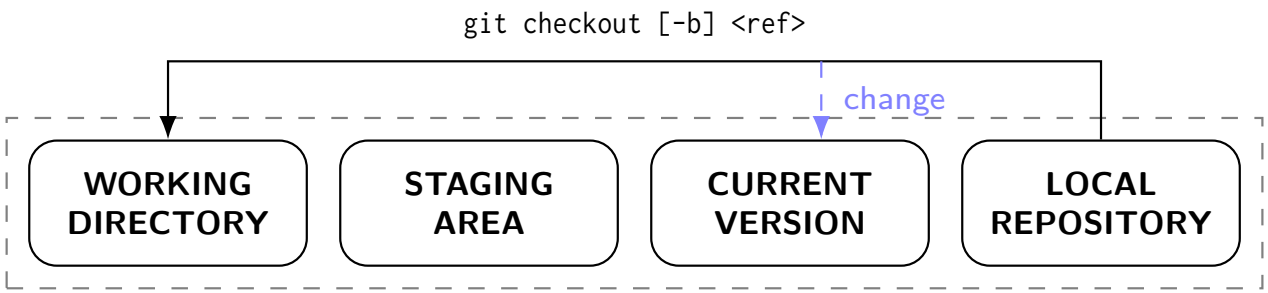
`$> git branch <ref>`

creates a named branch from the current branch

`$> git branch -d <ref>`

deletes a named branch

Diverging (checkout)



`$> git checkout <ref>`

changes the current branch

`$> git checkout -b <ref>`

creates a branch from the current branch and changes to it (= `git branch` + `git checkout`)

Diverging (merge)

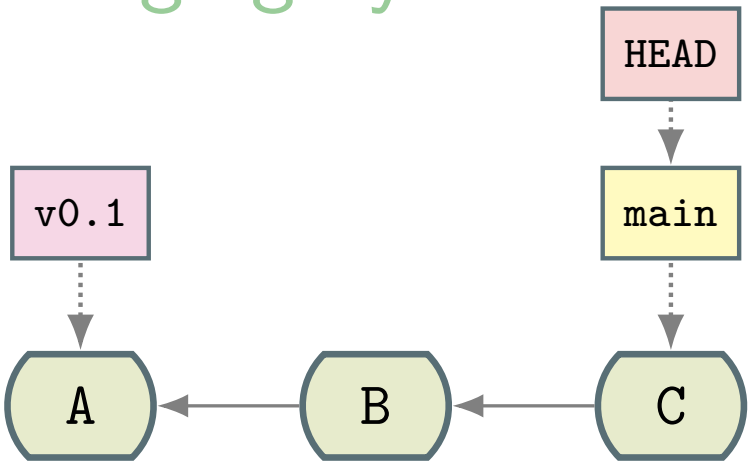
- Starting point: 2 branches (`main` + `newawesomefeature`), `HEAD` points to `main`

```
$> git merge newawesomefeature
```

integrate changes from `newawesomefeature` branch into `main`

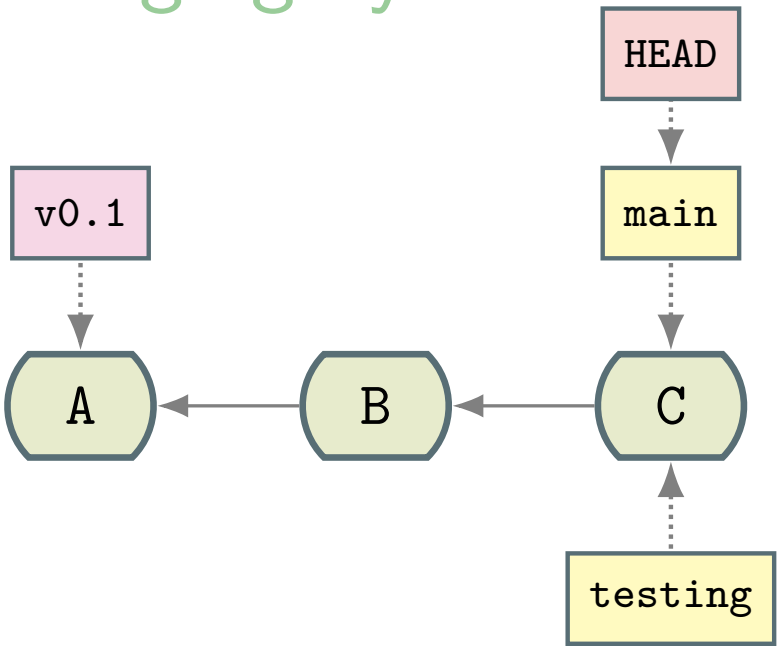
- Two situations
  - no conflict: changes from `newawesomefeature` are integrated in the main (local) line, time to push
  - conflicts: resolution needed in order to be able to push
- Conflict resolution:
  1. fix the conflicts (edit the files, keep/remove stuff)
  2. add the changes
  3. commit

