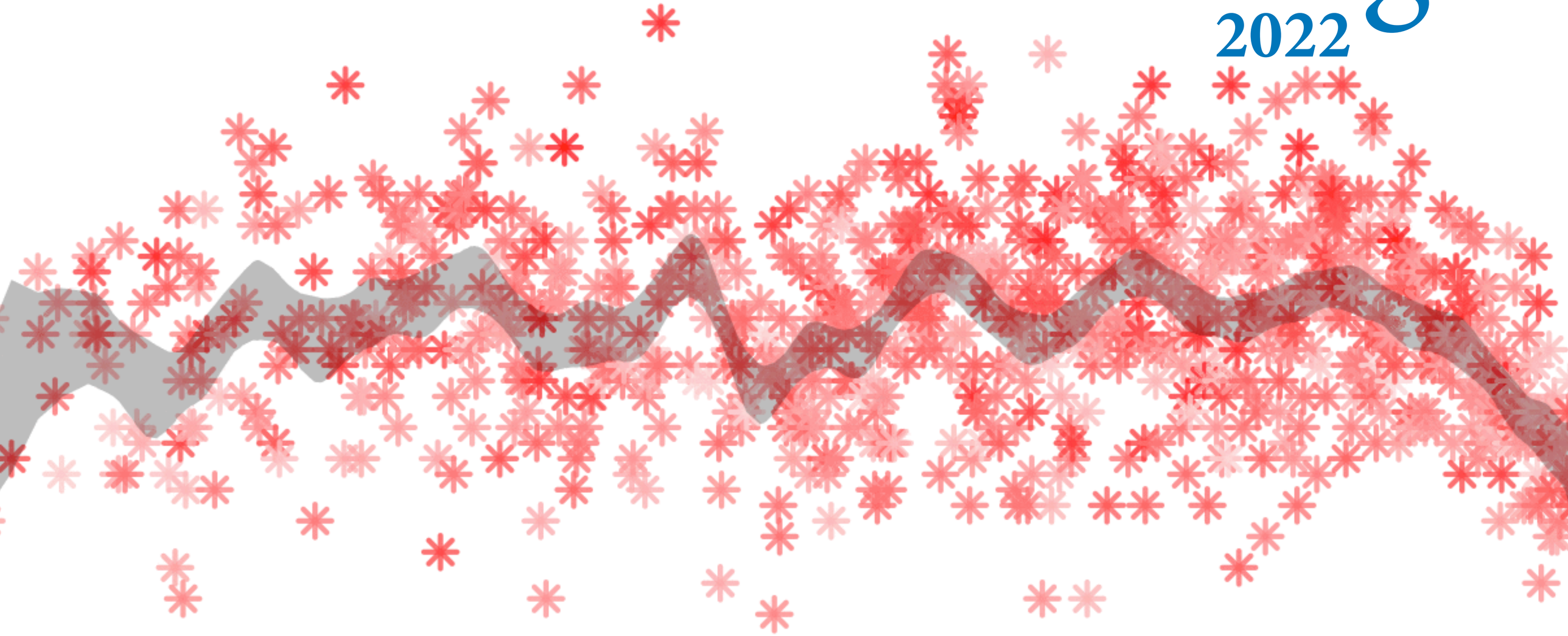
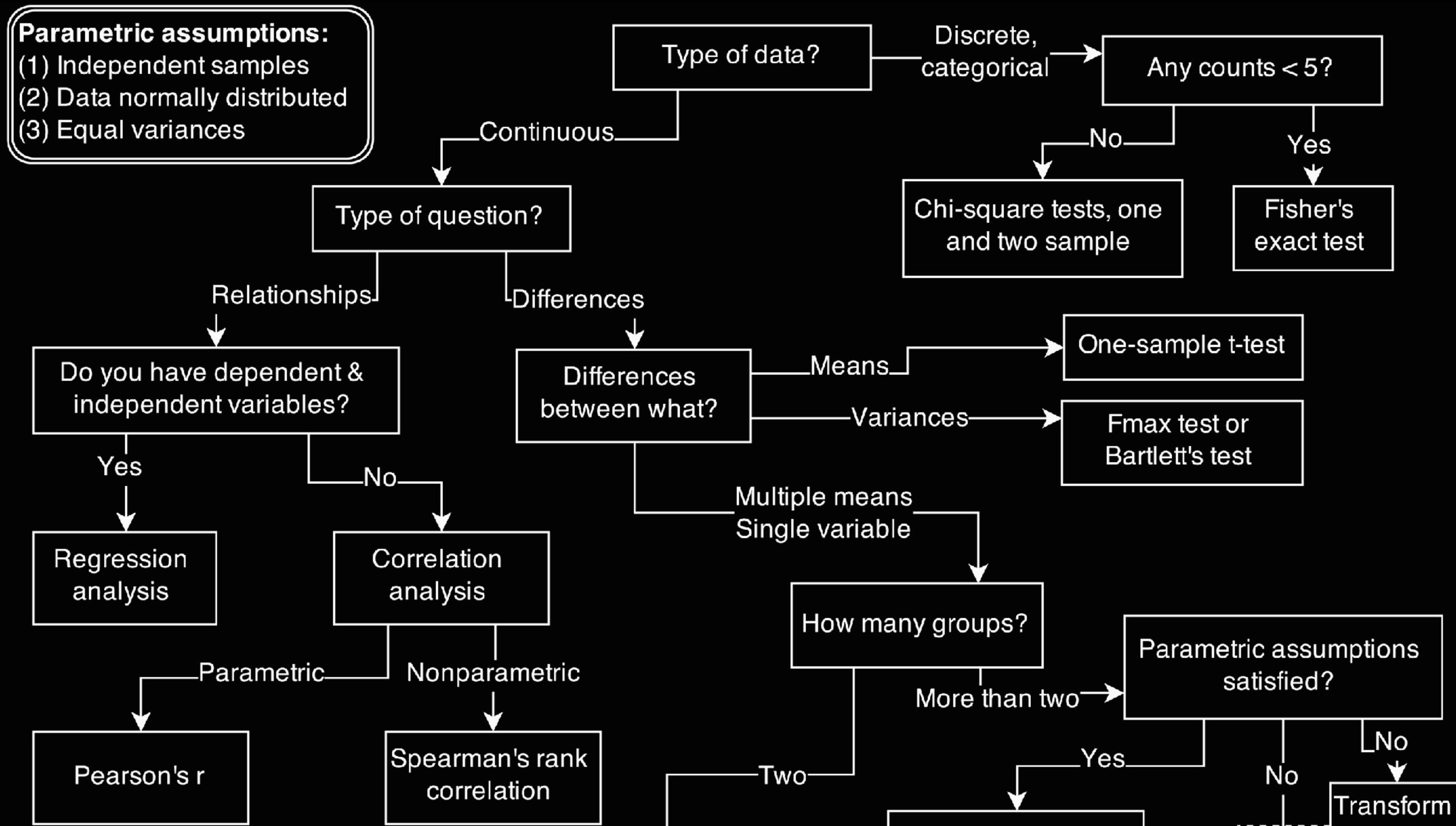
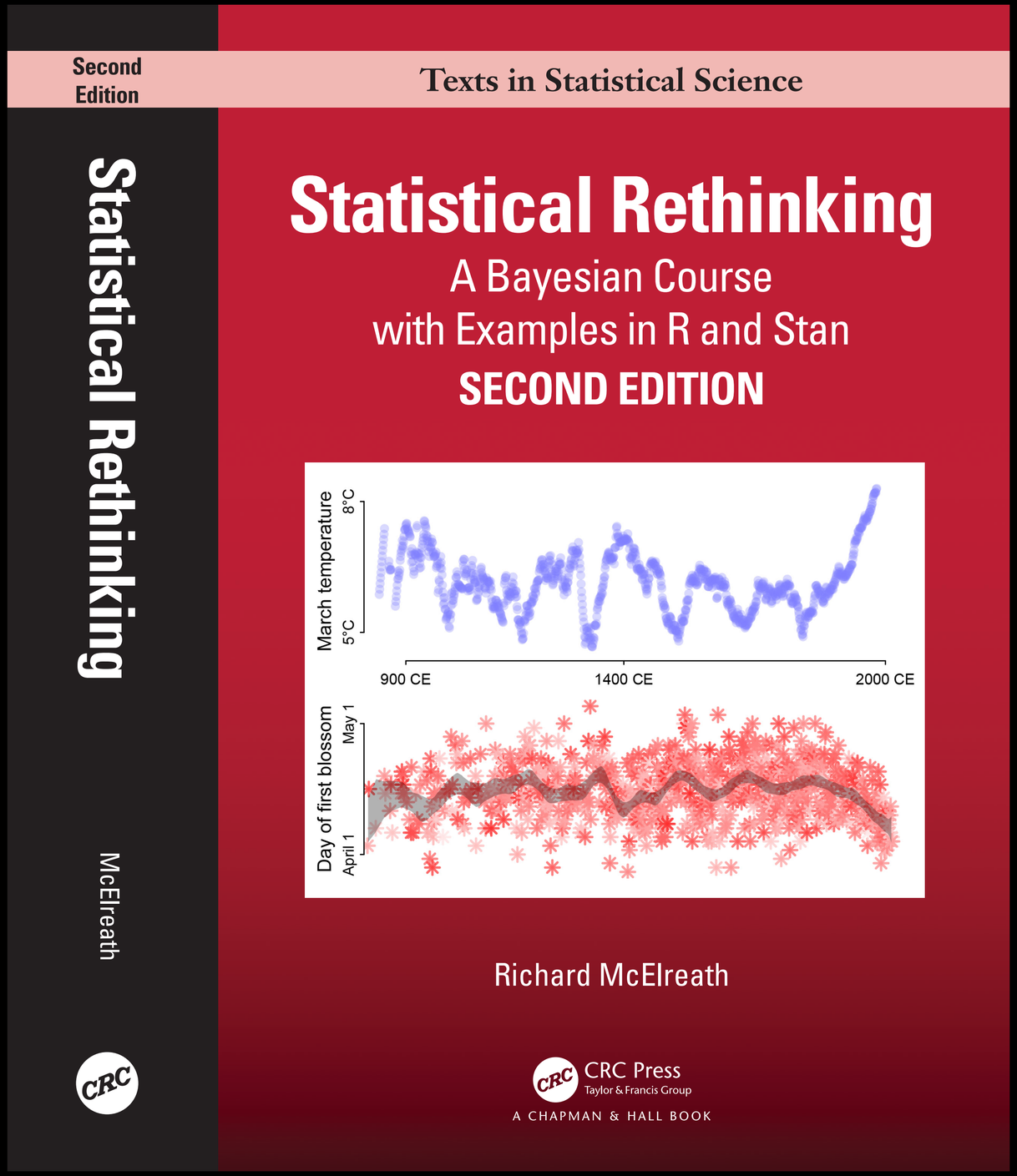
Statistical Rethinking

2022



(1) The Golem of Prague


Parametric assumptions:
(1) Independent samples
(2) Data normally distributed
(3) Equal variances
Type of data?
Discrete, categorical
Any counts < 5?
No
Yes
Chi-square tests, one and two sample
Fisher's exact test
Continuous
Type of question?
Relationships
Differences
Do you have dependent & independent variables?
Yes
No
Regression analysis
Correlation analysis
Parametric
Nonparametric
Pearson's r
Spearman's rank correlation
Differences between what?
Means
One-sample t-test
Variances
Fmax test or Bartlett's test
Multiple means Single variable
How many groups?
Two
More than two
Parametric assumptions satisfied?
Yes
No
No
Transform



