Deep Learning for Healthcare

3. Machine Learning Basics

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ILLINOIS

Outline

Supervised learning

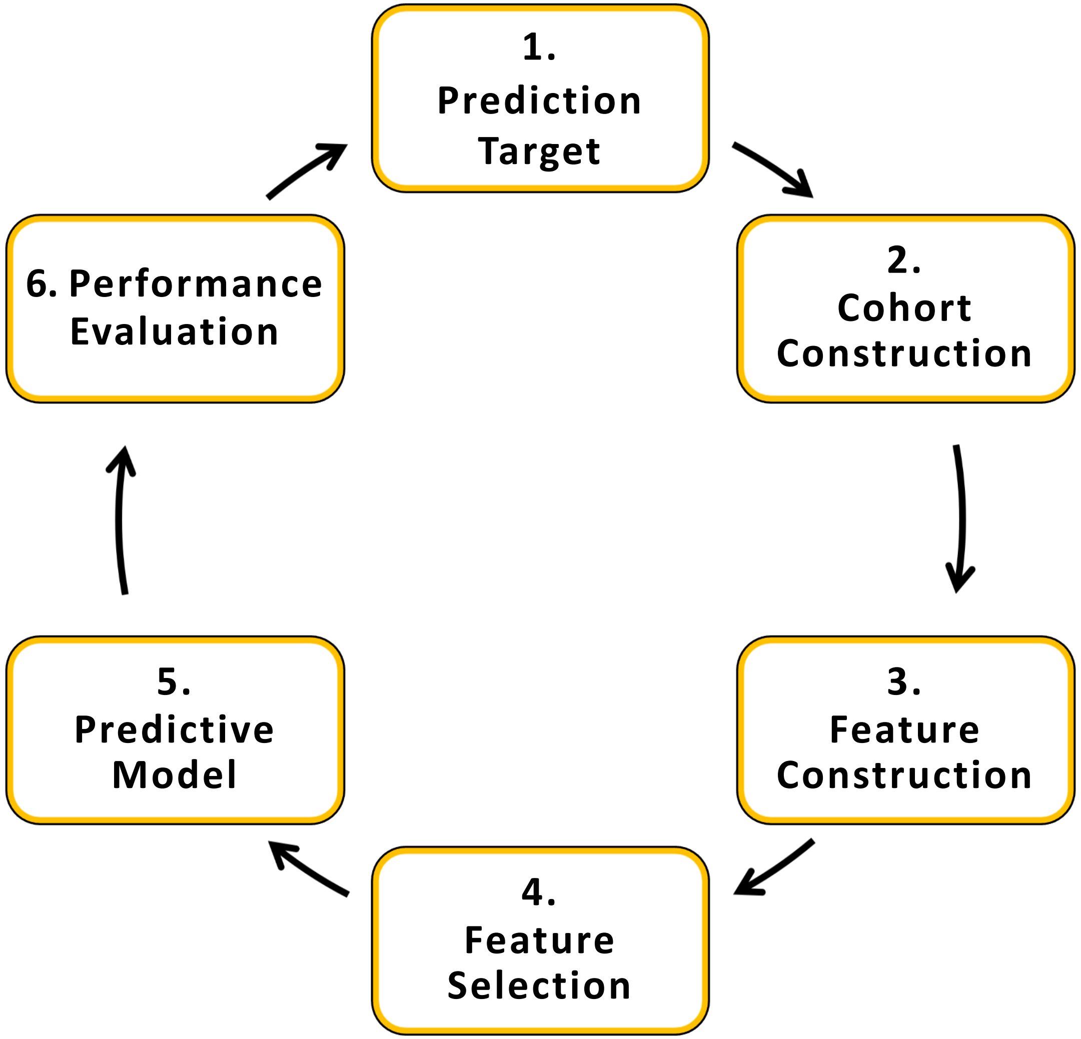
Unsupervised learning

Evaluation metrics

Supervised learning

- Predictive Modeling Pipeline
- Gradient and Stochastic gradient descent

Predictive Modeling Pipeline



1. Prediction Target

2. Cohort Construction

3. Feature Construction

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5. Predictive Model

6. Performance Evaluation

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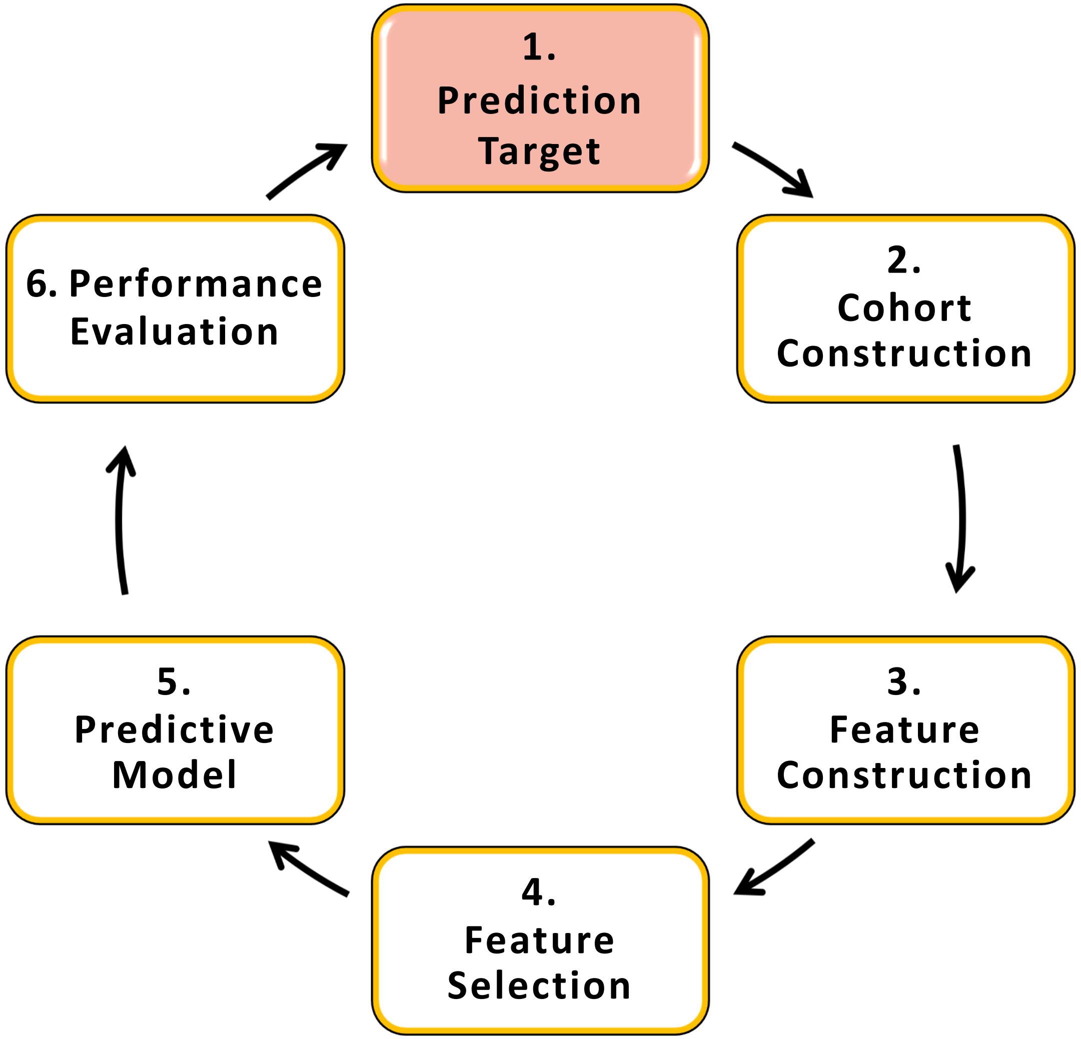
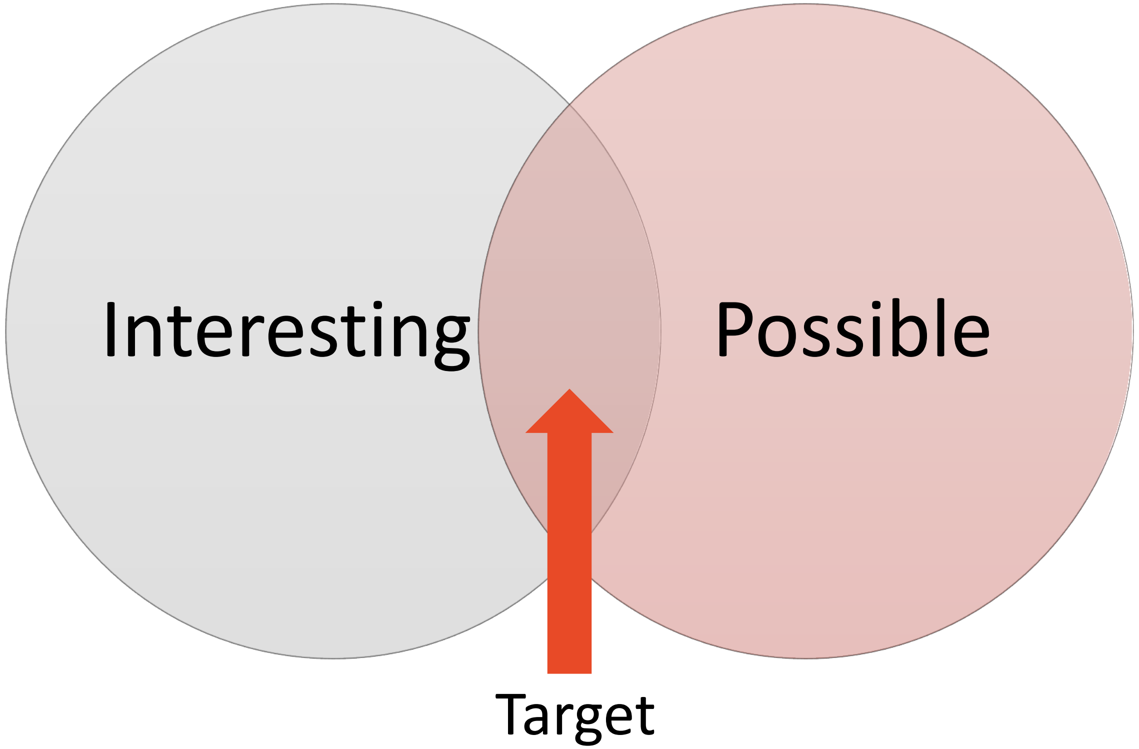
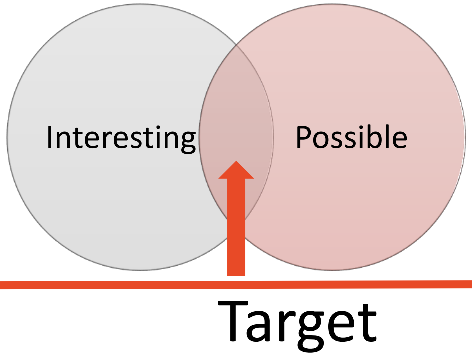


