Class Logistics

- Is everybody getting the announcements from Canvas?
- Any problem with A/V, recorded lessons?
- Are we going too fast through the slides?
- Are we taking enough breaks?
  - 50 mins of class and 10 mins of decompression
- We are going to record the lesson
  - Please come to class so we can do hands-on labs
- Anything else we should improve upon?
  - How can we make class more interactive?
  - There is always something it can be done better
  - Do not be shy
  - Send emails

UMD DATA605 - Big Data Systems
Git
Data Pipelines

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with thanks to Prof.
Alan Sussman
Amol Deshpande

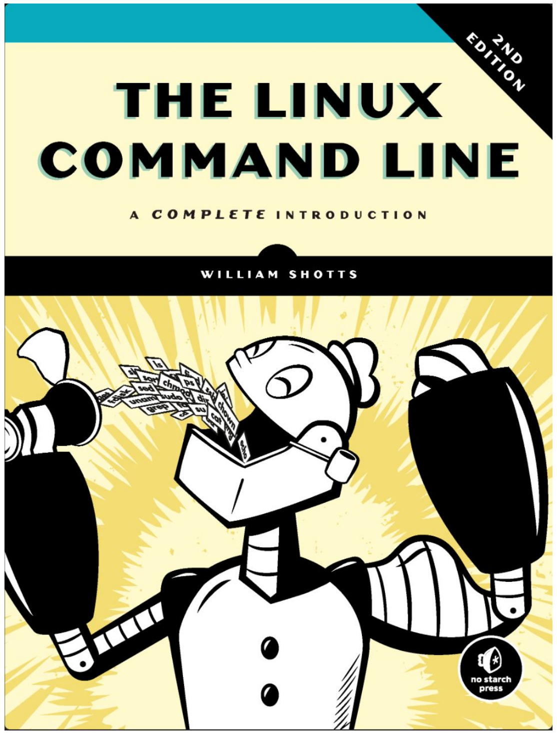
UMD DATA605 - Big Data Systems

Git

Data Pipelines

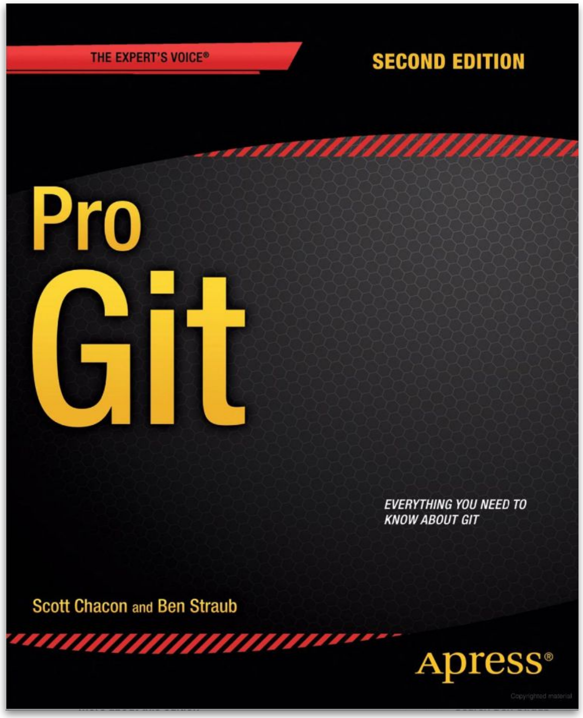
Bash / Linux: Resources

- Command line
  - https://ubuntu.com/tutorials/command-line-for-beginners
- E.g., `find`, `xargs`, `chmod`, `chown`, symbolic, and hard links
- How Linux works
  - Processes
  - File ownership and permissions
  - Virtual memory
  - How to administer a Linux box as root
- Mastery
  - https://linuxcommand.org/tlcl.php

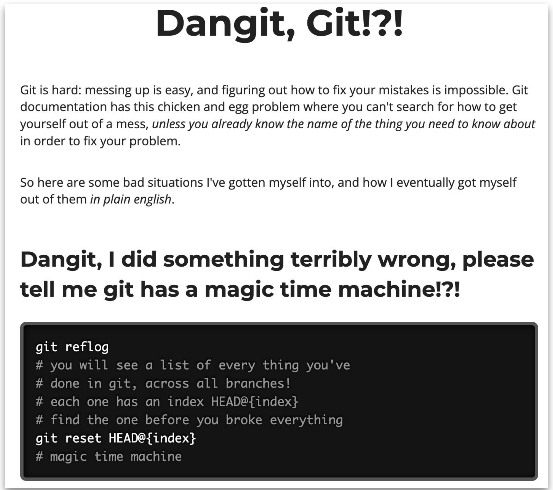


Git: Resources

- Concepts in the slides
- Tutorial: tutorial_git
- We will use Git during the project
- Mastery: Pro Git (free)
- Web resources:
  - https://githowto.com
  - dangitgit.com (without swearing)
  - Oh Sh*t, Git!?! (with swearing)
- Playgrounds
  - https://learngitbranching.js.org



THE EXPERT'S VOICE®
SECOND EDITION
Pro Git
EVERYTHING YOU NEED TO KNOW ABOUT GIT
Scott Chacon and Ben Straub
Apress®



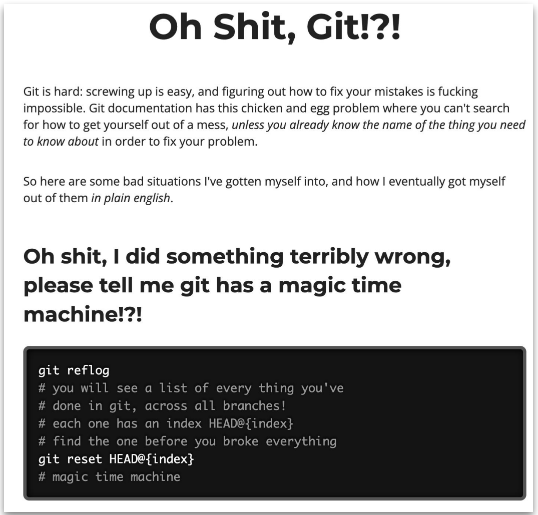
Dangit, Git!?!

Git is hard: messing up is easy, and figuring out how to fix your mistakes is impossible. Git documentation has this chicken and egg problem where you can't search for how to get yourself out of a mess, *unless you already know the name of the thing you need to know about* in order to fix your problem.

So here are some bad situations I've gotten myself into, and how I eventually got myself out of them *in plain english*.

Dangit, I did something terribly wrong, please tell me git has a magic time machine!?!

```
git reflog
# you will see a list of every thing you've
# done in git, across all branches!
# each one has an index HEAD@{index}
# find the one before you broke everything
git reset HEAD@{index}
# magic time machine
```



Oh Shit, Git!?!

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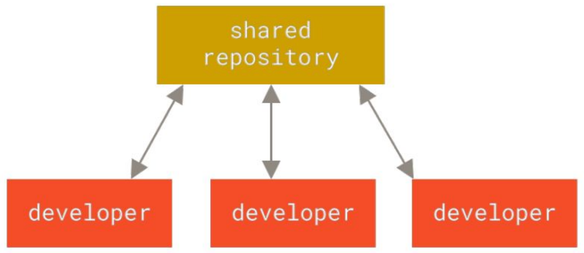
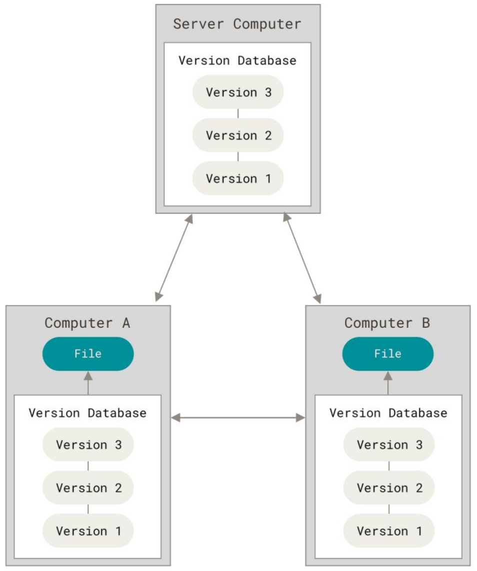
Version Control Systems

- A Version Control System (**VCS)** is a system that allows to:
  - Record changes to files
  - Recall specific versions later (like a “file time-machine”)
  - Compare changes to files over time
  - Track *who* changed *what* and *when* and *why*

- **Simplest “VCS”**
  - Make a copy of a dir and add `_v1` (bad) or add a timestamp `_20220101` (better)
  - **Cons**: It kind of works for one person, but doesn’t scale
- **Centralized VCS**
  - E.g., Perforce, Subversion
  - A server stores the code, clients connect to it
  - **Cons**: If the server is down, nobody can work
- **Distributed VCS**
  - E.g., Git, Mercurial, Bazaar, Dart
  - Each client has the entire history of the repo locally
  - Each node is both a client and a server
  - **Cons**: complex