Rethinking the role of statistical analysis in research

20 lectures

GOLEMS

OWLS

DAGS

Prague 16th century

Art from: “Breath of Bones: A Tale of the Golem” (2014)

Golems

Clay robots

Powerful

No wisdom or foresight

Dangerous

“Breath of Bones: A Tale of the Golem” (2014)

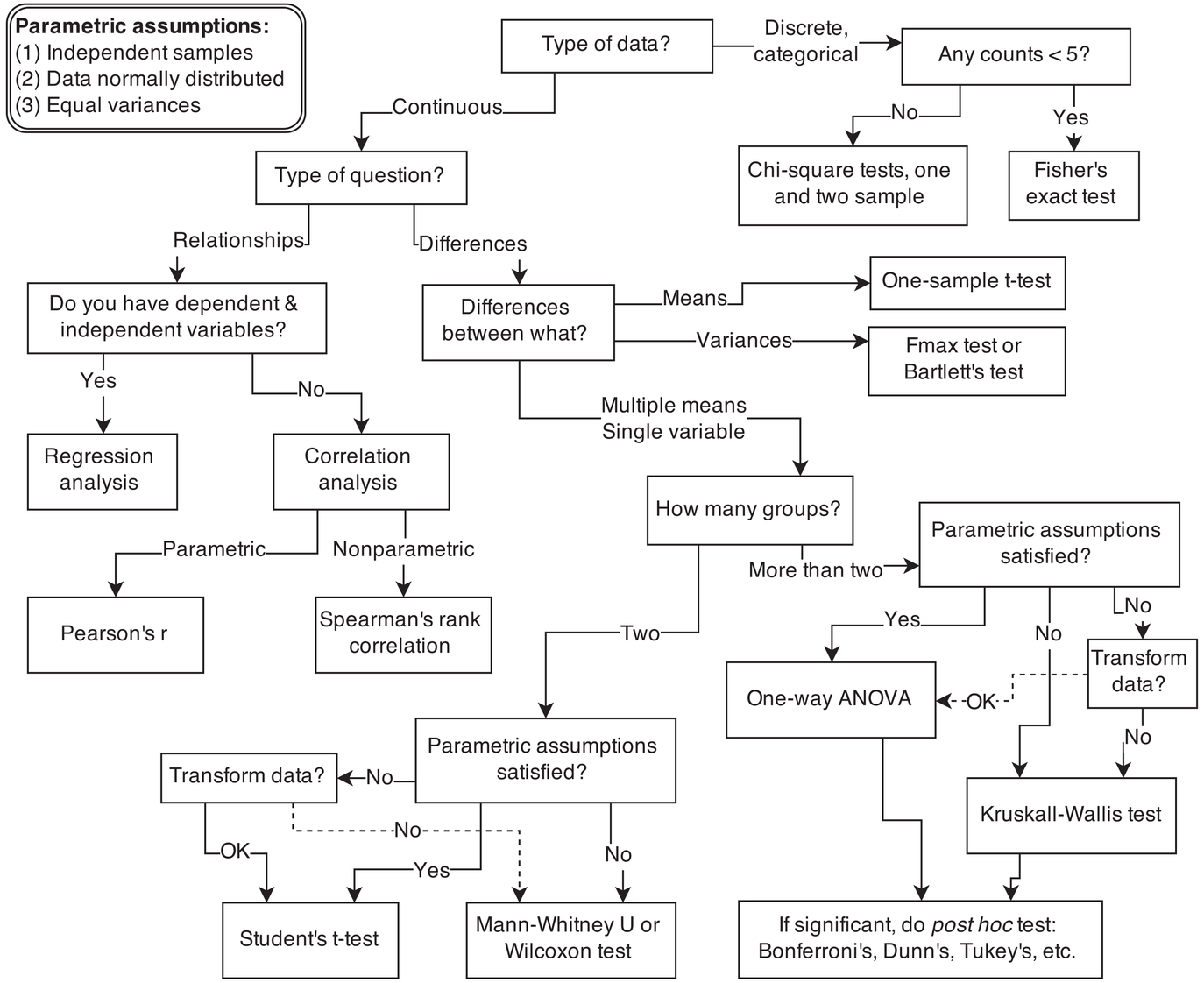
Statistical Models

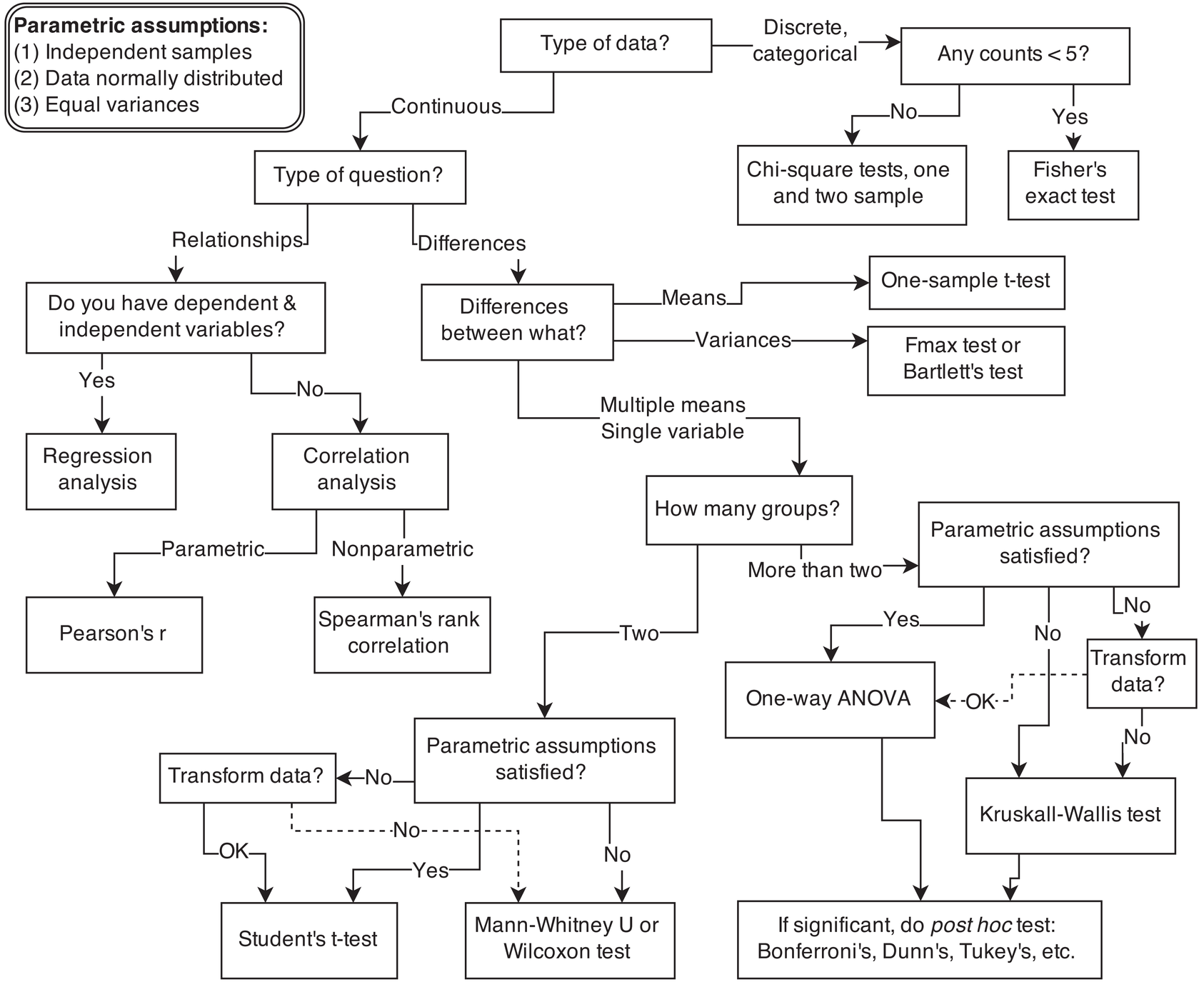
Clay robots

Powerful

No wisdom or foresight

Dangerous

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Differences between what?
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Variances
Fmax test or Bartlett's test
Multiple means Single variable
How many groups?
Two
More than two
Parametric assumptions satisfied?
Yes
No
One-way ANOVA
OK
Transform data?
No
Kruskall-Wallis test
Parametric assumptions satisfied?
Transform data?
No
OK
No
Yes
No
Student's t-test
Mann-Whitney U or Wilcoxon test
If significant, do post hoc test: Bonferroni's, Dunn's, Tukey's, etc.