Prediction Target

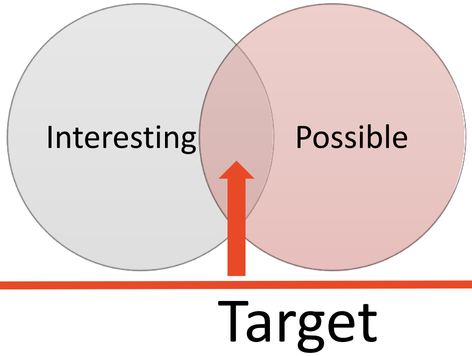


How do you know the target is interesting?



- Talk to domain experts
- Read domain publications
- General common sense metrics
  - High cost
  - Long time
  - Bad quality

How do you know the target is possible?

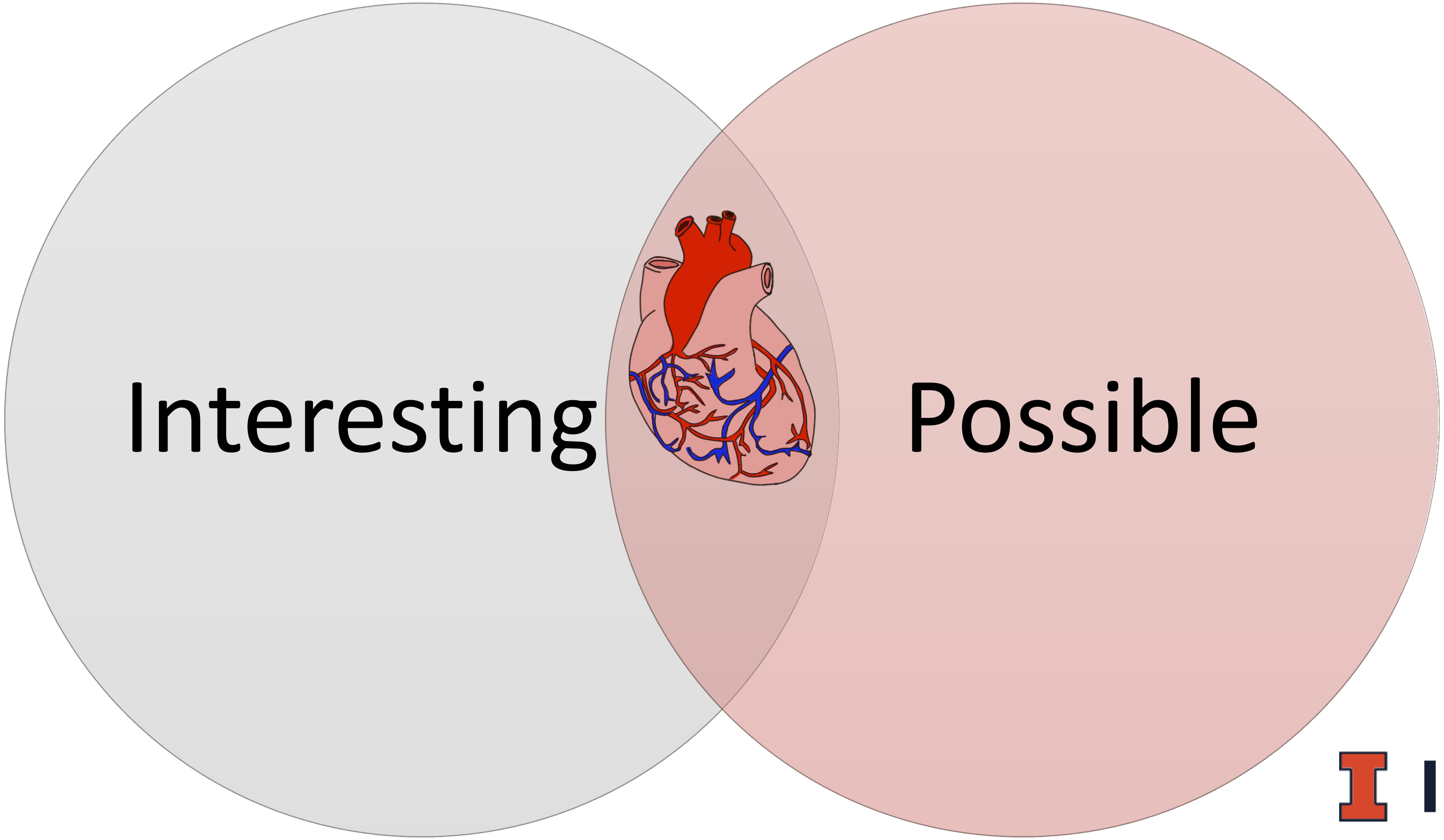


- Human performance

- Experience from similar projects

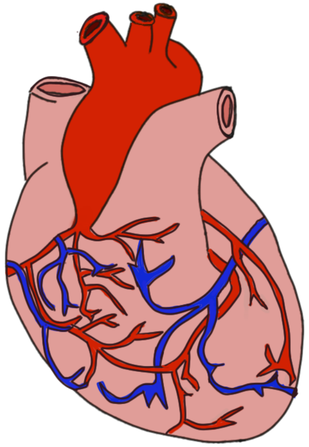
- Results from prior publications ?

Prediction Target



Heart Failure Quiz

How many new cases of heart failure occur each year in



□ A. 17,000

□ B. 260,000

☑ C. 550,000

□ D. 1,250,000

Motivations For Early Detection Of Heart Failure

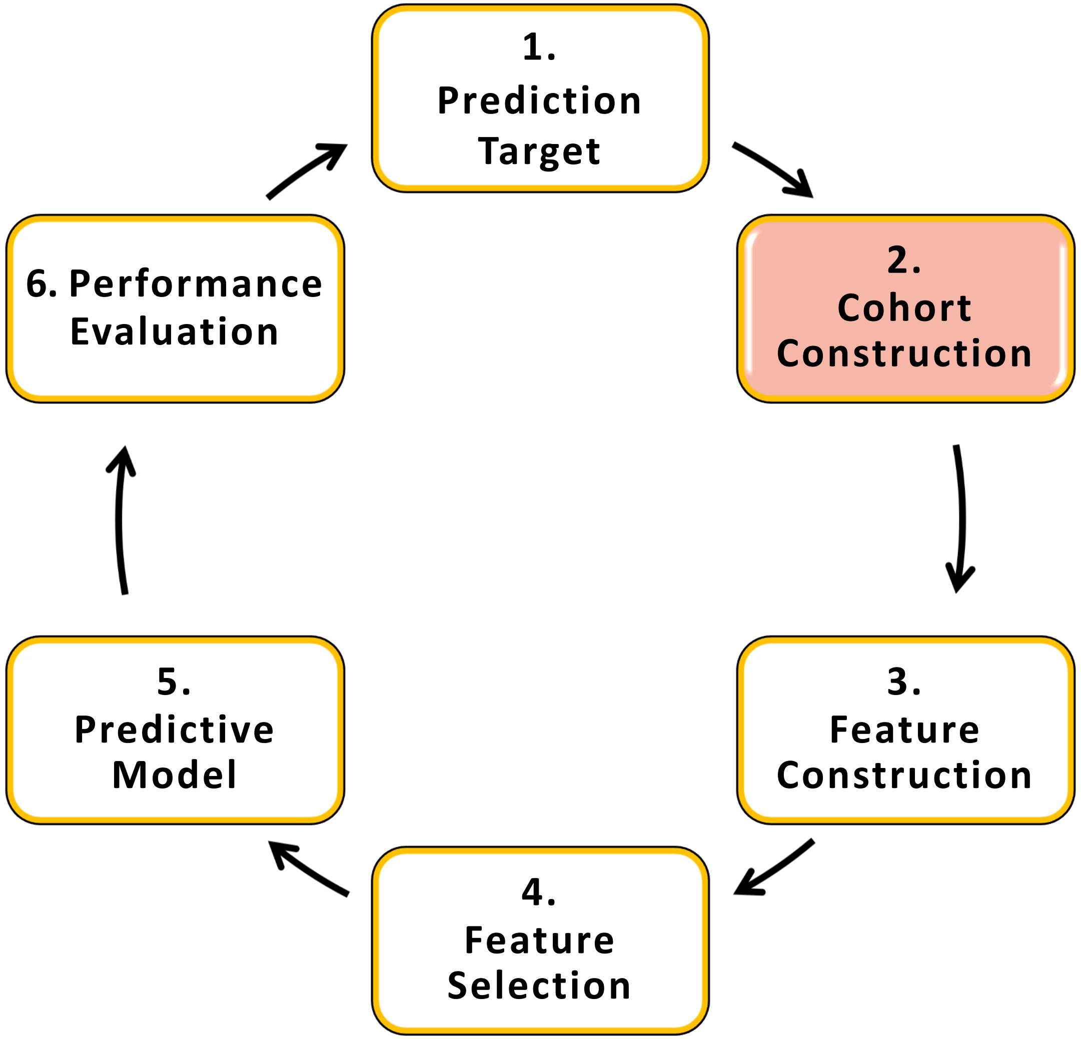
Heart failure is a complex disease.