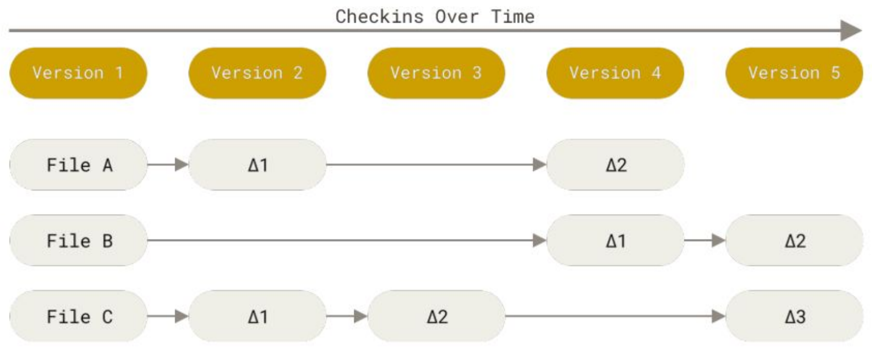
Centralized VCS

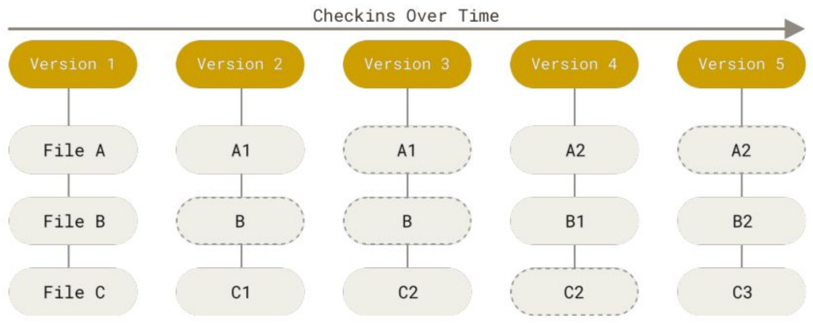


Distributed VCS

VCS: How to Track Data

- Consider a directory with project files inside
- How do you track changes to the data?
- **Delta-based VCS**
  - E.g., Subversion
  - Store the data in terms of patches (changes of files over time)
  - Can reconstruct the state of the repo by applying the patches
- **Stream of snapshots VCS**
  - E.g., Git
  - Store data in terms of snapshots of a filesystem
  - Take a “picture” of what files look like
  - Store reference (hash) to the snapshots
  - Save link to previous identical files





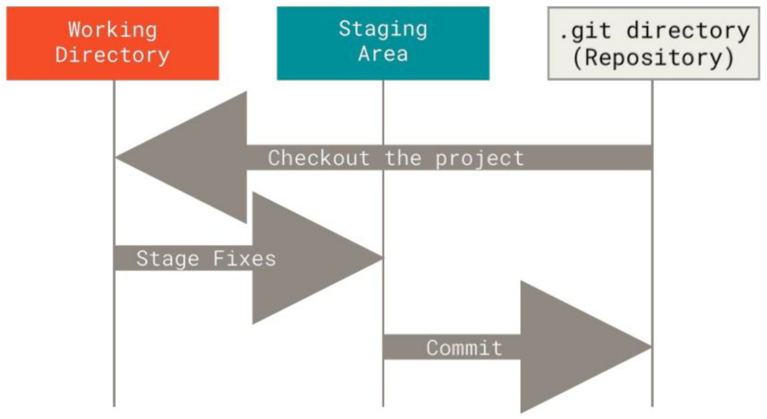
Git

- **Almost everything is local for Git**
  - The history is stored locally in each node
  - Diff-ing is done locally
    - For centralized VCS you need to access the server
  - You can commit to your local copy
    - Upload changes when there is network connection
- **Almost everything is undoable in Git**
  - No data corruption
    - Everything is checksummed
  - Nothing can be lost
  - Disclaimer:
    - As long as you commit (at least locally) or stash
    - As long as you don't precipitate in "git hell"
    - You need to know how to do it
- **Git is a mini key-value store with a VCS built on top**
  - This is actually exactly true
  - Two layers:
    - "porcelain": key-value store for a file-system
    - "plumbing": VCS layer

States of a File in Git

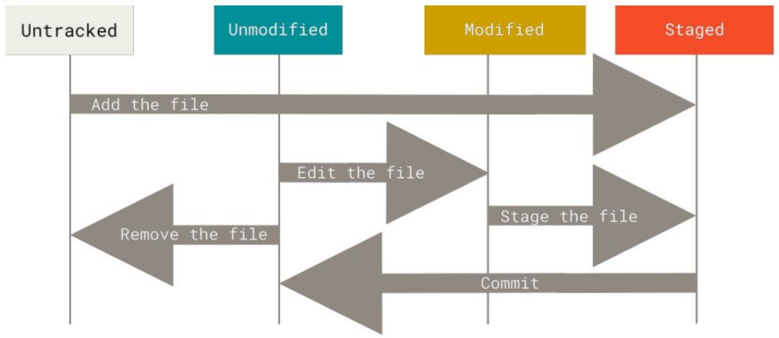
There are 3 main sections of a Git project:

- **Working tree** (aka *checkout*)
  - Version of the code placed on the filesystem for the user to use and modify
- **Staging area** (aka *cache*, *index*)
  - A file in `.git` that stores information about the next commit
- **Git directory** (aka *.git*)
  - Store metadata and objects (like a DB)
  - It is the repo itself with all history
  - When you clone, you get the `.git` of the project



Each file can be in 4 states from Git point-of-view

- **Untracked**: files that are not under Git version control
- **Modified**: you have changed the file, but not committed to DB yet
- **Staged**: you have marked a modified file to go into your next commit snapshot
- **Committed**: data is safely stored in your local DB



Git Tutorial

- Git tutorial on class repo
  - Read me
- How to use a tutorial
  - Type the commands from the tutorial one-by-one
    - Do not copy paste
  - Look at the results
    - Understand what each line means
  - Play with things
    - “What happens if I do this?”
    - “Does the result match my mental model?”
  - Learn command line before switching to the GUI
    - GUIs hide details and you become dependent on it
- Use one or more tutorials on-line
  - Ideally go through the Git book and the examples
- Build your own cheat sheet
  - Reusing other people cheat sheet works only if you already know
- Strive to achieve mastery of the basic tools of the trade
  - Bash, Git, editor
  - Python
  - Pandas
  - ...

Git: Daily Use

- Check out a project (`git clone`) or start from scratch (`git init`)
  - Only once per Git project client
- **Daily routine**
  - Modify files in working tree (`vi ...`)
  - Add files (`git add ...`)
  - Stage changes for the next commit (`git add -u ...`)
  - Commit changes to `.git` (`git commit`)
- **Use a branch to group commits together**
  - Isolate your code from changes in `master`
  - Merge `master` into your branch
  - Isolate `master` from your changes
  - Pull Request (aka PR) to get the code reviewed
  - Merge PR into upstream

Git Remote

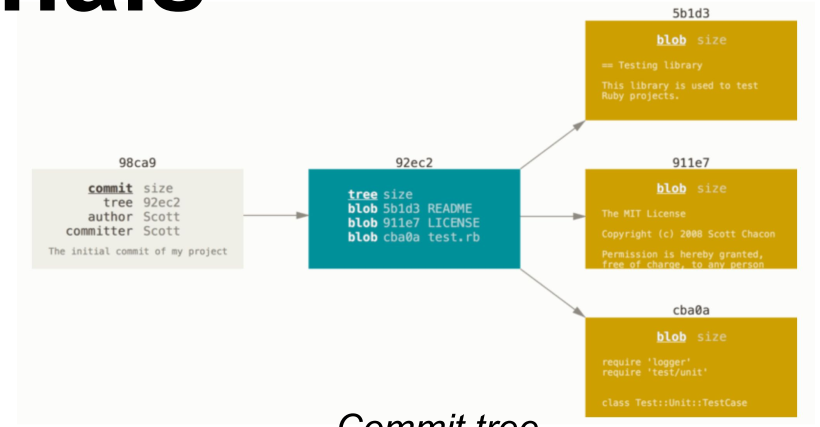
- Remote repos are versions of the project hosted on Internet/remote file system
  - To collaborate you need to manage remote repos
  - Push / pull changes
- You can have multiple forks of the same repo with different policies
  - E.g., read-only, read-write
- `git remote -v`: show what are the remotes
- `git fetch`: pull from the remote repo all the data (e.g., branches, commits) that you don't have locally
- `git pull`: short hand from `git fetch origin` + `git merge master --rebase`
- `git push <REMOTE> <BRANCH>`: push local data to a remote
  - E.g., `git push origin master`
- If somebody pushed to the remote, you can't push your changes right away, but you need to:
  - Fetch the changes
  - Merge changes to the branch in your client
  - Resolve conflicts, if needed
  - (Test project sanity, e.g., by running unit tests)
  - Push changes to the remote

Git Tagging

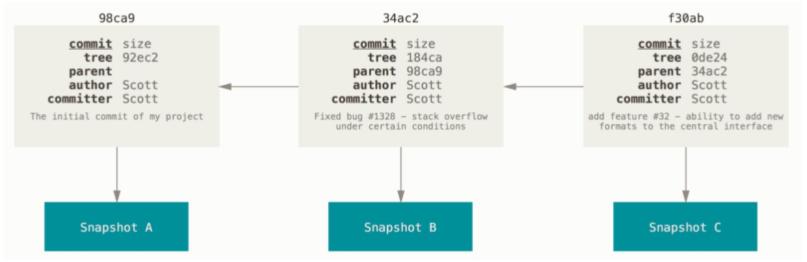
- Git allows to mark specific points in history with a tag
  - E.g., release points
- You can check out a tag
- You get in detached `HEAD` state
  - If you commit your change won’t be added to the tag or to the branch
  - The commit will be “unreachable”, i.e., reachable only by the commit hash