Diverging by the example



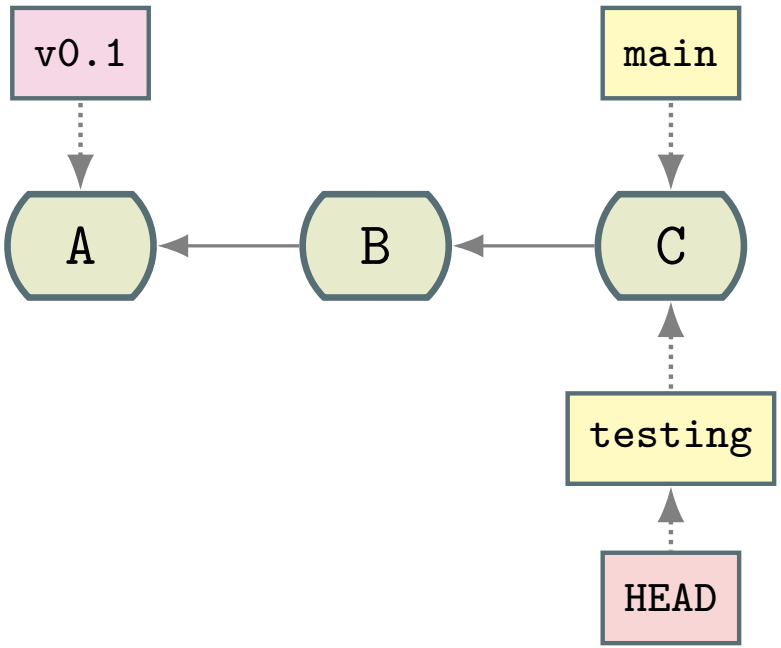
Initial situation

Diverging by the example



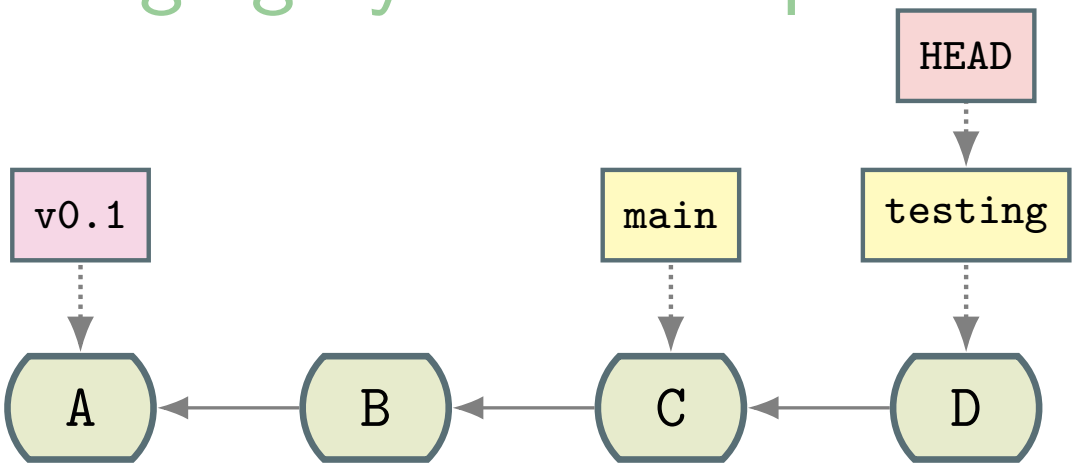

```
$> git branch testing
```

Diverging by the example



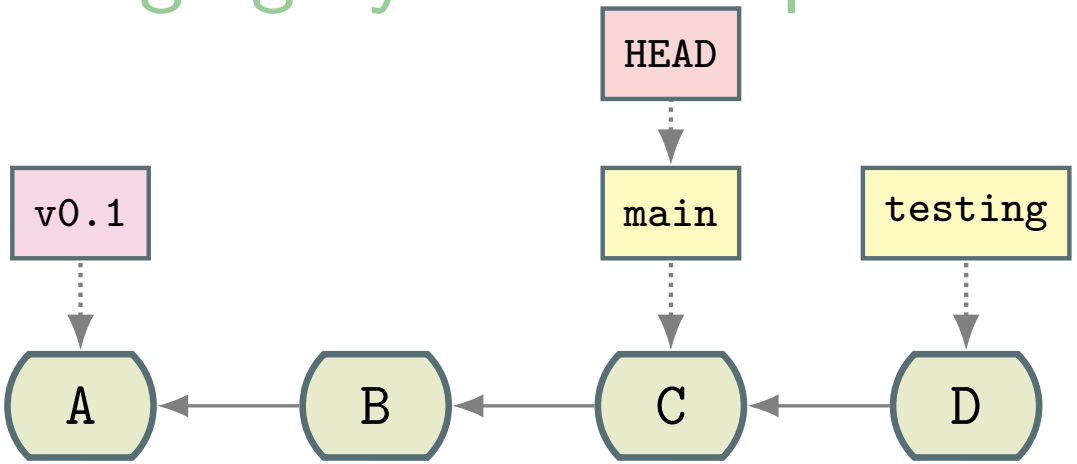

```
$> git checkout testing
```

Diverging by the example