Reduces cost and hospitalization.

Improves existing clinical guidelines of HF prevention.

Early intervention can slow down disease progression.

Predictive Modeling Pipeline



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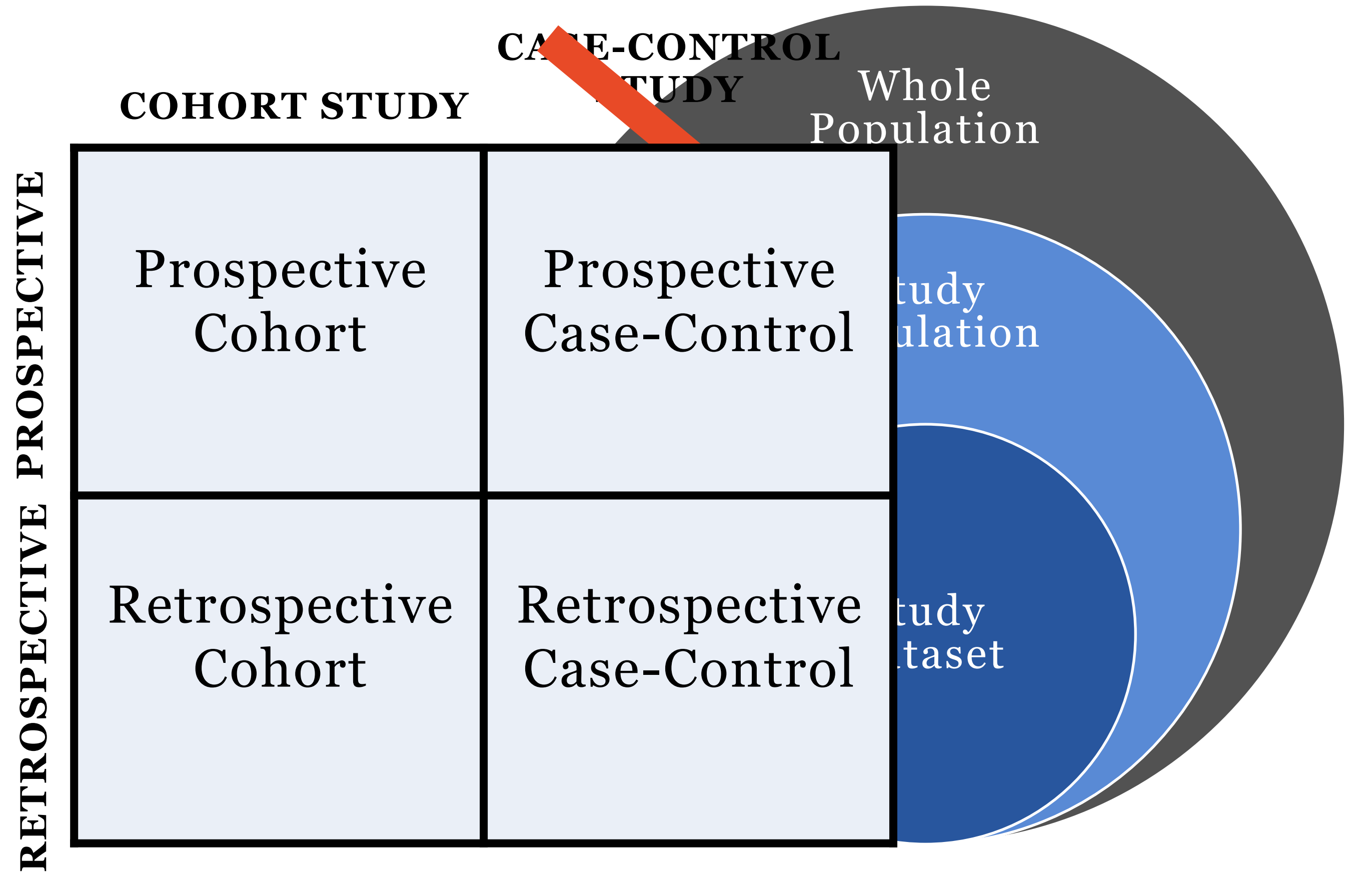
Why do we need cohort construction?

- General ML practice:
  - Give a dataset => build a model
- Healthcare predictive modeling
  - Create a dataset (cohort, feature) => build a model
- Reasons:
  - Avoid obvious models: e.g., age predicts mortality
  - Focus on the population of interests
  - Data acquisition cost

COHORT CONSTRUCTION - STUDY DESIGN

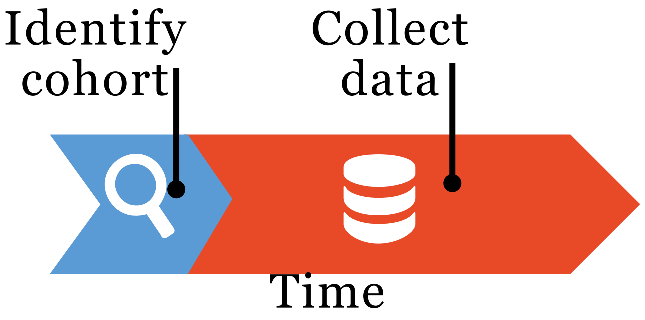
DEFINE



	COHORT STUDY	CASE-CONTROL STUDY
PROSPECTIVE	Prospective Cohort	Prospective Case-Control
RETROSPECTIVE	Retrospective Cohort	Retrospective Case-Control

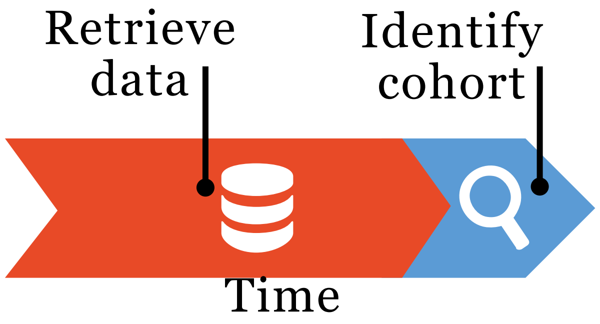
PROSPECTIVE VS. RETROSPECTIVE

PROSPECTIVE



- Identify the study population P
- Then start to collect data on P

RETROSPECTIVE



- Identify the study population P
- Trace back the historical data of P

QUIZ: PROSPECTIVE VS. RETROSPECTIVE

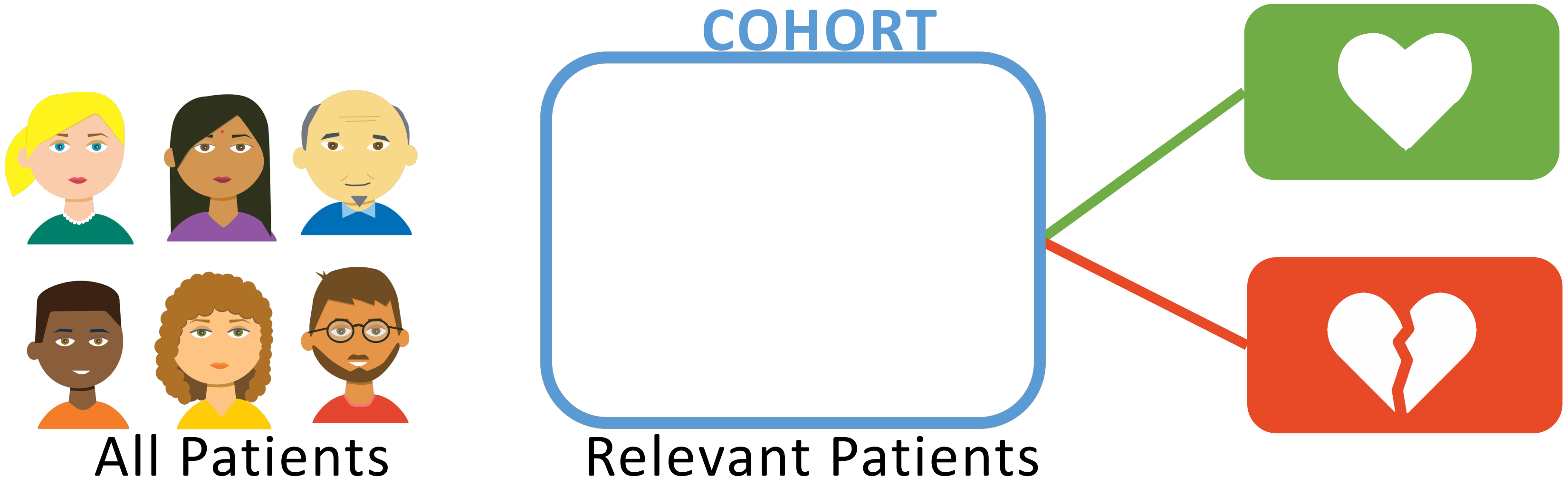
Property	Prospective Study	Retrospective Study
More noise in the data	□	☑
More expensive	☑	□
Takes a longer time	☑	□
Common on large dataset	□	☑

