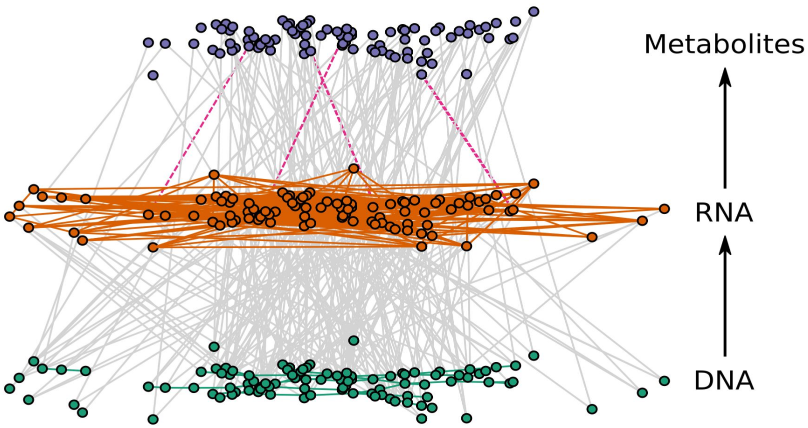
Lecture 0: Introduction to Applied Research in Health Data Science

CSCI6410/4148 & EPAH6410

Finlay Maguire (finlay.maguire@dal.ca)
TA: Ehsan Baratnezhad (ethan.b@dal.ca)

Why am I teaching this course?



- **PhD (Bioinformatics)**: using large noisy datasets to understand how microbial systems and mechanisms evolve.

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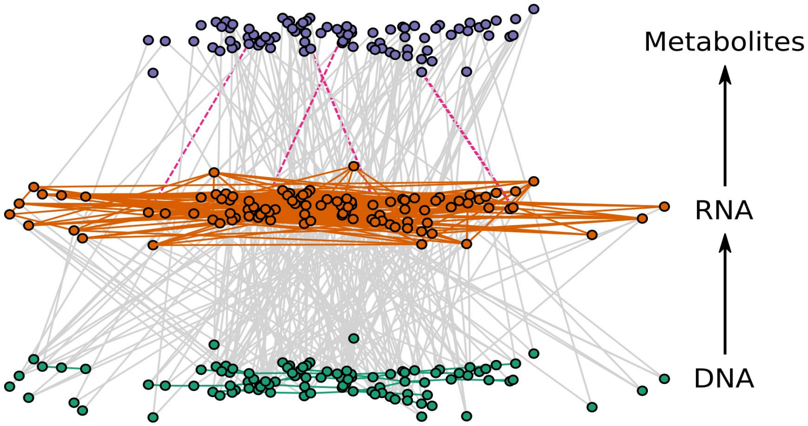

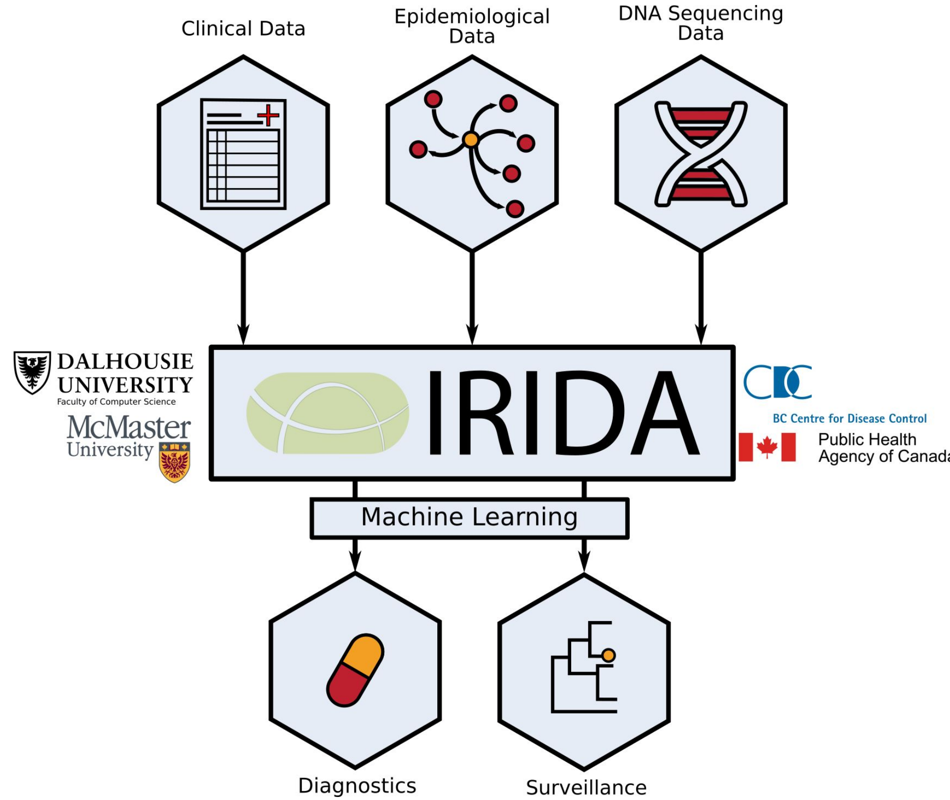

- **PhD (Bioinformatics)**: using large noisy datasets to understand how microbial systems and mechanisms evolve.
- **Postdoc (Genomic Epidemiology)**: using large noisy datasets to better diagnose, track and predict infectious diseases.

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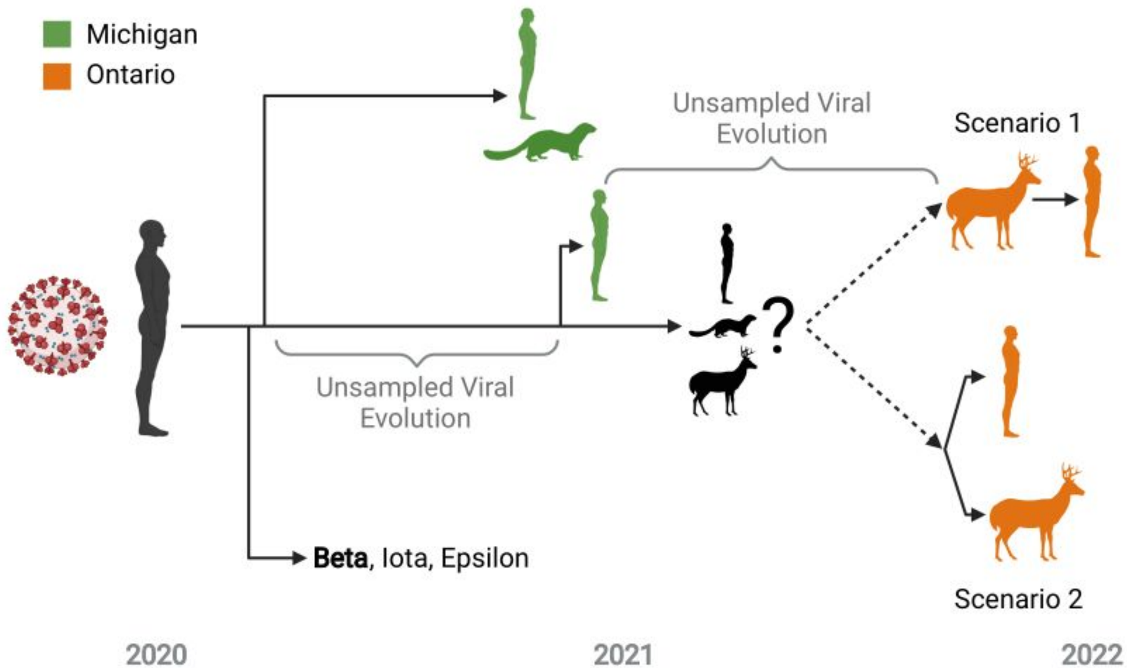

- **Research group**: using large noisy datasets:
  - Genomic epidemiology of infectious disease: **SARS-CoV-2**, **AMR**

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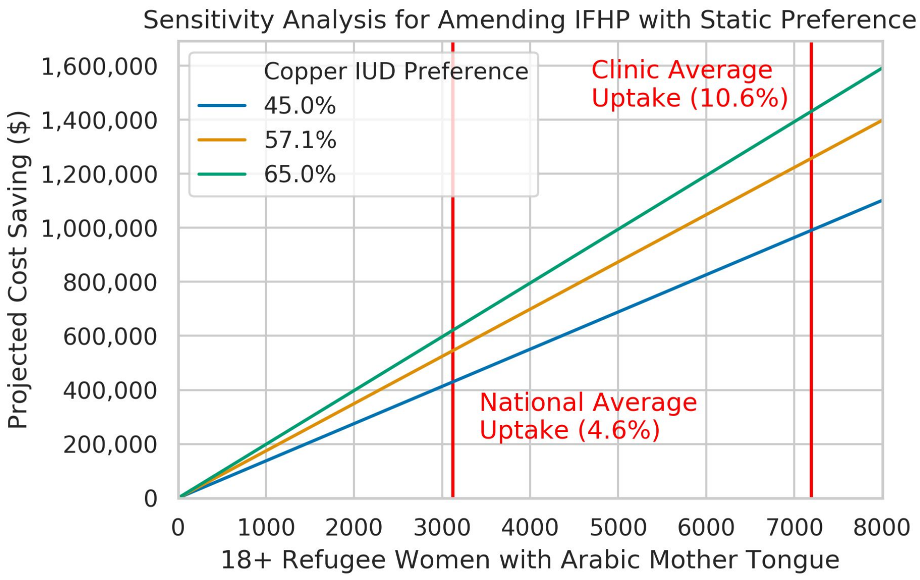
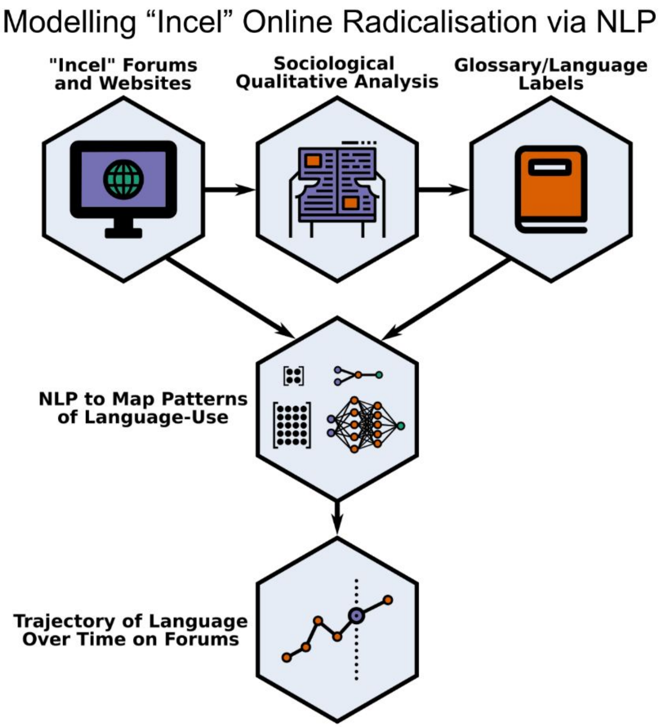
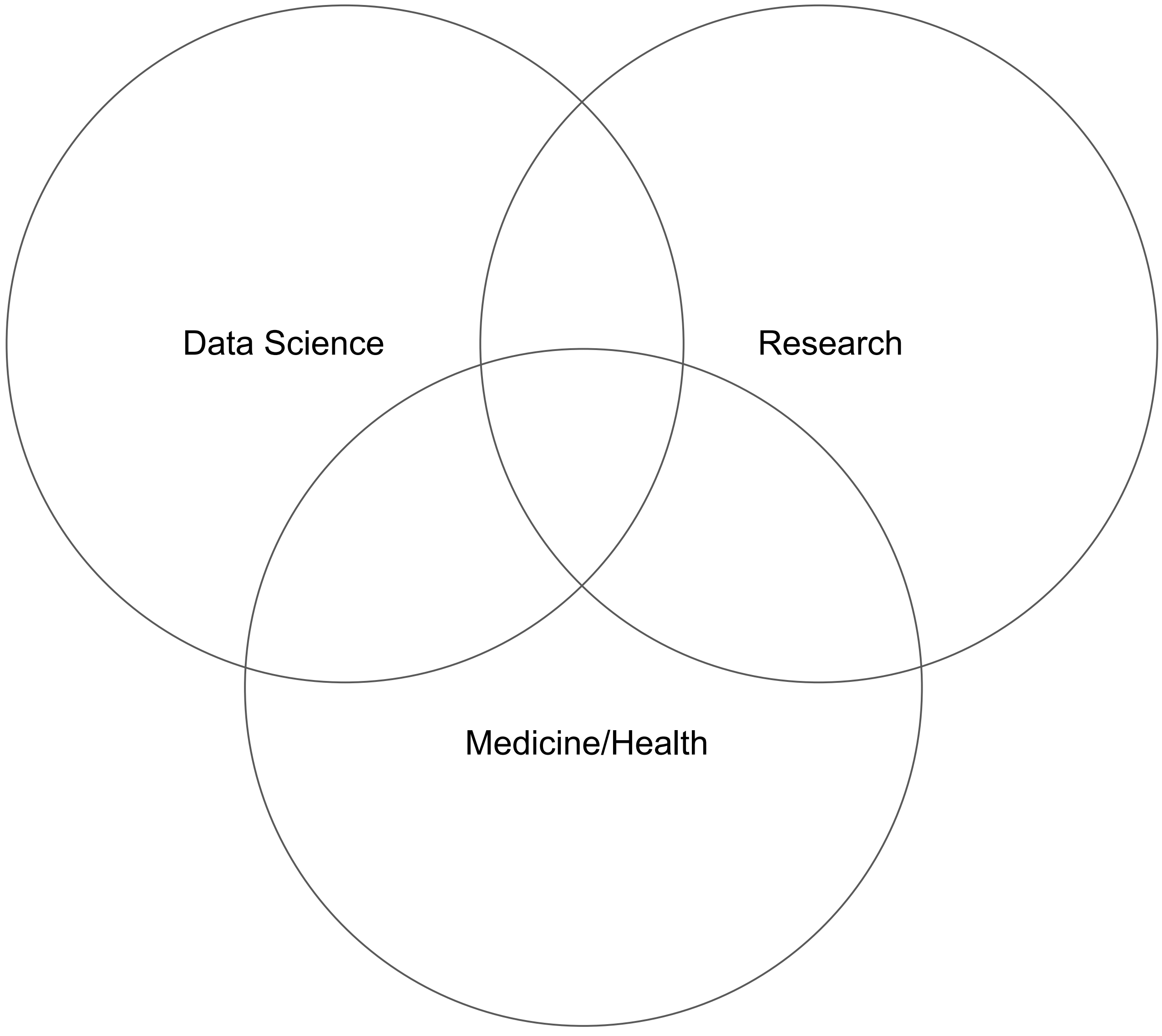




- **Research group**: using large noisy datasets:
  - Genomic epidemiology of infectious disease: **SARS-CoV-2**, **AMR**
  - Collaborations on socially/health focused problems: **refugee health**, **incel radicalisation, health inequality**

Overview of course

Applied Research in Health Data Science



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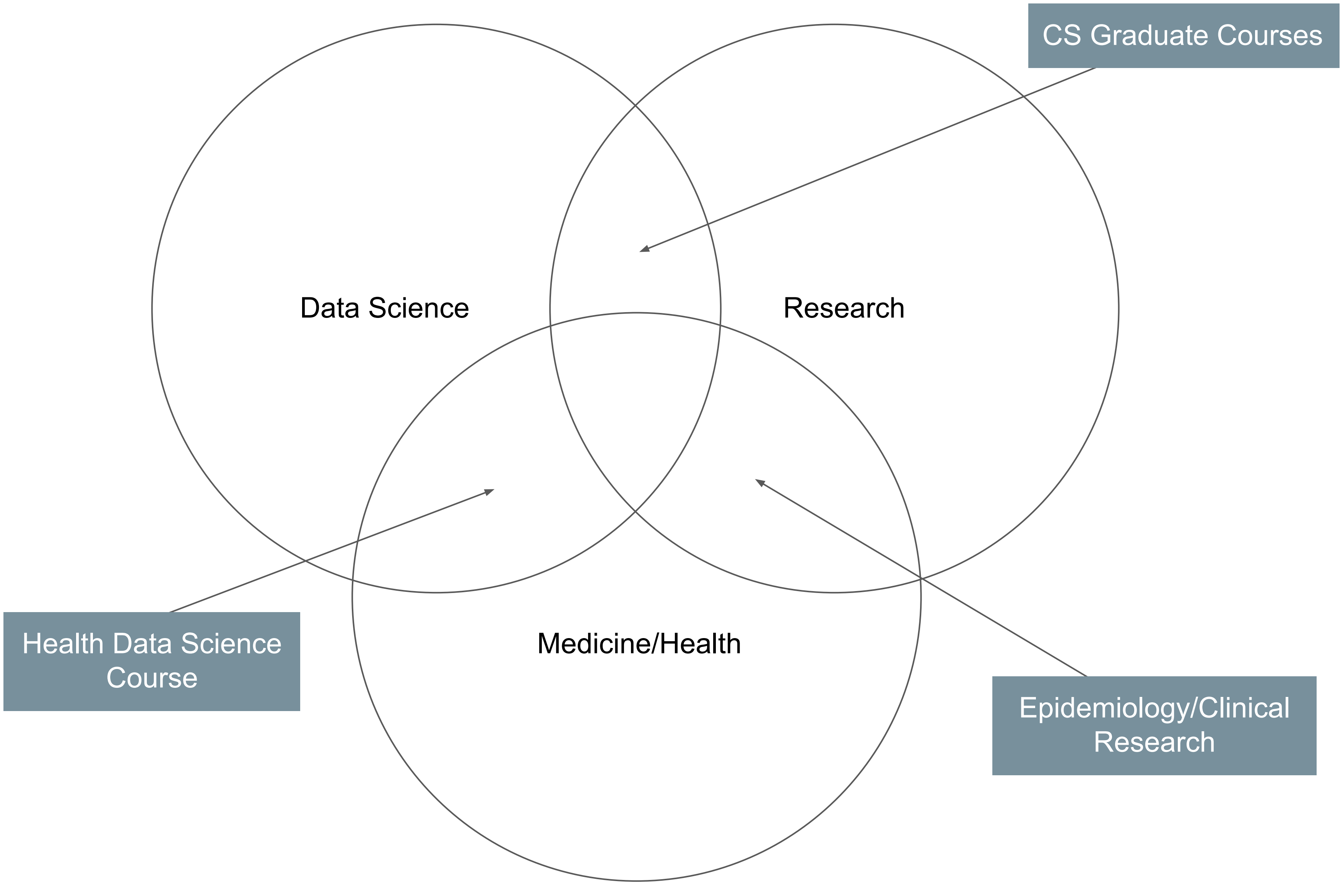