Figure 1.1

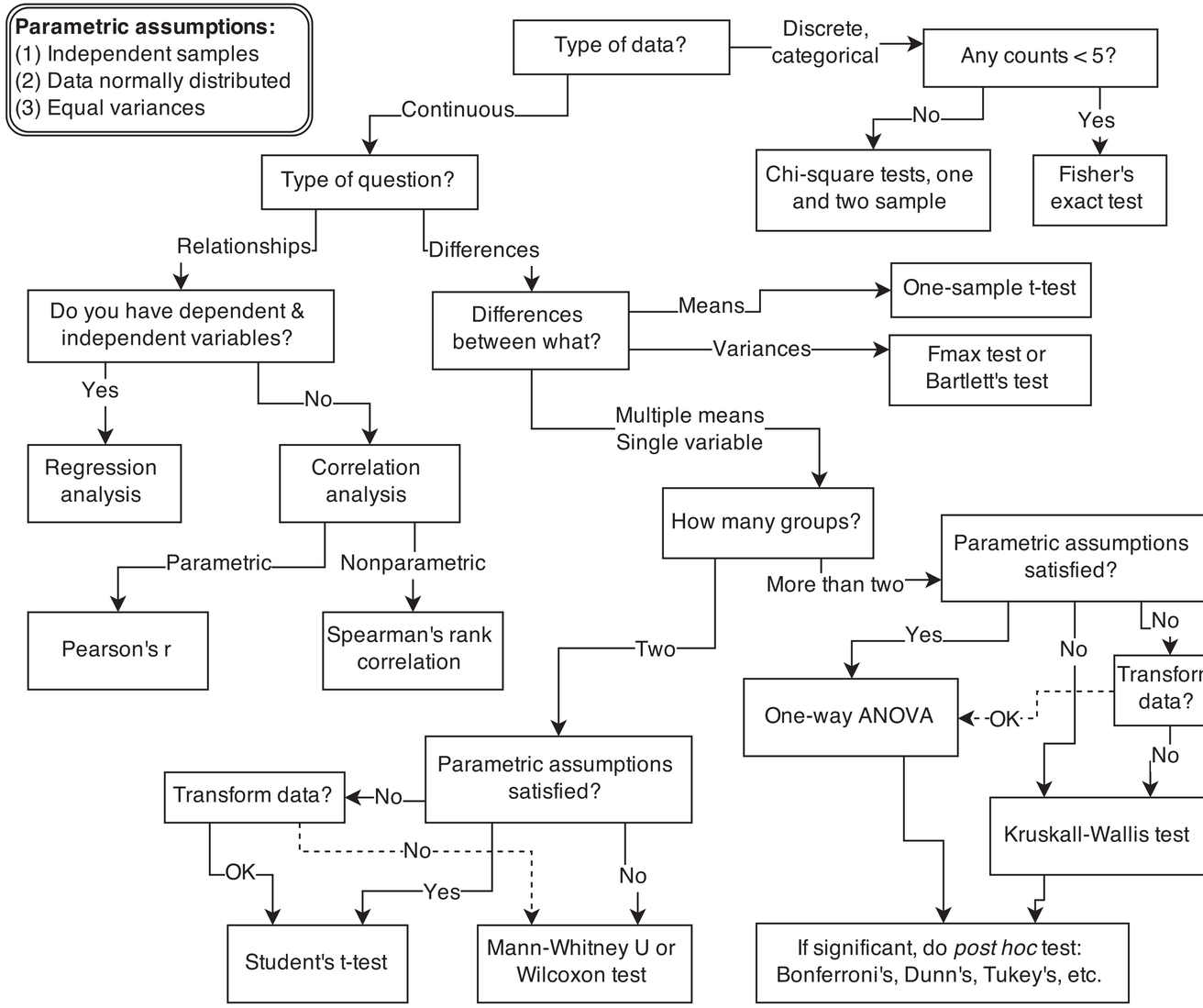
Statistical Models

Incredibly limiting

Focus on rejecting null hypotheses instead of research hypotheses

Relationship between hypothesis and test not clear

Industrial framework



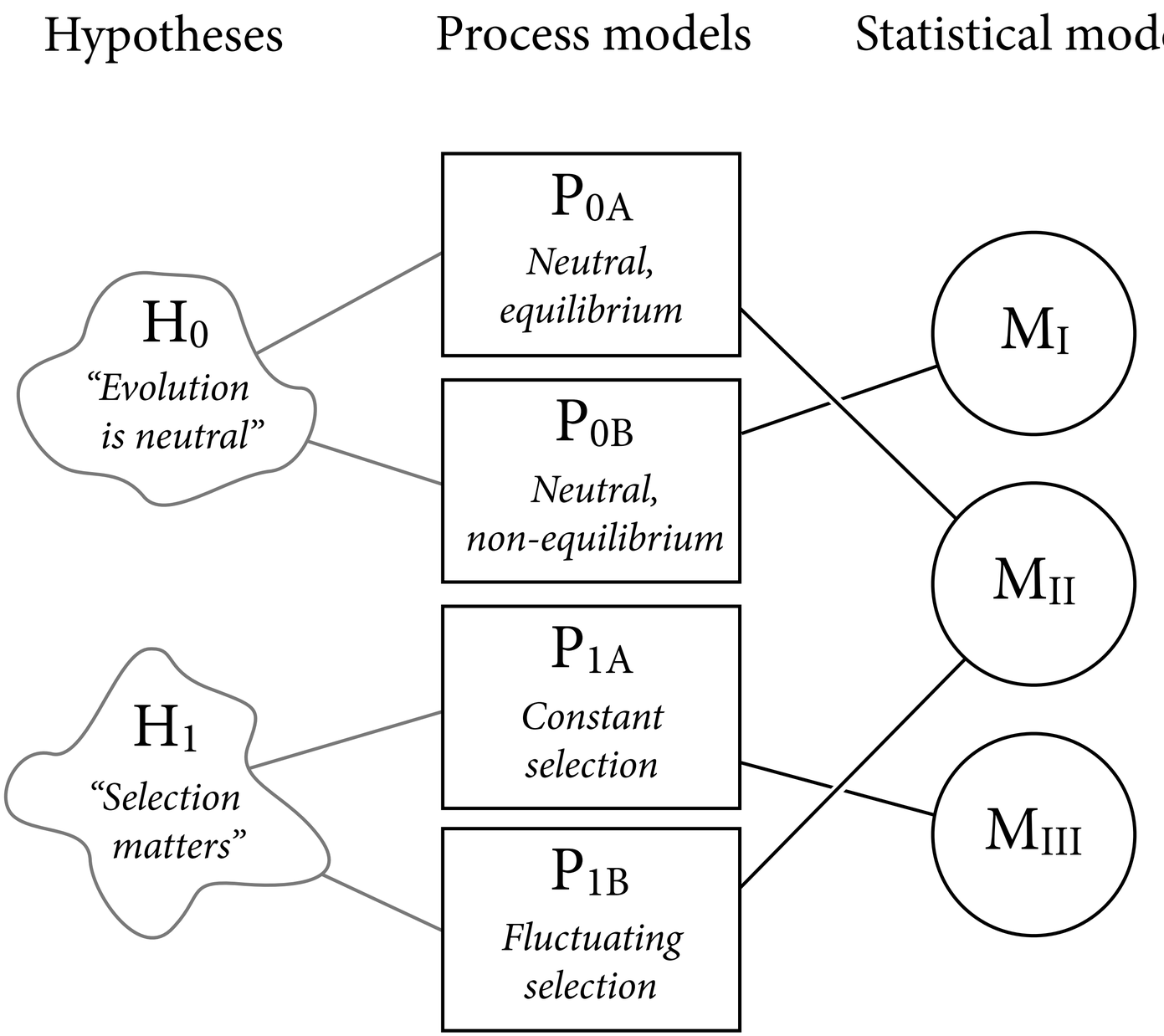

Hypotheses
Process models
Statistical models
H0
"Evolution is neutral"
H1
"Selection matters"
P0A
Neutral, equilibrium
P0B
Neutral, non-equilibrium
P1A
Constant selection
P1B
Fluctuating selection
MI
MII
MIII

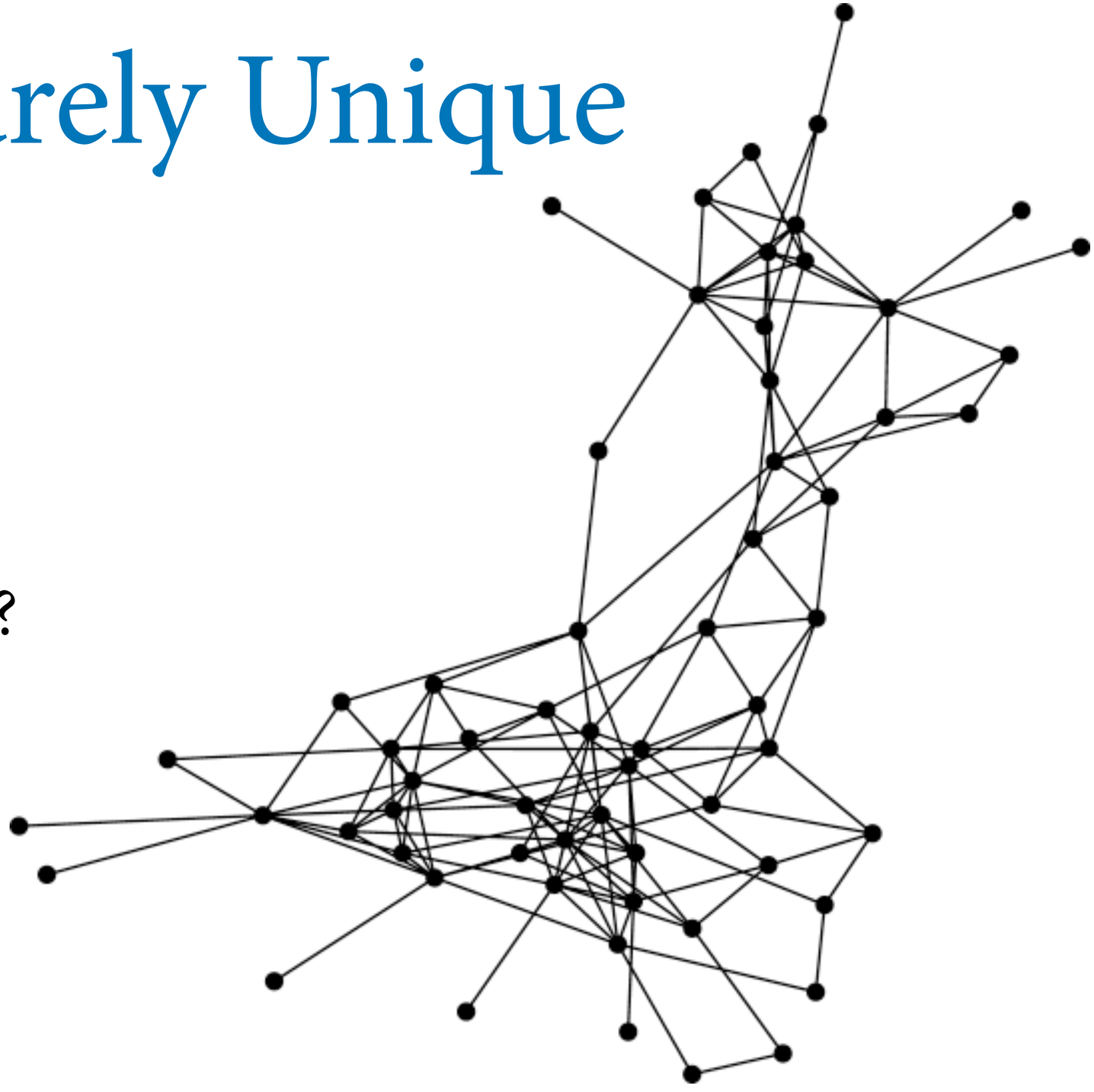
Figure 1.2

Null Models Rarely Unique

Null phylogeny?

Null ecological community?

Null social network?