Cohort Study

Select a group of patients who are exposed to the risk

TARGET: Heart Failure Readmission

- COHORT: all HF patients discharged from hospital
- KEY: define the right inclusion/exclusion criteria

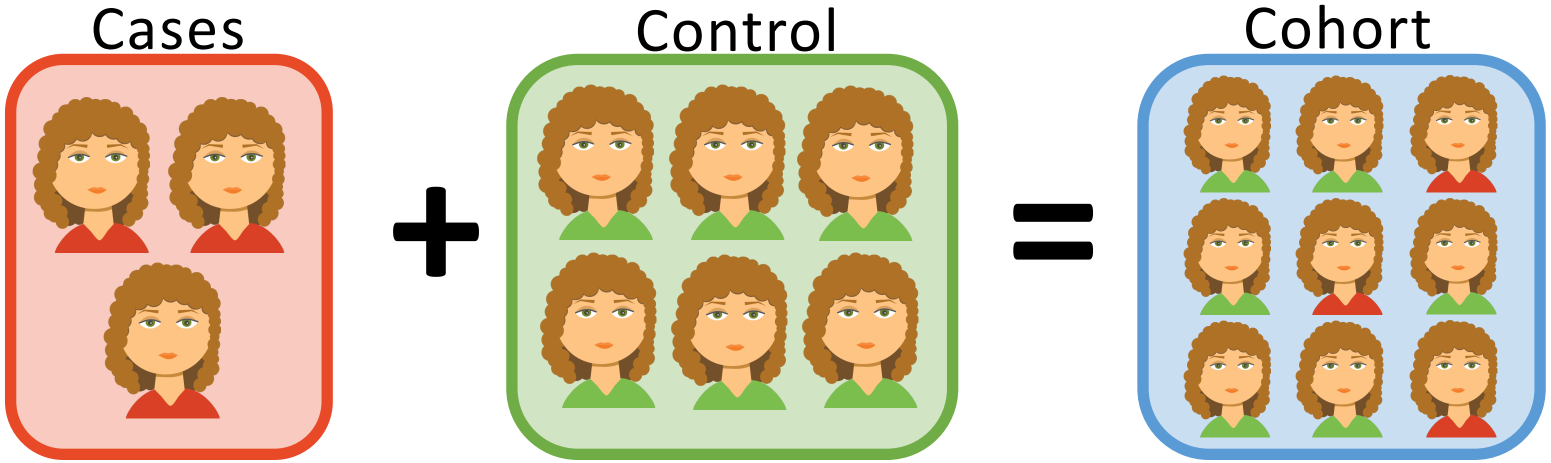


Case-control Study

CASES: patients with positive outcome (have the disease)

CONTROLS: patients with negative outcome (healthy) but otherwise similar

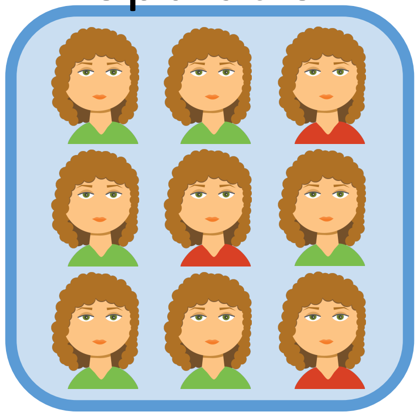
KEY: matching criteria between cases and controls

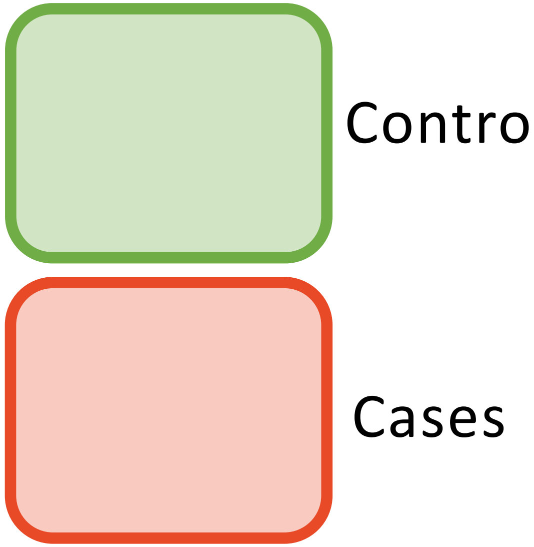


Example Of Case-control Study

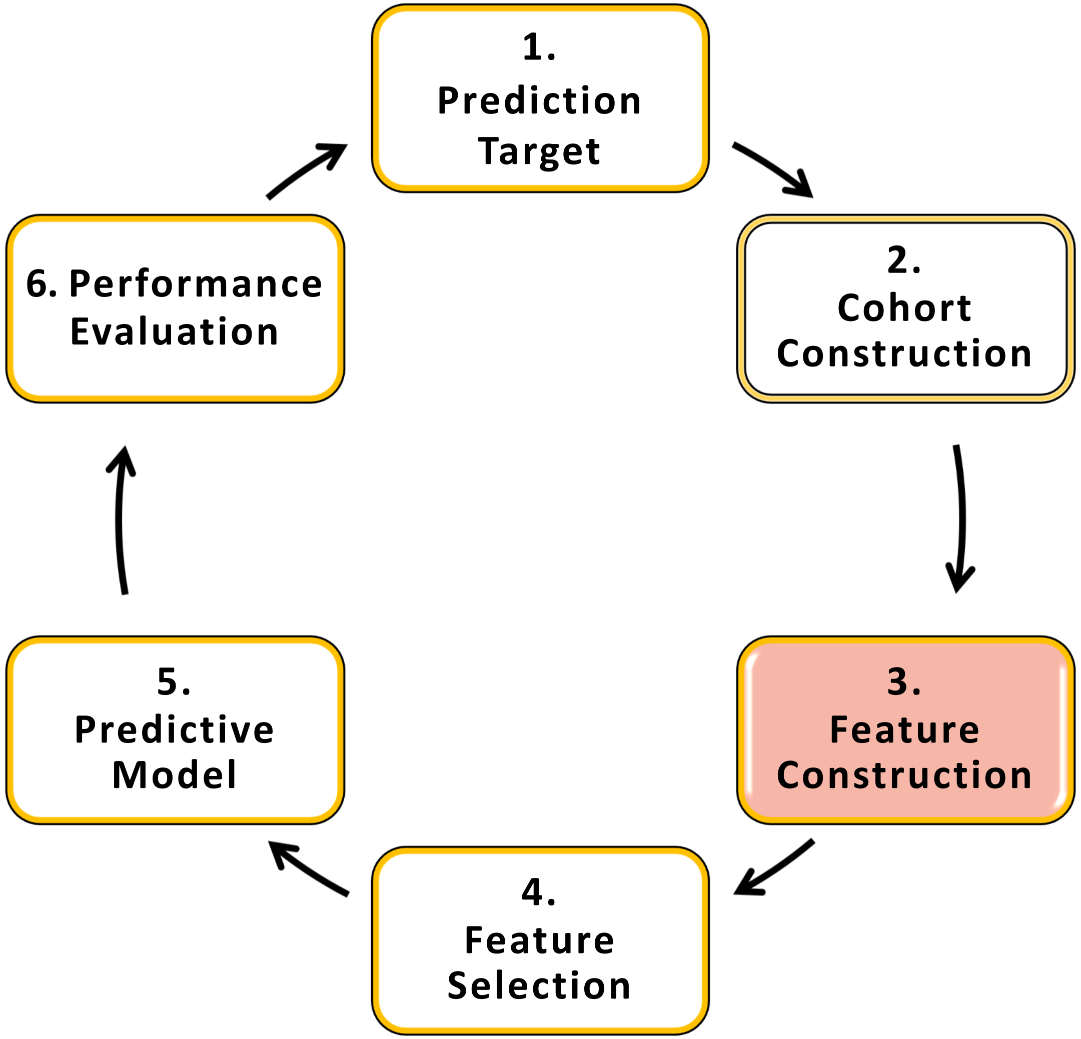
- Goal: Predict Heart Failure cases against control patients
- Population: 50,625 Patients
  - Case Patients: 4,644
  - Controls: 45,981 (matched on age, gender and clinic)