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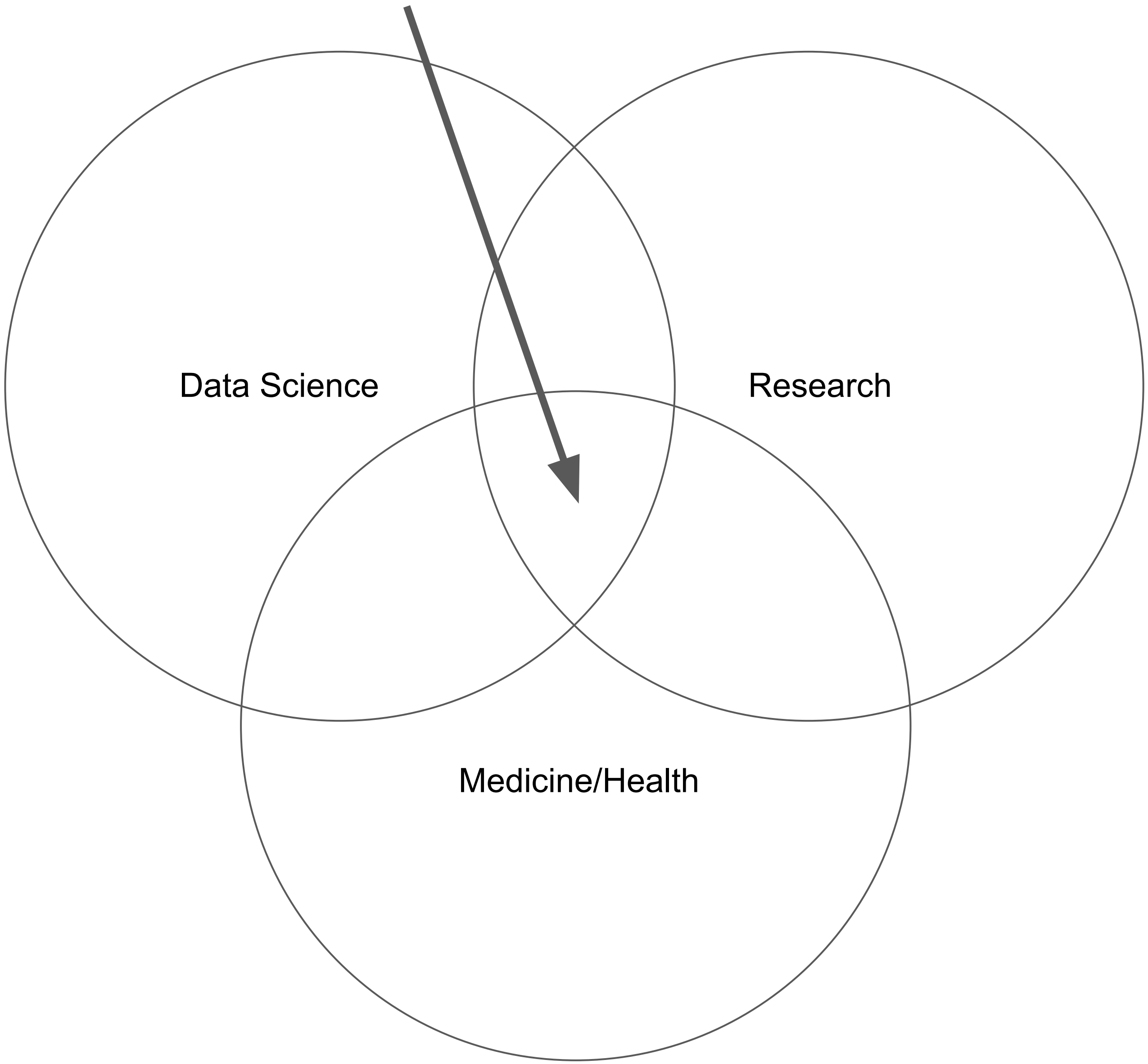

Learning Outcomes

1. Understand the **4 principal sources and data types** of medical data:
   a. longitudinal databases (tabular)
   b. electronic medical records (structured, semi-structured, and unstructured text)
   c. radiological imaging (image)
   d. physiological (signal and time-series).

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5. Critically **appraise research literature** in health data science.
6. Combine these skills to develop high-quality collaborative health data science **research proposals**

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- **Breadth/depth** of each data science method: *each could be multiple graduate CS courses*

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- **Breadth/depth** of each data science method: *each could be multiple graduate CS courses*
- **Breadth/depth** of medical research: *again could be a whole PhD program*
- True **messiness** of real data: *provide tools but experience is invaluable*
- Some important forms of medical data (e.g., genomics): *see CSCI4181/6810, EPAH6052 (partially), come speak to me if interested in this specifically.*

Course Structure

Overview of data types & analysis methods:

- **Lectures** (Monday/Wednesday)

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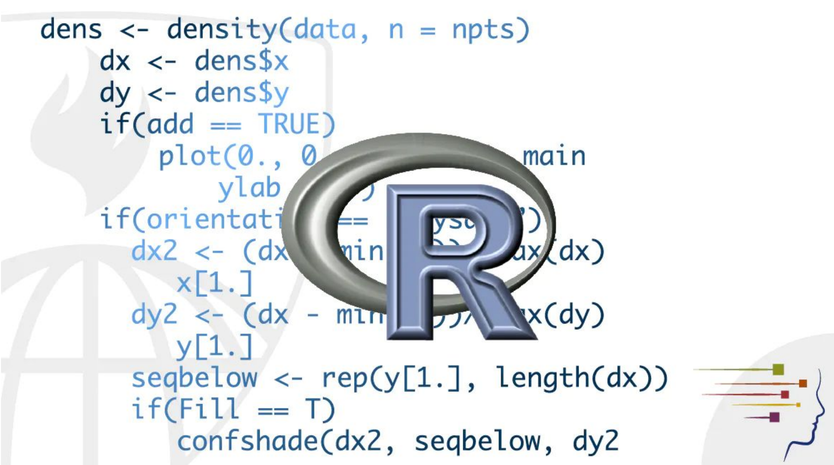
(CSCI4148: drop lowest scoring assignment)



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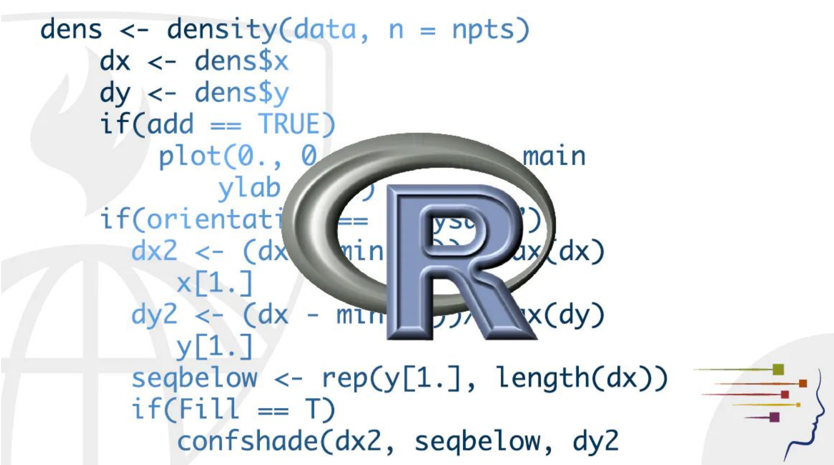

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- **Journal Club** (Wednesday/Friday)

2 papers per week, randomly assigned rota for leading discussion of paper with rest of class.

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Paper presentation (15%)

Participation in discussion (10%)

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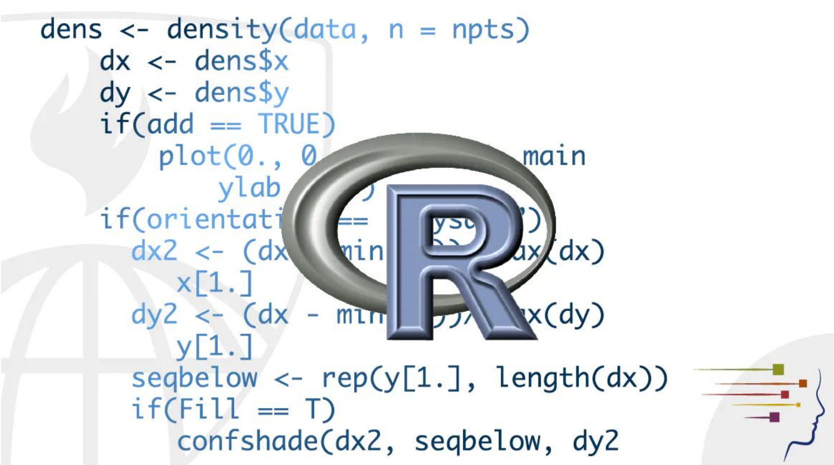

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Participation in discussion (10%)

Development of a research proposal:

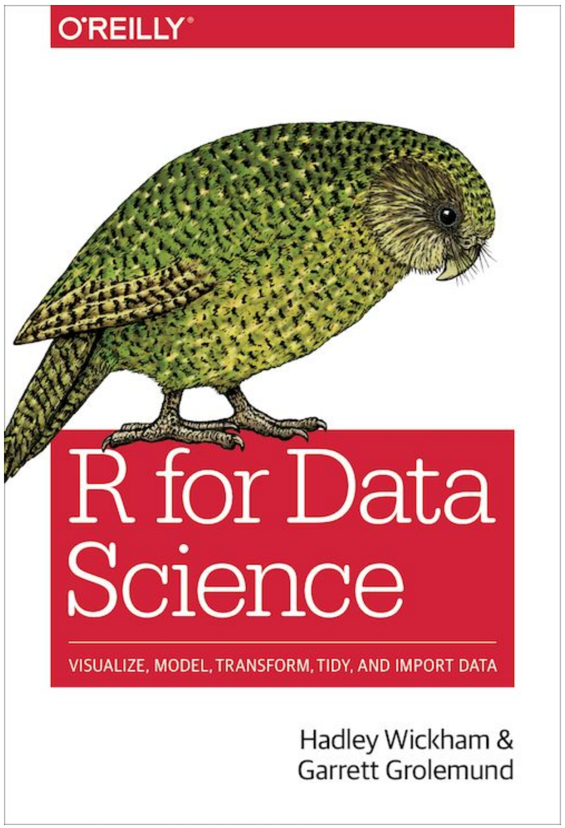
- **Class** (Wednesday/Friday)

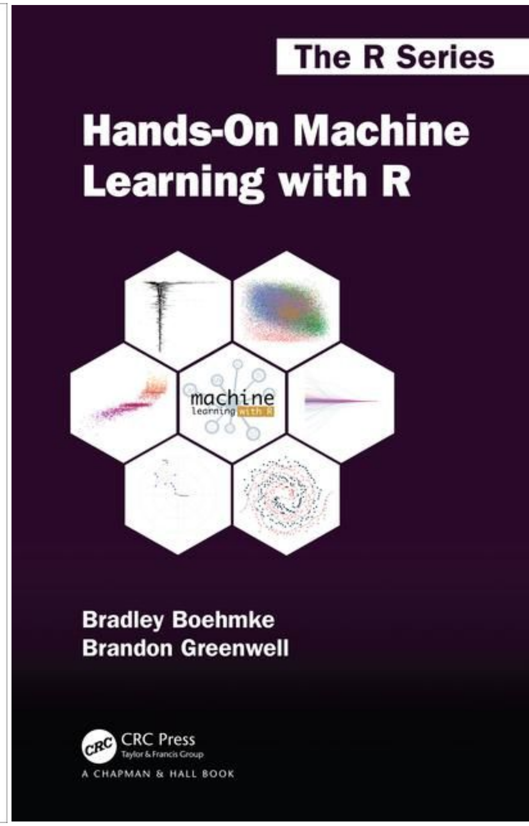
Assessment:

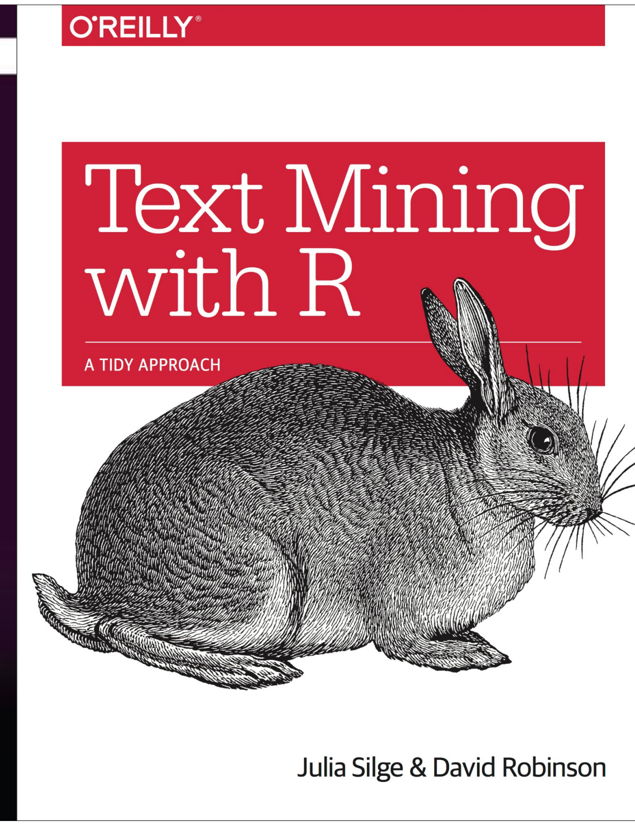
Presentation **last full week of class** (20%)

Submitted **final day of class** (15%)

Course Materials







https://r4ds.had.co.nz/

https://bradleyboehmke.github.io/HOML/

https://www.tidytextmining.com/

Course Website

https://maguire-lab.github.io/health_data_science_research_2025/

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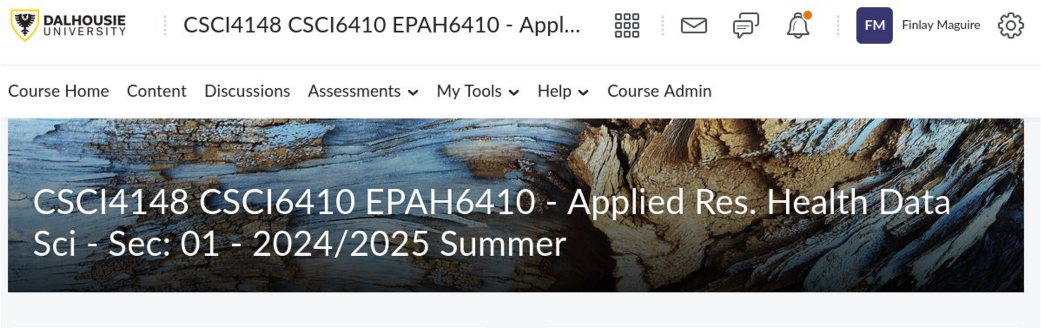
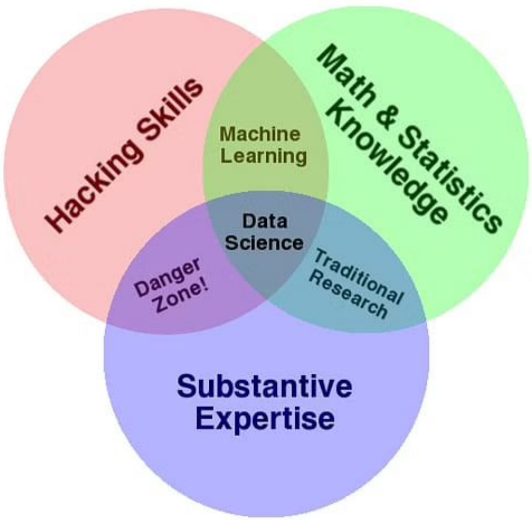


Grades/Submissions:
https://dal.brightspace.com/d2l/home/385844

What is ~~health~~ data science?

Data Science: *Data-intensive interdisciplinary approaches to understand and predict with secondary/live data*



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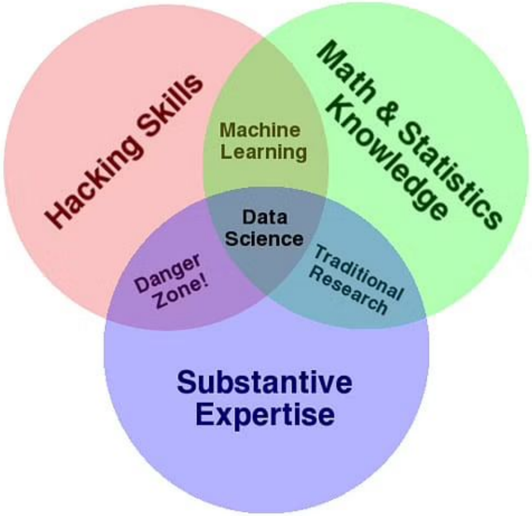
A range of partial and totally overlapping terms:



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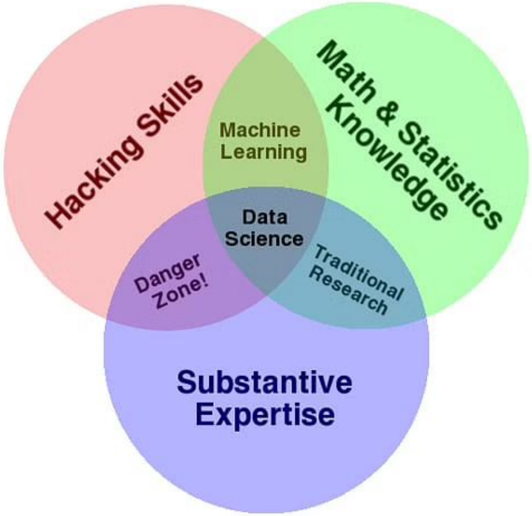
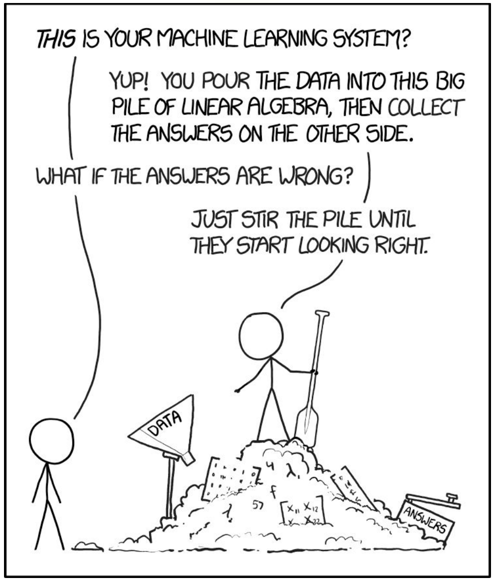
Data Science: *Data-intensive interdisciplinary approaches to understand and predict with secondary/live data*

A range of partial and totally overlapping terms:

- Data Analytics
- Data Engineering
- Data Mining
- {Health,Bio,Medical}Informatics
- Database Analysis
- Business Intelligence
- Epidemiology
- Statistics
- **Machine Learning**
- Pattern Recognition
- Predictive Analytics
- Quantitative Researcher
- Scientist
- Analyst
- Algorithmic Modeling





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So, it is just statistics?