Git Internals

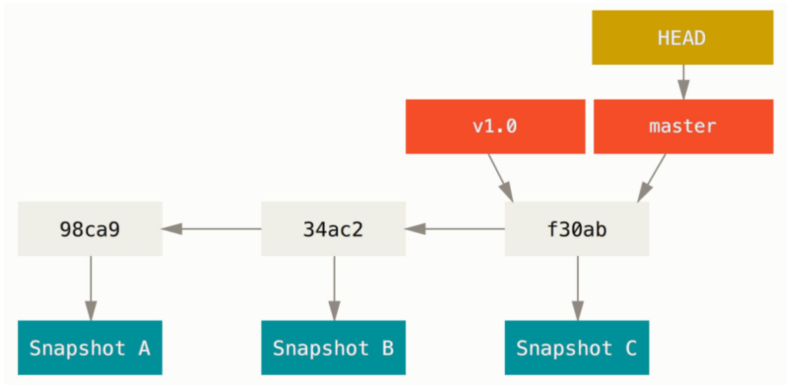
- **You can understand Git only if you understand the data model**
  - Git is a key-value store with a VCS user interface on top of it
  - Key = hash of a file
  - Value = content of a file
- **Git objects**
  - Commits: store pointers to the tree and commit metadata
  - Trees: represent directories and mapping between files and blobs
  - Blobs: content of files
- Refs:
  - Easy: [Understanding Git — Data Model]()
  - Hard-core: [Git internals]()



Commit tree



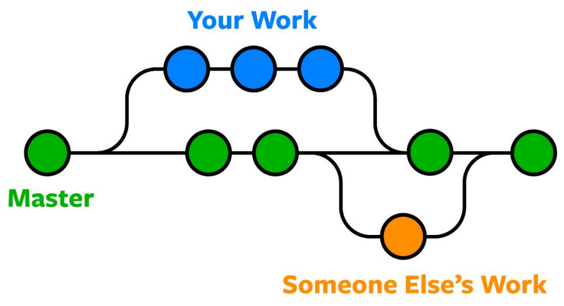
Commit parents



Commit history of a branch

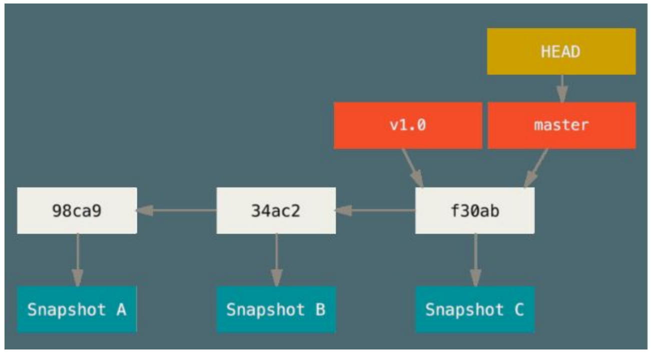
Git Branching

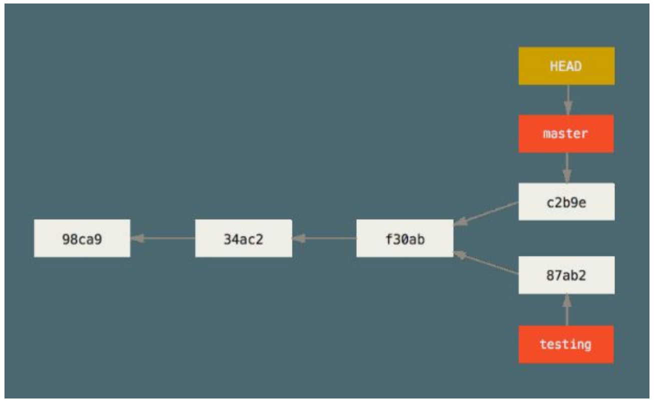
- **Branching**
  - = diverging from the main line of development
- **Why branch?**
  - Work without messing the rest of the code
  - Work without being affected by changes in the main branch
  - Merge the code downstream to pick up the changes
  - Once you are done working in your branch, merge code upstream
- **Git branching is lightweight**
  - It's instantaneous
  - A branch is just a pointer to a commit
  - Git doesn't store data as difference of files, but as a series of snapshot
- **Git workflows branch and merge often**
  - Even multiple times a day
  - This is surprising for people used to distributed VCS
    - E.g., you would start branching before going for lunch
  - Branches are cheap in Git
    - Use them all the times to isolate your work and organize it



Git Branching

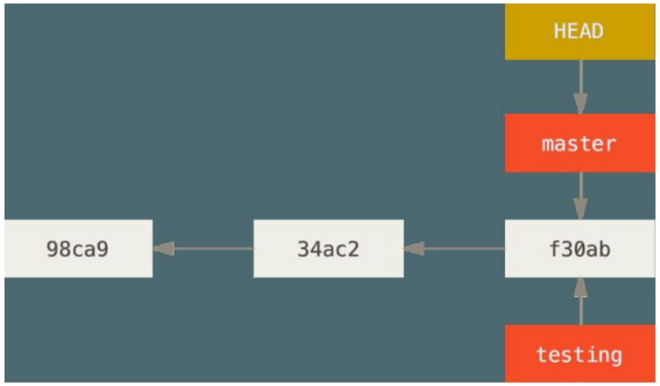
- `master` (or `main`) is just a normal branch
  - master is a pointer to the last commit
  - As you commit the pointer moves forward
- **`HEAD`**
  - Pointer to the local branch you are on
  - E.g., master, testing
  - `git checkout <BRANCH>` moves you across branches
- **`git branch testing`**
  - Create a new pointer `testing`
  - Point to the commit you are on
  - Pointer can be moved around
- Divergent history
  - When work progresses in two branches that are "split"

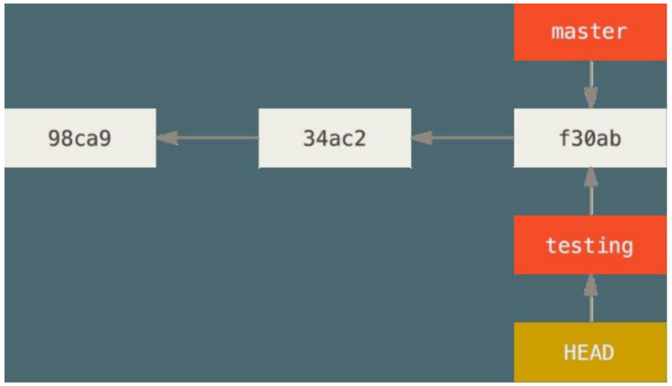


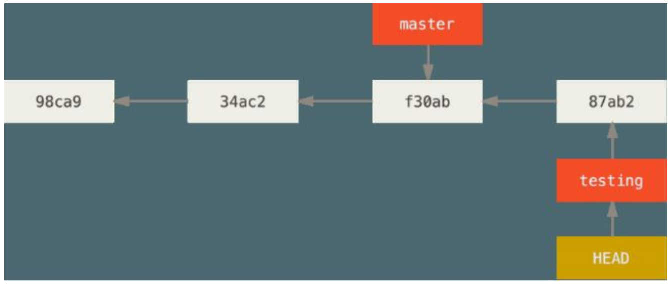


Git Checkout

- `git checkout` switches branch
  - Move `HEAD` pointer to the new branch
  - Change the files in the working dir to match the state corresponding to the branch pointer
- E.g., there are two branches master and testing
  - You are on master
  - `git checkout testing`
  - The pointer moves, the working dir is changed (not really in this case)
  - Then you can keep working by committing on `testing`
  - The pointer to `testing` moves forward (no divergent history)







Git Branching and Merging

Tutorials: Work on main, Hot fix

Start from a project with some commits

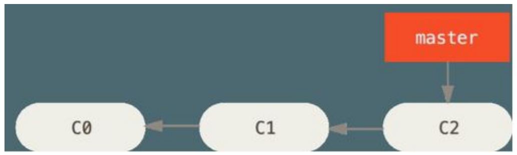
Branch to work on a new feature “Issue 53”

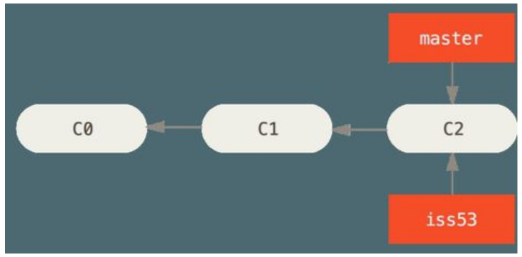
```
> git checkout -b iss53
work ... work ... work
> git commit
```

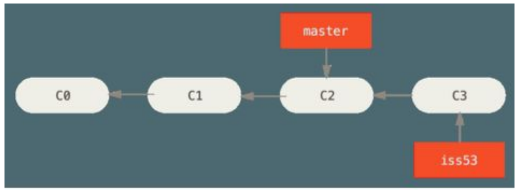
Need a hotfix to master

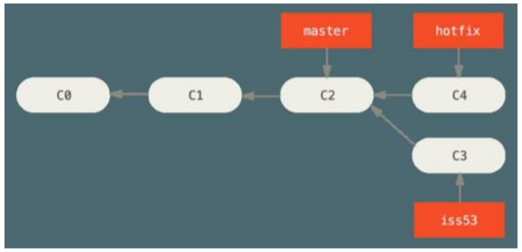
```
> git checkout master
> git checkout -b hotfix
fix ... fix ... fix
> git commit -am “Hot fix”
> git checkout master
> git merge hotfix
Fast forward
```