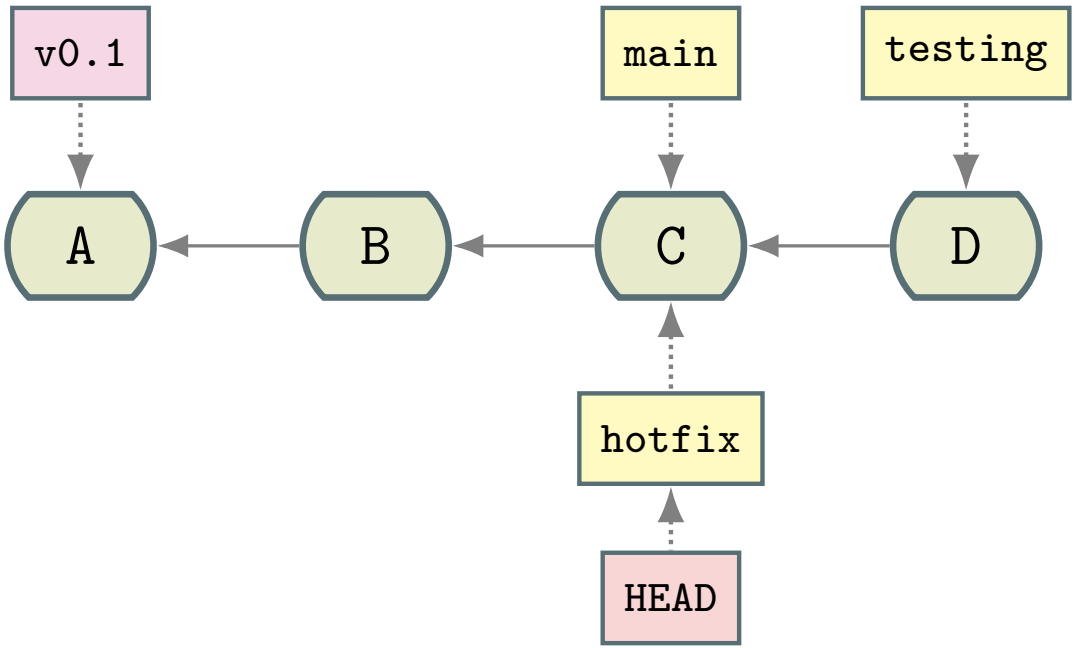
One commit later

Diverging by the example



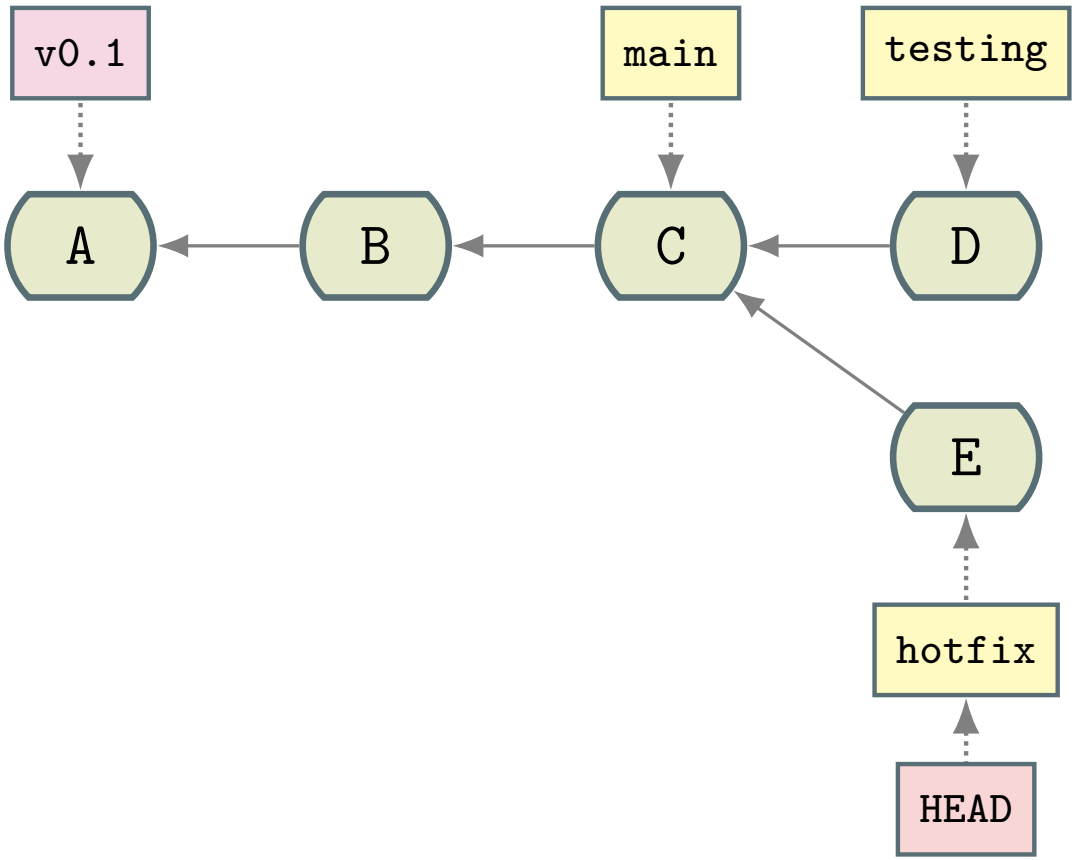

```
$> git checkout main
```

Diverging by the example



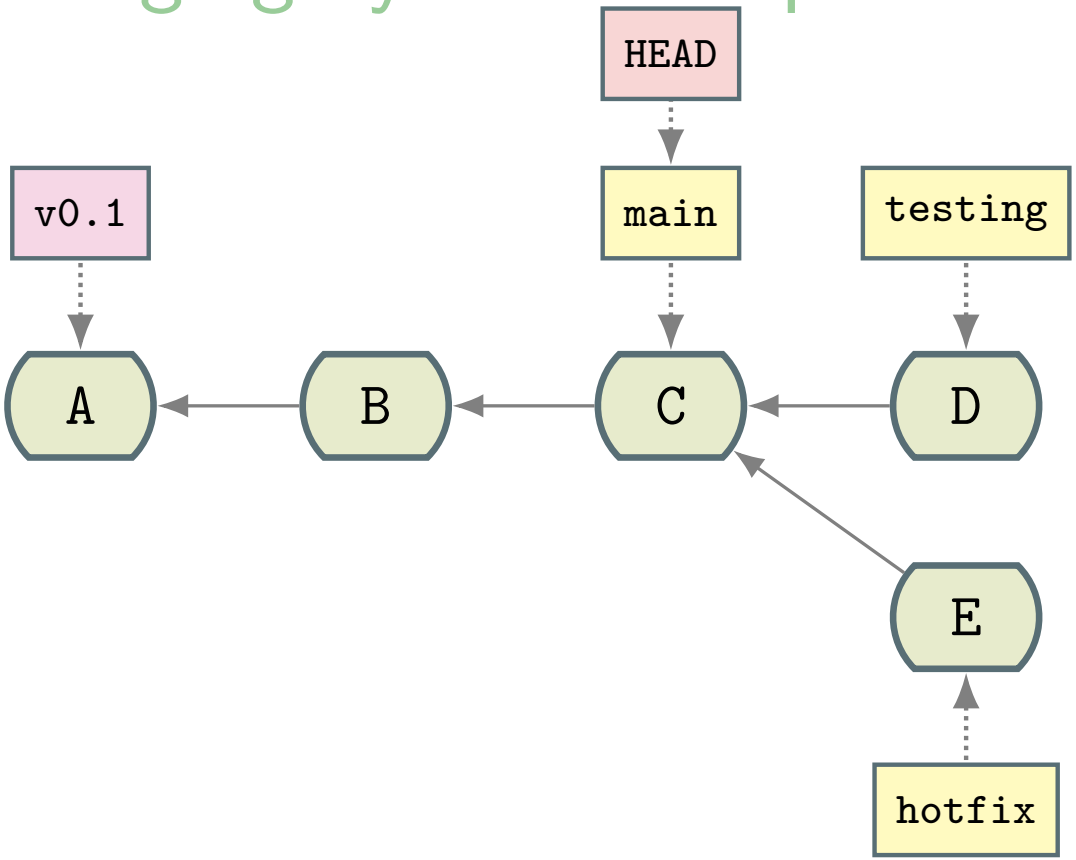

```
$> git checkout -b hotfix
```

Diverging by the example



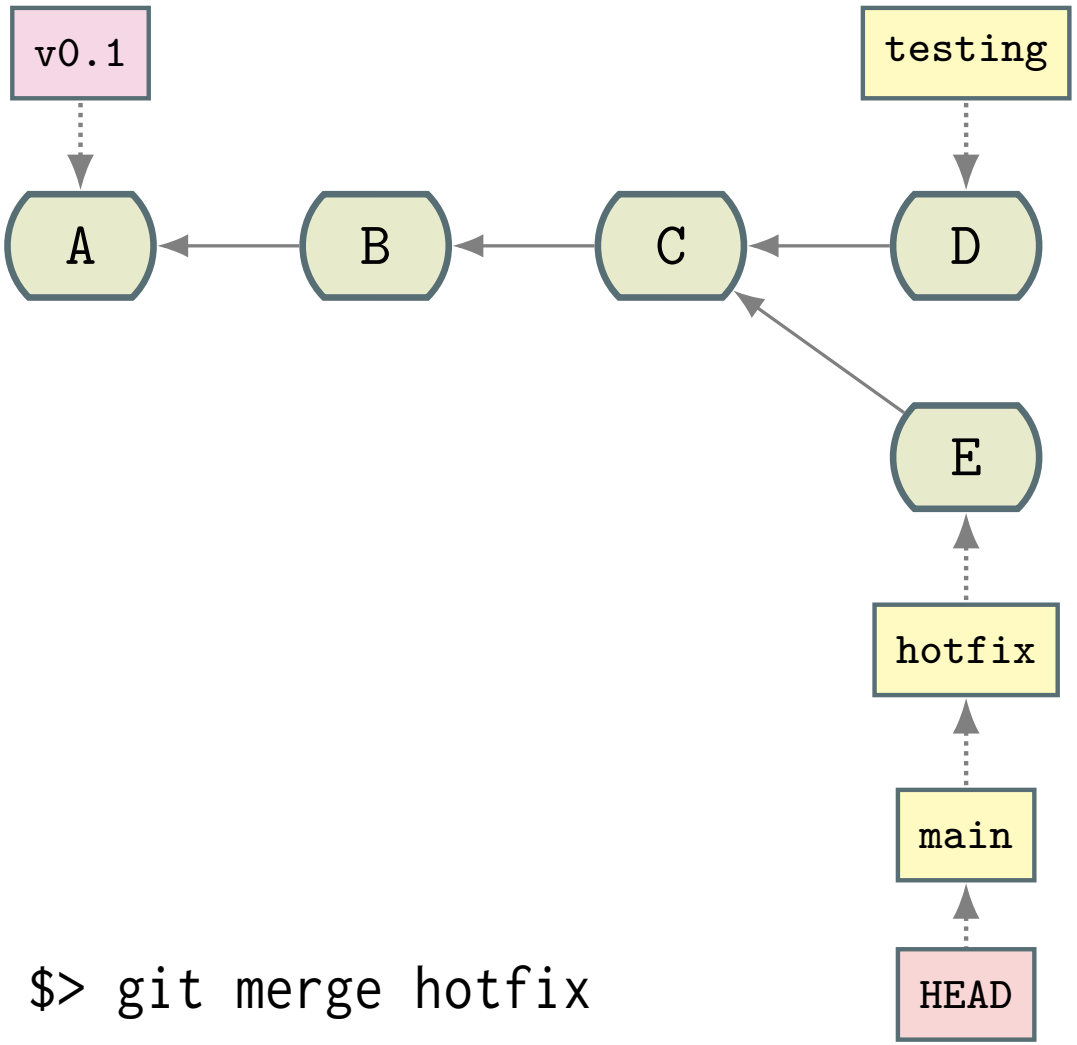