Data Science/ML vs Statistics

- Many shared methods
- Difference in focus/priorities/culture

https://stats.stackexchange.com/questions/442128/machine-learning-vs-statistical-learning-vs-statistics

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- Statistics ~ tries to understand how outcome was generated by data
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- Alternative framing:
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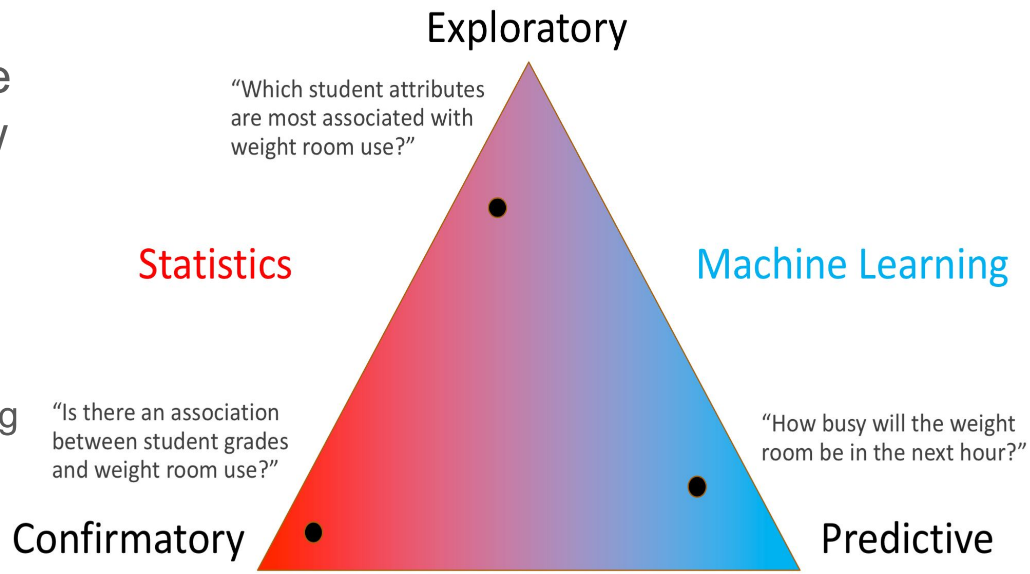

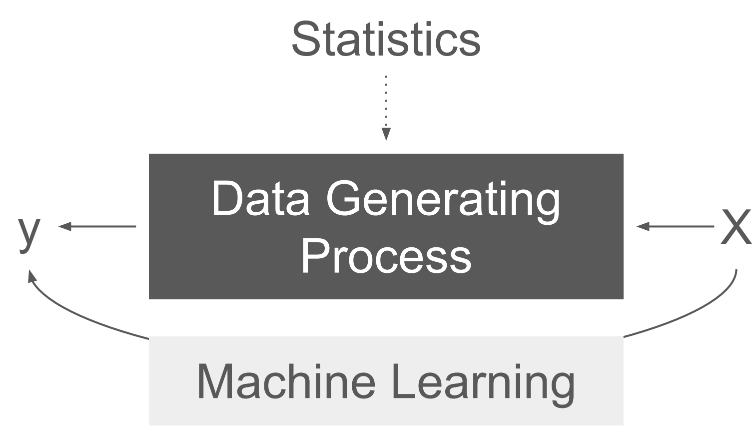

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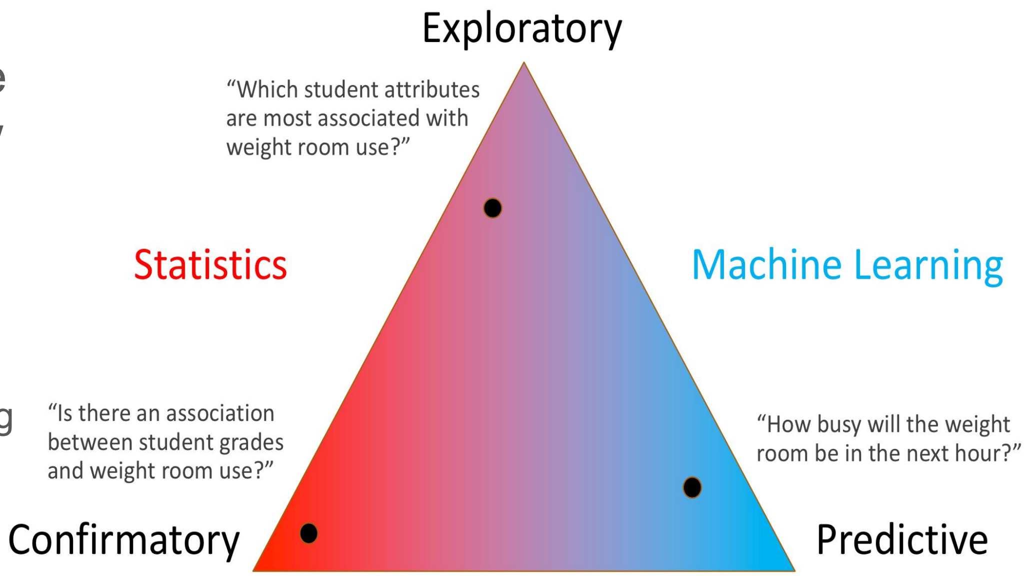
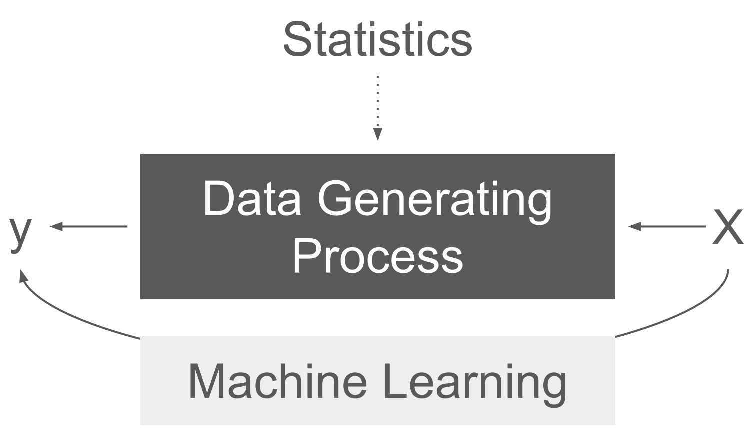
- DS/ML Pitfalls (can be):
    - Less rigorous/principled
    - Prone to reinventing the wheel
- DS/ML Benefits (can be):
    - More flexible
    - Less prescriptive/intimidating





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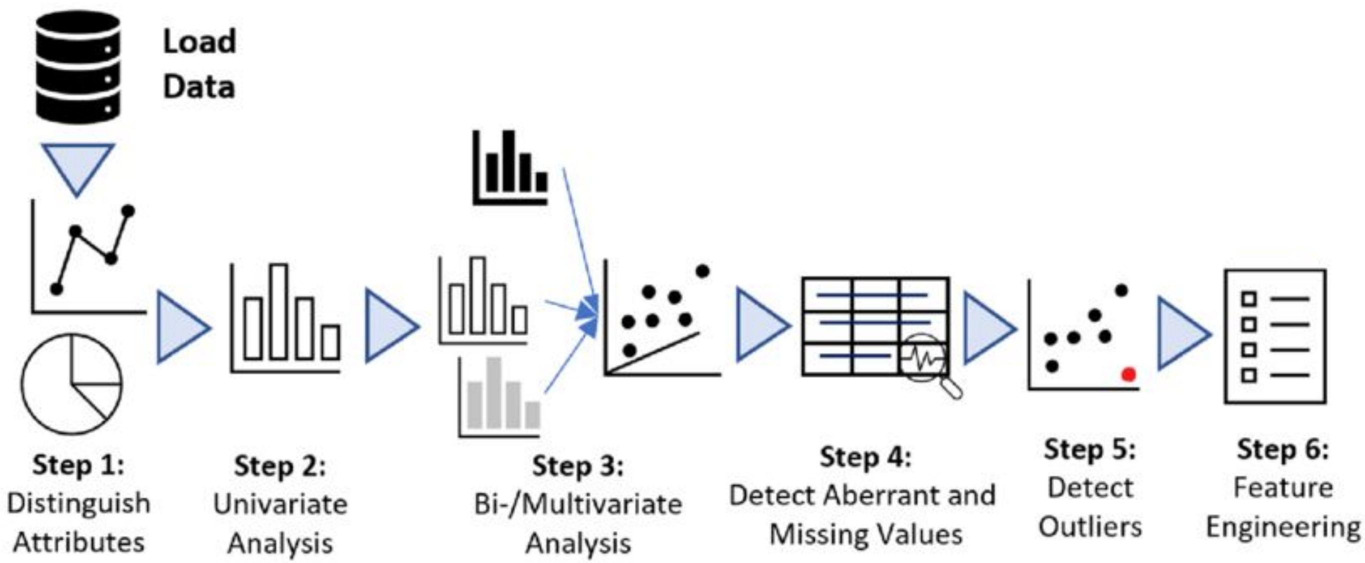
Data science centers exploratory data analysis



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Data science supports inductive approaches

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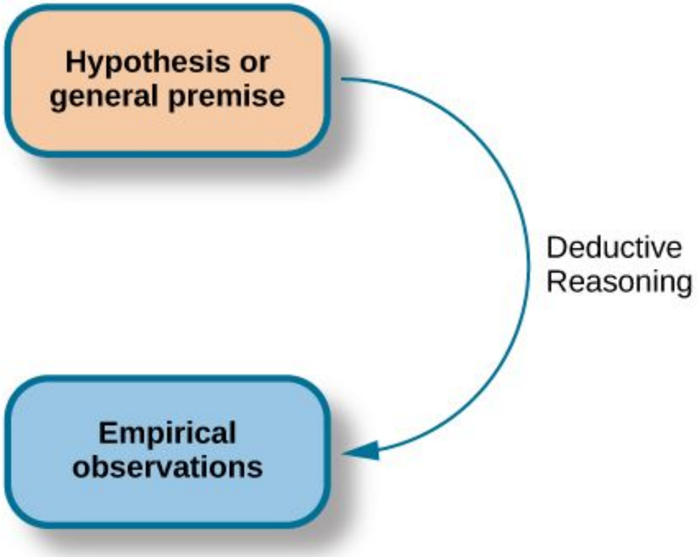
Deductive:

- “Condition X, causes Y”
- Collect data
- Perform (typically) frequentist statistical tests
- Reject or confirm null hypothesis



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Deductive:

- "Condition X, causes Y"
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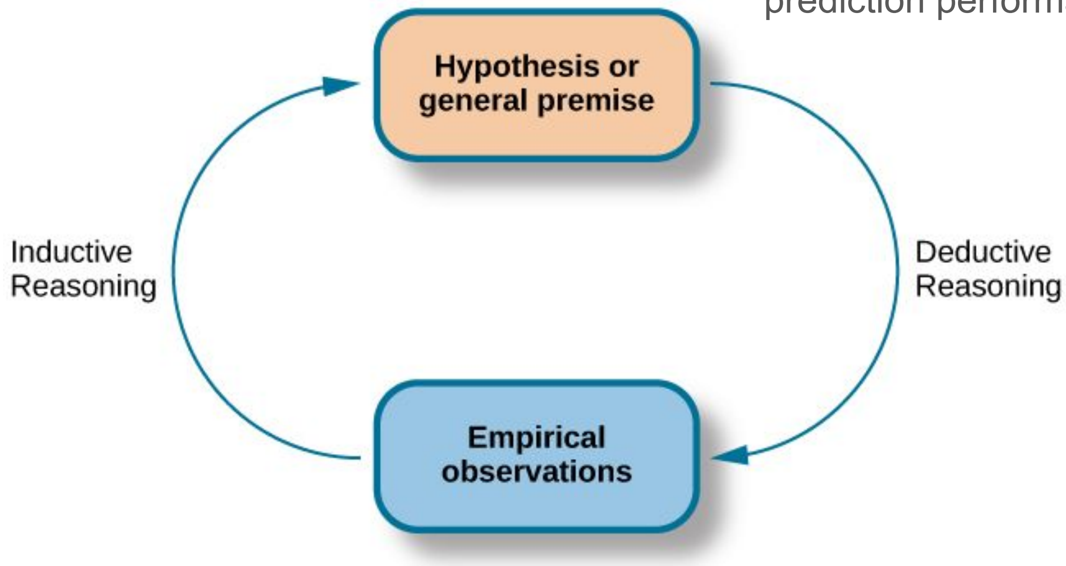
Inductive:

- Collect data
- Identify patterns in the data
- Observe X and Y seem connected somehow
- Quantify strength of association e.g., prediction performance



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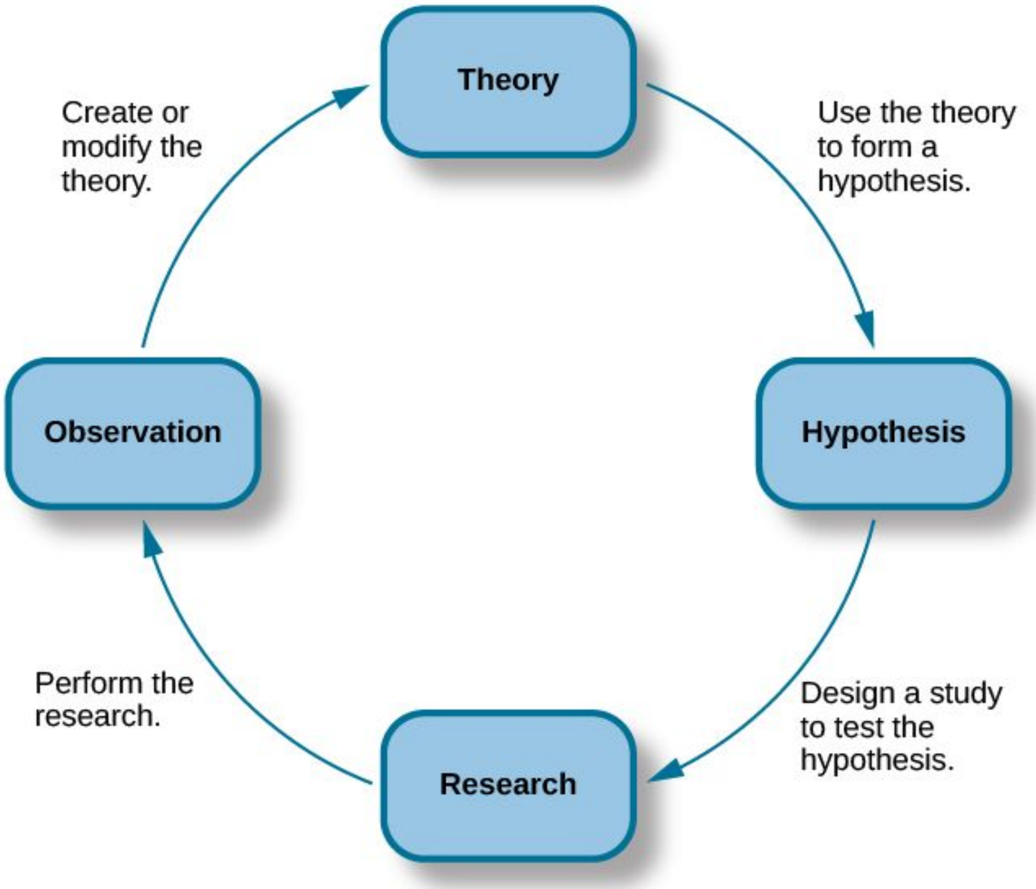
Data science aligns with knowledge cycle



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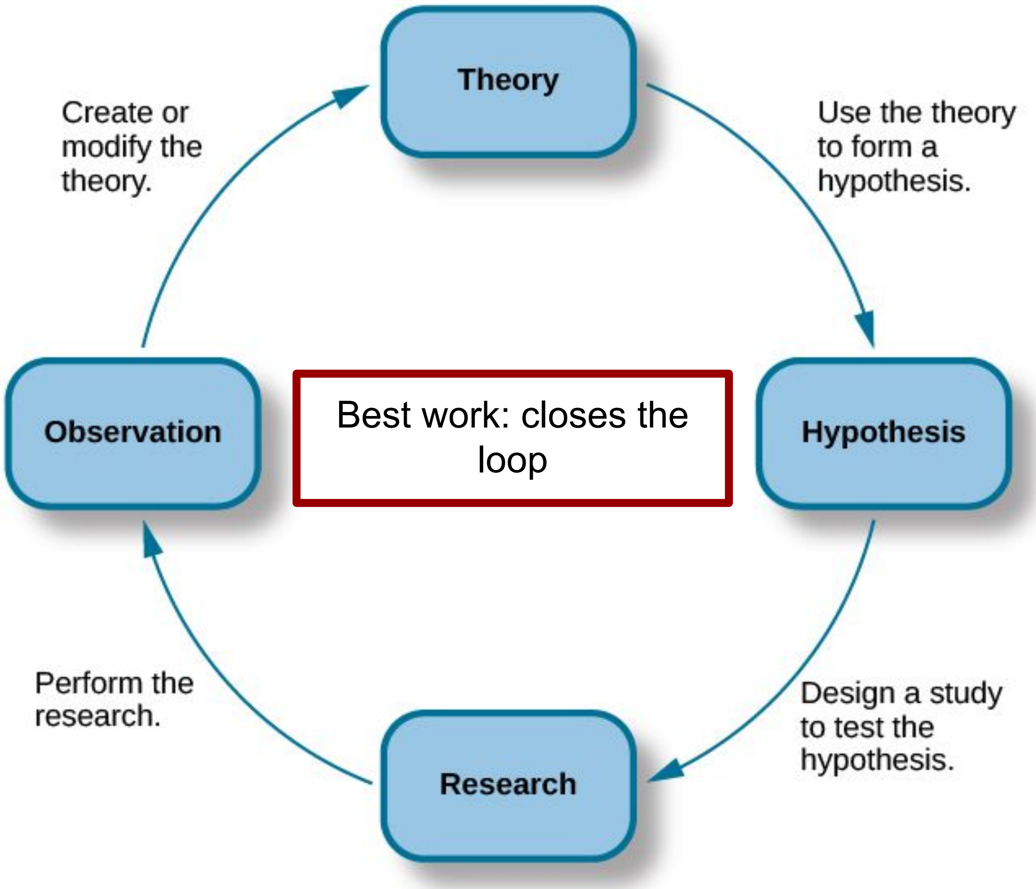