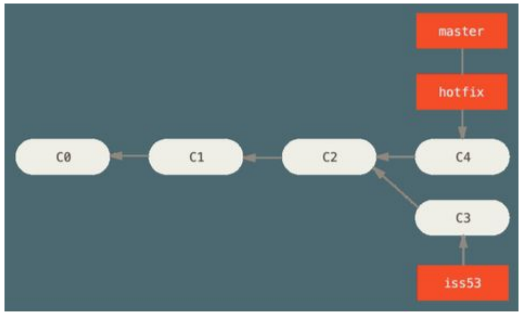
Now there is a divergent history between `master` and `iss53`











Git Branching and Merging

```
> git checkout iss53
work ... work ... work
```

The branch keeps diverging

At some point you are done with `iss53`

You want to merge your work back to `master`

Go to the target branch

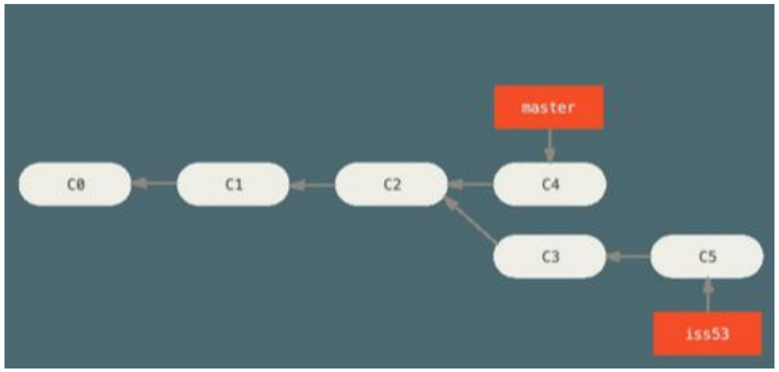
```
> git checkout master
> git merge iss53
```

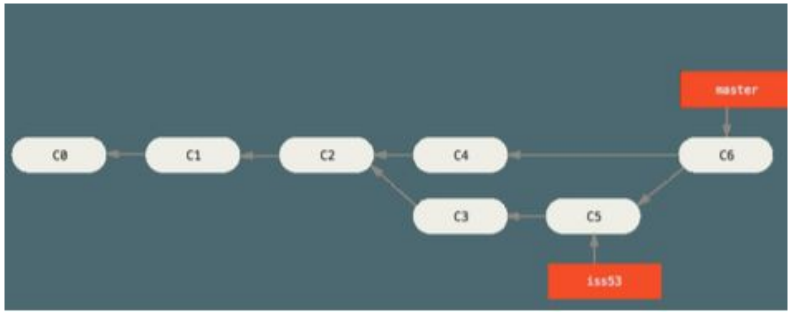
Git can’t fast forward

Git creates a new snapshot with the 3-way “merge commit” (commit with more than one parent)

Delete the branch

```
> git branch -d iss53
```


$$\begin{tikzcd}
 & & & \text{master} \arrow[d] & \\
C0 & C1 \arrow[l] & C2 \arrow[l] & C4 \arrow[l] & \\
 & & & C3 \arrow[ul] & C5 \arrow[l] \\
 & & & & \text{iss53} \arrow[u]
\end{tikzcd}$$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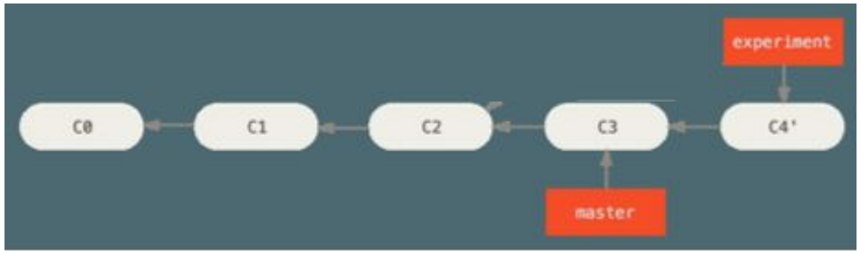
C0 & C1 \arrow[l] & C2 \arrow[l] & C4 \arrow[l] & & C6 \arrow[ll] \arrow[dl] \\
 & & & C3 \arrow[ul] & C5 \arrow[l] & \\
 & & & & \text{iss53} \arrow[u] &
\end{tikzcd}$$

Fast Forward Merge

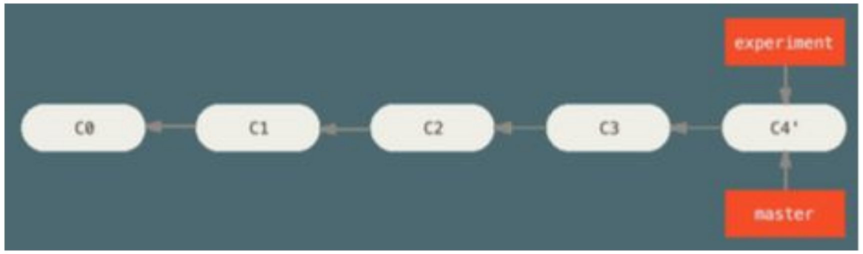
- **Fast forward merge** = merge a commit X with a commit Y that can be reached by following the history of commit X
- There is not divergent history to merge
- Git simply moves the branch pointer forward from X to Y
- **Mental model**: a branch is just a pointer that says where the tip of the branch is



- E.g., C4' is reachable from C3

```
> git checkout master
> git merge experiment
```

- Git moves the pointer of master to C4'



Merging Conflicts

- Tutorial:
  - Merging conflicts
- Sometimes Git can’t merge, e.g.,
  - The same file has been modified by both branches
  - One file was modified by one branch and deleted by another
- Git:
  - Does not create a merge commit
  - Pauses to let you resolve the conflict
  - Adds conflict resolution markers
- User merges manually
  - Edit the files **`git mergetool`**
  - **`git add`** to mark as resolved
  - **`git commit`**
  - Use PyCharm

```
$ git merge iss53
Auto-merging index.html
CONFLICT (content): Merge conflict in index.html
Automatic merge failed; fix conflicts and then commit the result.
```

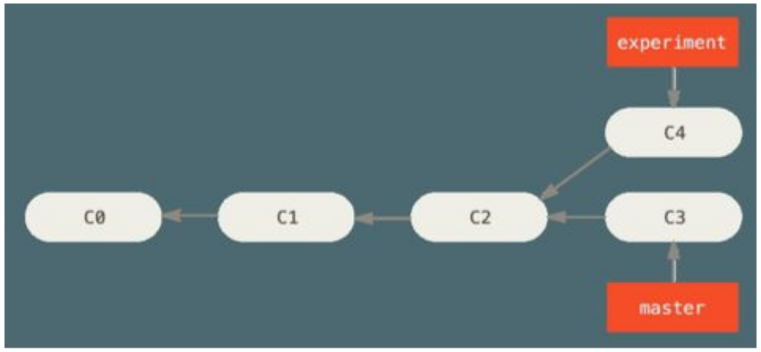
```
$ git status
On branch master
You have unmerged paths.
  (fix conflicts and run "git commit")

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

    both modified:      index.html

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

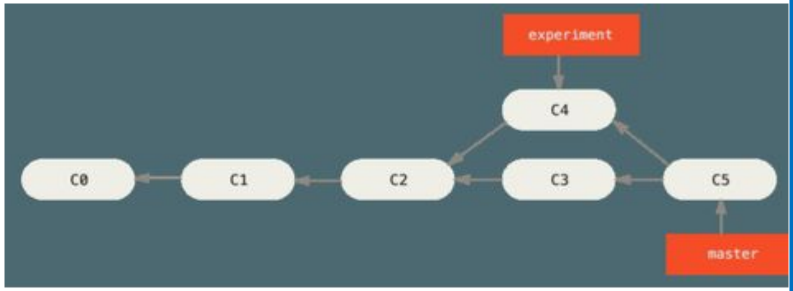
```
<<<<<<< HEAD:index.html
<div id="footer">contact : email.support@github.com</div>
=======
<div id="footer">
 please contact us at support@github.com
</div>
>>>>>>> iss53:index.html
```

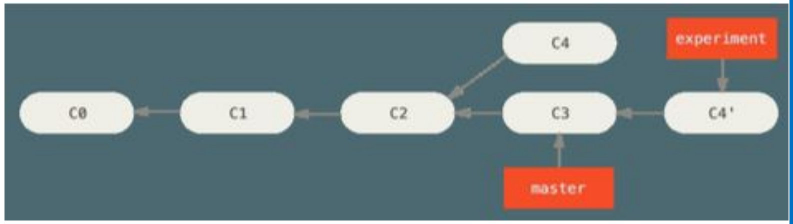
```
$ git status
On branch master
All conflicts fixed but you are still merging.
  (use "git commit" to conclude merge)