One commit later

Diverging by the example



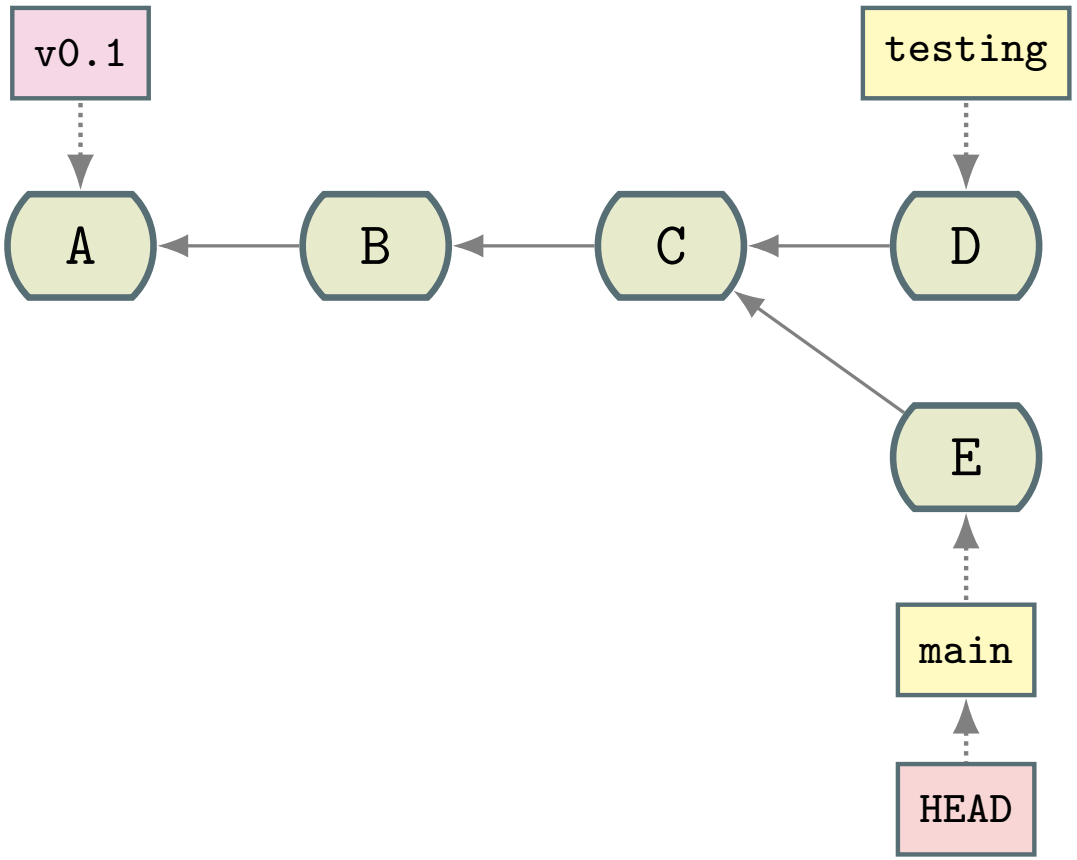

```
$> git checkout main
```

Diverging by the example



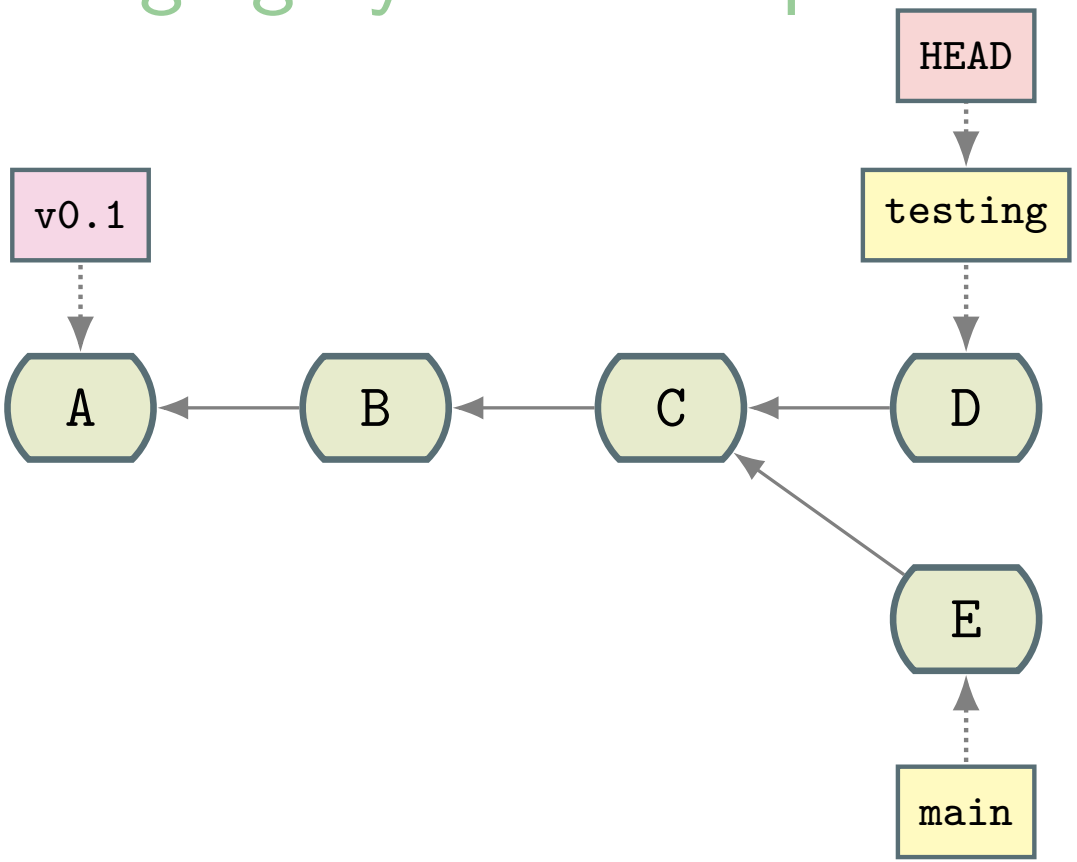

```
$> git merge hotfix
```

Diverging by the example



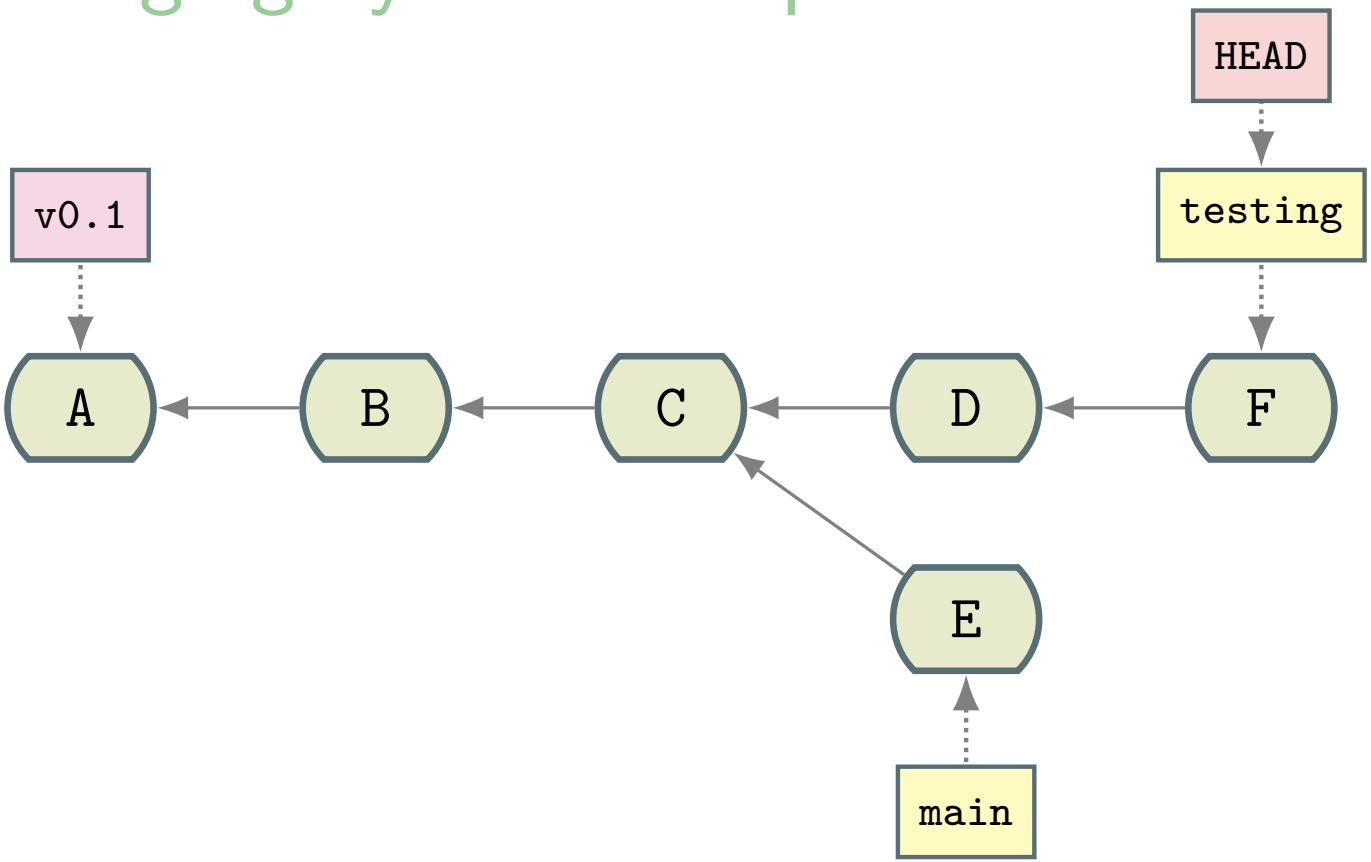

```
$> git branch -d hotfix