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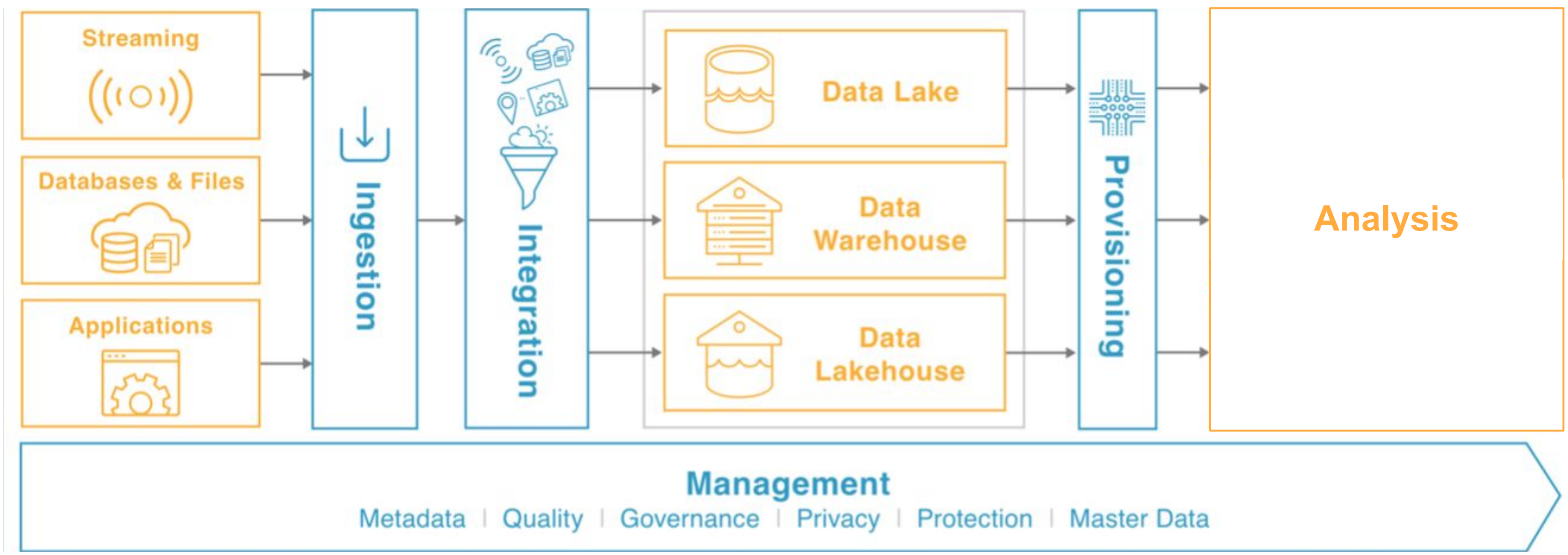
Data science is integrated into a data ecosystem



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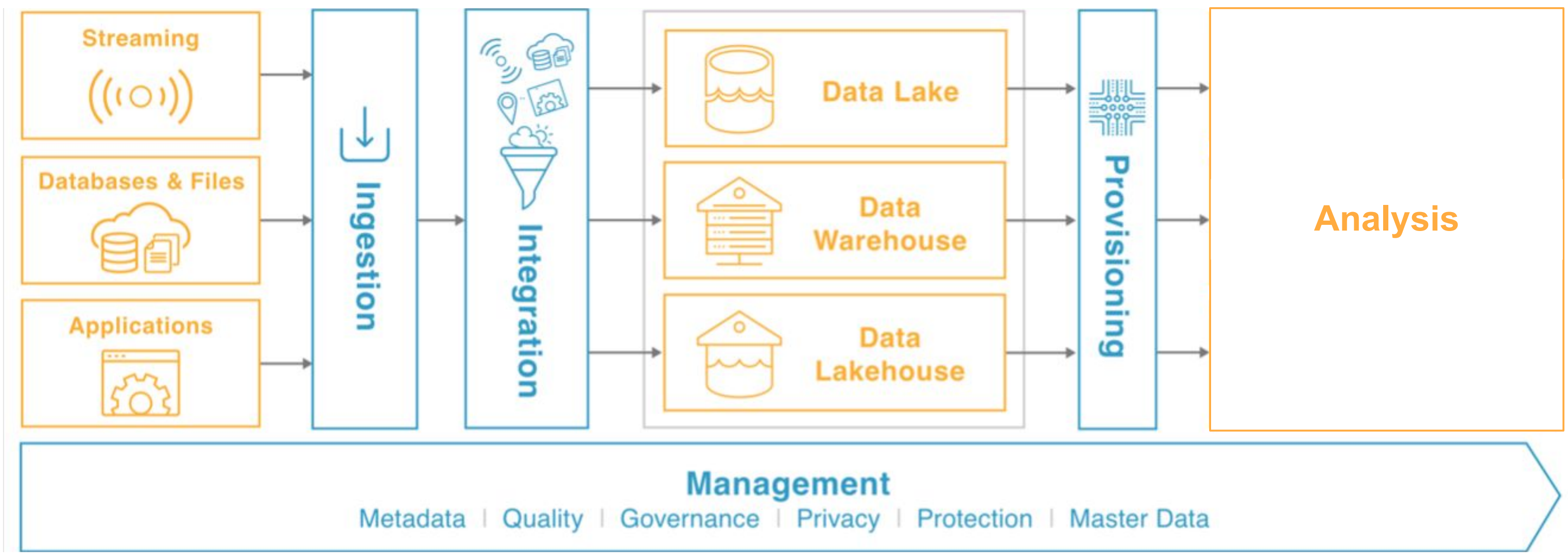

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Some Open-Source Orchestration Tools:

Apache Airflow DAGSTER DVC Flyte

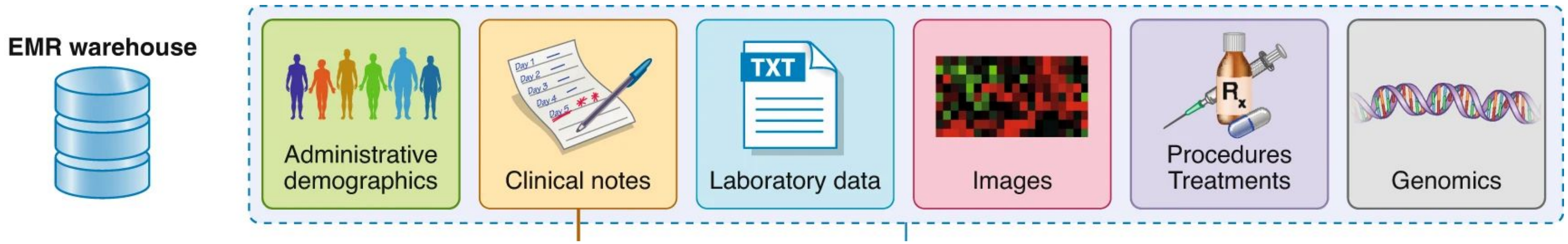
Kale Kedro Kubeflow Luigi METAFLOW

Ploomber TensorFlow Extended

https://ploomber.io/blog/survey/

OK, what is **Health** Data Science?

Data Science applied to Health Data



Why “health data” instead of “medical data”: health encompasses medical ***(contentious)***

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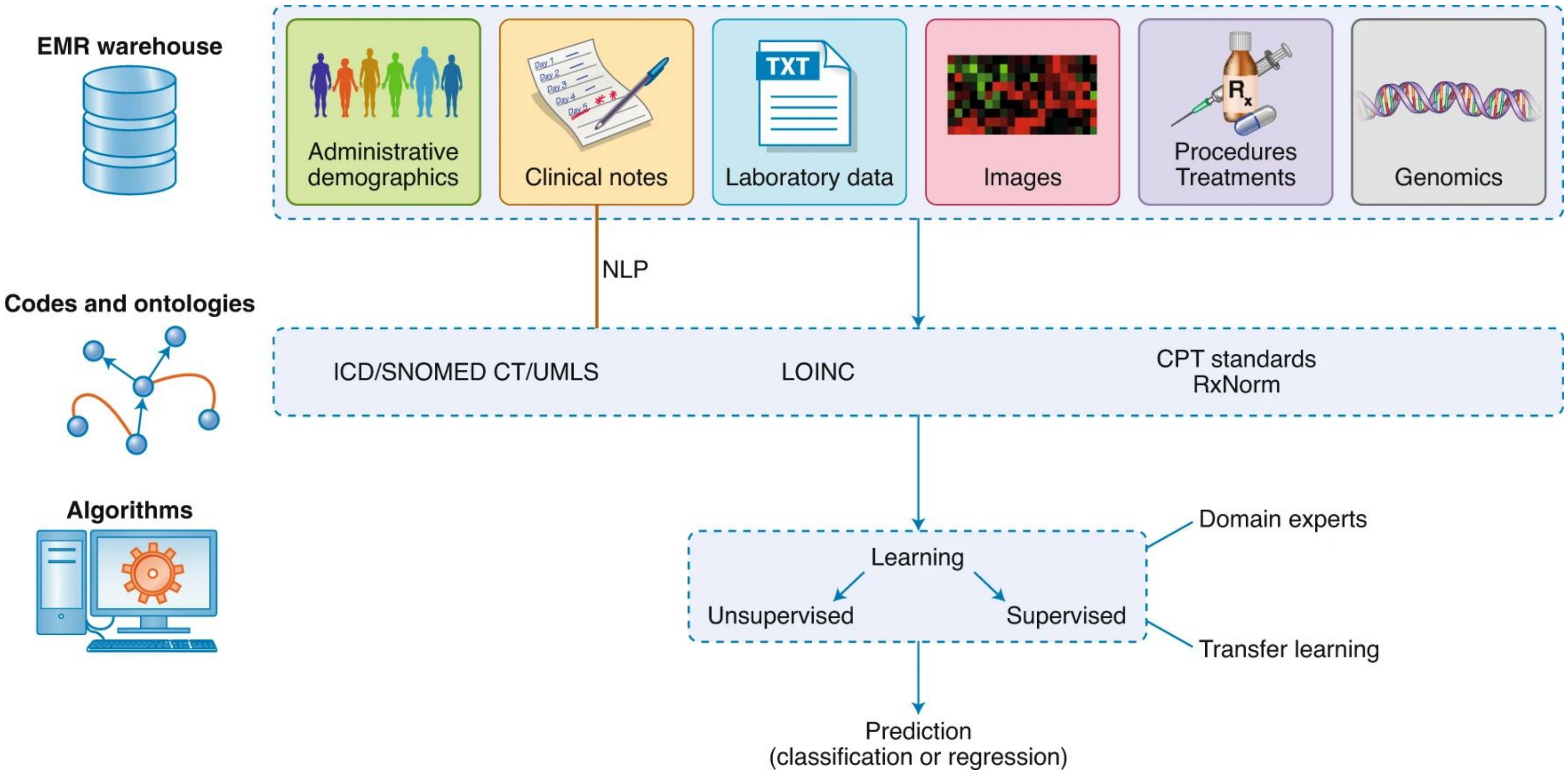

https://www.nature.com/articles/s41588-020-0698-y/figures/2

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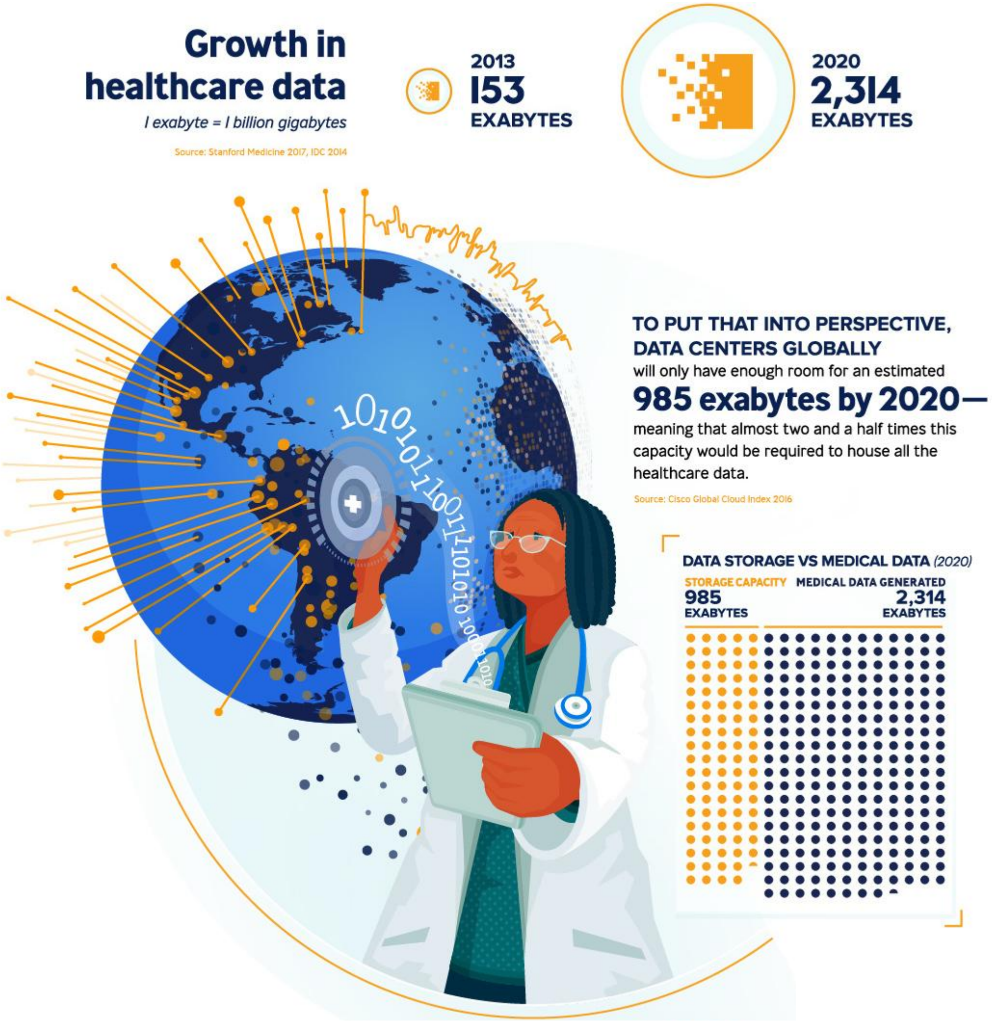
Opportunity of Health Data Science

Benefits (and pitfalls!) of data science in general combined with:

- Huge amounts of health data



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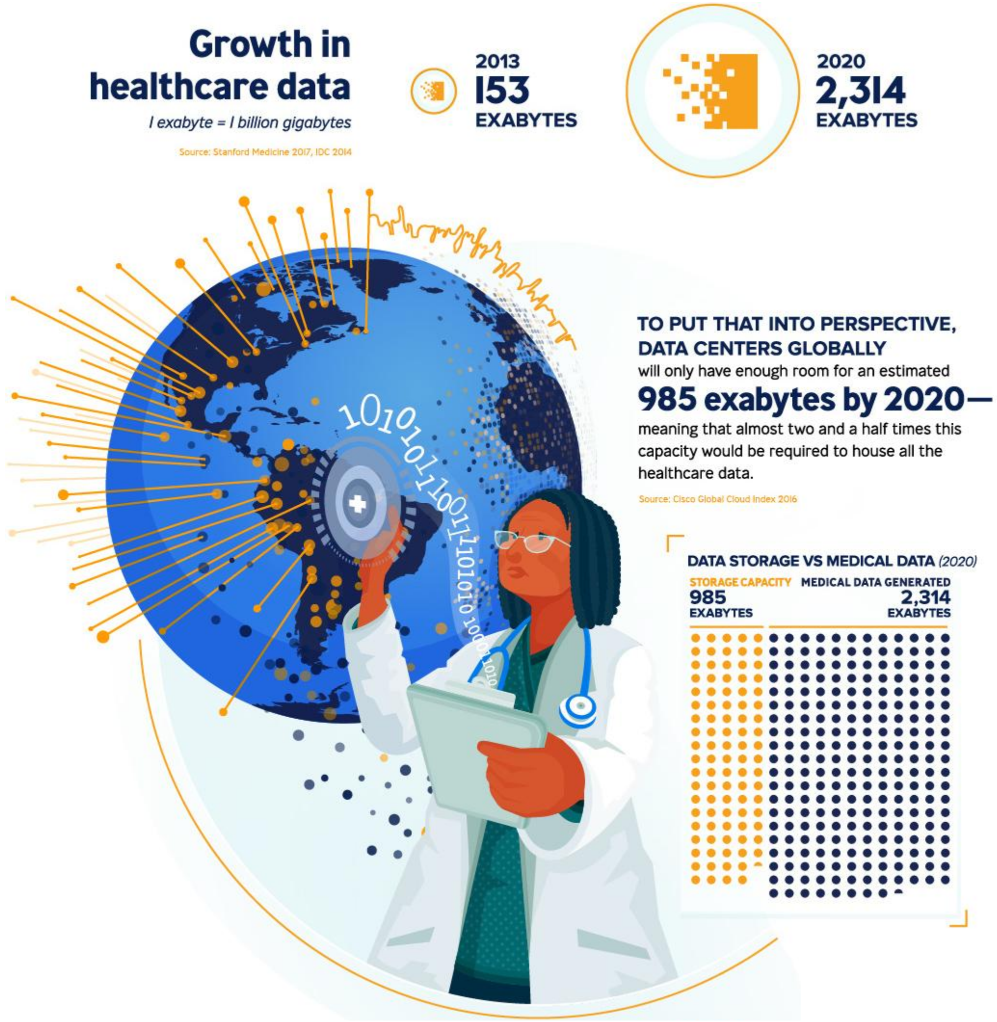