Hypotheses and Models

Research requires more than than tiny null robots

Also requires:

Precise process model(s)

Statistical model (procedure, golem) justified by implications of process model(s) and question (estimand)

OWLS

HOW TO DRAW AN OWL

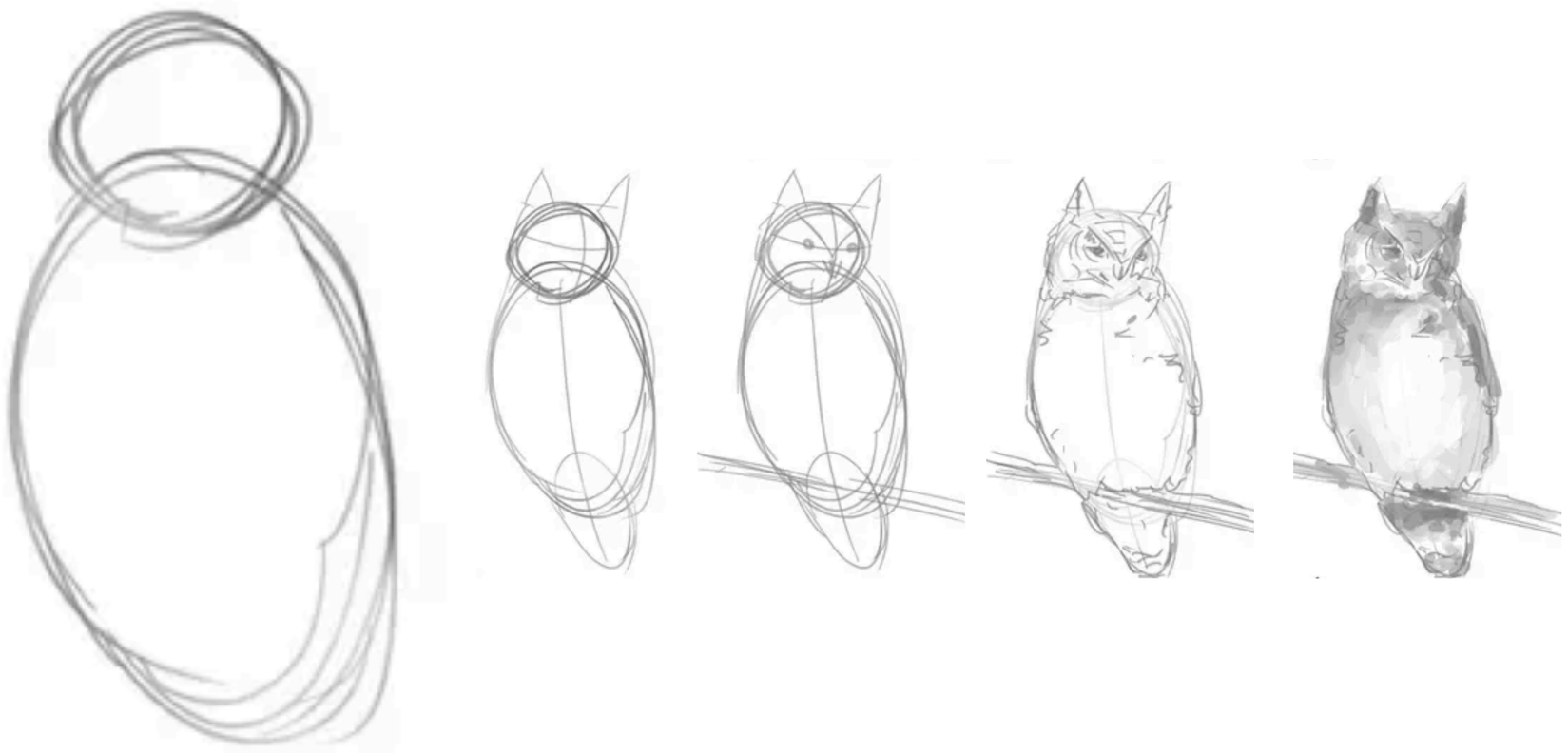
1. Draw some circles

HOW TO DRAW AN OWL

1. Draw some circles

2. Draw the rest of the owl

HOW TO DRAW AN OWL



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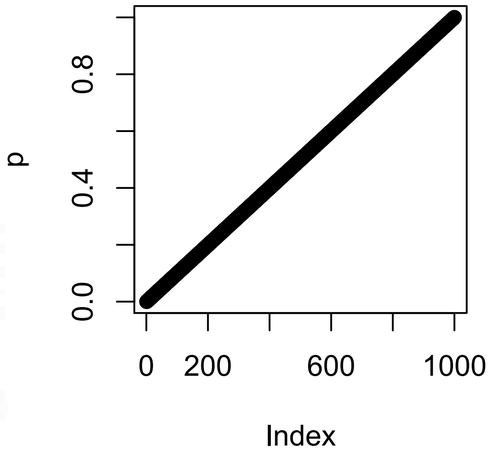
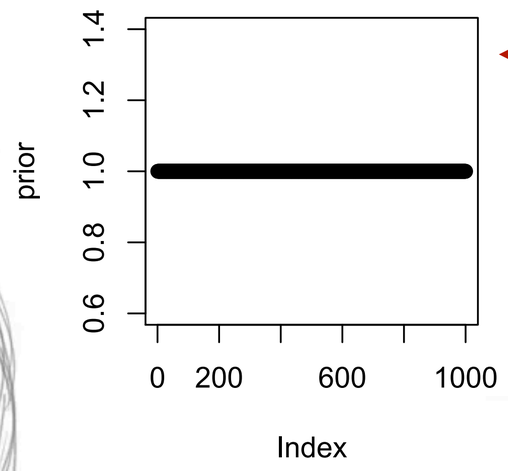
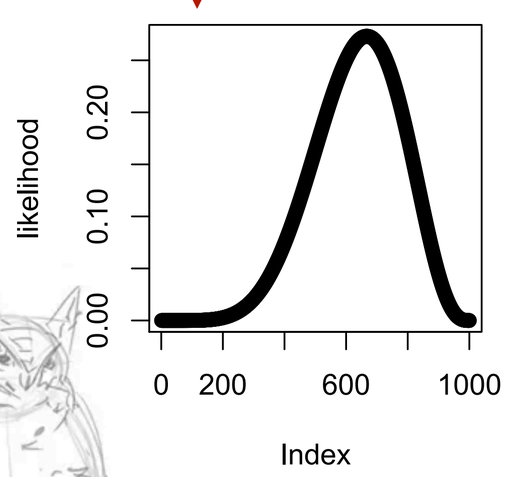
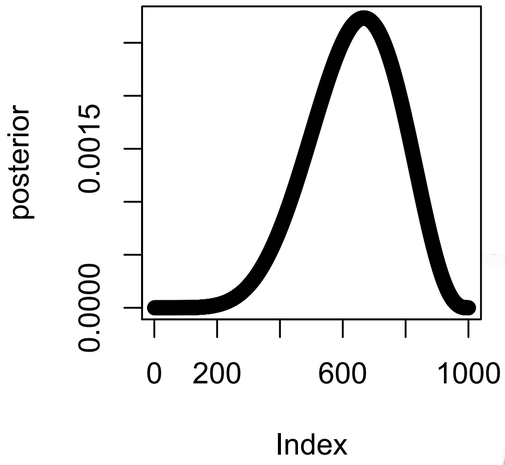
2. Draw the rest of the owl




```
p_grid <- seq( from=0 , to=1 , length.out=1000 )
prob_p <- rep( 1 , 1000 )
prob_data <- dbinom( 6 , size=9 , prob=p_grid )
posterior <- prob_data * prob_p
posterior <- posterior / sum(posterior)
```







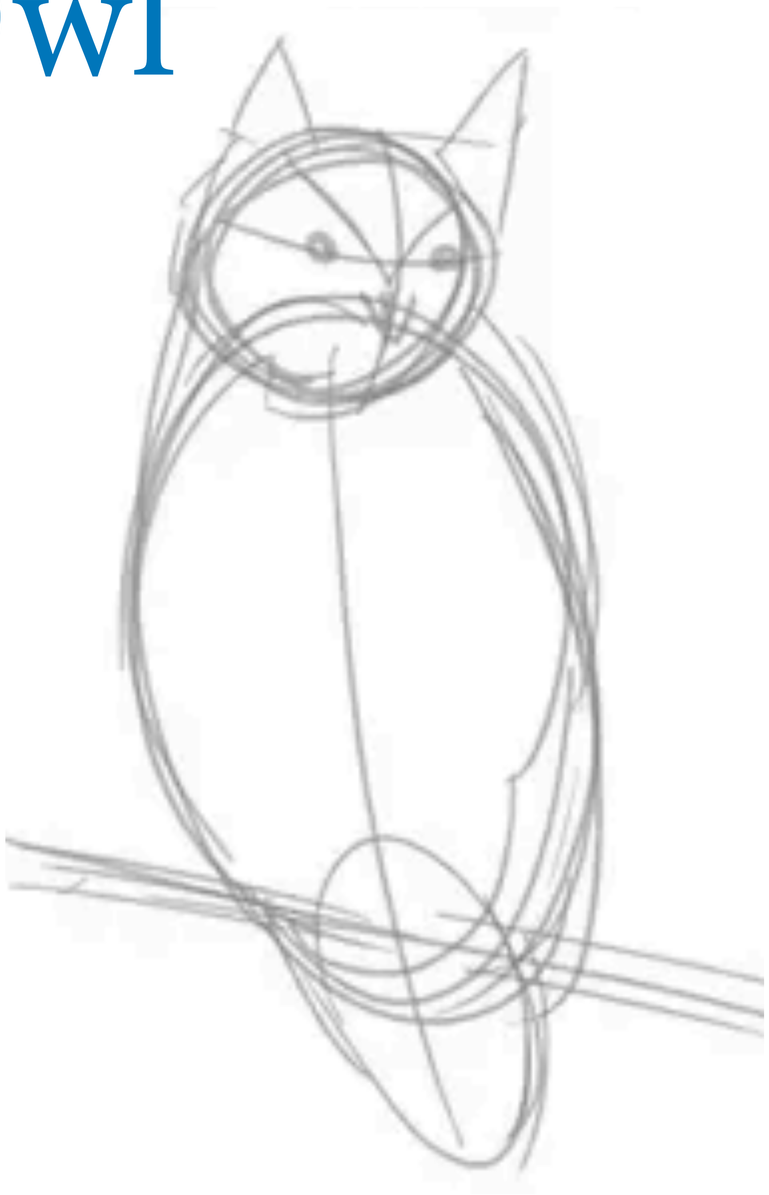
Drawing the Bayesian Owl

Three modes:

Understand what you are doing

Document your work, reduce error

Respectable scientific workflow



Drawing the Bayesian Owl

1. Theoretical estimand
2. Scientific (causal) model(s)
3. Use 1 & 2 to build statistical model(s)
4. Simulate from 2 to validate 3 yields 1
5. Analyze real data