```

Diverging by the example



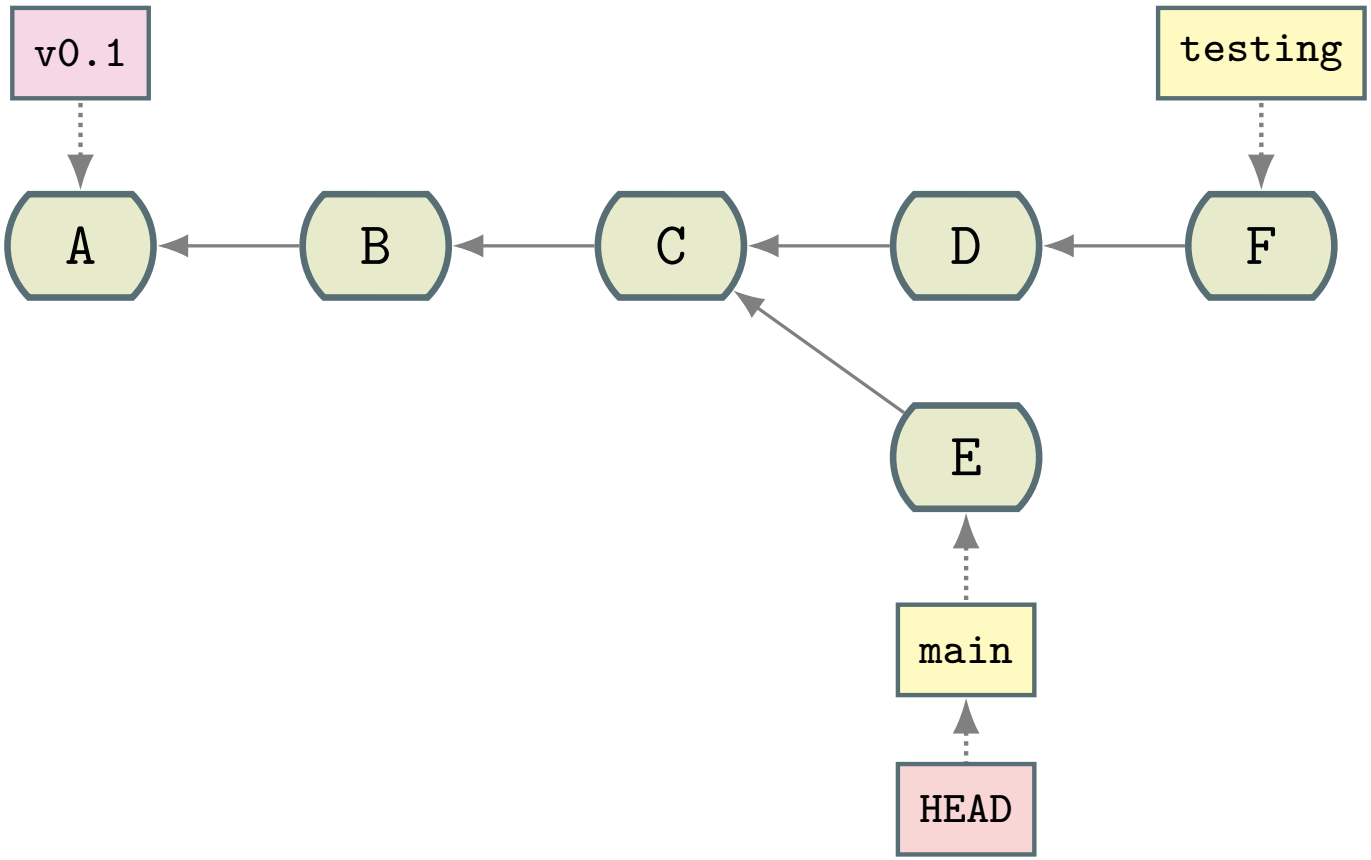

```
$> git checkout testing
```

Diverging by the example



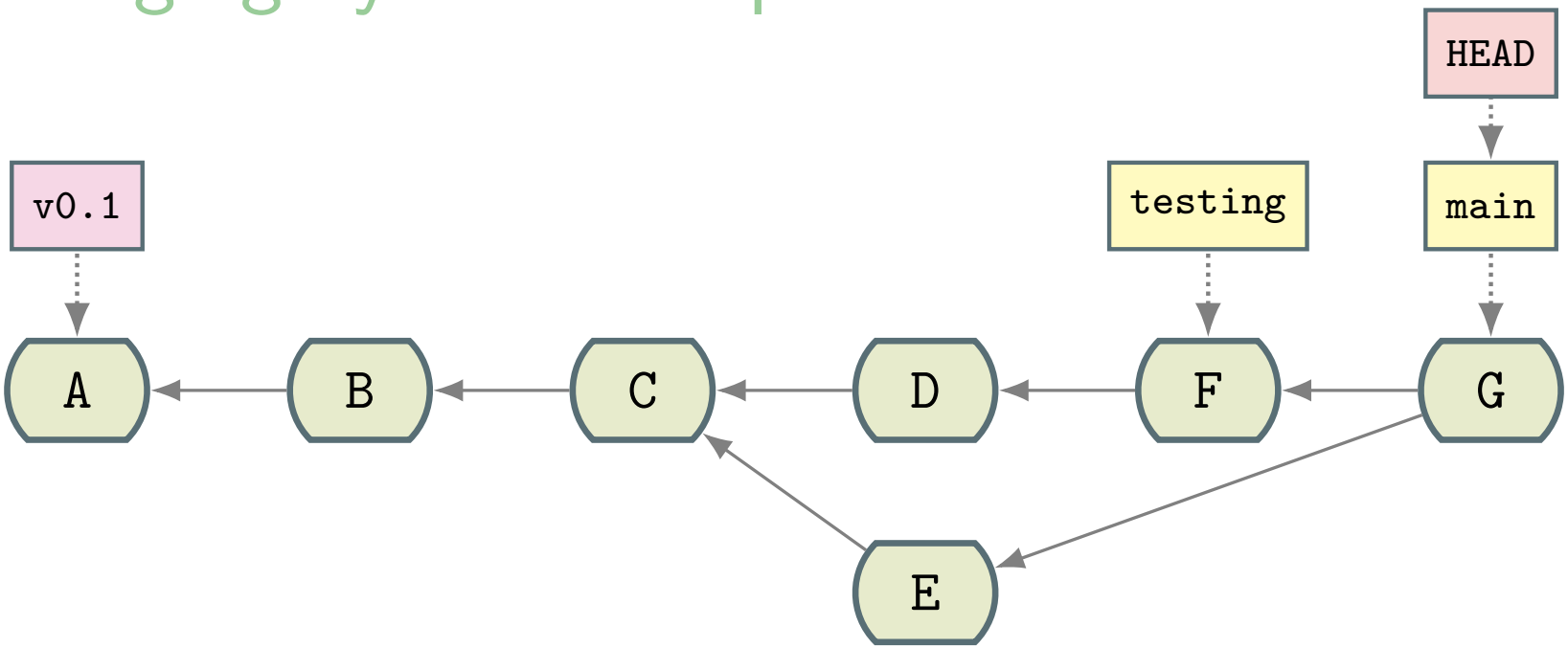
One commit later

Diverging by the example



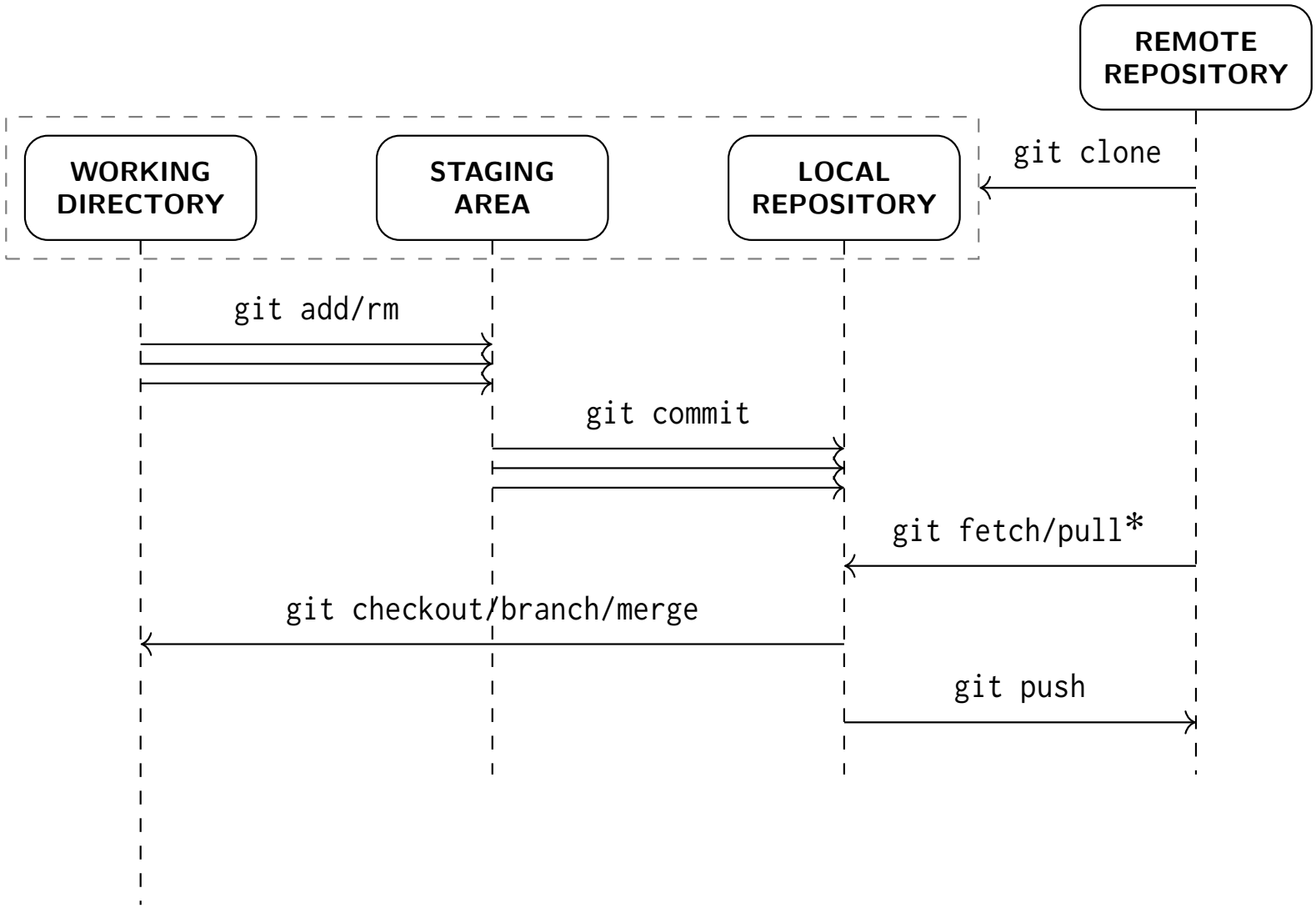

```
$> git checkout main
```

Diverging by the example