Changes to be committed:

    modified:   index.html
```

Git Rebasing

- In Git there are two ways of merging divergent history
  - E.g., `master` and `experiment` have a common ancestor C2
- **Merge**
  - Go to the target branch
  - `> git checkout master`
  - `> git merge experiment`
  - Create a new snapshot C5 and commit
- **Rebase**
  - Go to the branch to rebase
  - `> git checkout experiment`
  - `> git rebase master`
  - Rebase algo:
    - Get all the changes committed in the branch (C4) where we are on (experiment) since the common ancestor (C2)
    - Sync to the branch that we are rebasing onto (master at C3)
    - Apply the changes C4'
    - Only the branch where we are is affected
  - Finally fast forward master

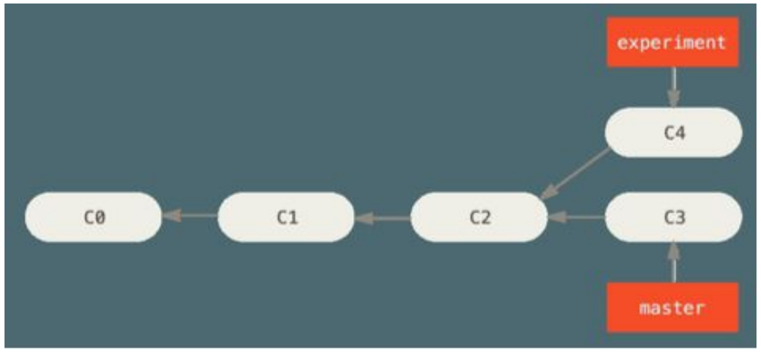


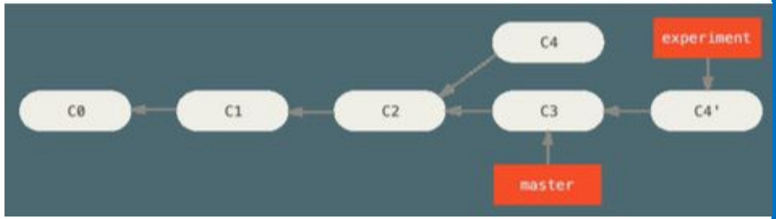




Uses of Rebase

- **Rebasing makes for a cleaner history**
  - The history looks like all the work happened in series
  - Although in reality it happened in parallel to the development in master
- **Rebasing to contribute to a project**
  - Developer
    - You are contributing to a project that you don't maintain
    - You work on your branch
    - When you are ready to integrate your work, rebase your work onto `origin/master`
  - The maintainer
    - Does not have to do any integration work
    - Does just a fast forward or a clean apply (no conflicts)



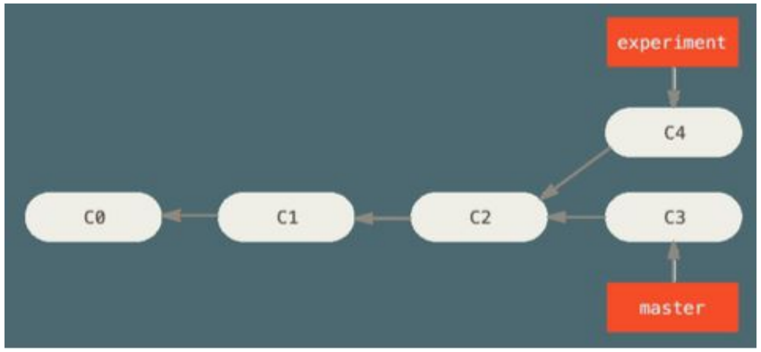


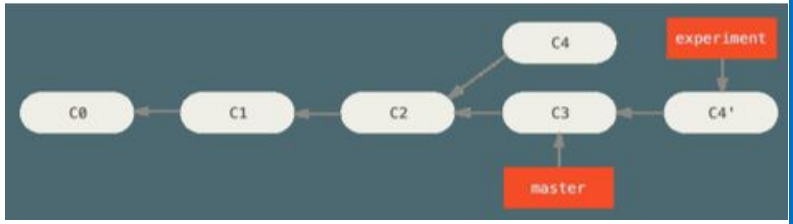
Golden Rule of Rebasing

- **Remember**: rebasing means abandoning existing commits and creating new ones that are similar but different
- **Problem**
  - 1. You push your commits to a remote somewhere
  - 2. Others pull your commits down and base their work on them
  - 3. You rewrite those commits with `git rebase`
  - 4. You push them again with `git push --force`
  - 5. Your collaborators have to re-merge their work
- **Solution**

  Strict version: "Do not *ever* rebase commits that exist outside your repository"

  Loose version: “It’s ok to rebase your branch even if you pushed to a server, as long as you are the only one to use it”

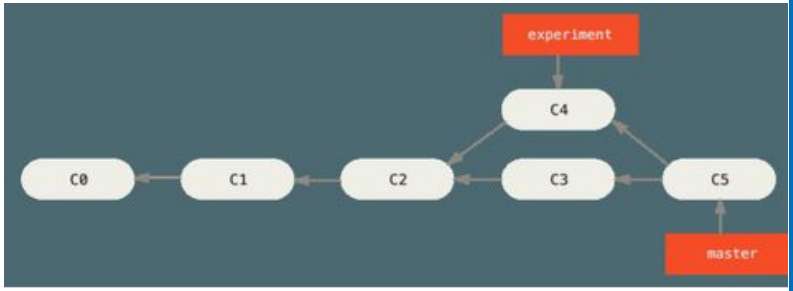




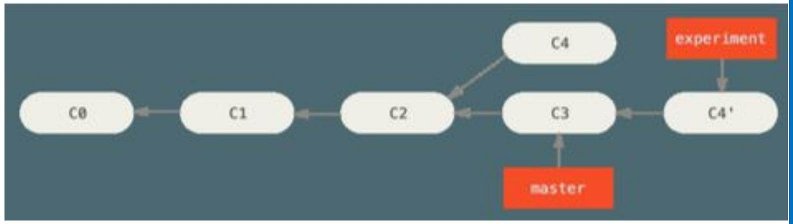
Rebase vs Merge: Philosophical Considerations

- Rebase-vs-merge depend on the answer to the question:
- **What does the commit history of a repo mean?**

- **a) History is the record of what actually happened**
- *"History should not be tampered with!"*
- *Q: What if there is a series of messy merge commits?*
- *A: This is how it happened. The repo should preserve this*
- Use `git merge`

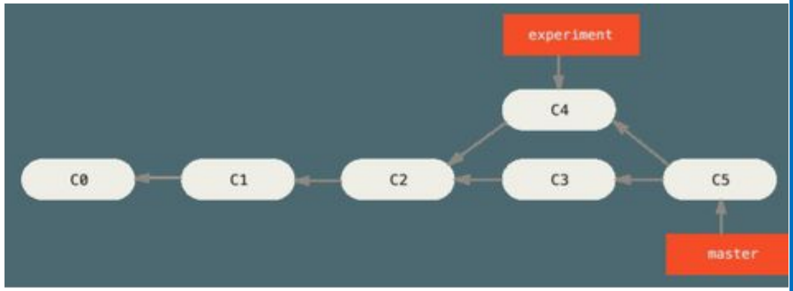


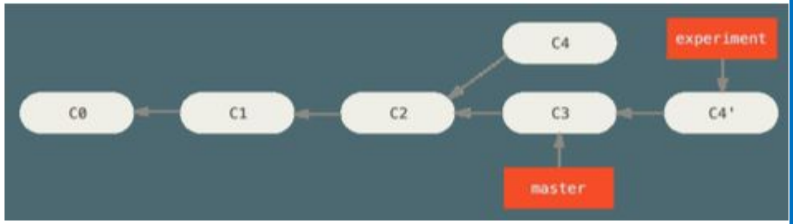
- **b) History represents how a project should have been made**
- *"You would not publish a book as a sequence of drafts and correction, but rather the final version"*
- *You should tell the history in the way that is best for future readers*
- Use `git rebase` and filter-branch



Rebase vs Merge: Philosophical Considerations

- Many man-centuries have been wasted discussing rebase-vs-merge at the watercooler
  - Total waste of time! Tell people to get back to work!
- When you contribute to a project often people decide for you based on their preference
- **Best of the merge-vs-rebase approaches**
- Rebase changes you've made in your local repo
  - Even if you have pushed but you know the branch is yours
  - Use `git pull --rebase` to clean up the history of your work
  - If the branch is shared with others then you need to definitively `git merge`
- Only `git merge` to master to preserve the history of how something was built
- **Personally**
- I like squash-and-merge branches to master
  - My commits are just my checkpoints
  - Rarely they are "complete"





Remote Branches

- Remote branches are pointers to branches in remote repos
  - `> git remote -v`
  - `origin  git@github.com:gpsaggese/umd_data605.git (fetch)`
  - `origin  git@github.com:gpsaggese/umd_data605.git (push)`
- **Tracking branches**
  - Local references representing the state of the remote repo
  - E.g., `master` tracks `origin/master`
  - You can't change the remote branch (e.g., `origin/master`)
  - You can change tracking branch (e.g., `master`)
  - Git updates tracking branches when you do `git fetch origin` (or `git pull`)
- To share code in a local branch you need to push it to a remote
  - `> git push origin serverfix`
- To work on it
  - `> git checkout -b serverfix origin/serverfix`

Git Workflows

Git workflows

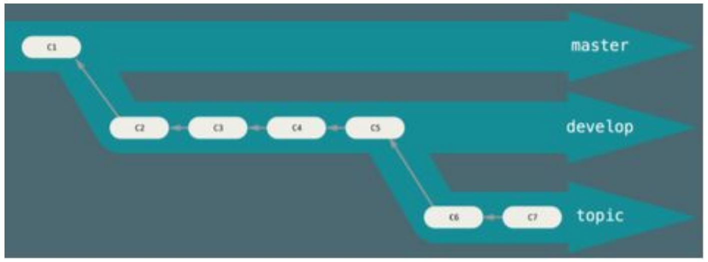
- = ways of working and collaborating using Git

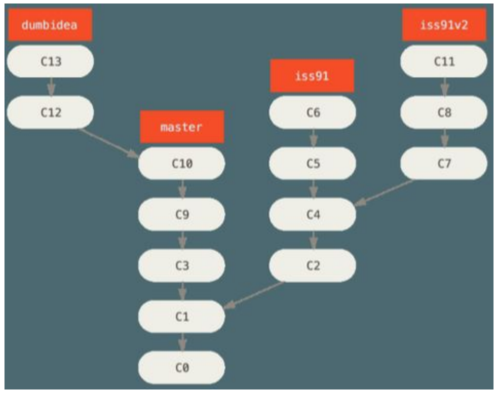
Long-running branches

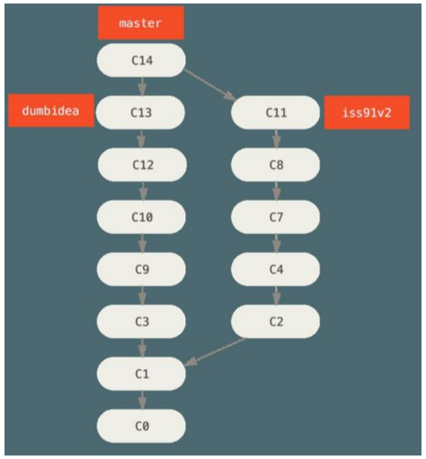
- Branches at different level of stabilities, that are always open
- 1. *master* is always ready to be released
- 2. *develop* branch to develop in
- 3. *topic / feature* branches
- When branches are "stable enough" they are merged up

Topic branches

- Short-lived branches for a single feature