Saturn, Galileo 1610

Drawing the Bayesian Owl

Bayesian approach is permissive, flexible

Express uncertainty at all levels

Direct solutions for measurement error, missing data

Focus on scientific modeling

DAGS


BAYES
FREQUENTISM

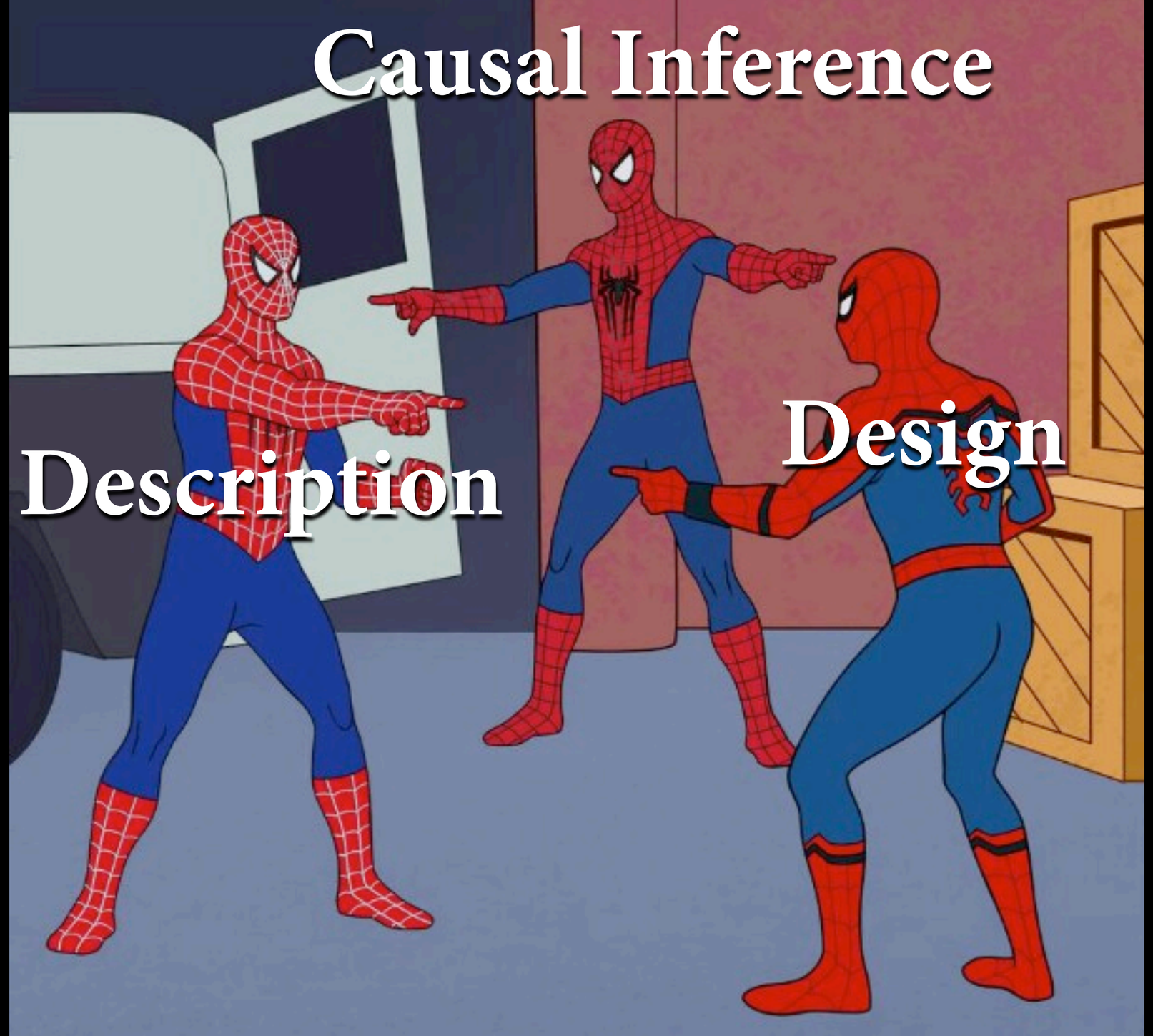

CAUSAL
INFERENCE
imgflip.com

Science Before Statistics

For **statistical models** to produce scientific insight, they require additional **scientific (causal) models**

The **reasons** for a statistical analysis are not found in the data themselves, but rather in the **causes** of the data

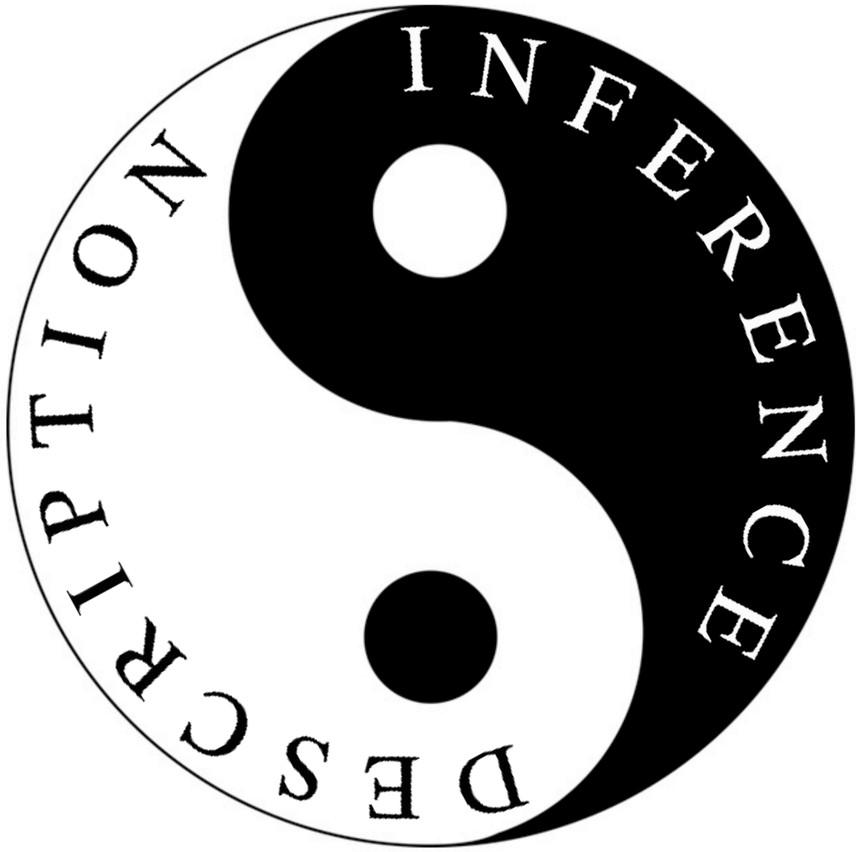
The **causes** of the data cannot be extracted from the data alone. No causes in; no causes out.


Causal Inference
Description
Design

Causes Are Not Optional

Even when goal is **descriptive**, need causal model

The **sample** differs from the **population**; describing the population requires causal thinking

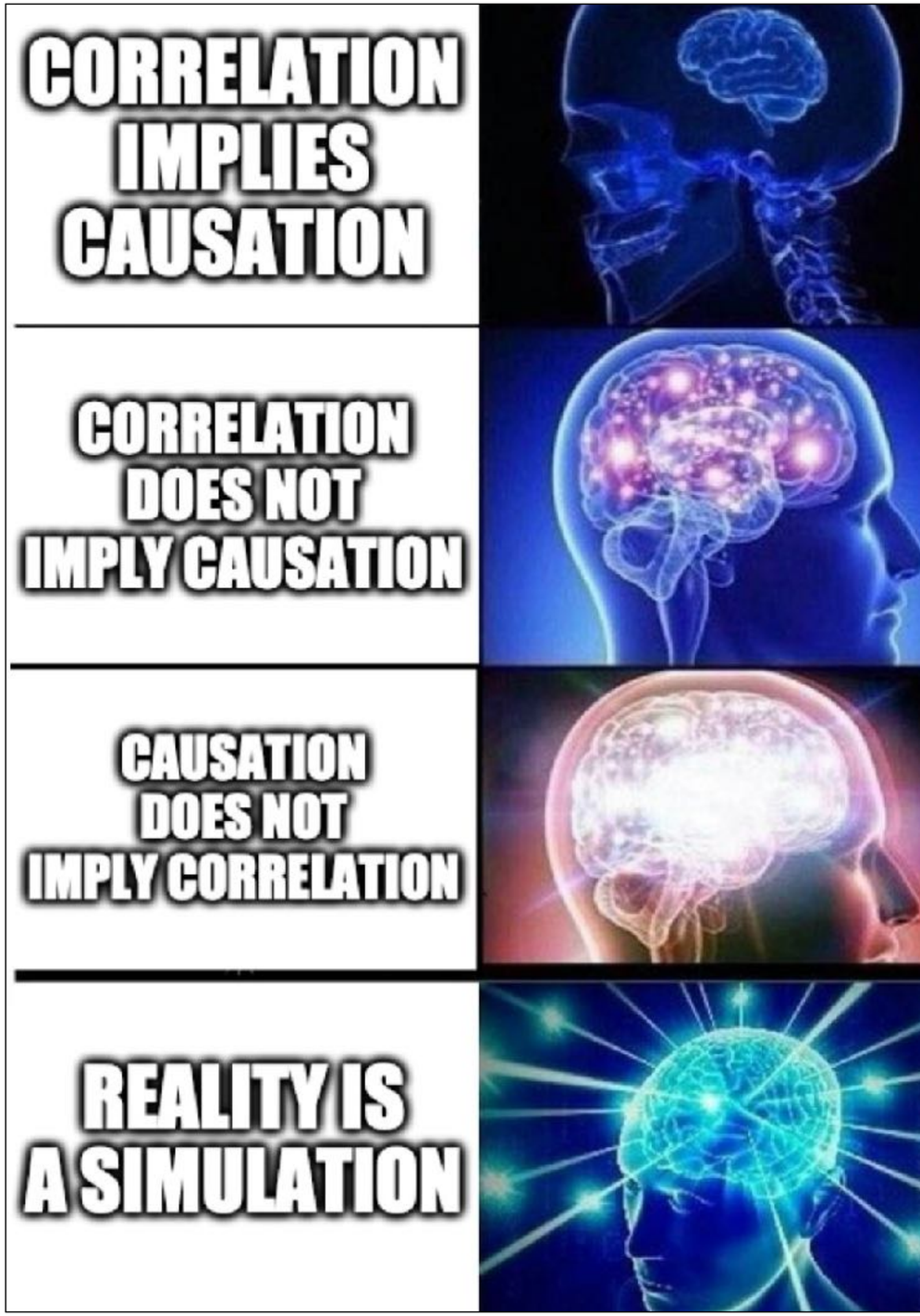


What is Causal Inference?

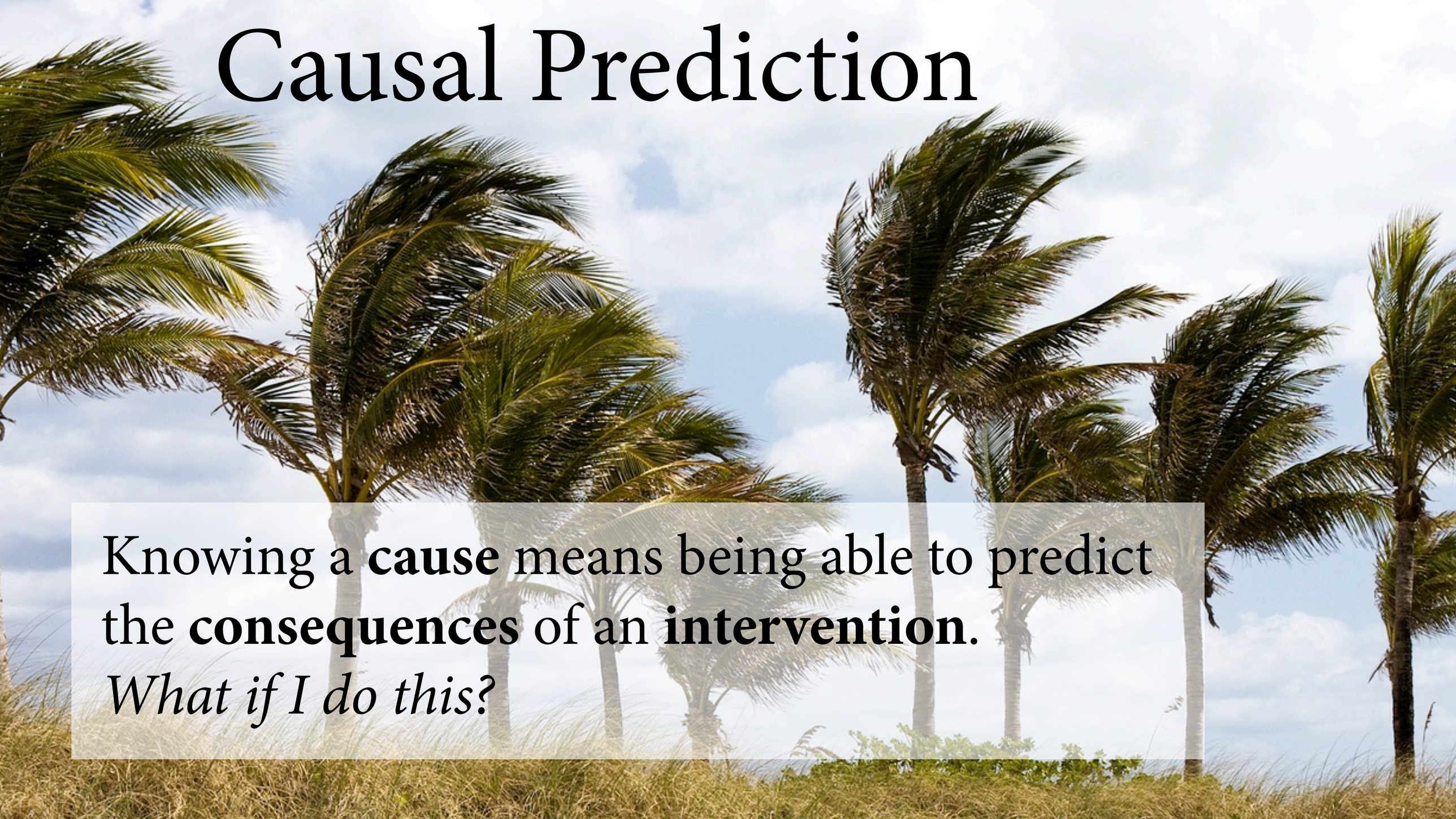
More than **association** between variables