```
$> git merge testing
```

Summary of a typical Git workflow



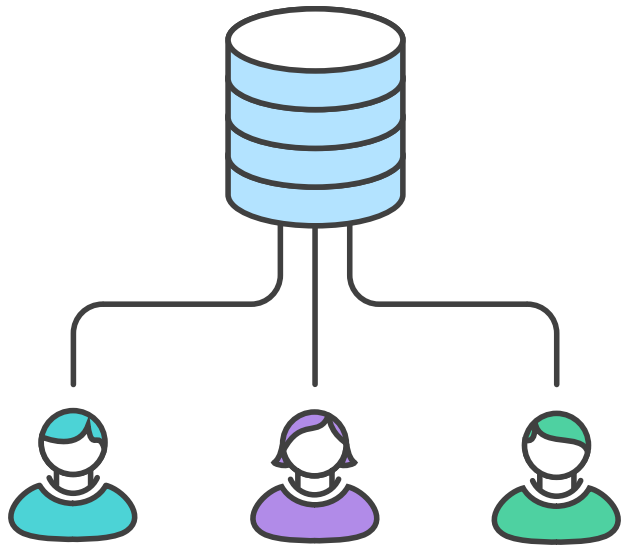
Progress

Adopting a workflow

- One tool, many usages
- Tools alone do not solve development problems
- Need of a process that fits the team
- Many possible Git workflows (examples later)
  - centralised workflow