Population

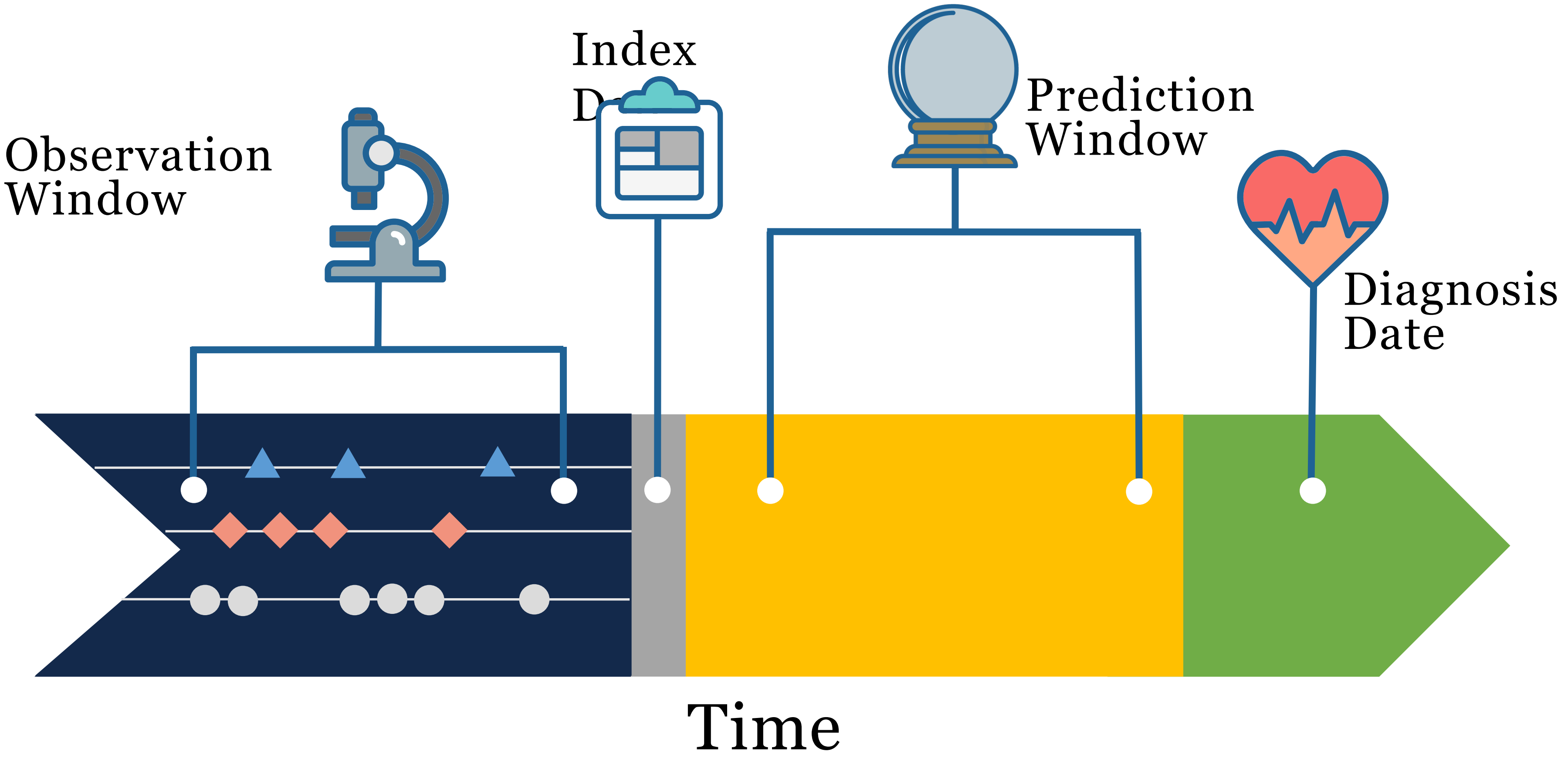




Predictive Modeling Pipeline

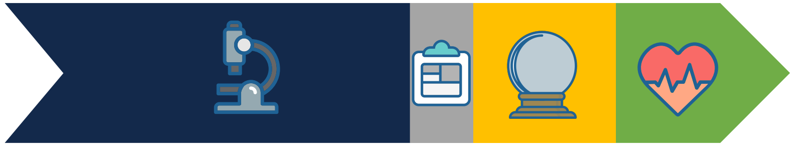


Feature Construction

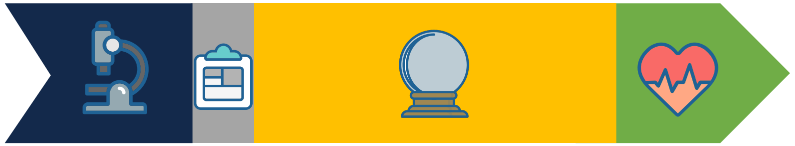


Feature Construction Quiz 1

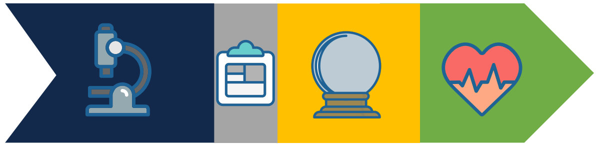
Which one of these timelines is the easiest for modeling?



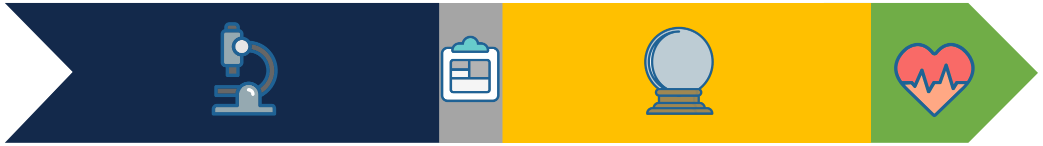
A. ☑



B. □



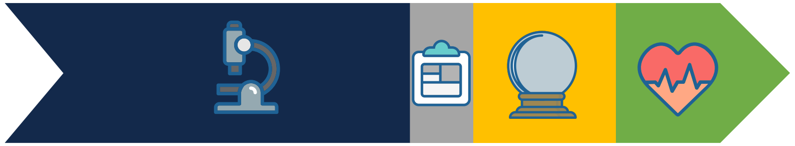
C. □



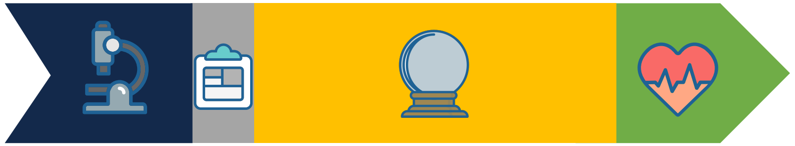
D. □

FEATURE CONSTRUCTION QUIZ 2

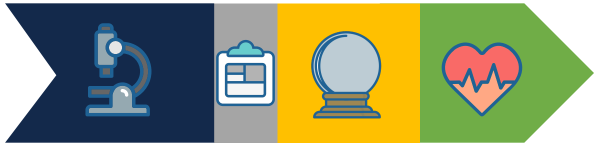
Which one of these timelines is the most useful model?