  - E.g., `hotfix`, `wip-XYZ`
- Easy to review
- Silo-ed from the rest
- This is typical of Git since other VCS support for branches is not good enough
- E.g.,
  - You start `iss91`, then you cancel some stuff, and go to `iss91v2`
  - Somebody starts `dumbidea` branch and merge to `master` (!)
  - You squash-and-merge your `iss91v2`



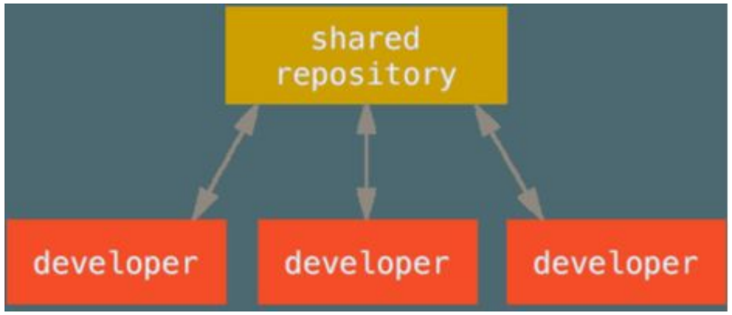




Centralized Workflow

Centralized workflow in centralized VCS

- Developers:
  - Check out the code from the central repo on their computer
  - Modify the code locally
  - Push it back to the central hub (assuming no conflicts with latest copy, otherwise they need to merge)



Centralized workflow in Git

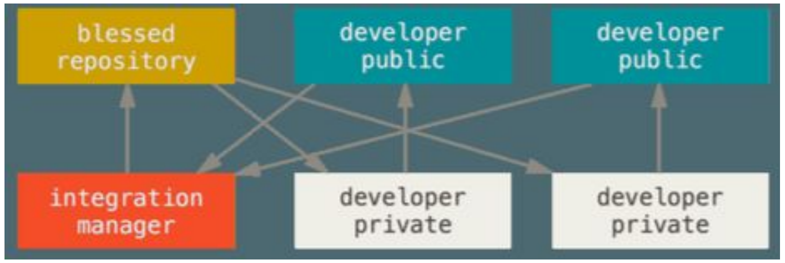
- Developers:
  - Have push (i.e., write) access to the central repo
  - Need to fetch and then merge
  - Cannot push code that will overwrite each other code (only fast-forward changes)

Forking Workflows

- Typically devs don't have permissions to update directly branches on a project
  - Read-write permissions for core contributors
  - Read-only for anybody else
- **Solution**
  - "Forking" a repo
  - External contributors
    - Clone the repo and create a branch with the work
    - Create a writable fork of the project
    - Push branches to fork
    - Prepare a PR with their work
  - Project maintainer
    - Reviews PRs
    - Accepts PRs
    - Integrates PRs
  - In practice it's the project maintainer that pulls the code when it's ready, instead of external contributors pushing the code
- **Aka "GitHub workflow"**
  - "Innovation" was forking (Fork me on GitHub!)
  - GitHub acquired by Micro$oft for $7.5b

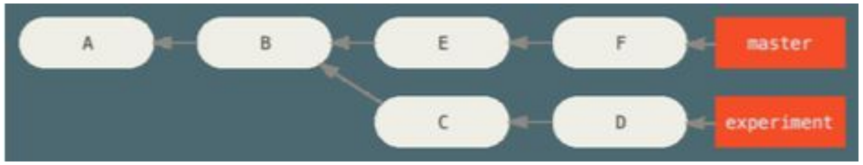
Integration-Manager Workflow

- This is the classical model for open-source development
  - E.g., Linux, GitHub (forking) workflow
- **1. One repo is the "official" project**
  - Only the project maintainer pushes to the public repo
  - E.g., `sorrentum/sorrentum`
- **2. Each contributor**
  - Has read access to everyone else's public repo
  - Forks the project into a private copy
    - Write access to their own public repo
    - E.g., `gpsaggese/sorrentum`
  - Makes changes
  - Pushes changes to his own public copy
  - Sends email to maintainer asking to pull changes (pull request)
- **3. The maintainer**
  - Adds contributor repo as a remote
  - Merges the changes into a local branch
  - Tests changes locally
  - Pushes branch to the official repo



Git log

- `git log` reports info about commits
- `refs` are references to:
  - HEAD (commit you are working on, next commit)
  - origin/master (remote branch)
  - experiment (local branch)
  - d921970 (commit)
- ^ after a reference resolves to the parent of that commit
  - HEAD^ = commit before HEAD, i.e., last commit
  - ^2 means ^^
  - A merge commit has multiple parents
- **Double-dot notation**
  - `1..2` = commits that are reachable from 2 but not from 1 (difference)
  - `git log master..experiment → D,C`
  - `git log experiment..master → F,E`
- **Triple-dot notation**
  - `1...2` = commits that are reachable from either branch but not from both (union excluding intersection)
  - `git log master...experiment → F,E,D,C`



Advanced Git

- stashing
  - Copy state of your working dir (e.g., modified and staged files), save it in a stack, to apply later
- cherry-picking
  - Rebase for a single commit
- rerere
  - = “Reuse Recorded Resolution”
  - Git caches how to solve certain conflicts
- tagging
  - Give a name to a specific commit (e.g., v1.3)
- submodules / subtrees
  - Project including other Git projects
- bisect
  - Sometimes a bug shows up at top of tree
  - You don't know at which revision it started manifesting
  - You have a script that returns 0 if the project is good and non-0 if the project is bad
  - `git bisect` can find the revision at which the script goes from good to bad
- filter-branch
  - Rewrite repo history in some script-able way
    - E.g., change your email, remove a file (with passwords or large file)
  - Check out each version, run a command, commit the result
- hooks
  - Run scripts before each commit, merging, ...

GitHub

- GitHub acquired by MSFT for $7.5b
- **GitHub: largest host for Git repos**
  - Git hosting (100m+ open source projects)
  - PRs, forks
  - Issue tracking
  - Code review
  - Collaboration
  - Wiki
  - Actions (CI / CD)
- **“Forking a project”**
  - In open-source communities
    - It had a negative connotation
    - Take a project, modify it, and make it a competing project
  - In GitHub parlance
    - Make a copy of a project so that you can contribute to it even if you don’t have push / write access

GitHub: Tutorial

Tutorial: GitHub

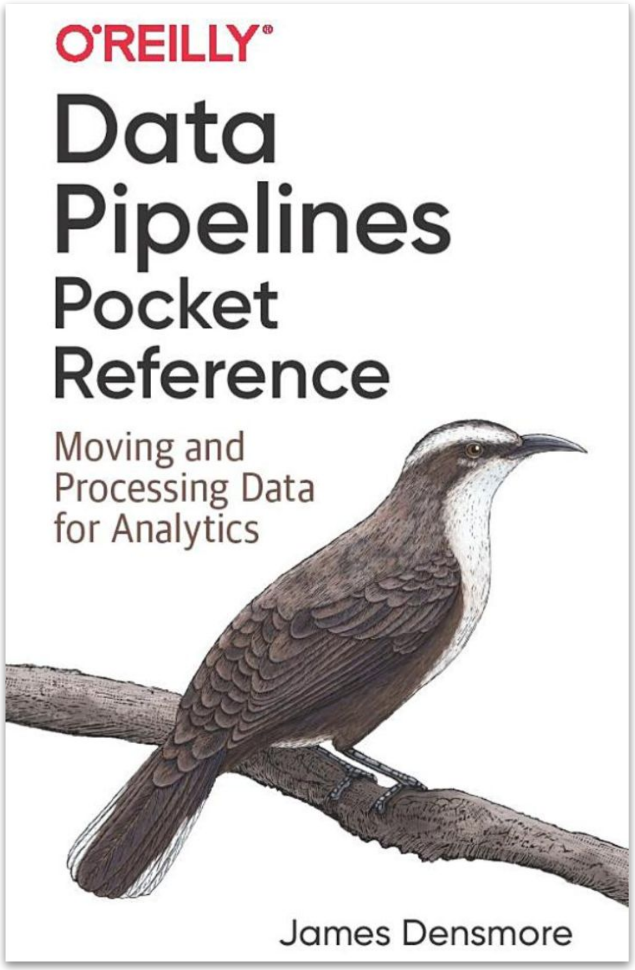
UMD DATA605 - Big Data Systems

Git

Data Pipelines

Data Pipelines - Resources

- Concepts in the slides
- Class project
- Mastery
  - Data Pipelines Pocket Reference: Moving and Processing Data for Analytics

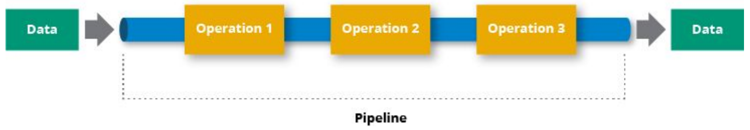