  - feature branch workflow
  - gitflow workflow
  - forking workflow
  - ...

Centralised workflow

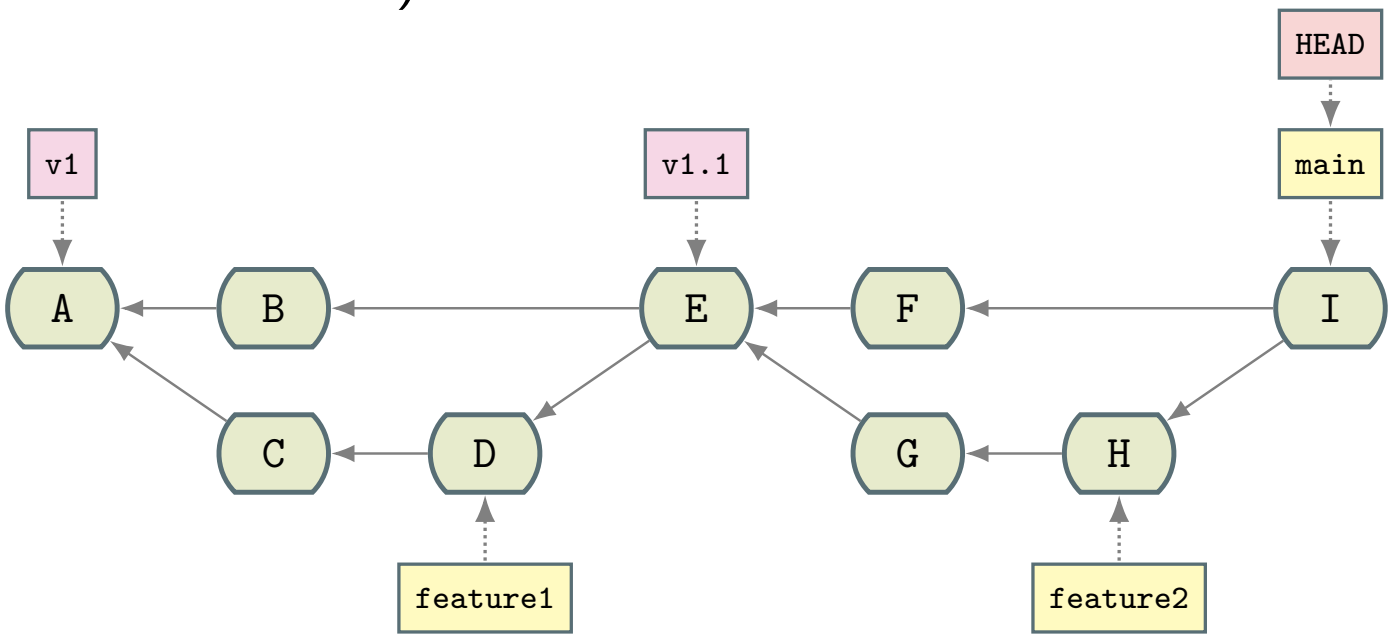
- One central repository, one branch (main)
- Common when coming from centralised systems like Subversion
- Common for small size teams
- Easy to understand for a newcomer