Causal inference is **prediction** of intervention

Causal inference is **imputation** of missing observations

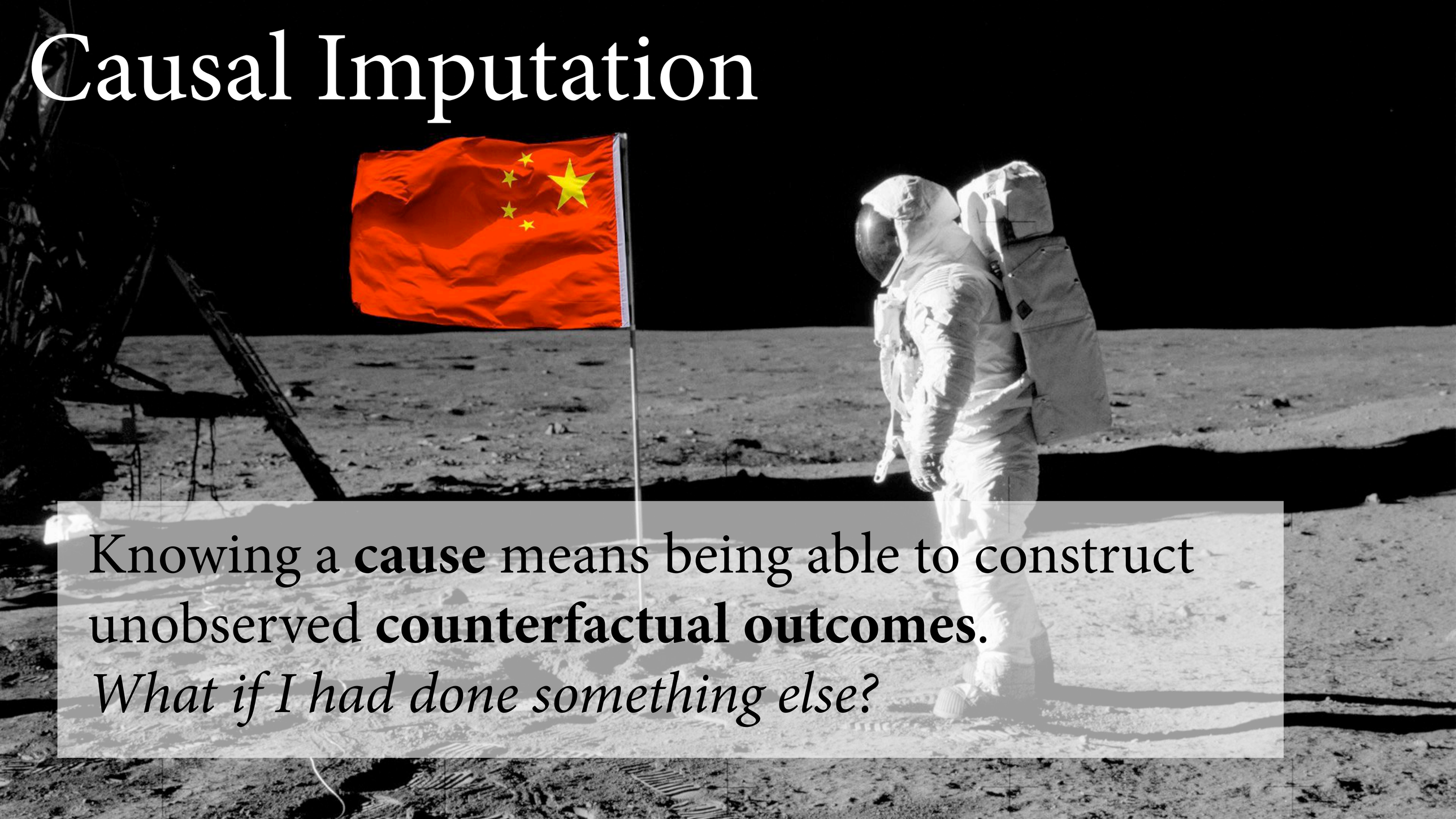


Causal Prediction



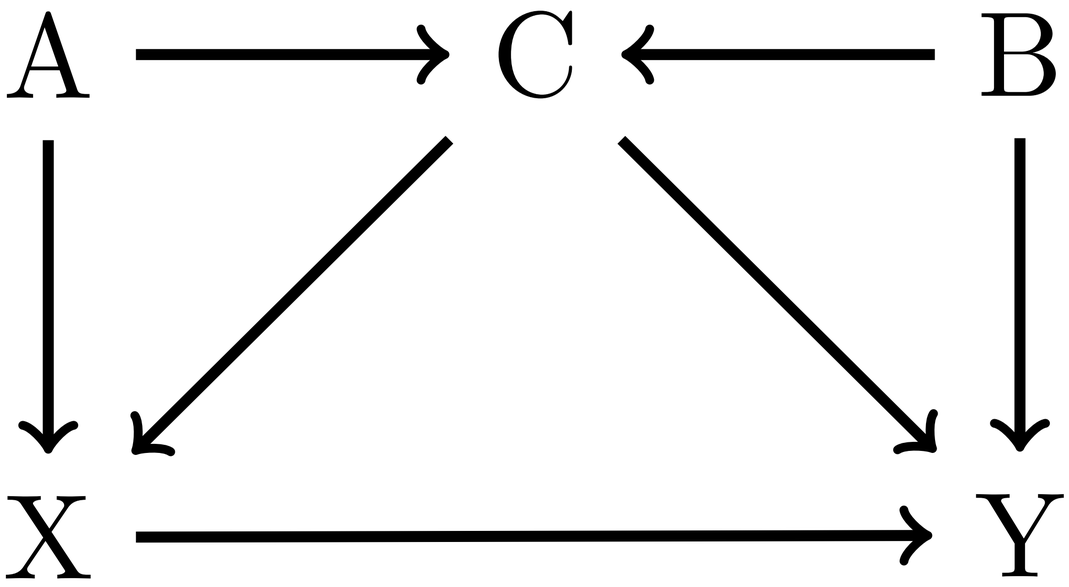
Knowing a **cause** means being able to predict the **consequences** of an **intervention**.
What if I do this?

Causal Imputation



Knowing a **cause** means being able to construct unobserved **counterfactual outcomes**.
What if I had done something else?