O'REILLY
Data Pipelines Pocket Reference
Moving and Processing Data for Analytics
James Densmore

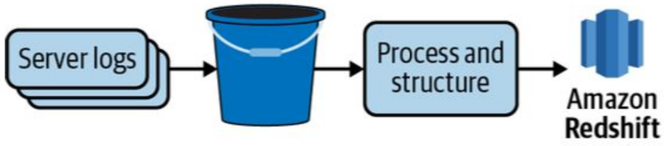
Data as a Product

- **Many services today "sell" data**
  - Services are typically powered by data and machine learning
  - Data products, e.g.,
    - Personalized search engine (Google)
    - Sentiment analysis on user-generated data (Facebook)
    - A recommendation engine + e-commerce (Amazon)
    - Streaming data (Netflix, Spotify)
- **Several steps are required to generate data products**
  - Data ingestion
  - Data pre-processing
    - Cleaning, tokenization, feature computation
  - Model training
  - Model deployment
    - MLOps
  - Model monitoring
    - Is model working?
    - Is model getting slower?
    - Are model performance getting worse?
  - Collect feedback from deployment
    - E.g., recommendations vs what users bought
    - Ingest data from production for future versions of the model

Data Pipelines

- “Data is the new oil”
  - ... but oil needs to be refined
- **Data pipelines**
  - Processes that move and transform data
  - **Goal**: derive new value from data through analytics, reporting, machine learning
- Data needs to be:
  - Collected
  - Pre-processed / cleaned
  - Validated
  - Processed
  - Combined
- **Data ingestion**
  - Simplest data pipeline
  - Extract data (e.g., from REST API)
  - Load data into DB (e.g., SQL table)





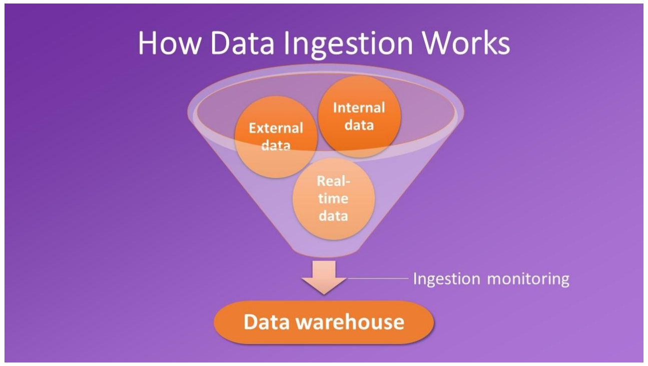
Roles in Building Data Pipelines

- **Data engineers**
  - Build and maintain data pipelines
  - Tools:
    - Python / Java / Go / No-code
    - SQL / NoSQL stores
    - Hadoop / MapReduce / Spark
    - Cloud computing
- **Data scientists**
  - Build predictive models
  - Tools:
    - Python / R / Julia
    - Hadoop / MapReduce / Spark
    - Cloud computing
- **Data analysts**
  - E.g., marketing, MBAs, sales, ...
  - Build metrics and dashboards
  - Tools:
    - Excel spreadsheets
    - GUI tools (e.g., Tableaux)
    - Desktop

- **Recurring practical problems**
- Who is responsible for the data?
- Issues with scaling
  - Performance
  - Memory
  - Disk
- Build-vs-buy
  - Which tools?
  - Open-source vs proprietary?
- Architecture
  - Who is in charge of it?
  - Conventions
  - Documentation
- Service level agreement (SLA)
- Talk to stakeholders on a regular basis
- Getting stuff done
  - Done is better than perfect

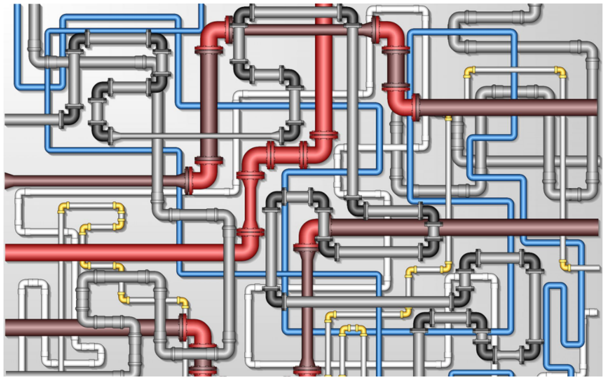
Data Ingestion

- **Data ingestion**
  - = extract data from one source and load it into another store
- **Data sources / sinks**
  - DBs
    - E.g., Postgres, MongoDB
  - REST API
    - Abstraction layer on top of DBs
  - Network file system / cloud
    - E.g., CSV files, Parquet files
  - Data warehouses
  - Data lakes
- **Source ownership**
  - An organization can use 10-1000s of data sources
  - Internal
    - E.g., DB storing shopping carts for a e-commerce site
  - 3rd-parties
    - E.g., Google analytics tracking website usage



Data Pipeline Paradigms

- There are several styles of building data pipelines
- Multiple phases
  - Extract
  - Load
  - Transform
- Phases arranged in different ways depending on philosophy about data / roles
  - ETL
  - ELT
  - EtLT



ETL Paradigm: Phases

- **Extract**
  - Gather data from various data sources, e.g.,
    - Internal / external data warehouse
    - REST API
    - Data downloading from API
    - Web scraping
- **Transform**
  - Raw data is combined and formatted to become useful for analysis step
- **Load**
  - Move data into the final destination, e.g.,
    - Data warehouse
    - Data lake

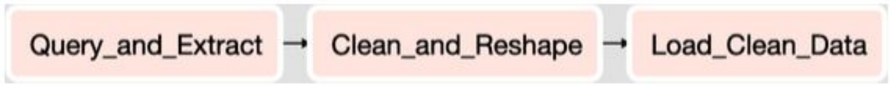
- **Data ingestion pipeline = E + L**
  - Move data from one point to another
  - Format the data
  - Make a copy
  - Have different tools to operate on the data

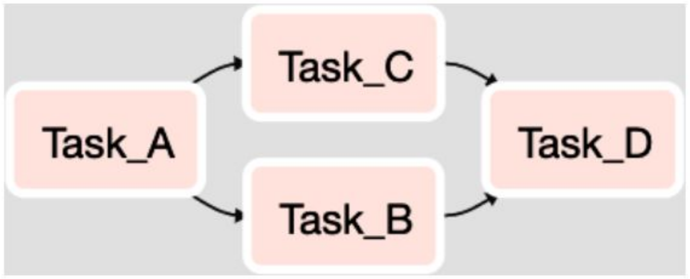
ETL Paradigm: Example

- Extract
  - Buy-vs-build data ingestion tools
    - Vendor lock-in
- Transform
  - Data conversion (e.g., parsing timestamp)
  - Create new columns from multiple source columns
    - E.g., year, month, day -> yyyy/mm/dd
  - Aggregate / filter through business logic
    - Try not to filter, better to mark
  - Anonymize data
- Load
  - Organize data in a format optimized for data analysis
    - E.g., load data in relational DB
  - Finally data modeling

Workflow Orchestration

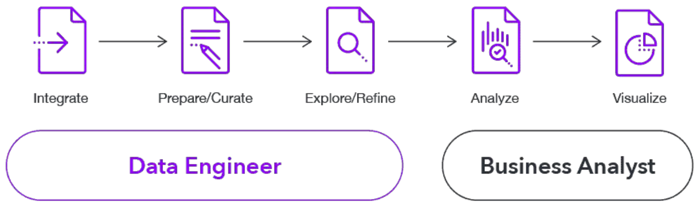
- Companies have many (10-1000s) data pipelines
- Orchestration tools, e.g.,
  - Apache Airflow (from AirBnB)
  - Luigi (from Spotify)
  - AWS Glue
  - Kubeflow
- Schedule and manage flow of tasks according to their dependencies
  - Pipeline and jobs are represented through DAGs
- Monitor, retry, and send alarms





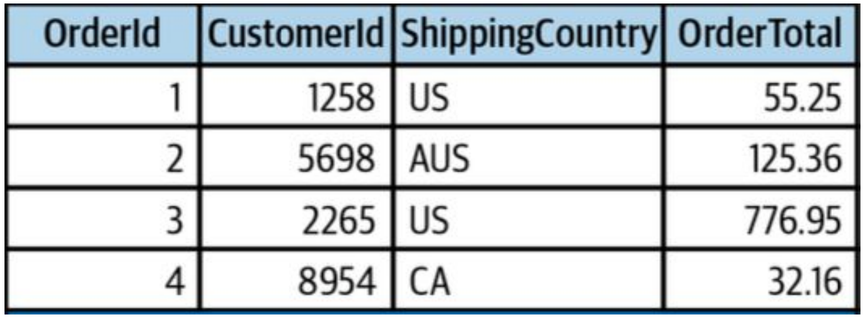
ELT paradigm

- **ETL has been the standard approach for long time**
  - Extract → Transform → Load
  - **Cons**
    - Need to understand the data at ingestion time
    - Need to know how the data will be used
- **Today ELT is becoming the pattern of choice**