Source: Atlassian

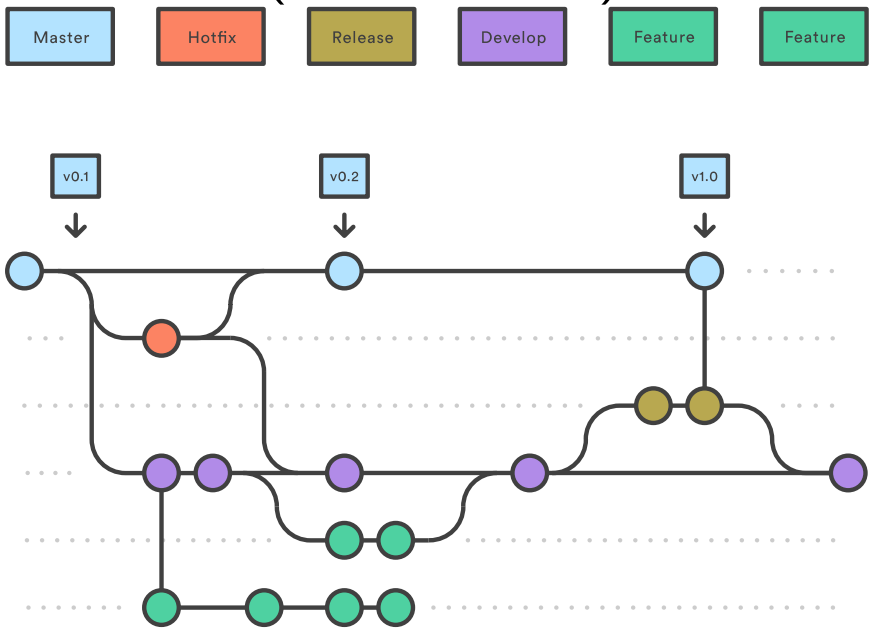
Feature branch workflow

- Central repository + main branch = official project history
- One branch per feature: no direct commit on the main branch
- Feature branches are pushed to the central repository
- Branches are then merged (after pull requests, feedbacks, conflict resolutions)



Gitflow workflow

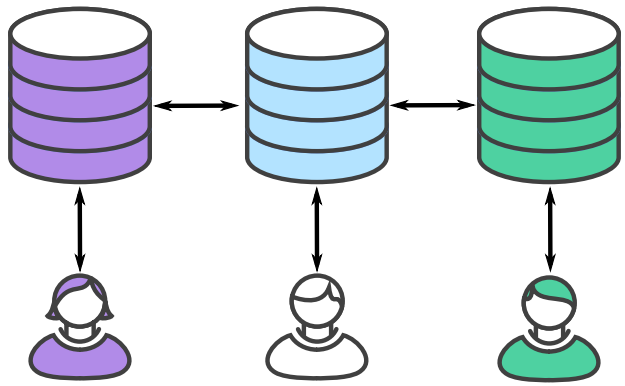
- Strict branching model designed around the project release
- Well-suited for large projects with deadlines (releases)
- One branch one role, workflow defines their interactions
- Can be combined with feature branch workflow
- Project history = main (the releases) + development branch



Source: Atlassian

Forking workflow

- One serverside repository per developer
- Each developer manages her repository and make pull requests to the reference repository
- Typical model when contributing to a FLOSS project hosted on GitHub: “Fork us on GitHub”



Source: Atlassian

Workflows: summary

- Chosen workflow depends on the team's concerns and organisation
  - no one-size-fits-all Git workflow
- Feature workflow: business domain oriented
- Forking and gitflow workflows: repository oriented
- What is a good workflow?
  - enhance or limit team efficiency?
  - scale with team size?
  - easy to undo mistakes and errors?
  - impose any new unnecessary cognitive overhead to the team?
  - does it limit conflicts?

Progress

VCS pratices

- Git
  - useful and powerful tool
  - but a tool alone does not solve all problems. It can also create ones

  $\Rightarrow$ developers do not only need tools, but also working processes
- Good practices
  - formalizing the process/workflow
  - coordinating with co-workers
  - testing before sending changes
  - updating before sending a change
  - commiting meaningful changes
  - commiting often
  - adding meaningful messages for commits
  - not commiting generated files
  - short-lived branches

VCS in practice: how to start?

- By practicing
  - during every lab sessions, even in non-CS context
  - at home
- One usually needs a server to host repositories
  - but it is not mandatory: you can use Git in serverless mode!
- Some questions to ask before chosing
  - do you want to make your project public?
  - is there any security, privacy or IP problems with the project?
  - is your project a cornerstone of your business?
- Your answers should drive your choices of VCS hosting
  - simple and free non-professional account on an open platform
  - paid service on a platform
  - installation of your own VCS server

Git in practice: which platform to start with?

- IMTA infrastructure for academic projects and for learning:
  - Gitlab: `https://gitlab-df.imt-atlantique.fr/`
- Many platforms can be used without any fee:
  - Assembla: `https://www.assembla.com/`
  - Bitbucket: `https://bitbucket.org/`
  - Codeberg: `ihttps://codeberg.org/`
  - Gitea: `https://about.gitea.com/`
  - Gitlab: `https://about.gitlab.com/`
  - GitHub: `https://github.com/`
  - Sourcehut: `https://sourcehut.org/`

  ... and probably many other
- You can also install your own server!

Serverless mode: a simple way to start with Git

- Git can also be used without any other host

1. `$> mkdir mycode`
2. `$> cd mycode`
3. `$> git init`
   initialize a new Git repository

- That type of Git repository can be shared
  - as every folder (copy/paste on an USB key,)
  - or using a Git command to add a remote repository (it has to exist)

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

Git integration

- If you use a mainstream IDE, Git is probably already integrated
  - Eclipse
    - Window > Perspective > Open Perspective > Other > Git
  - vscode
    - Ctrl+Shift+G
    - nice and useful plugins: *Git graph* and *GitLens*
  - IntelliJ
    - Alt+‘
  - well-configured Vim or Emacs: you don’t need any help 😎
    - maybe a TUI: *tig*, *lazygit*

Conclusion

- Basic principles of VCS
  - basic principles
  - two main families: centralised vs decentralised
  - tools diversity
- Some good practices for VCS usage
- Importance of a workflow
  - should be simple
  - should enhance the team productivity
  - should be oriented by business requirements
- VCS usage should be an habit, not a constraint
- Basics for a specific (but probably the most common) VCS: Git
  - discover Git in the practical work!

Resources

- VCS
  - https://homes.cs.washington.edu/~mernst/advice/version-control.html
  - https://betterexplained.com/articles/a-visual-guide-to-version-control/
  - https://betterexplained.com/articles/intro-to-distributed-version-control-illustrated/
- Git
  - https://git-scm.com/
  - https://git-scm.com/book/en/v2/ (Pro Git book)
  - http://justinhileman.info/article/git-pretty/
  - https://betterexplained.com/articles/aha-moments-when-learning-git/
  - https://rachelcarmena.github.io/2018/12/12/how-to-teach-git.html
- Subversion: http://svnbook.red-bean.com/
- Mercurial: https://www.mercurial-scm.org/

Gentle reminder

⚠ Important notes

- if you do not understand something, please ask your questions. *We cannot answer the questions you do not ask*
- if you disagree with us, please say it (politely)
- people don't learn computer science by only reading few academic slides: practicing is fundamental