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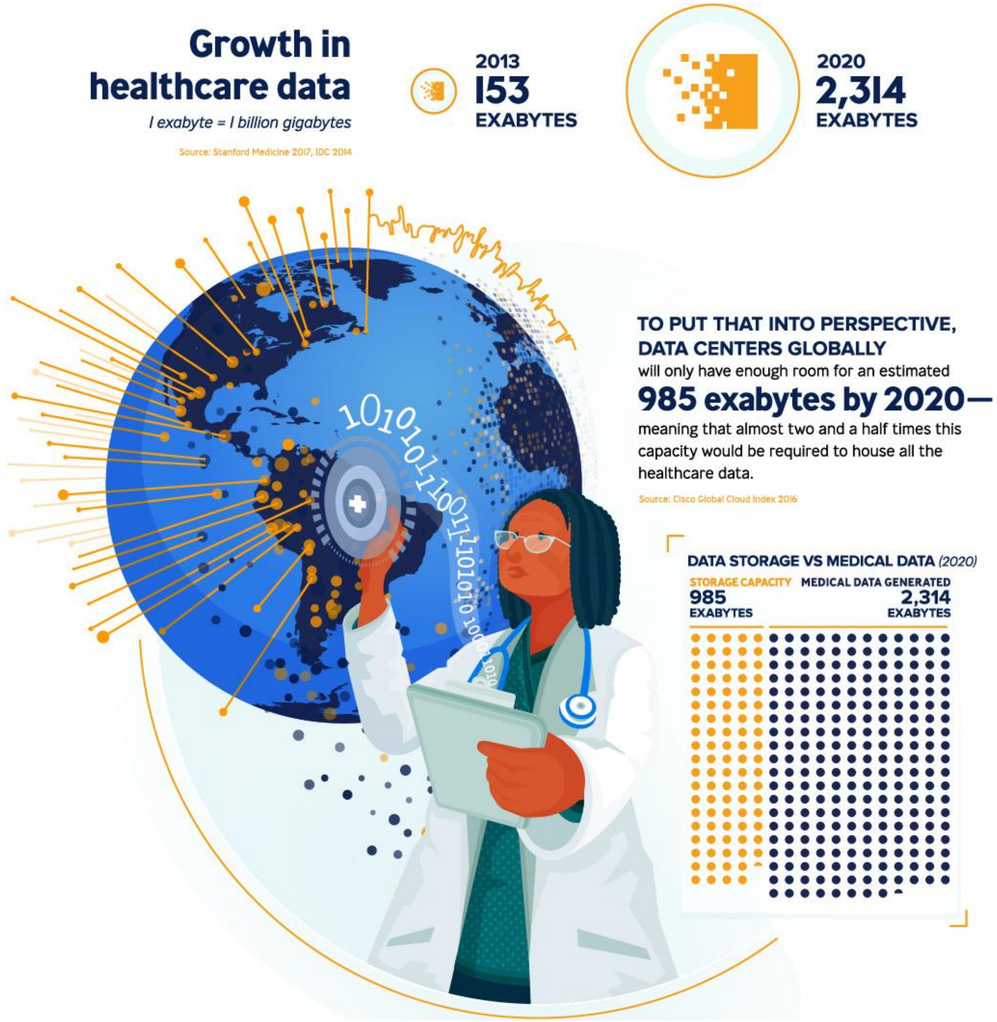

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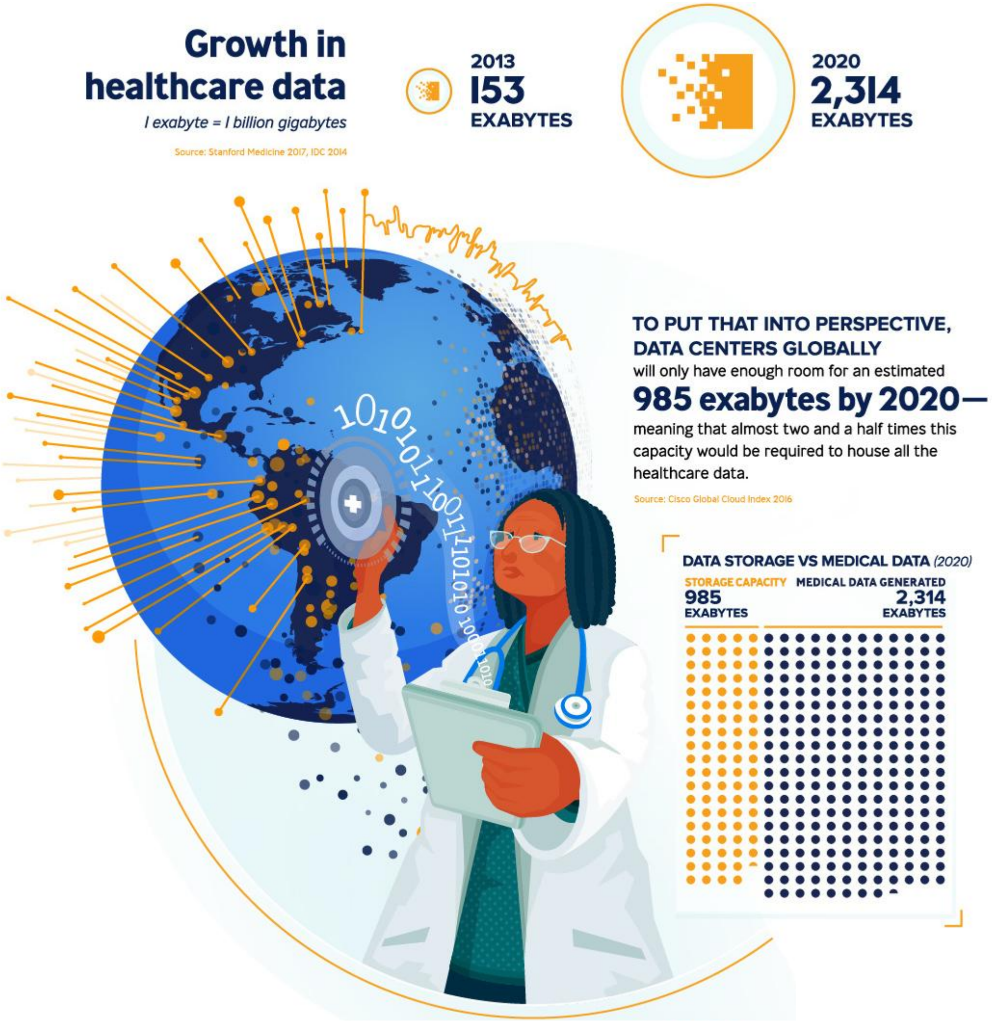
- Many **interesting** and **important problems**
- Many domain experts desperate for data-related help with these problems
- Relative few skilled data science practitioners



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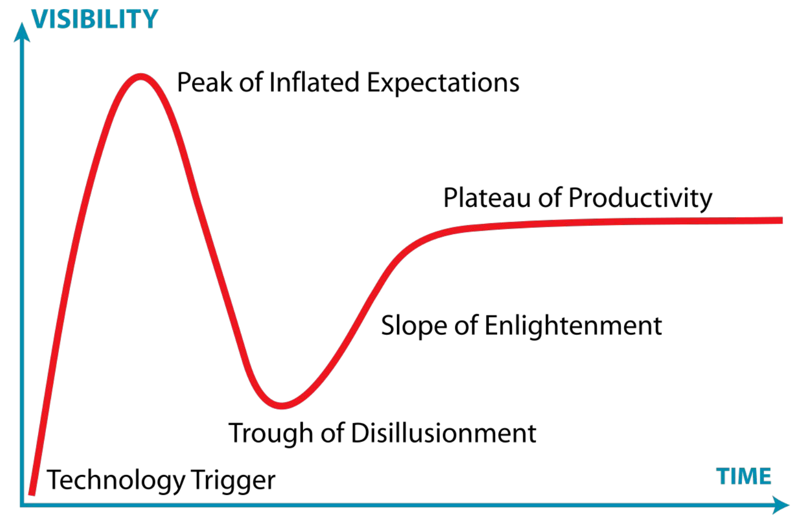
(Some) Challenges of Health Data Science

- Lots of hype



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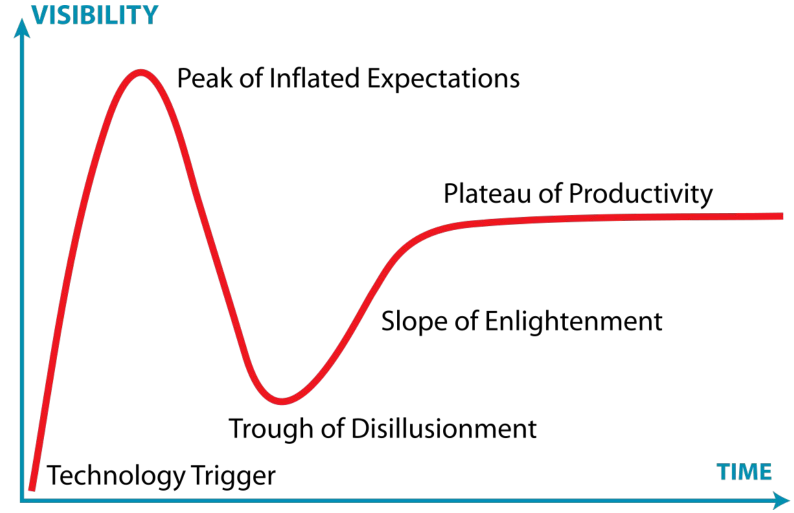
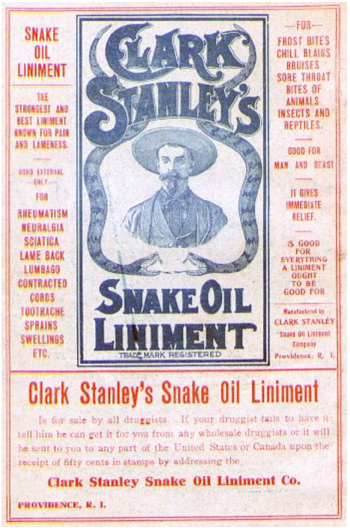
- Lots of grifters





https://upload.wikimedia.org/wikipedia/commons/9/94/Gartner_Hype_Cycle.svg
https://commons.wikimedia.org/wiki/File:Clark_Stanley%27s_Snake_Oil_Liniment.png

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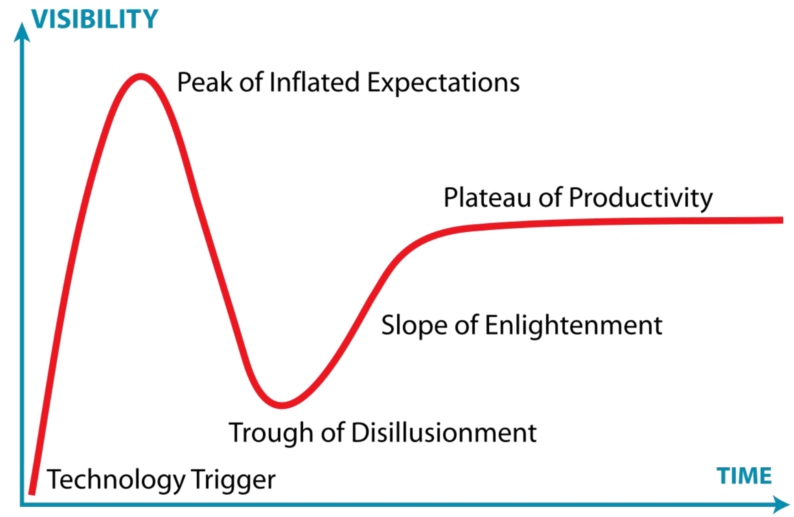
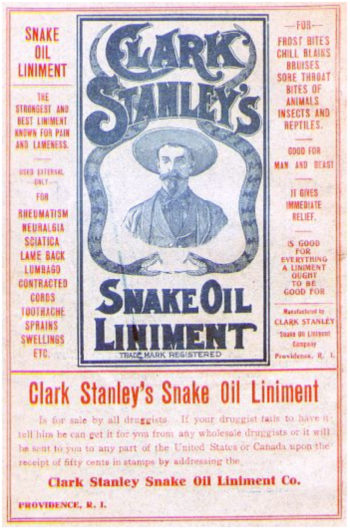
- Lots of grifters
- Data quality issues
- Contextual/Metadata quality issues





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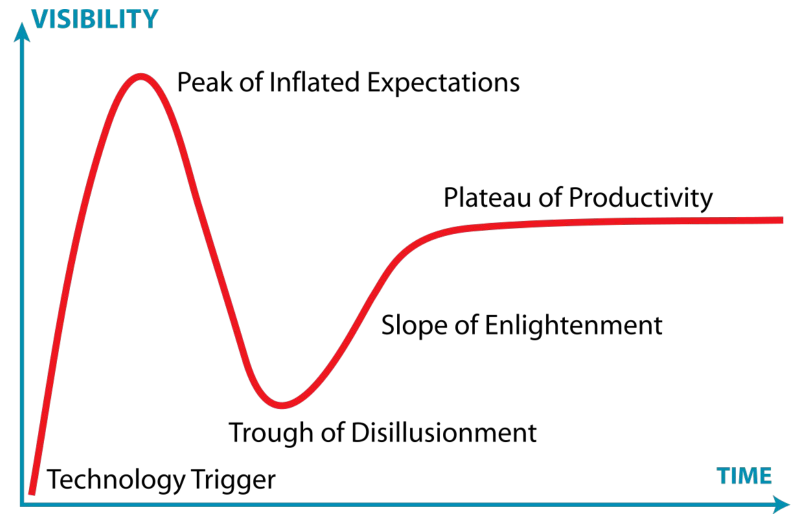
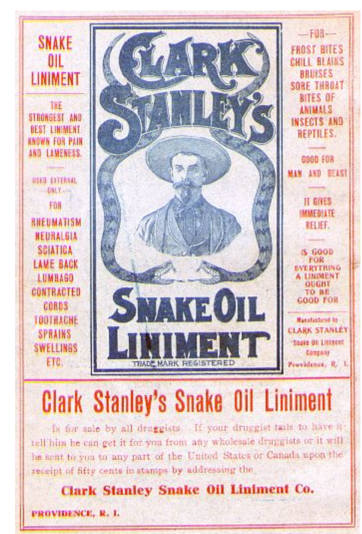
(Some) Challenges of Health Data Science

- Lots of hype
- Lots of grifters
- Data quality issues
- Contextual/Metadata quality issues
- Regulatory challenges
- Influence of US health system
- Ethical pitfalls
- Treatment to the mean
- Knowledge Translation and Operations: **Hard**



https://www.r-bloggers.com/2019/08/new-course-learn-advanced-data-cleaning-in-r/



https://upload.wikimedia.org/wikipedia/commons/9/94/Gartner_Hype_Cycle.svg
https://commons.wikimedia.org/wiki/File:Clark_Stanley%27s_Snake_Oil_Liniment.png

What parts of health data science will this course cover?

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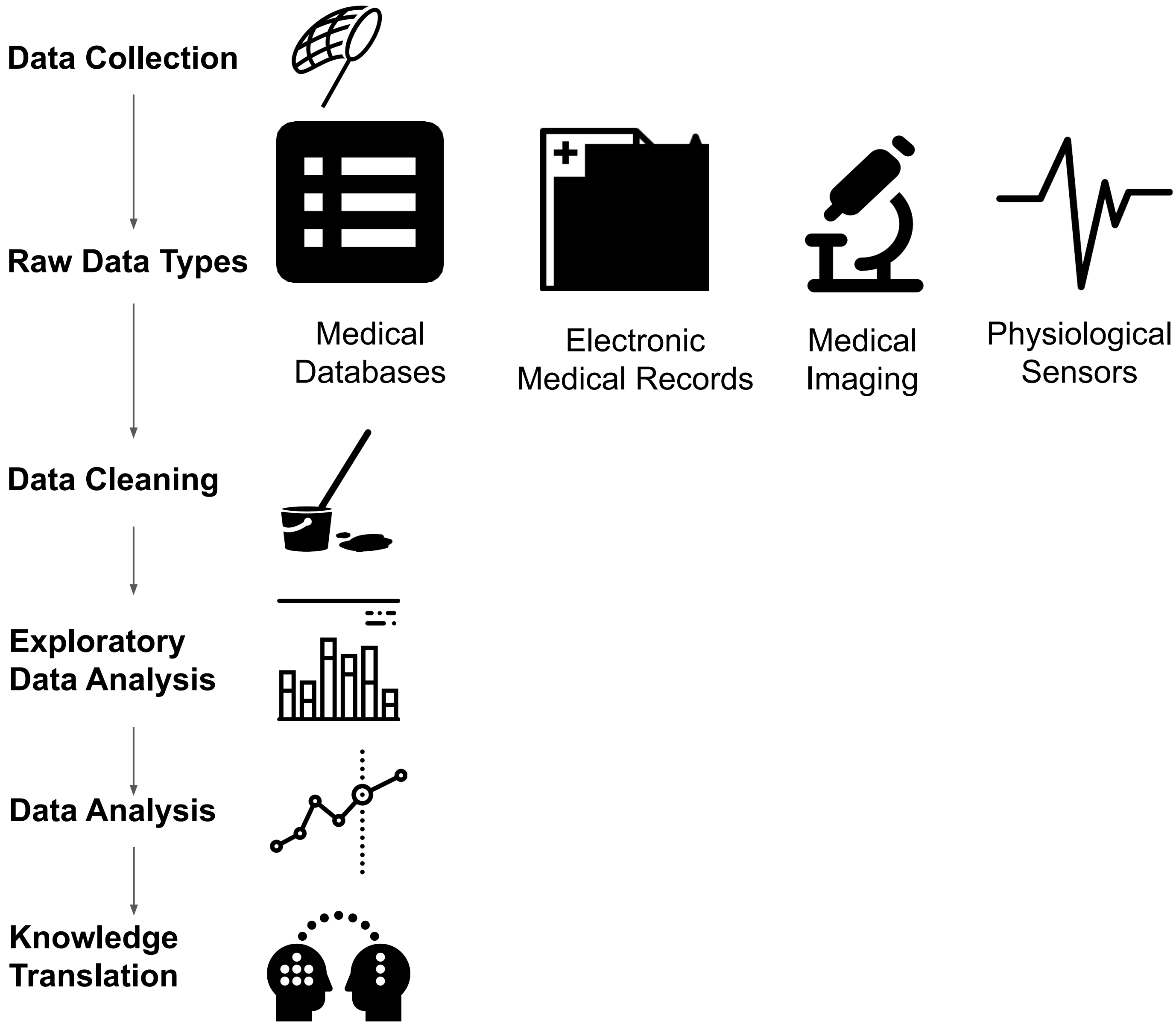