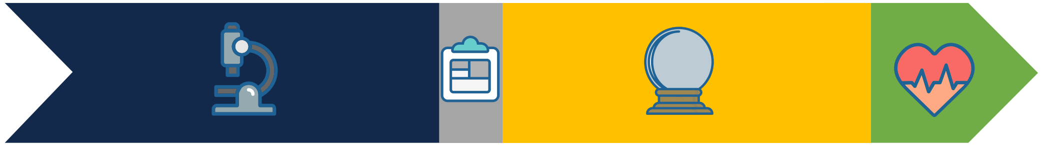
A. □



B. ☑

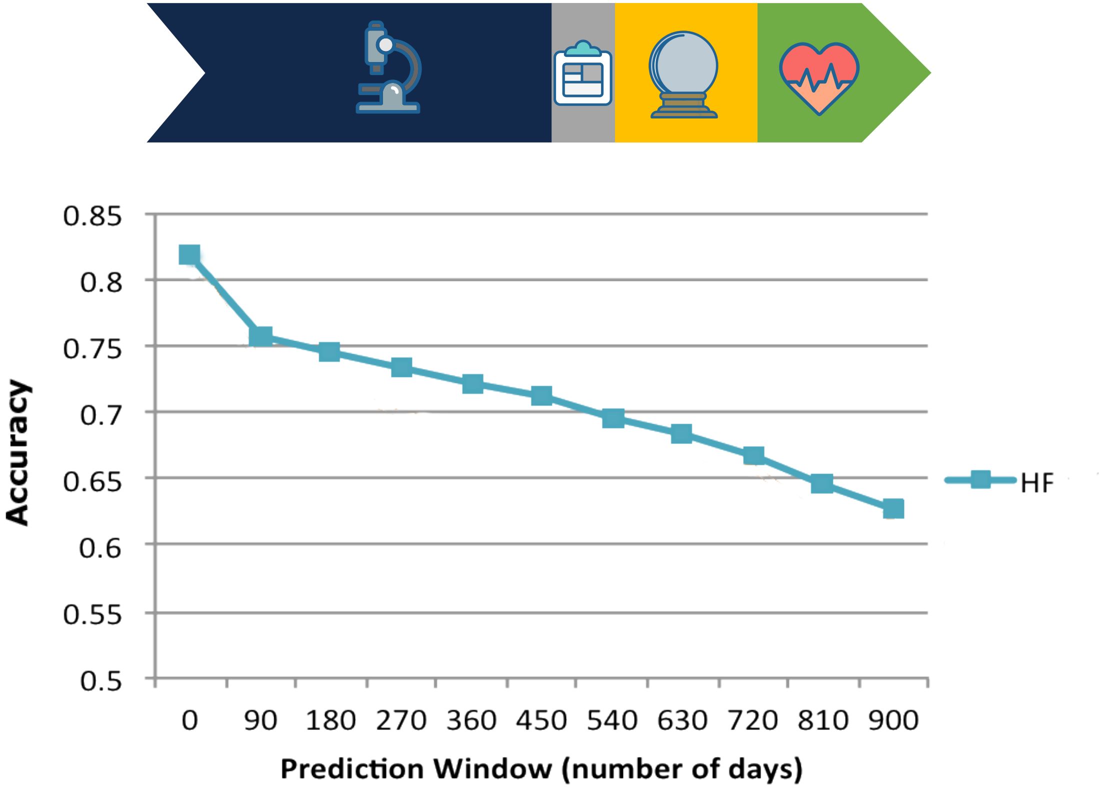


C. □



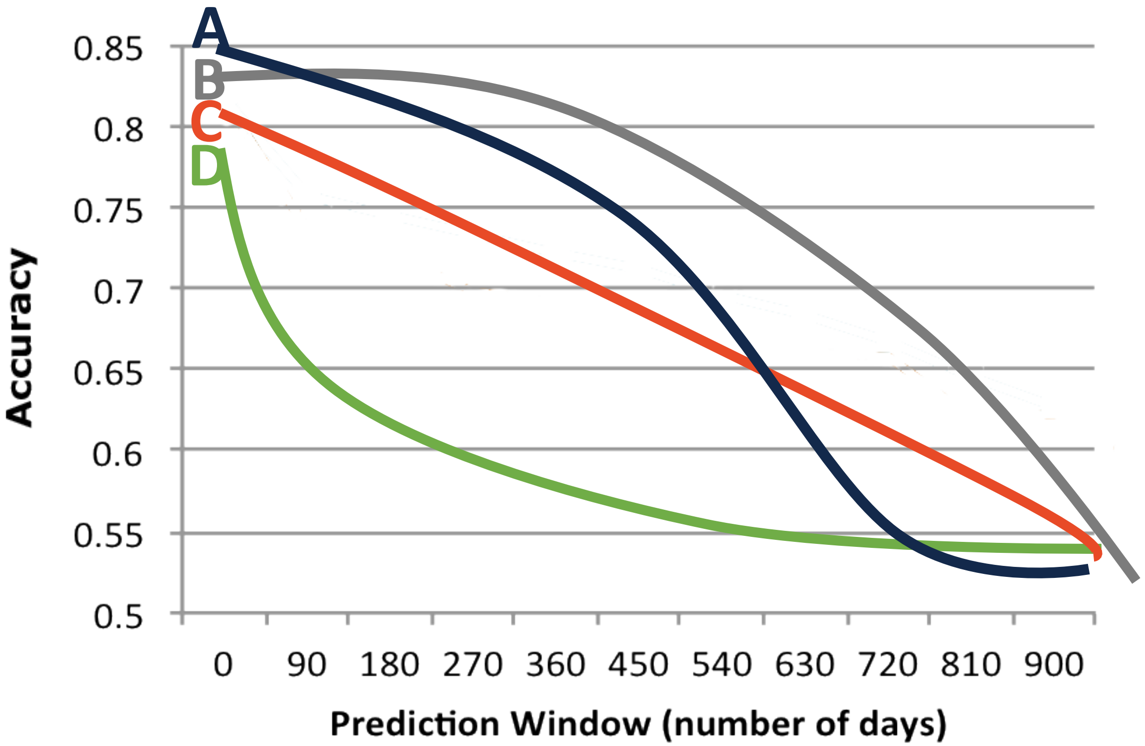
D. □

Prediction Performance On Different Prediction Windows



Prediction Window Quiz

Which of these options is the most desirable prediction curve?



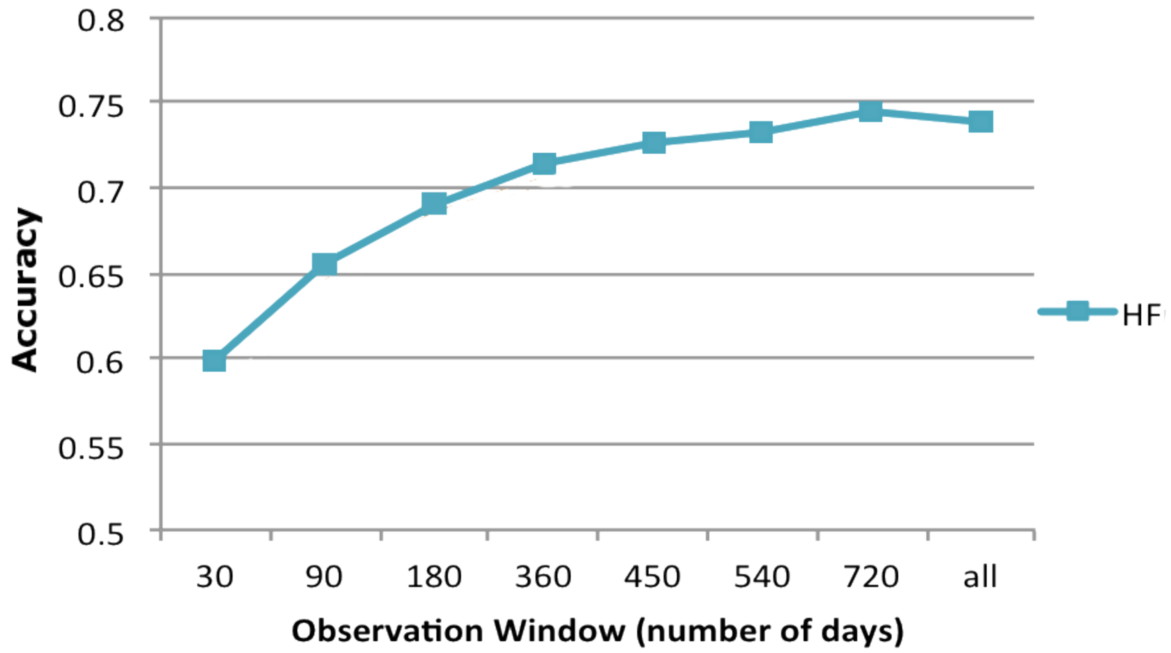
□ A

☑ B

□ C

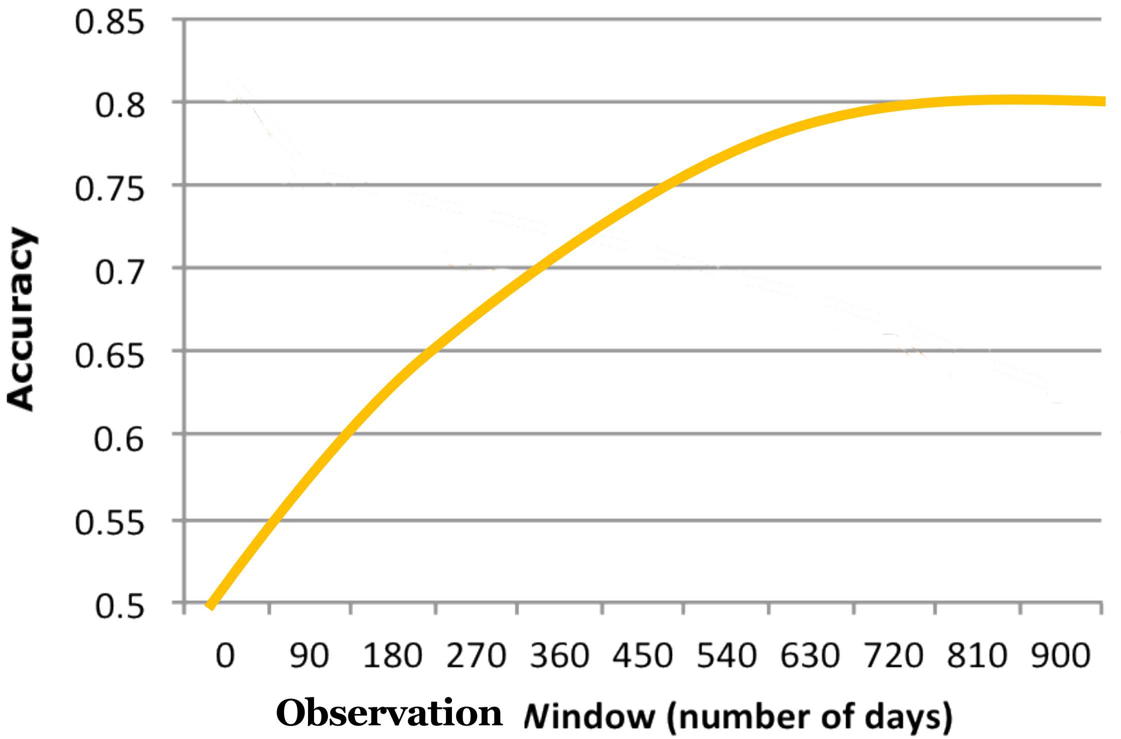
□ D

Prediction Performance On Different Observation Windows



Observation Window Quiz

What is the optimal observation window?