  - Extract → Load → Transform
  - **Pro**:
    - No need to know how the data will be used
    - Separate data engineers and data scientists / analysts
    - Data engineers focus on data ingestion (E + L)
    - Data scientists focus on transform (T)
- **ETL → ELT enabled by new technologies**
  - Large storage to save all the raw data (cloud computing)
  - Distributed data storage and querying (e.g., HDFS)
  - Columnar DBs
  - Data compression

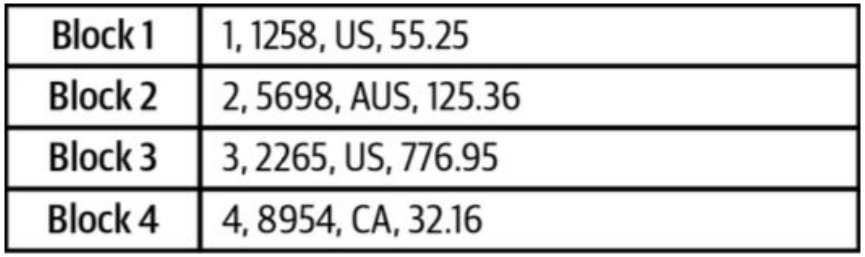


Row-based vs Columnar DBs

- **Row-based DBs**
  - E.g., MySQL, Postgres
  - Optimized for reading / writing rows
  - Read / write small amounts of data frequently
- **Columnar DBs**
  - E.g., Amazon Redshift, Snowflake
  - Read / write large amounts of data infrequently
  - Analytics requires a few columns
  - Better data compression



OrderId	CustomerId	ShippingCountry	OrderTotal
1	1258	US	55.25
2	5698	AUS	125.36
3	2265	US	776.95
4	8954	CA	32.16



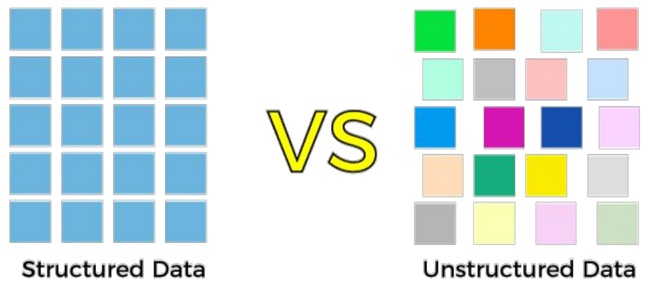
Block 1	1, 1258, US, 55.25
Block 2	2, 5698, AUS, 125.36
Block 3	3, 2265, US, 776.95
Block 4	4, 8954, CA, 32.16

EtLT

- **ETL**
  - Extract → Transform → Load
- **ELT**
  - Extract → Load → Transform
  - Transformation / data modeling (“T”) according to business logic
- **EtLT**
  - Sometimes transformations with limited scope (“t”) are needed
    - De-duplicate records
    - Parse URLs into individual components
    - Obfuscate sensitive data (for legal or security reasons)
  - Then implement rest of “LT” pipeline

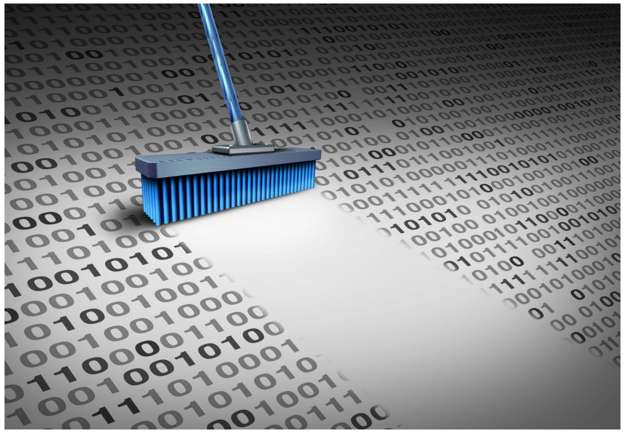
Structure in Data (or Lack Thereof)

- **Structured data**: there is a schema
  - Relational DB
  - CSV
  - DataFrame
  - Parquet
- **Semi-structured**: subsets of data have different schema
  - Logs
  - HTML pages
  - XML
  - Nested JSON
  - NoSQL data
- **Unstructured**: no schema
  - Text
  - Pictures
  - Movies
  - Blobs of data



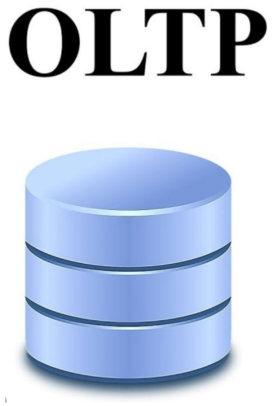
Data Cleaning

- **Data cleanliness**
  - Quality of source data varies greatly
  - Data is typically messy
    - Duplicated records
    - Incomplete or missing records (nans)
    - Inconsistent formats
      - E.g., phone with / without dashes
    - Mislabeled or unlabeled data
- **When to clean it?**
  - As soon as possible
  - As late as possible
  - In different stages
  - → Pipeline style: ETL vs ELT vs EtLT
- **Heuristics**
  - Hope for the best, assume the worst
  - Validate data early and often
  - Don't trust anything
  - Be defensive



OLAP vs OLTP Workloads

- There are two classes of data workloads
- OLTP
  - **O**n-**L**ine **T**ransactional **P**rocessing
  - Execute large numbers of transactions by a large number of processes in real-time
  - **Lots of concurrent small read / write transactions**
  - E.g., online banking, e-commerce, travel reservations
- OLAP
  - **O**n-**L**ine **A**nalytical **P**rocessing
  - Perform multi-dimensional analysis on large volumes of data
  - **Few large read or write transactions**
  - E.g., data mining, business intelligence

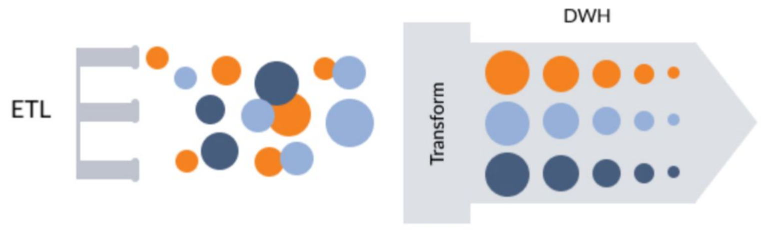


Challenges with Data Pipelines

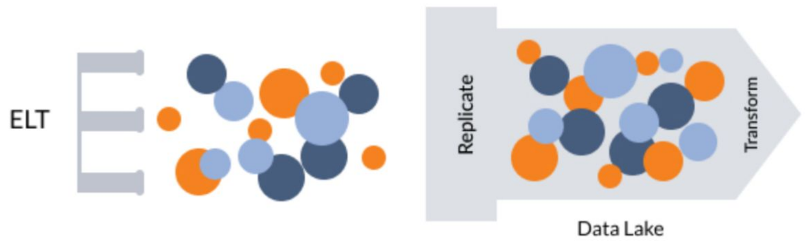
- High-volume vs low-volume
  - Lots of small reads / writes
  - A few large reads / writes
- Batch vs streaming
  - Real-time constraints
- API rate limits / throttling
- Connection time-outs
- Slow downloads
- Incremental mode vs catch-up

Data Warehouse vs Data Lake

- **Data warehouse**
  - = DB storing data from different systems in a structured way
  - Corresponds to ETL data pipeline style
  - E.g., a large Postgres instance with many DBs and tables
  - E.g., AWS Athena, RDS, Google BigQuery



- **Data lake**
  - = data stored in a semi-structured or without structure
  - Corresponds to ELT data pipeline style
  - E.g., an AWS S3 bucket storing blog posts, flat files, JSON objects, images



Data Lake: Pros and Cons

- Data lake = stores data in a semi-structured or without structure
- **Pros**
  - Storing data in cloud storage is cheaper
  - Making changes to types or properties is easier since it's unstructured or semi-structured (with no predefined schema)
    - E.g., JSON documents
  - Data scientists
    - Don't know initially how to access and use the data
    - Want to explore the raw data
- **Cons**
  - It is not optimized for querying like a structured data warehouse
    - There are tools that allow to query data in a data lake similar to SQL
    - E.g., AWS Athena, Redshift Spectrum

Advantages of Cloud Computing

- **Ease of building and deploying:**
  - Data pipelines
  - Data warehouses
  - Data lakes
- **Managed services**
  - No need for admin and deploy
  - Highly scalable DBs
    - E.g., Amazon Redshift, Google BigQuery, Snowflake
- **Rent-vs-buy**
  - Easy to scale up and out
  - Easy to upgrade
  - Better cash-flow
- **Cost of storage and compute is continuously dropping**
  - Economy of scale
  - The flexibility has a cost (2x-3x more expensive than owning)
  - Vendor lock-in