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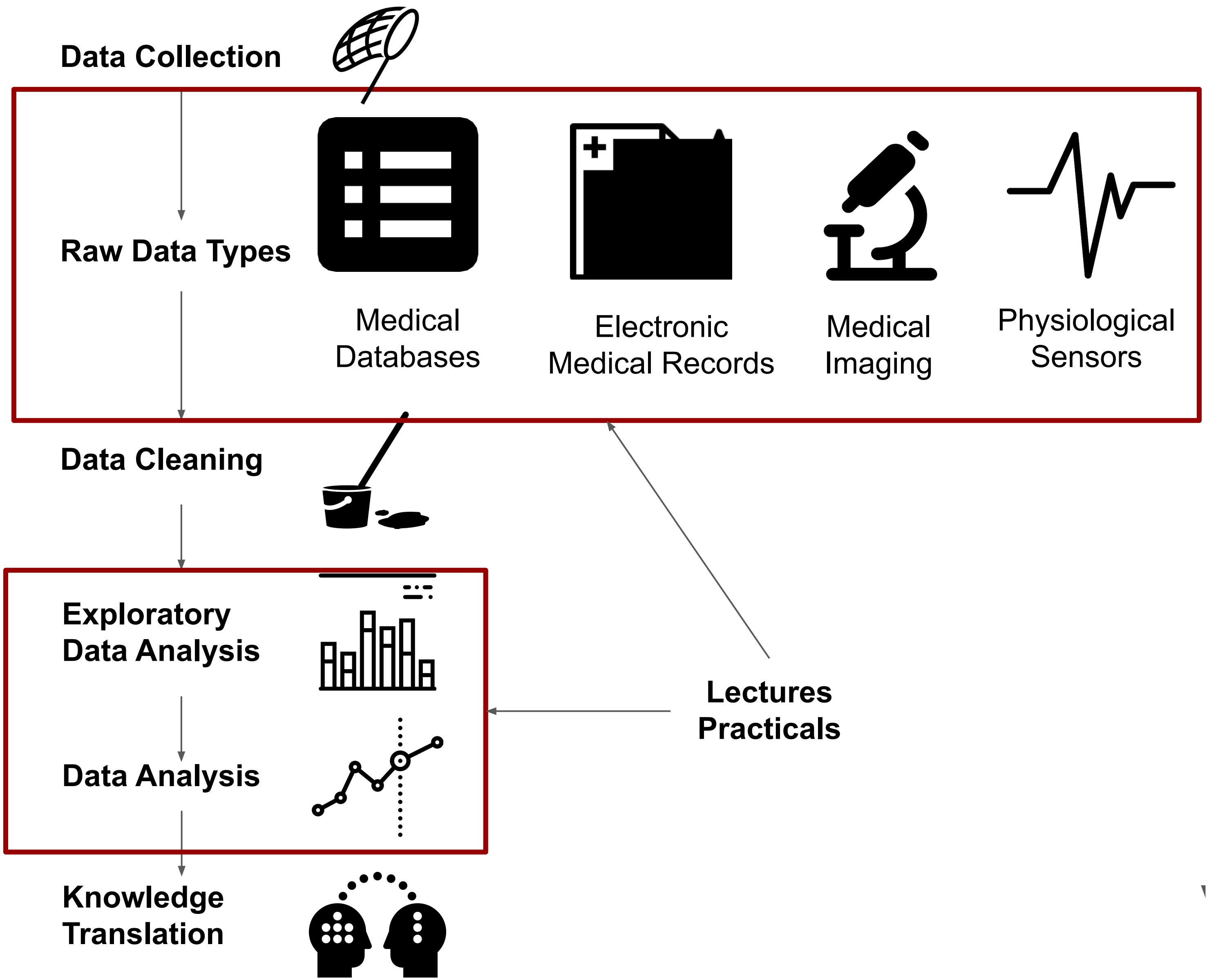

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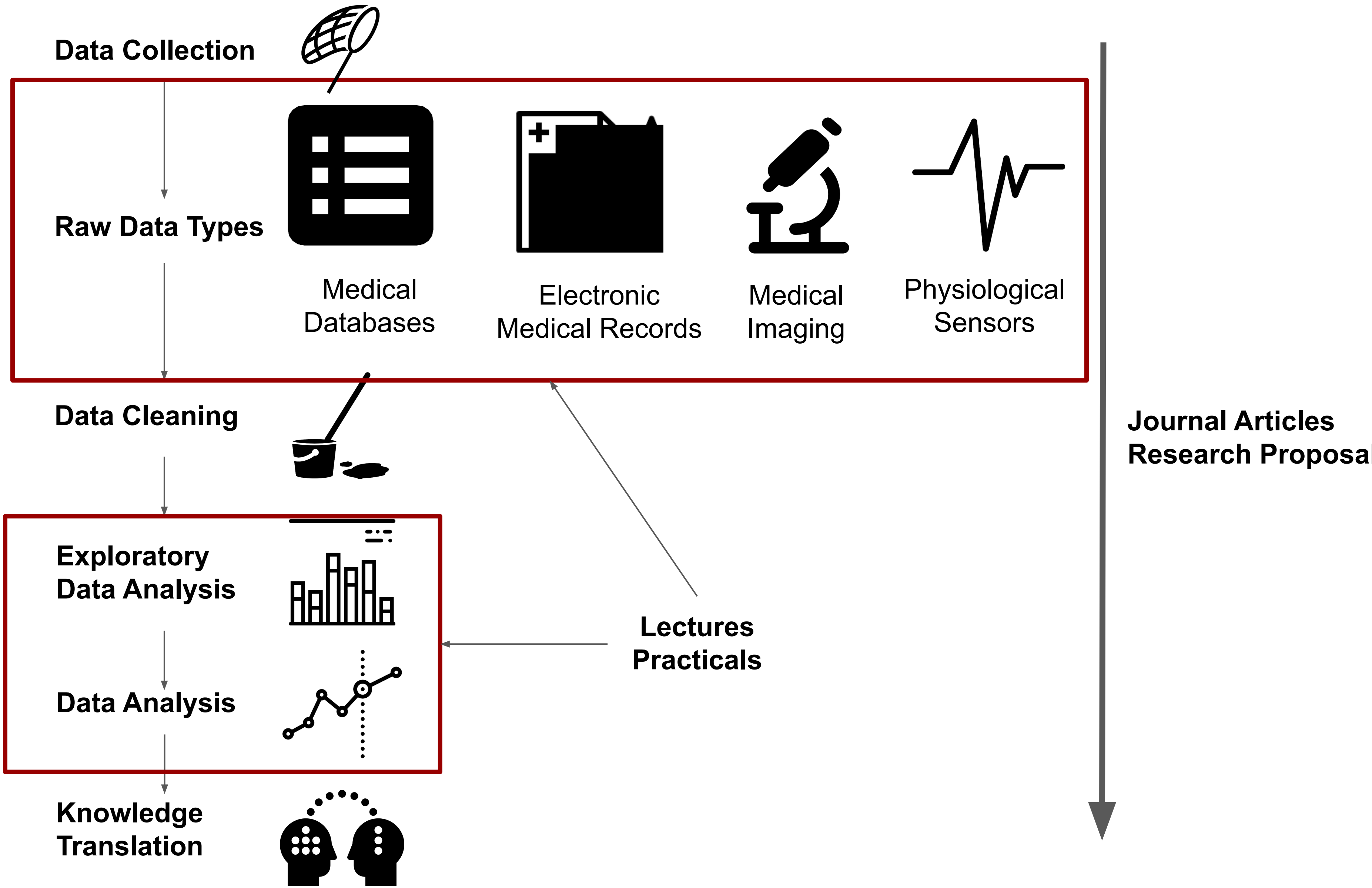


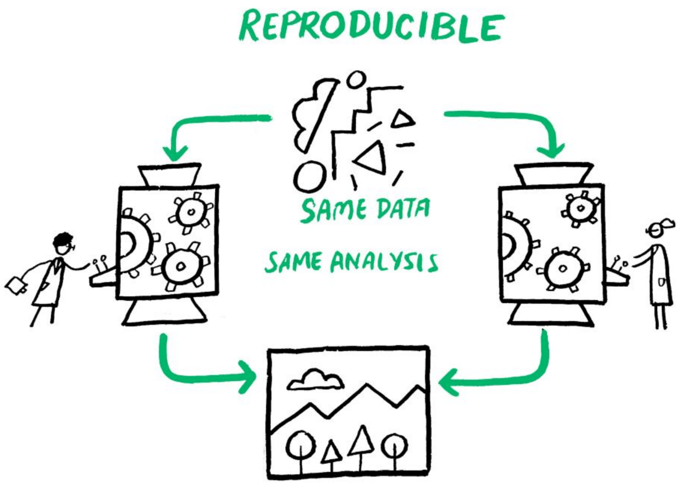
Let’s take a 5 minute break!

Tools for Reproducible Health Data Science

Rstudio, Rmarkdown, Git

Why do we care about reproducibility?

Reproducibility should be the bare minimum



oliviergimenez.github.io/reproducible-science-workshop

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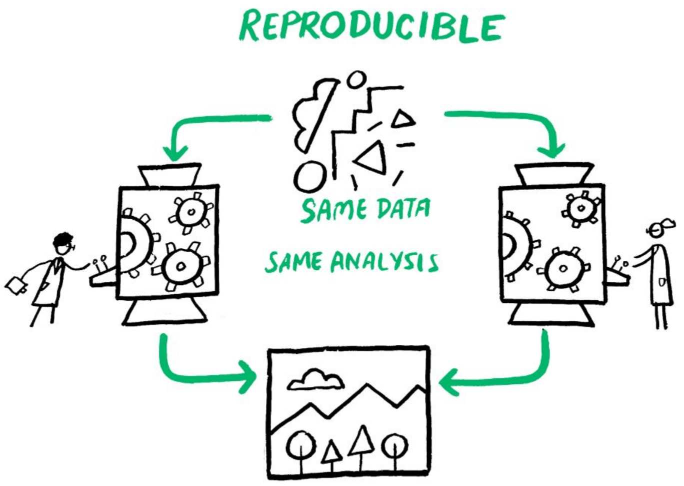

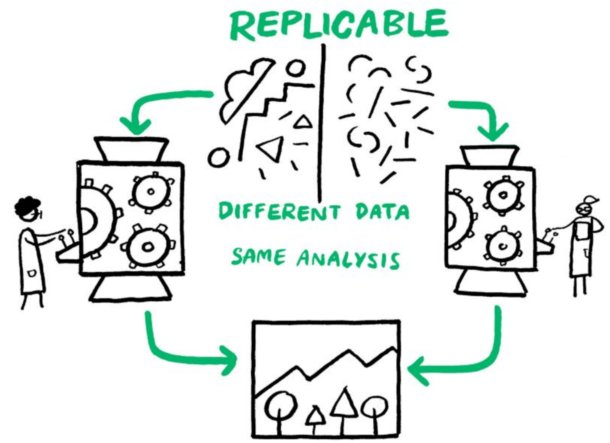

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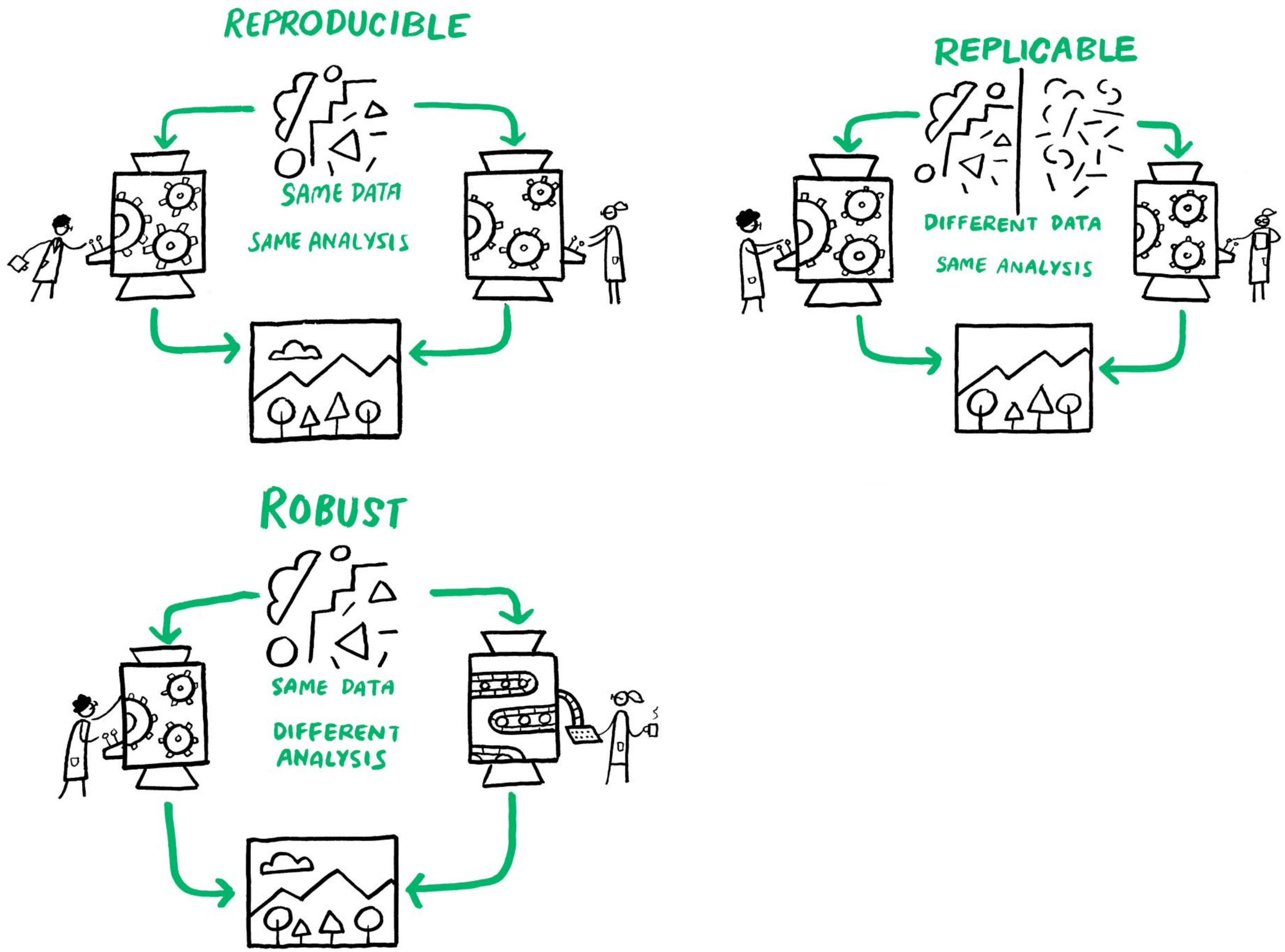

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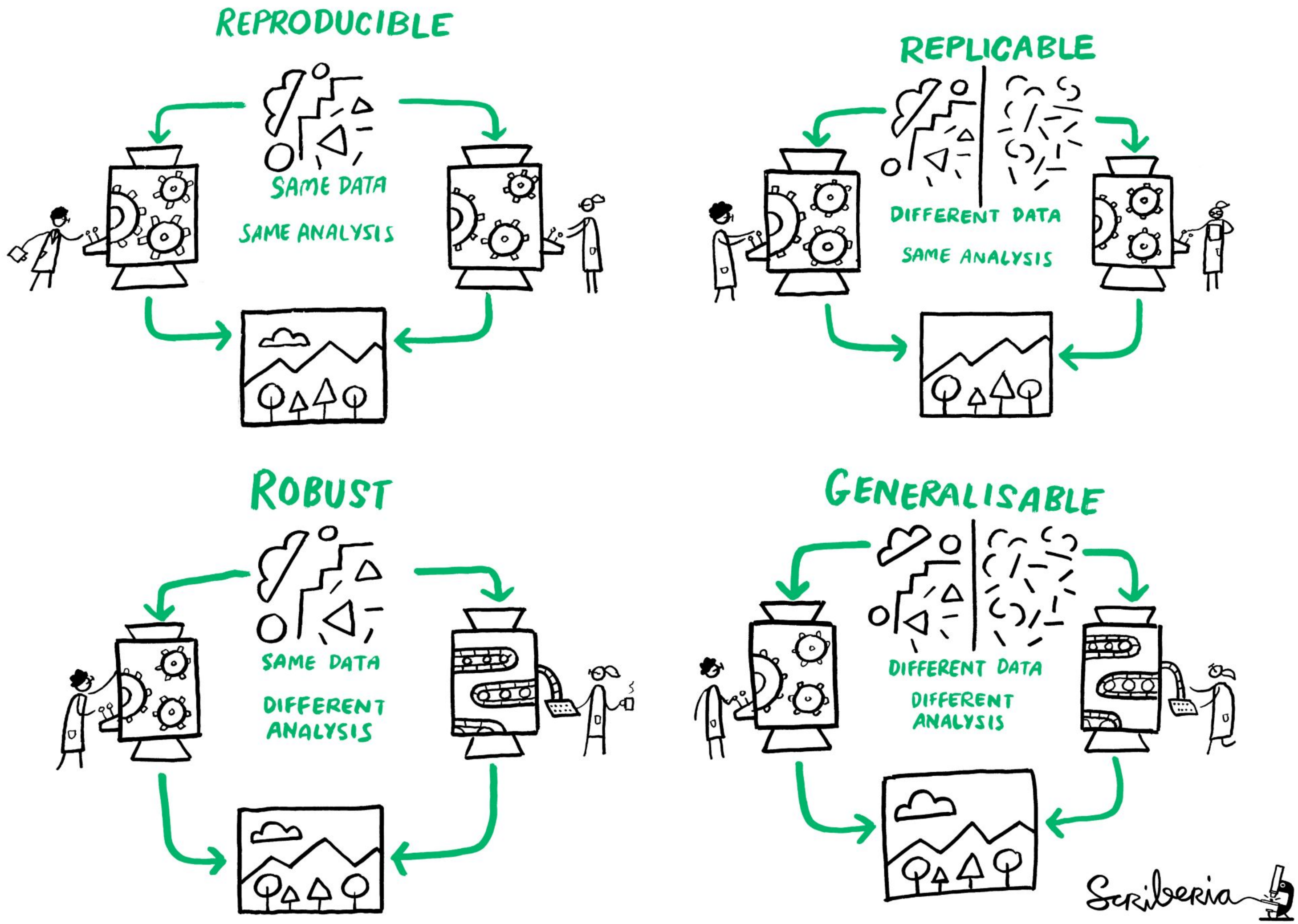

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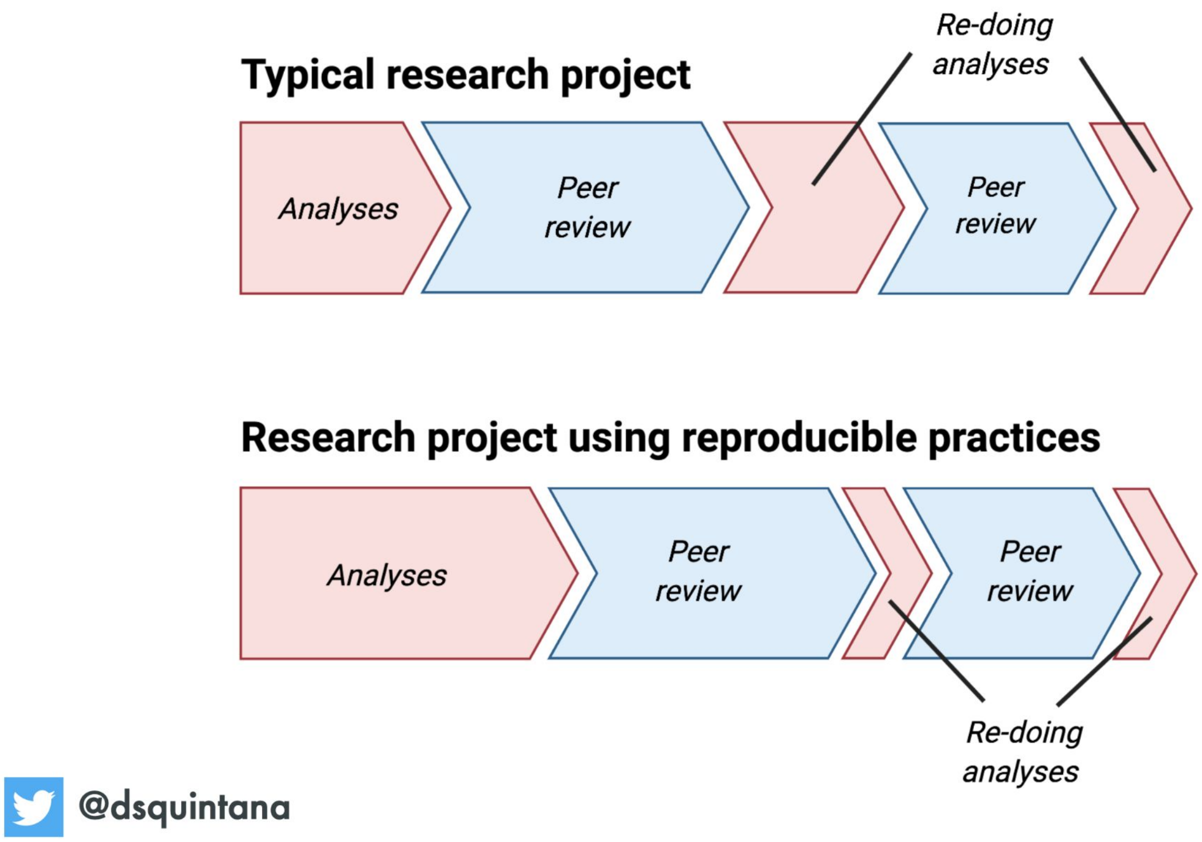
Makes your own life easier



oliviergimenez.github.io/reproducible-science-workshop

What do we need to do to have reproducible research?