DAGs



Directed Acyclic Graphs

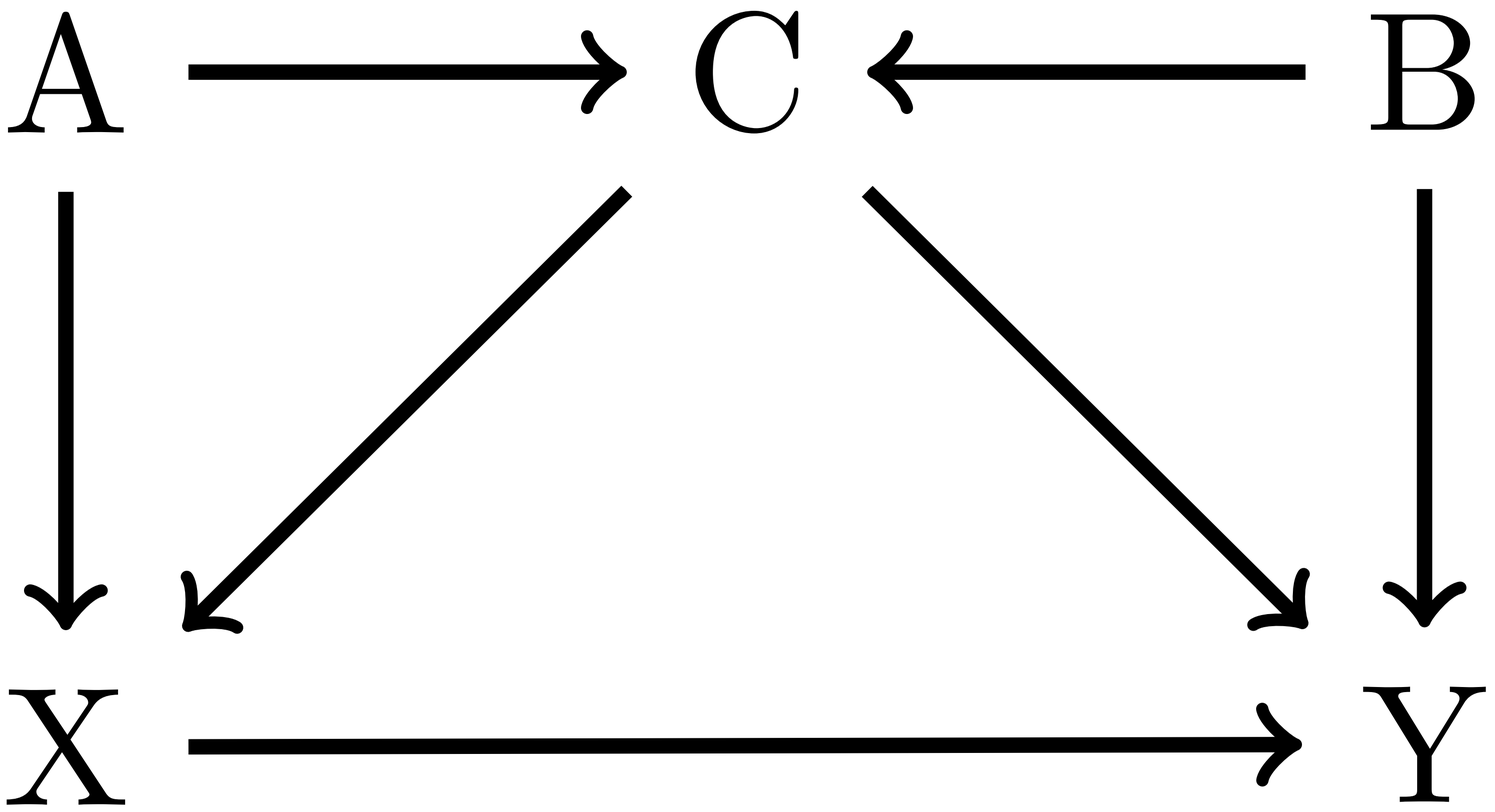
Heuristic causal models

Clarify scientific thinking

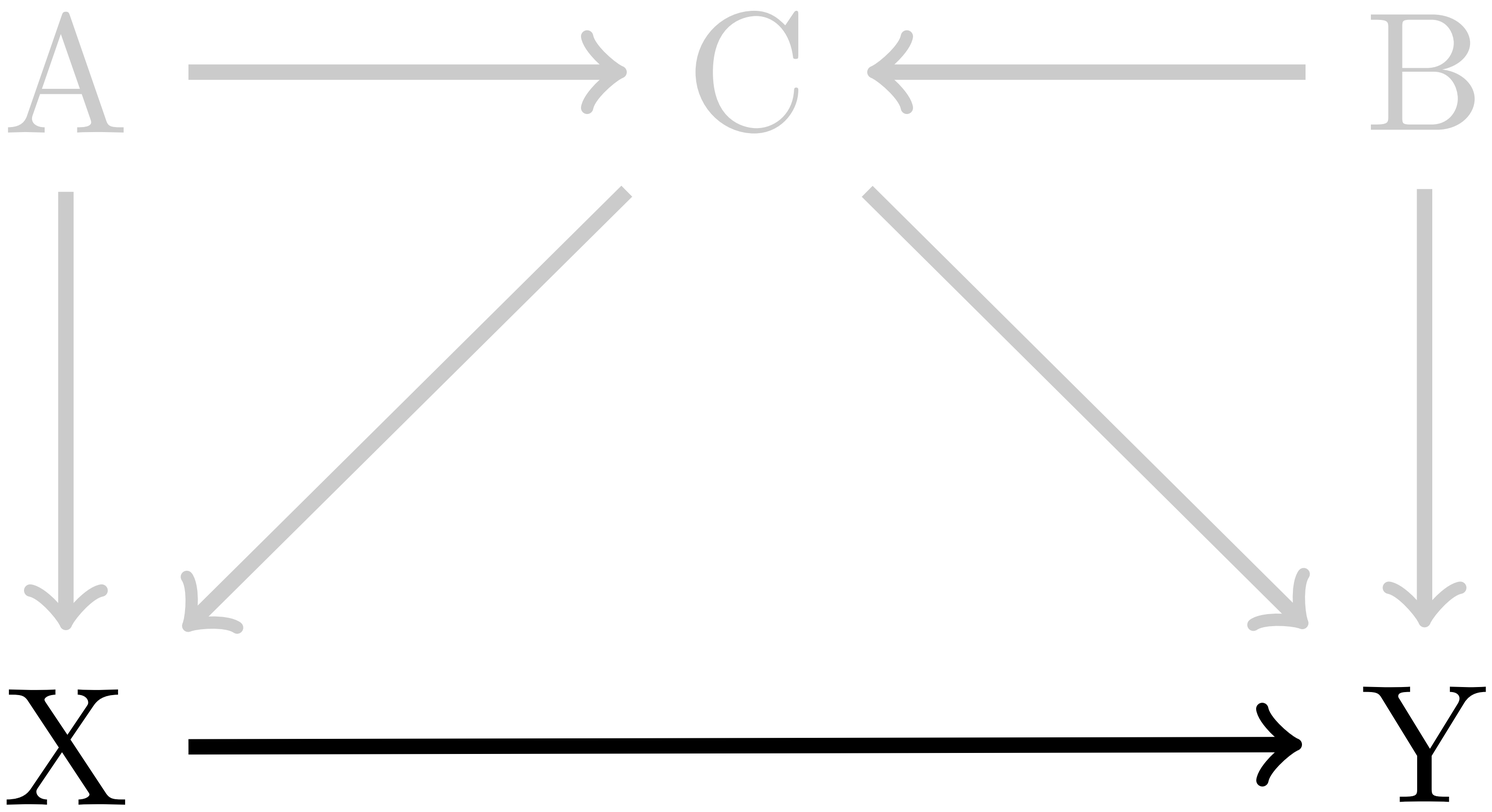
Analyze to deduce appropriate statistical models

Much more as the course develops

DAGs



DAGs



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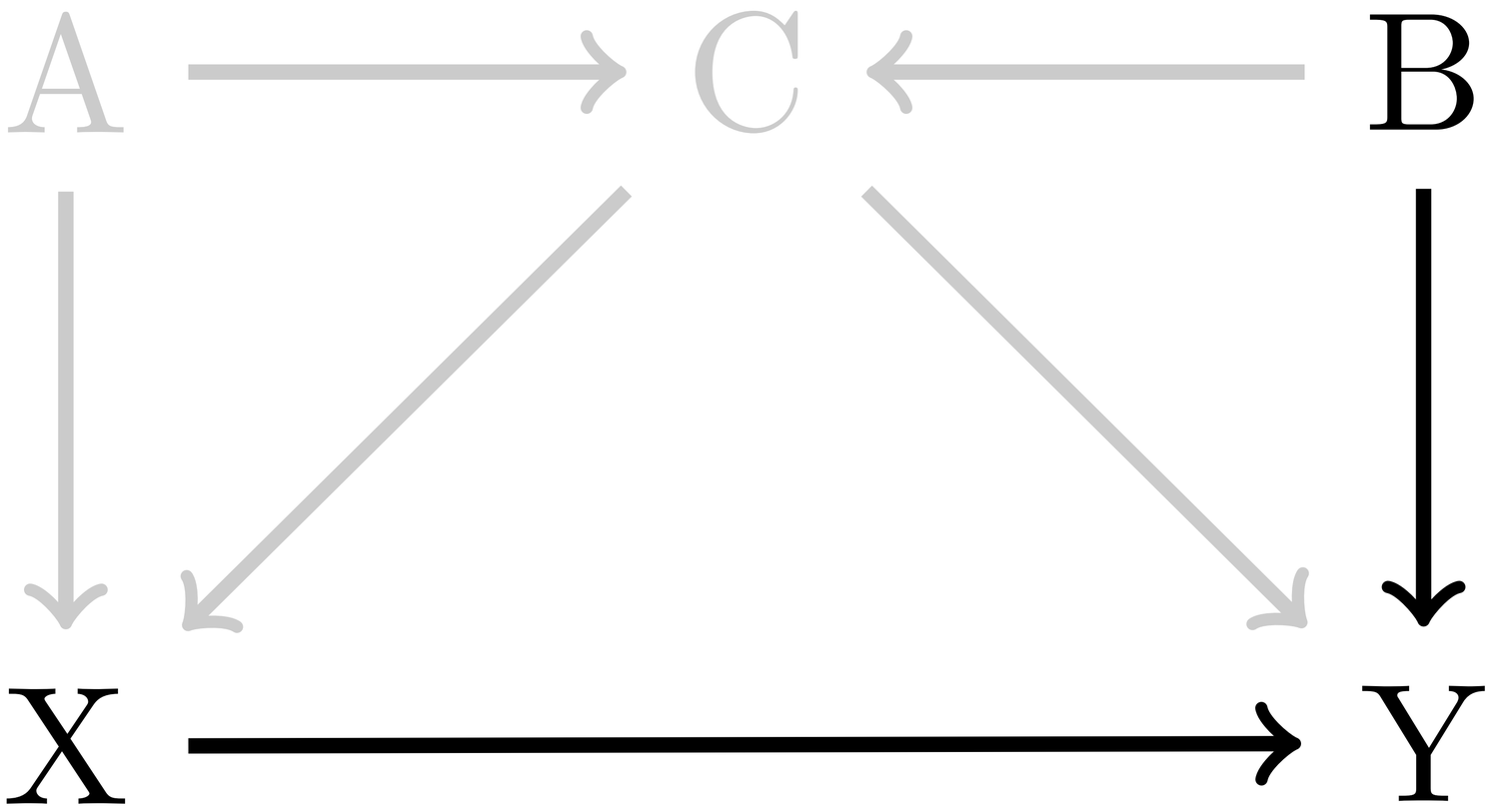
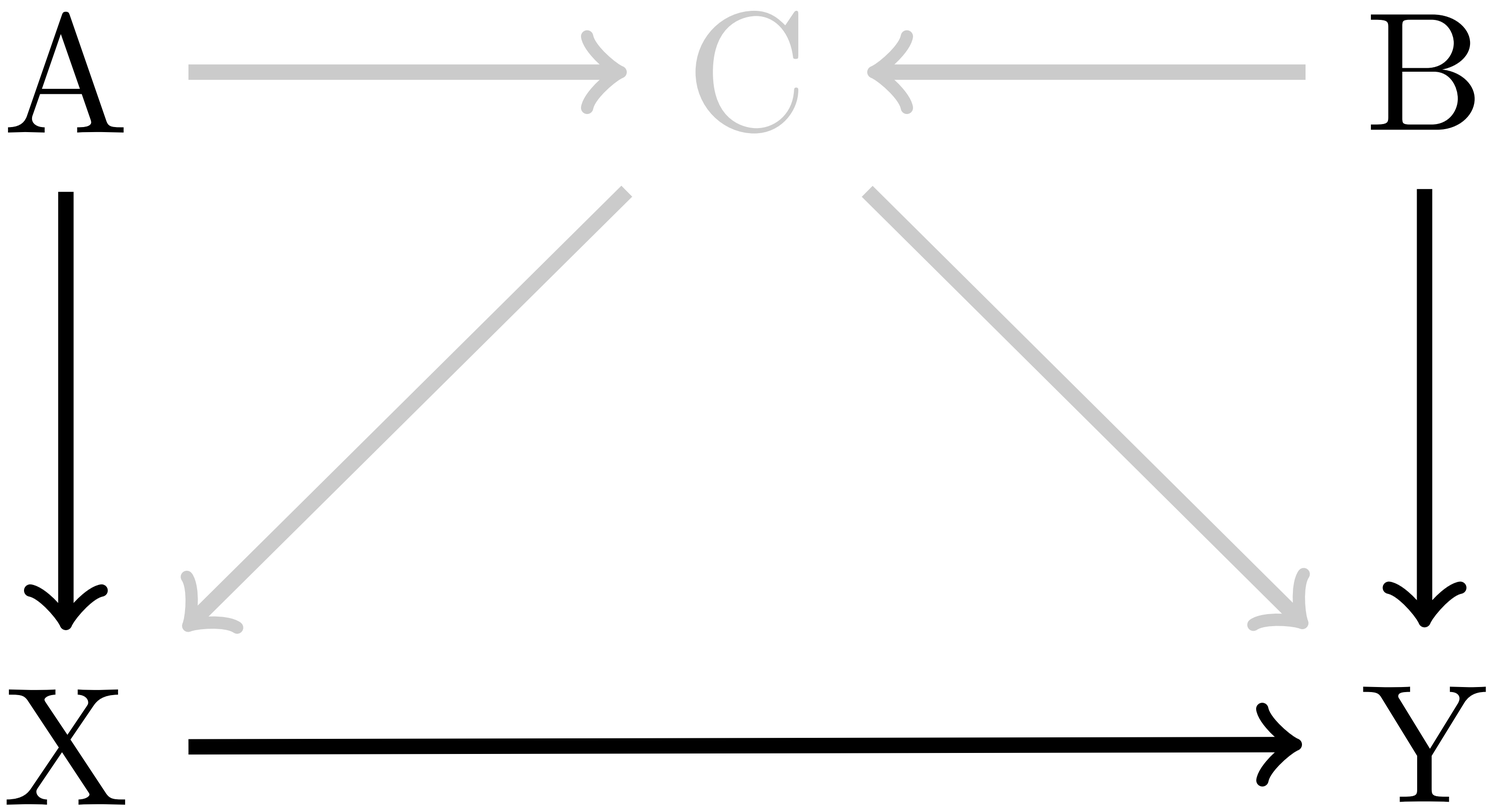