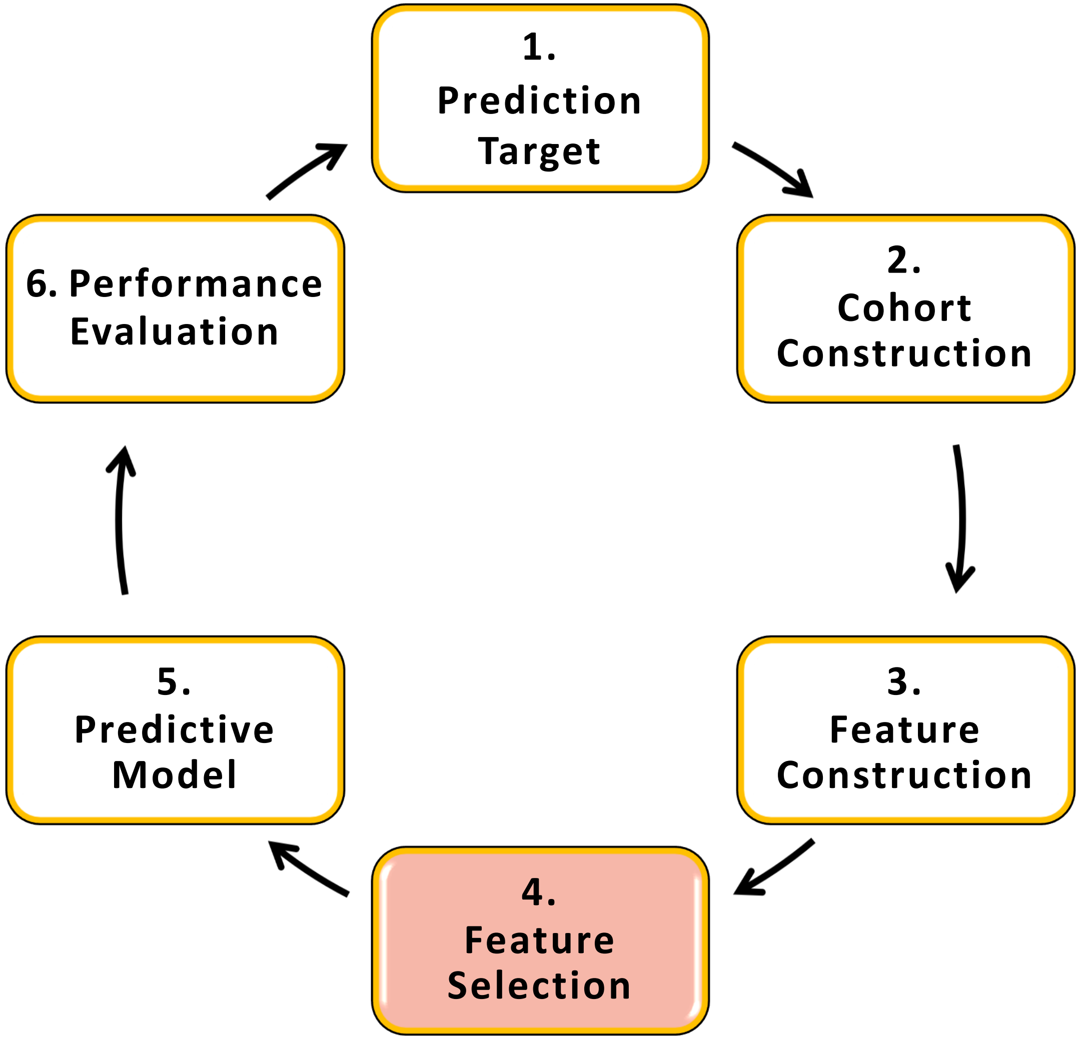
□ A. 90 days

□ B. 270 days

☑ C. 630 days

□ D. 900 days

Predictive Modeling Pipeline



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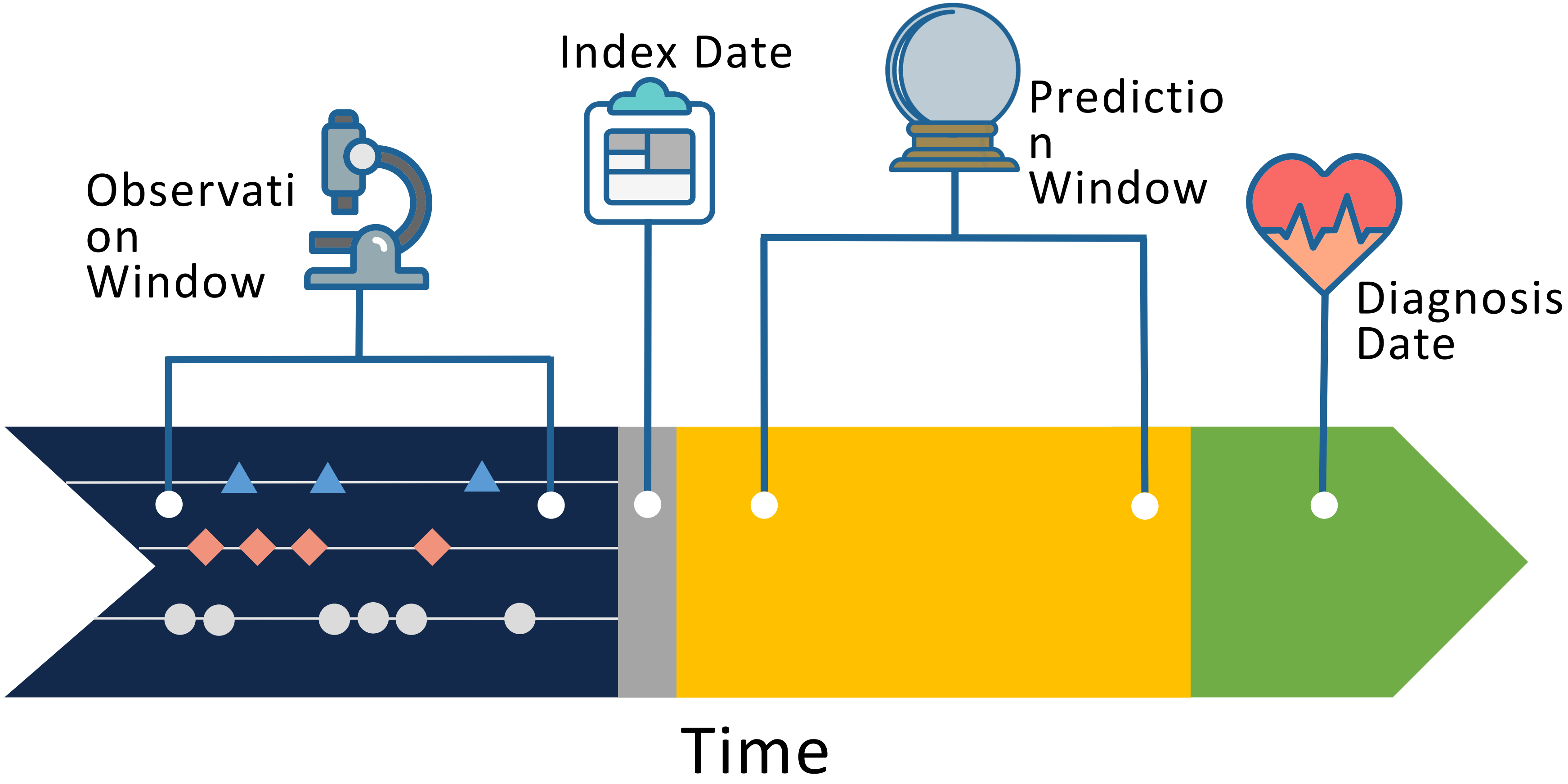
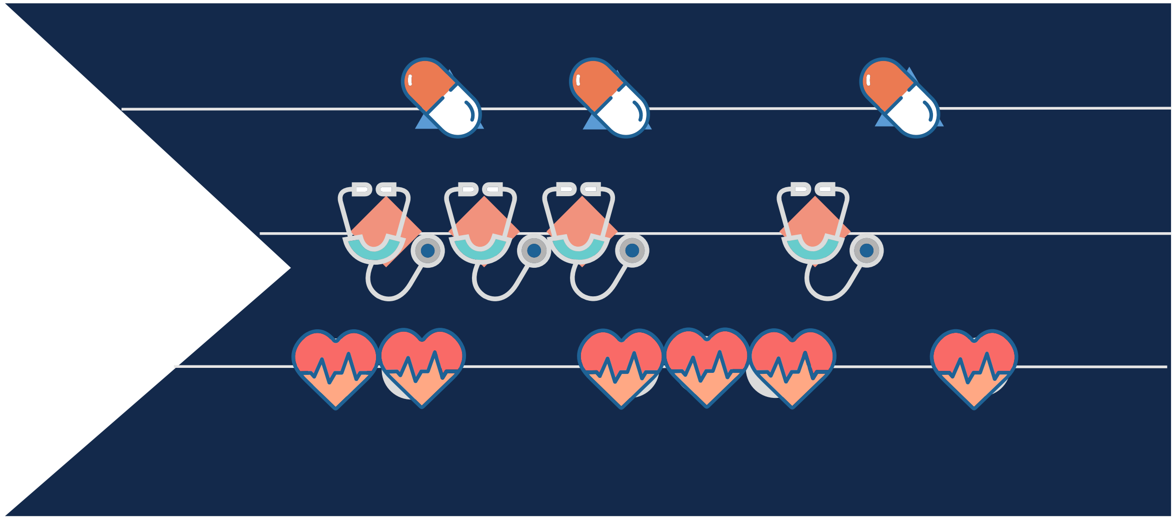
Feature Selection