Reproducibility checklist

- Don’t do anything by hand (even “one-off” tasks)

Reproducibility checklist

- Don’t do anything by hand (even “one-off” tasks)
- Script every interaction with data:
  - Data collection
  - Moving data on your computer
  - Formatting datasets
  - Cleaning data
  - Exploratory data analysis
  - Main analyses
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- Keep track of the exact version of every library/program you use

How do we actually do these things?

Choose a language that makes it easy to do most/all of your analysis

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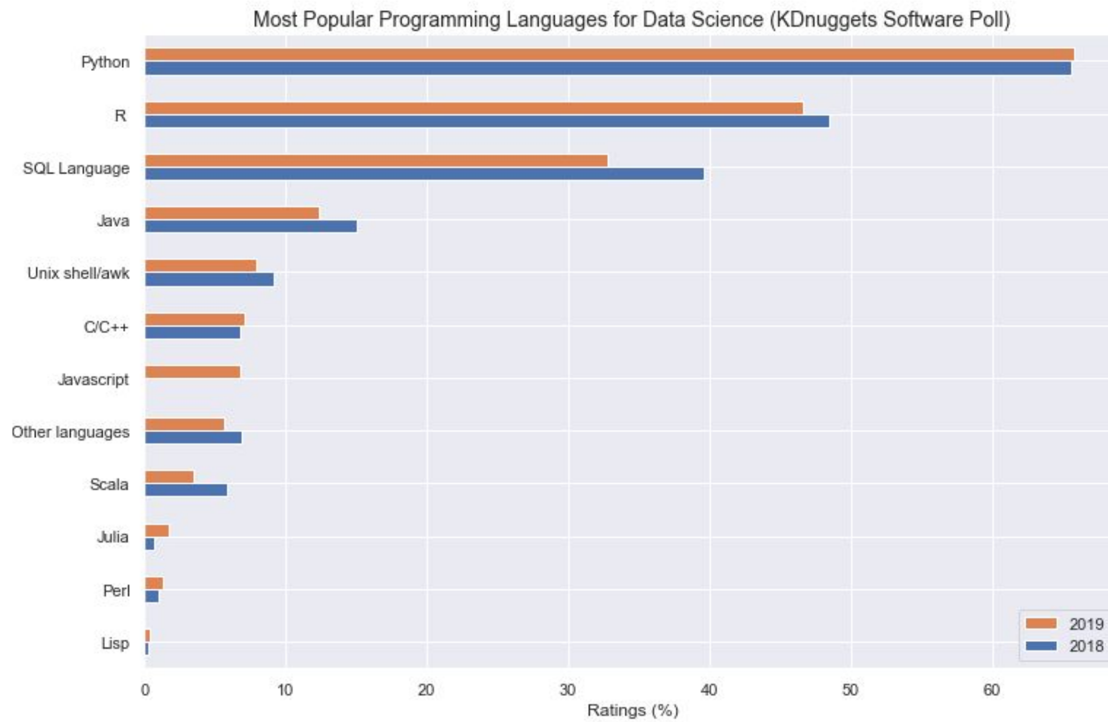

https://www.kdnuggets.com/2019/05/poll-top-data-science-machine-learning-platforms.html

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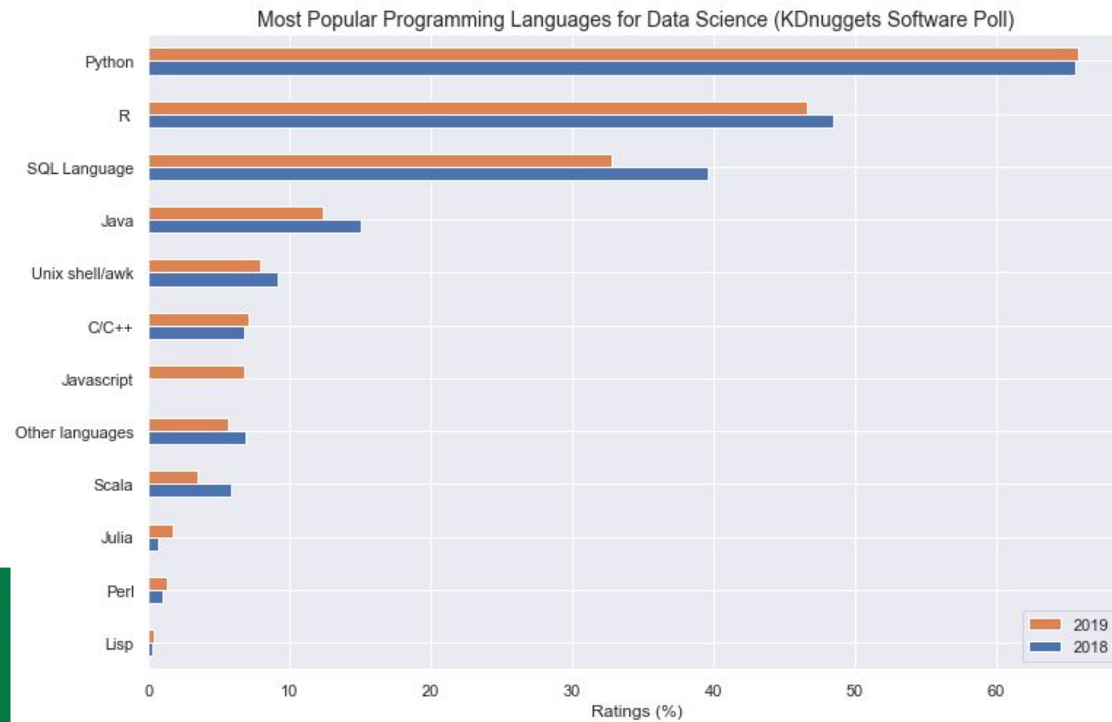
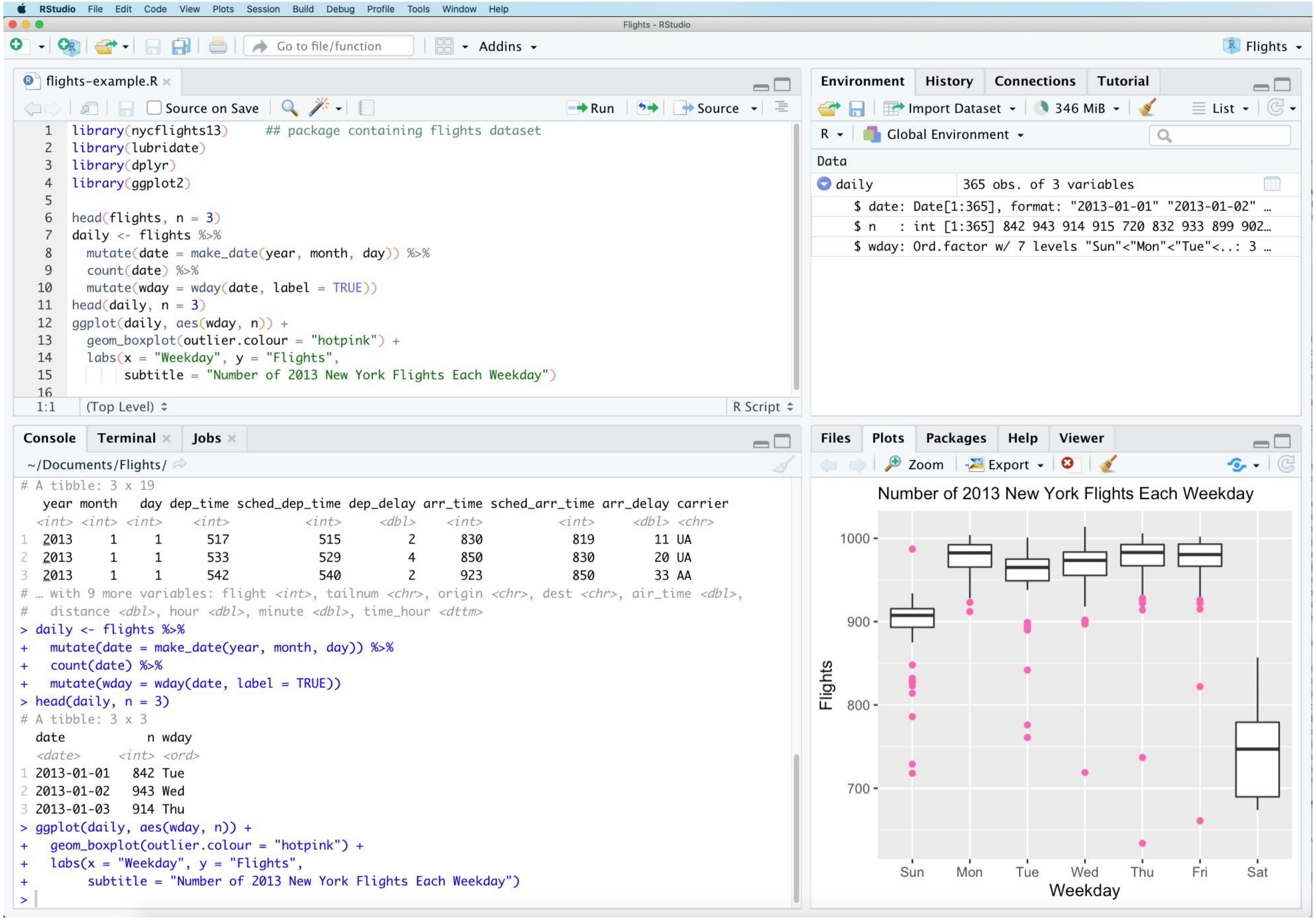


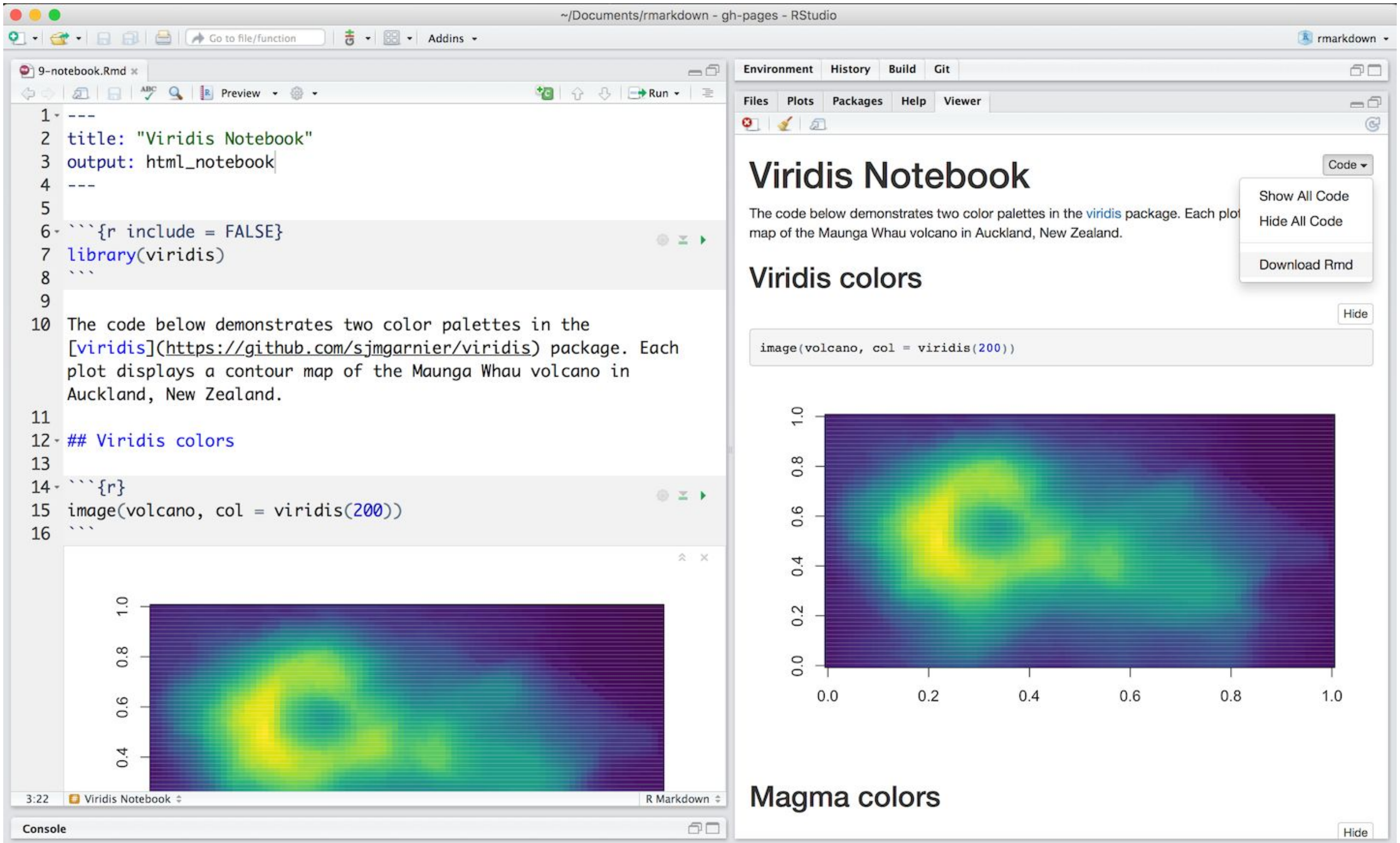
https://www.kdnuggets.com/2019/05/poll-top-data-science-machine-learning-platforms.html

Use a data science focused IDE: Rstudio

set.seed()
sessionInfo()



Use notebooks to document analyses: Rmarkdown/Quarto



Use notebooks to document analyses: Rmarkdown/Quarto

settings). Therefore, from this time onward, case counts are likely underestimated and the sequenced virus diversity is not necessarily representative of the virus circulating in the overall population.

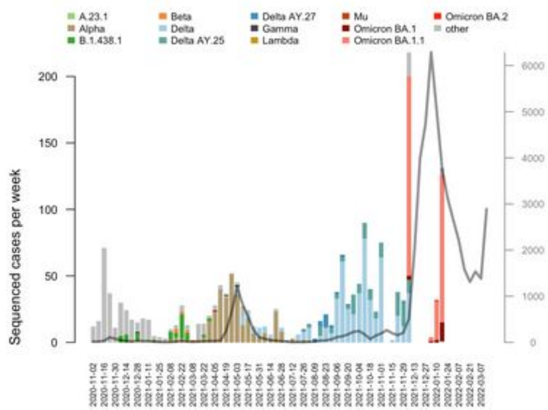
BC AB SK MB ON QC **NS** NB NL

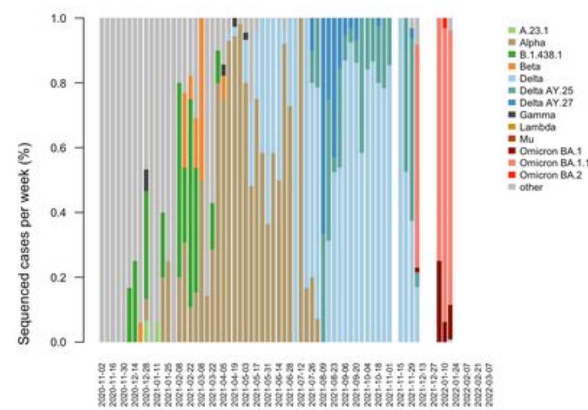
Nova Scotia

Additional up-to-date COVID data for this province can be found here:
https://experience.arcgis.com/experience/204d6ed723244dfbb763ca3f913c5cad

Hide

```
plot.variants(region='Nova Scotia')
plot.variants(region='Nova Scotia', scaled=T)
```

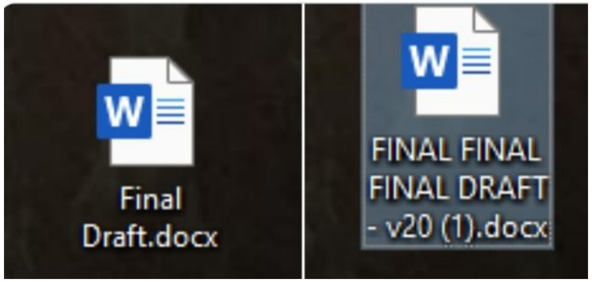


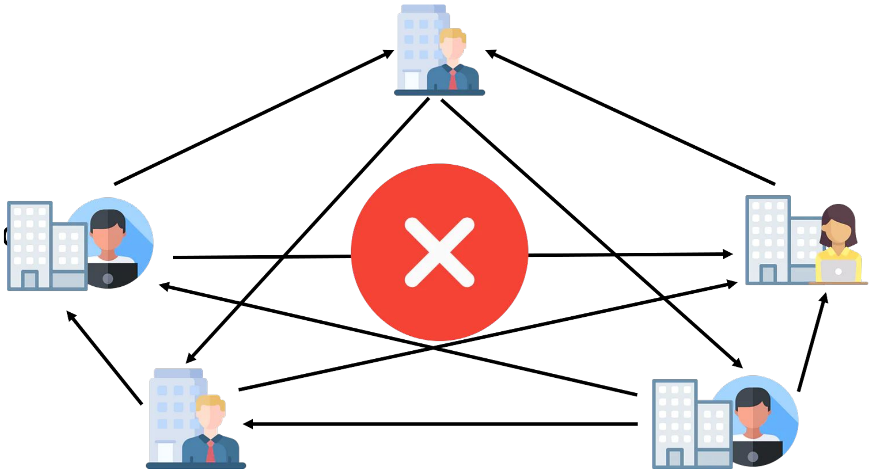


https://covarr-net.github.io/duotang/duotang.html#

Use standard version control systems

- Ever had a nightmare of versioning even when just you?
- Add more people and the chaos grows exponentially!