DAGs



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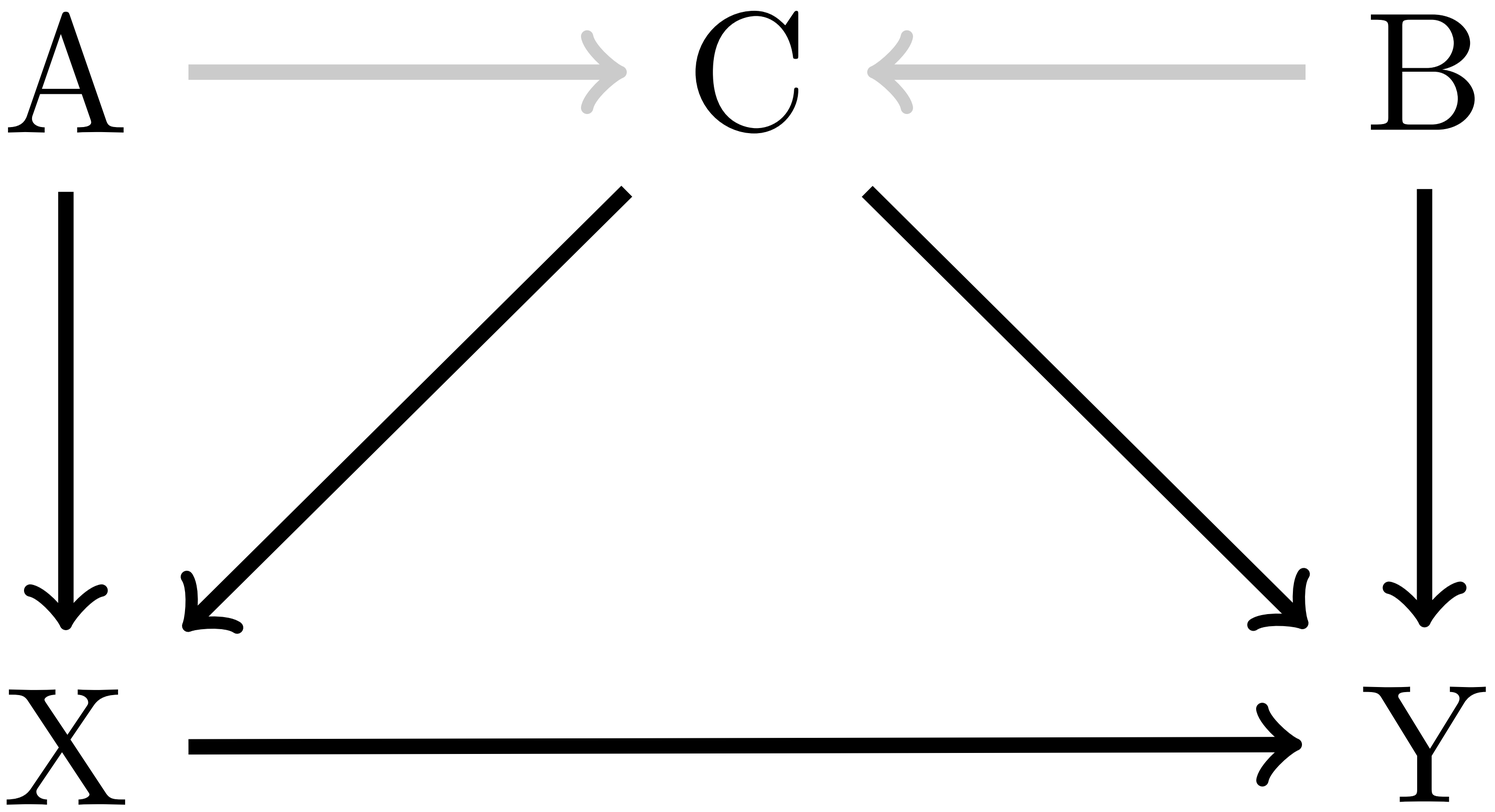

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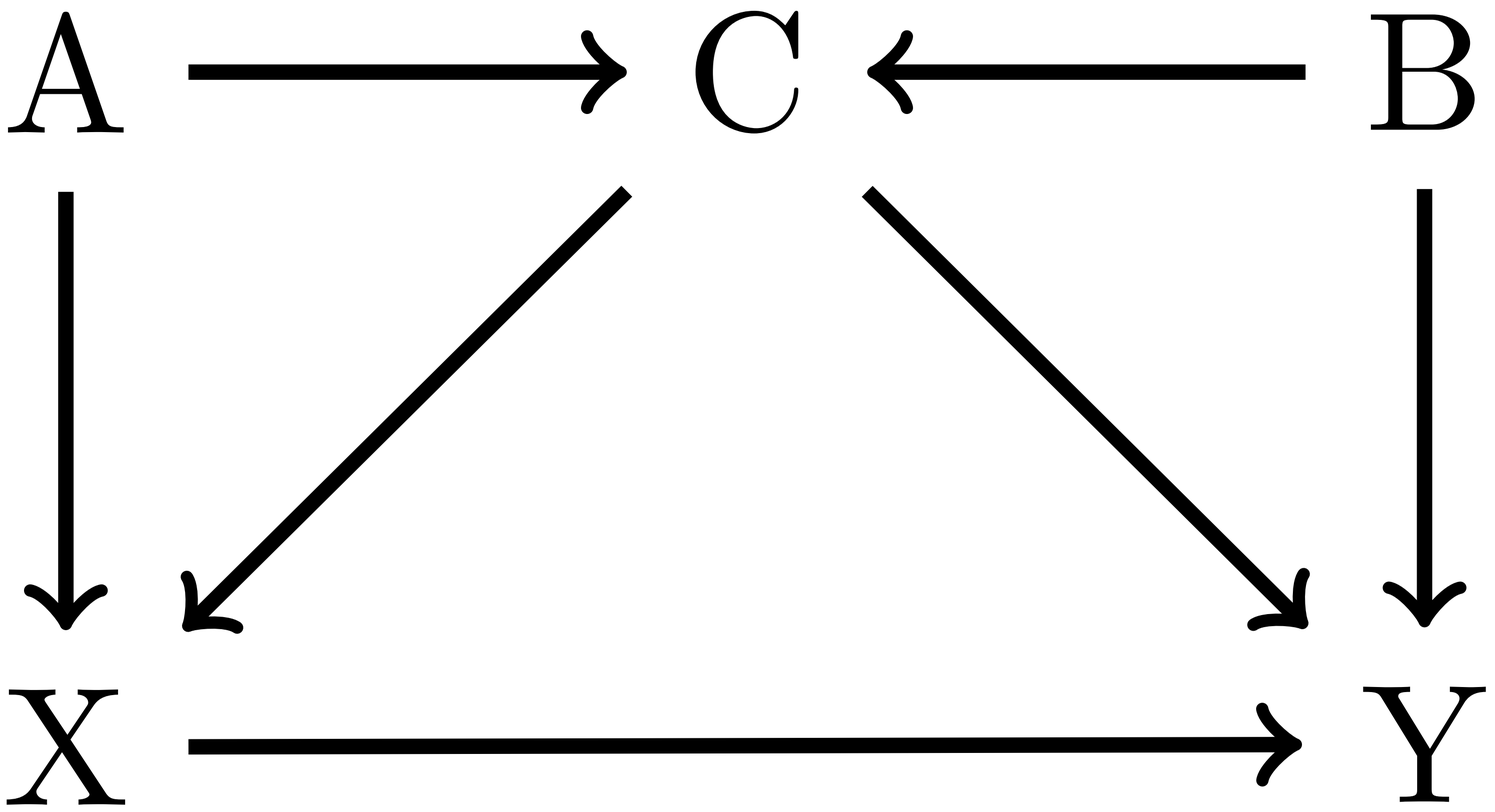

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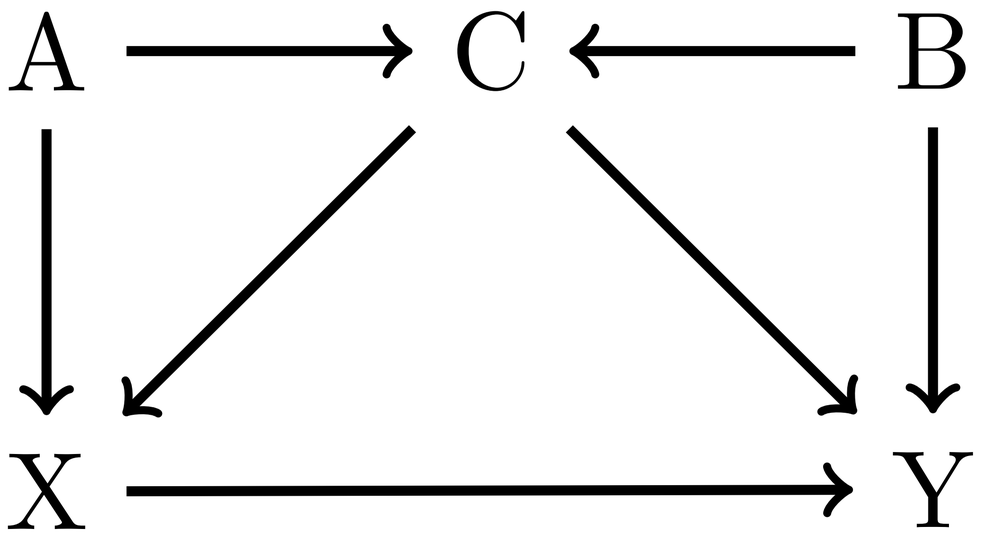

Different queries, different models

Which control variables?

Absolute not safe to add everything — bad controls

How to test the causal model?

With more scientific knowledge, can do more

Golems, Owls, DAGs

Golems: Brainless, powerful statistical models

Owls: Documented, objective procedures

DAGs: Transparent scientific assumptions to
justify scientific effort
expose it to useful critique
connect theories to golems

Course Schedule

Week 1	Bayesian inference	Chapters 1, 2, 3
Week 2	Linear models & Causal Inference	Chapter 4
Week 3	Causes, Confounds & Colliders	Chapters 5 & 6
Week 4	Overfitting / Interactions	Chapters 7 & 8
Week 5	MCMC & Generalized Linear Models	Chapters 9, 10, 11
Week 6	Integers & Other Monsters	Chapters 11 & 12
Week 7	Multilevel models I	Chapter 13
Week 8	Multilevel models II	Chapter 14
Week 9	Measurement & Missingness	Chapter 15
Week 10	Generalized Linear Madness	Chapter 16

`https://github.com/rmcelreath/statrethinking_2022`