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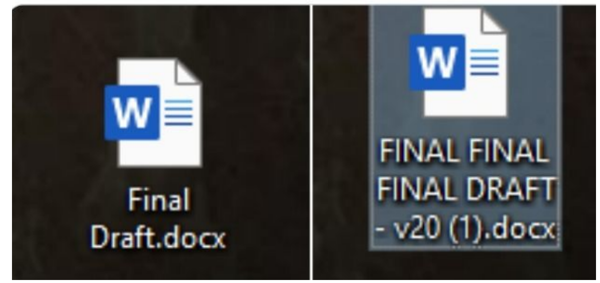
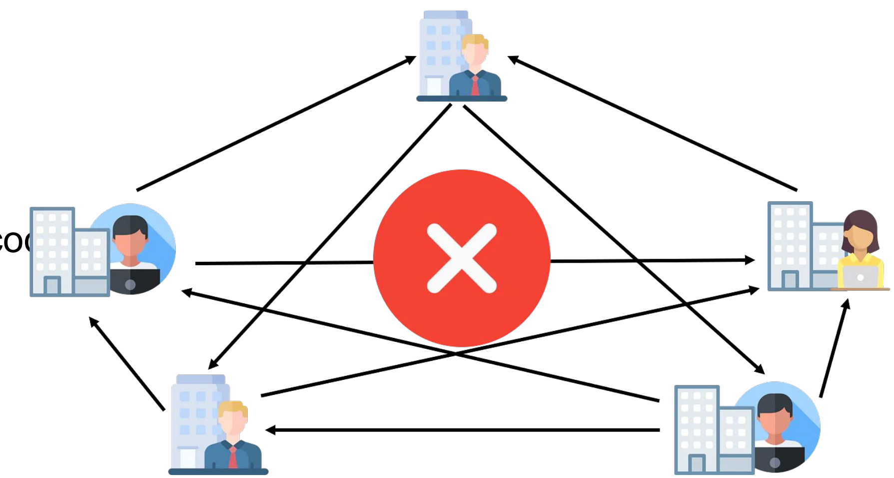
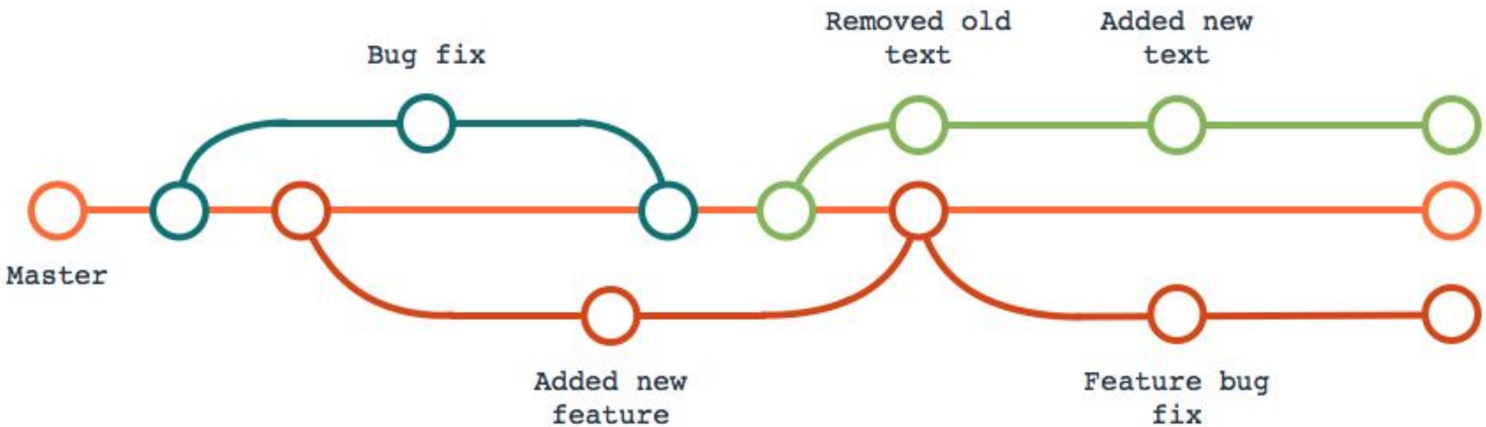


Version control let's you:

- Revert mistakes
- Acts as a comprehensive backup
- Let's you maintain multiple versions of your analysis
- Let's you compare different versions of your co
- Track down the who/what broke the analysis
- Work out why you did something in the past
- Build on someone else's work
- Share your own work
- Experiment without risk

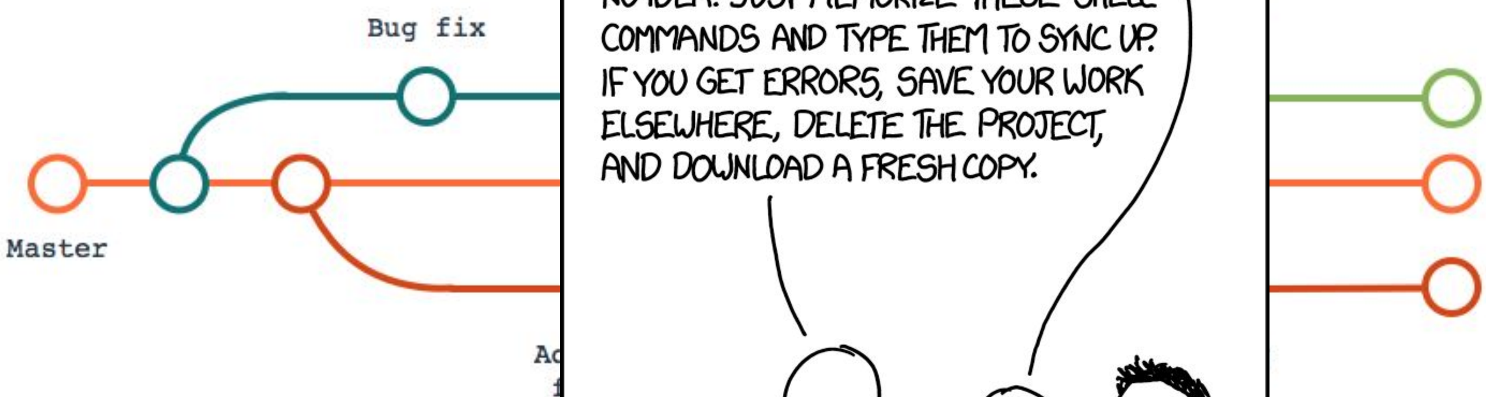


Git Version Control



- Most popular
- Decentralised
- Designed for
- GitLab/GitHub Services

Git Version Control



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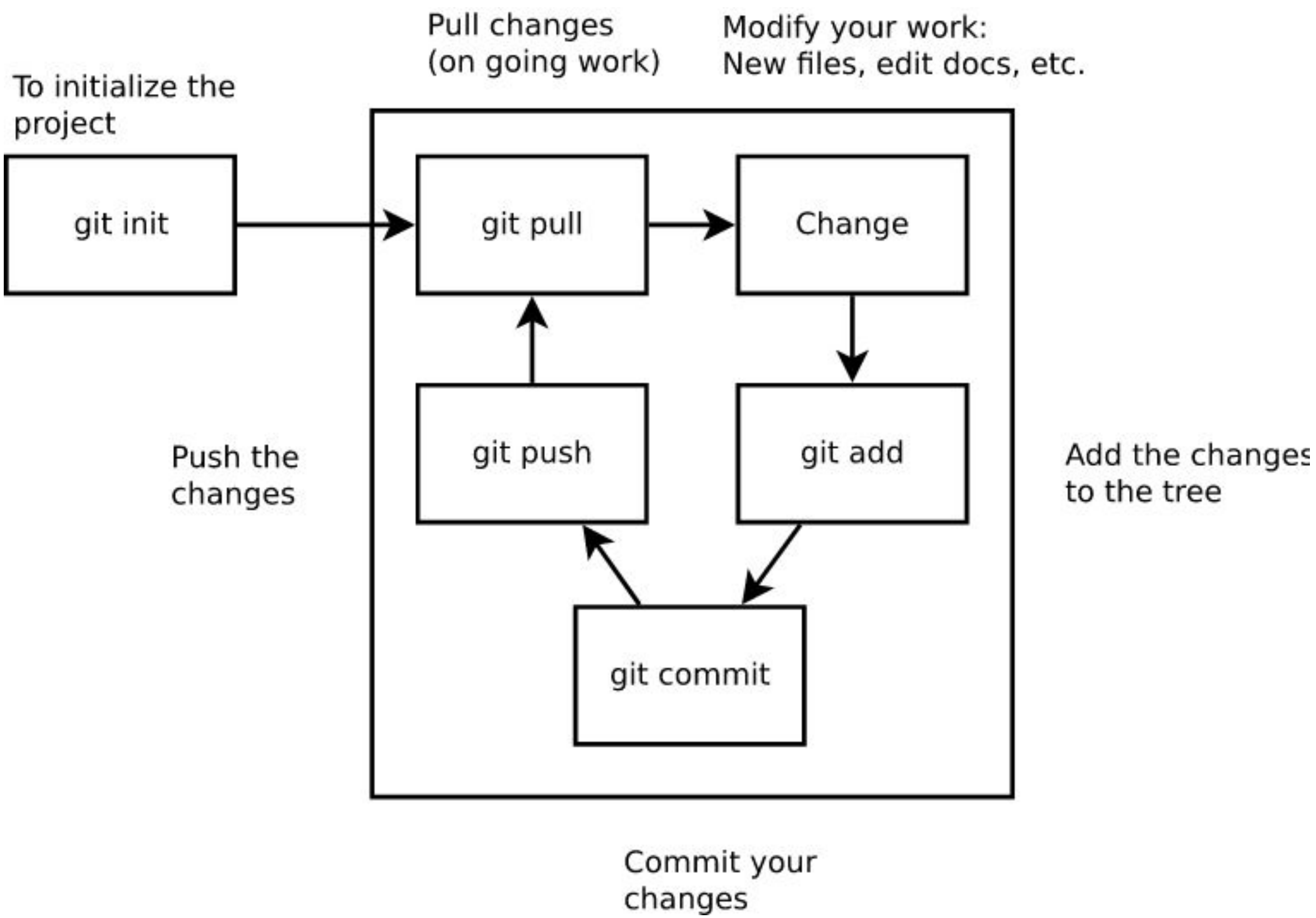
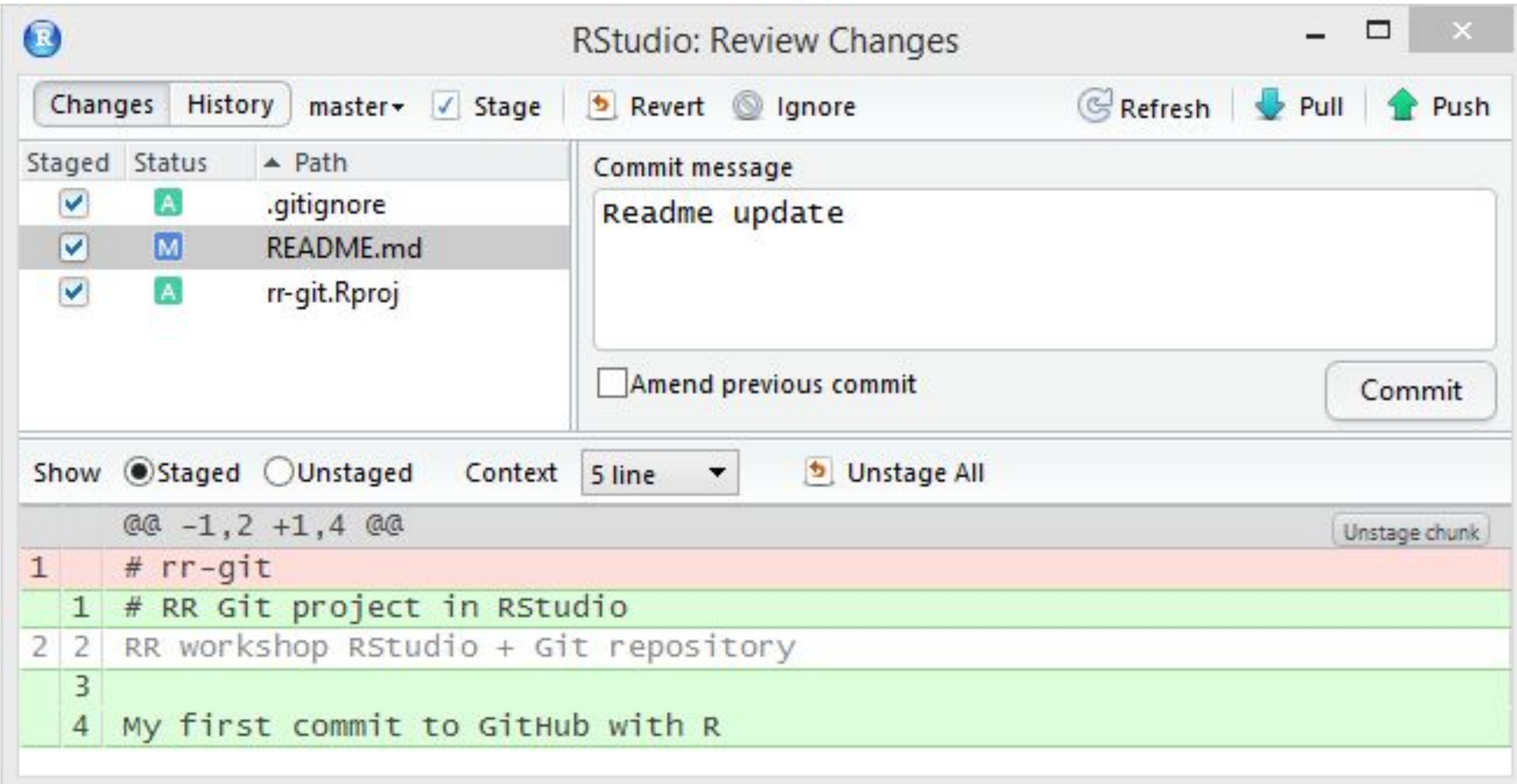
Git Workflow



https://uscbiostats.github.io/PM566/slides/02-version-control/slides.html#8

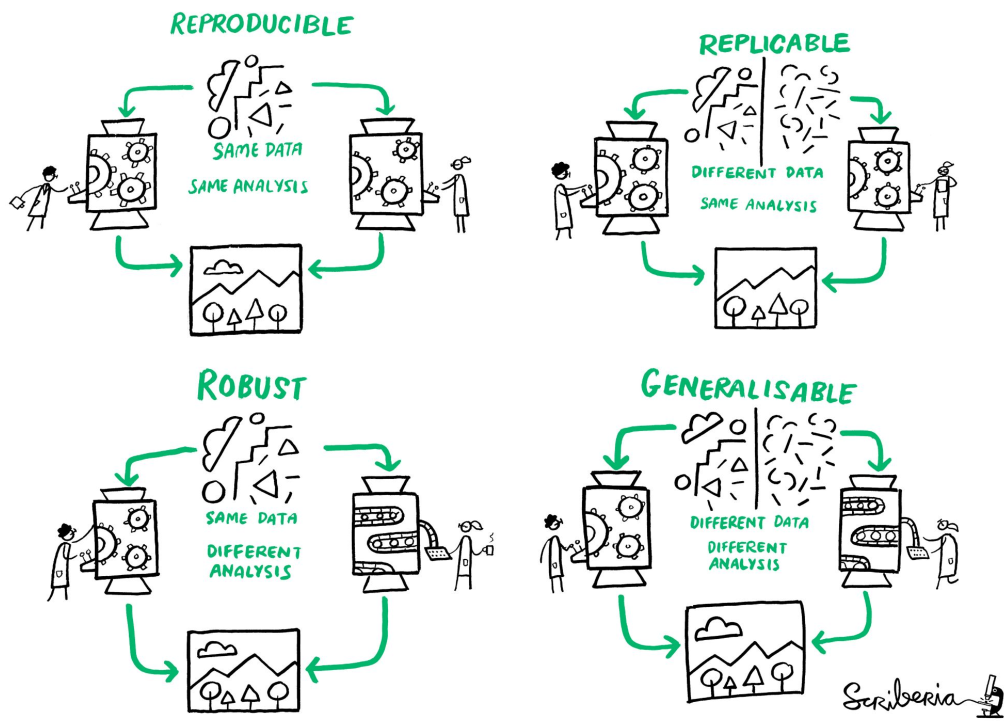
Git is integrated into Rstudio!



Combine Git+Rmd Notebooks for Reproducibility

1. Add analysis to notebook
2. Add changes to git
3. Find out you made a mistake
4. Revert changes

1. Share notebook with collaborator
2. They make changes
3. You make changes
4. Merge changes into single analysis



Summary

- Overview of course: Database/EMR/Imaging/Signal
- Main assessments: practicals, journal article presentations, research proposal
- Data science is statistics with an EDA/Inductive/Data-focused Spin
- Health Data Science is a massive and growing area with lots of opportunity and challenges
- R is a powerful and useful tool for health data science
- Reproducibility is vital to good ~~health data~~ science
- Rstudio, Rmarkdown notebooks and Git based version control facilitate that reproducibility

Friday’s Practical

- Will go over the practical use of R, Rstudio, Rmd Notebooks, Git
- Try and install rstudio, git, and rmarkdown beforehand.
- 1st practical will not contribute to your course grade

Wednesday’s Journal Articles

- **Reproducibility in machine learning for health research: Still a ways to go**

  Matthew B. A. McDermott Shirly Wang Nikki Marinsek Rajesh Ranganath Luca Foschini Marzyeh Ghassemi
  Science Translational Medicine • 24 Mar 2021 • Vol 13, Issue 586 • DOI: 10.1126/scitranslmed.abb1655

- **A Beginner's Guide to Conducting Reproducible Research**

  Jesse M. Alston, Jessica A. Rick First published: 15 January 2021 https://doi.org/10.1002/bes2.1801