Feature Selection



Feature Types

- Demographics
- Diagnosis
- Lab result
- Symptoms
- Medications
- Vitals

Feature Selection

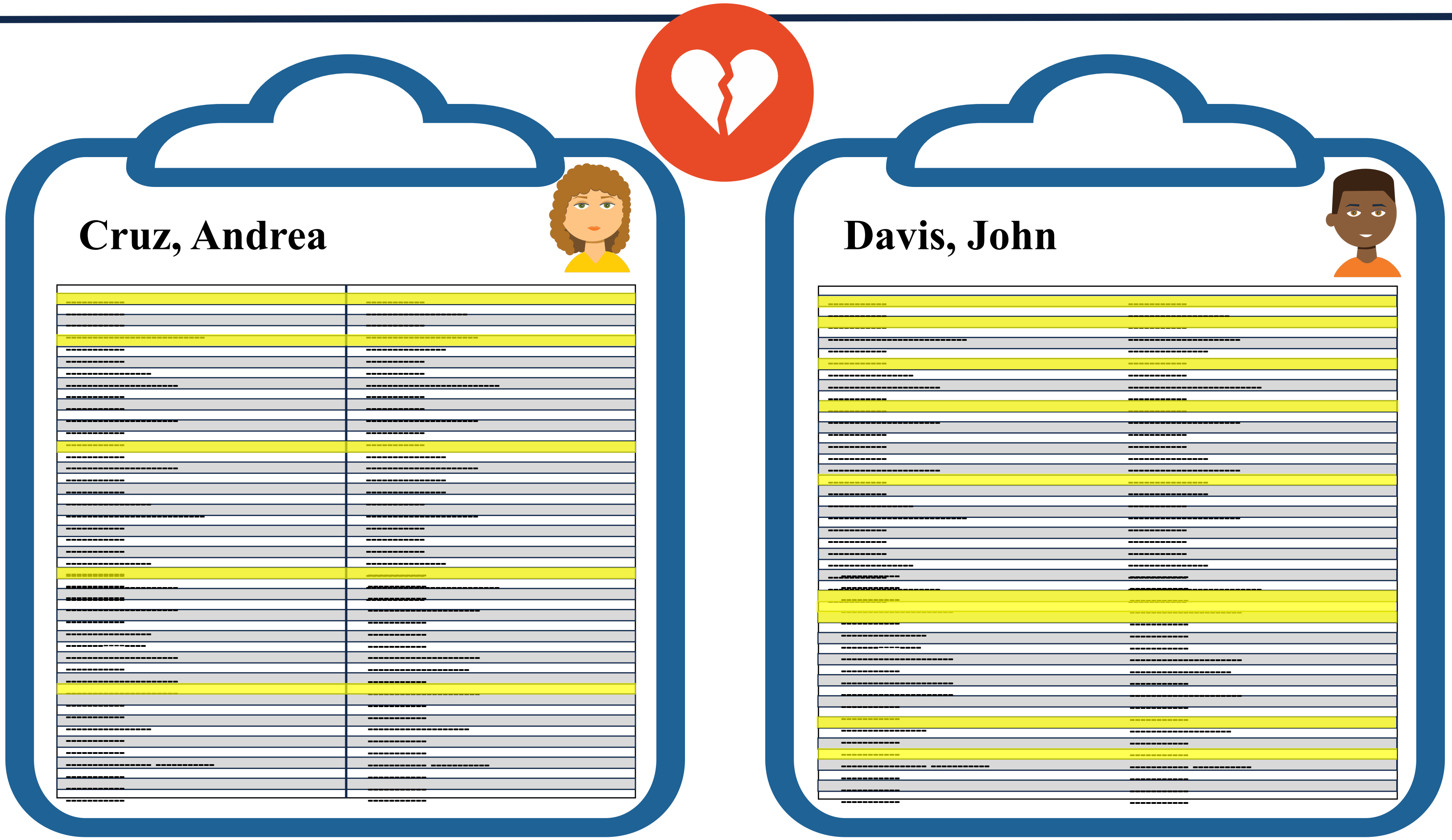
Cruz, Andrea

Age	34
Sex	F
Race	White
Blood Pressure	114/72
Diabetes, Type II	YES
Hypertension	NO

Davis, John

Age	67
Sex	M
Race	African American
Blood Pressure	160/100
Diabetes, Type II	NO
Hypertension	YES

Feature Selection



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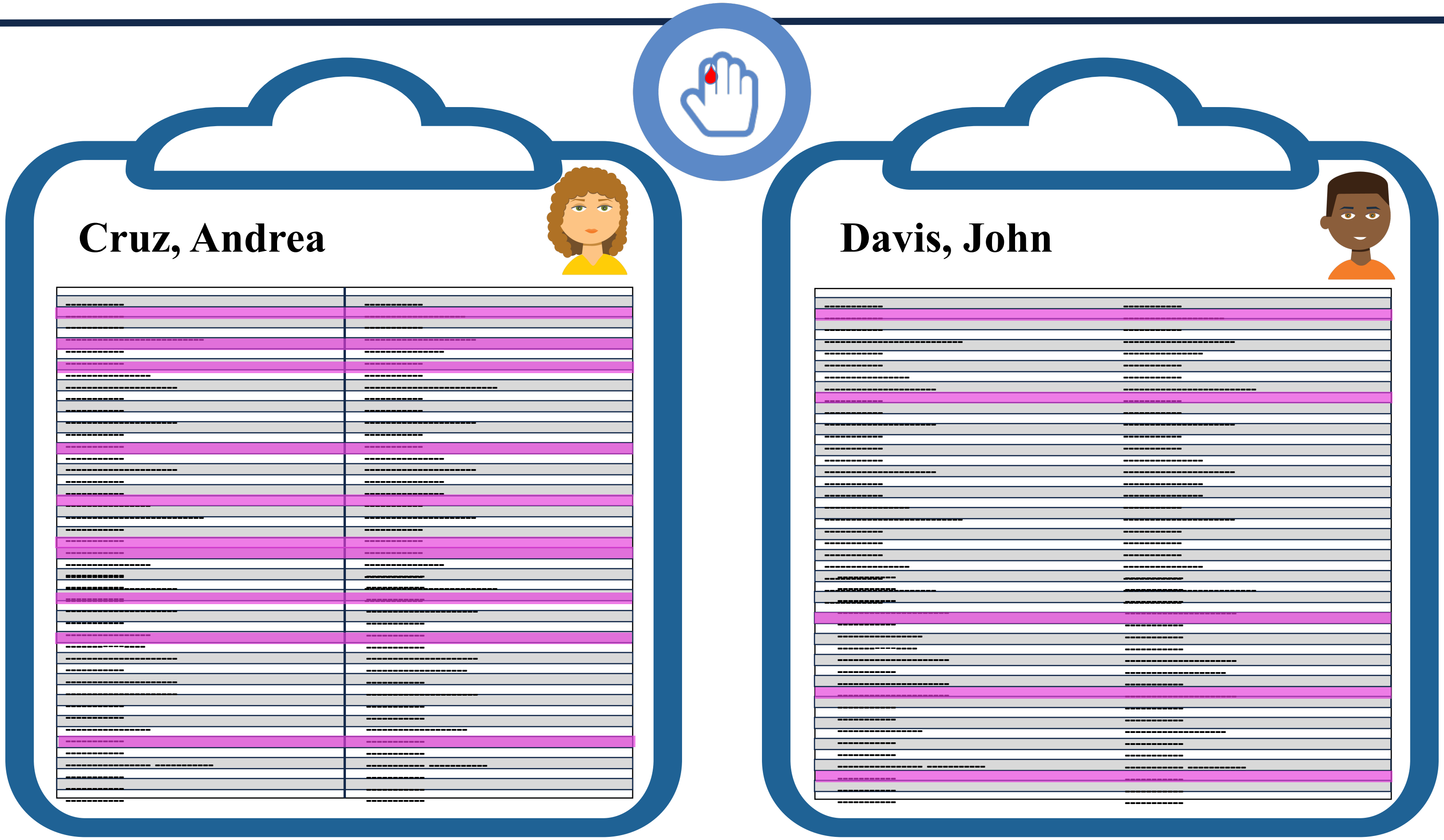

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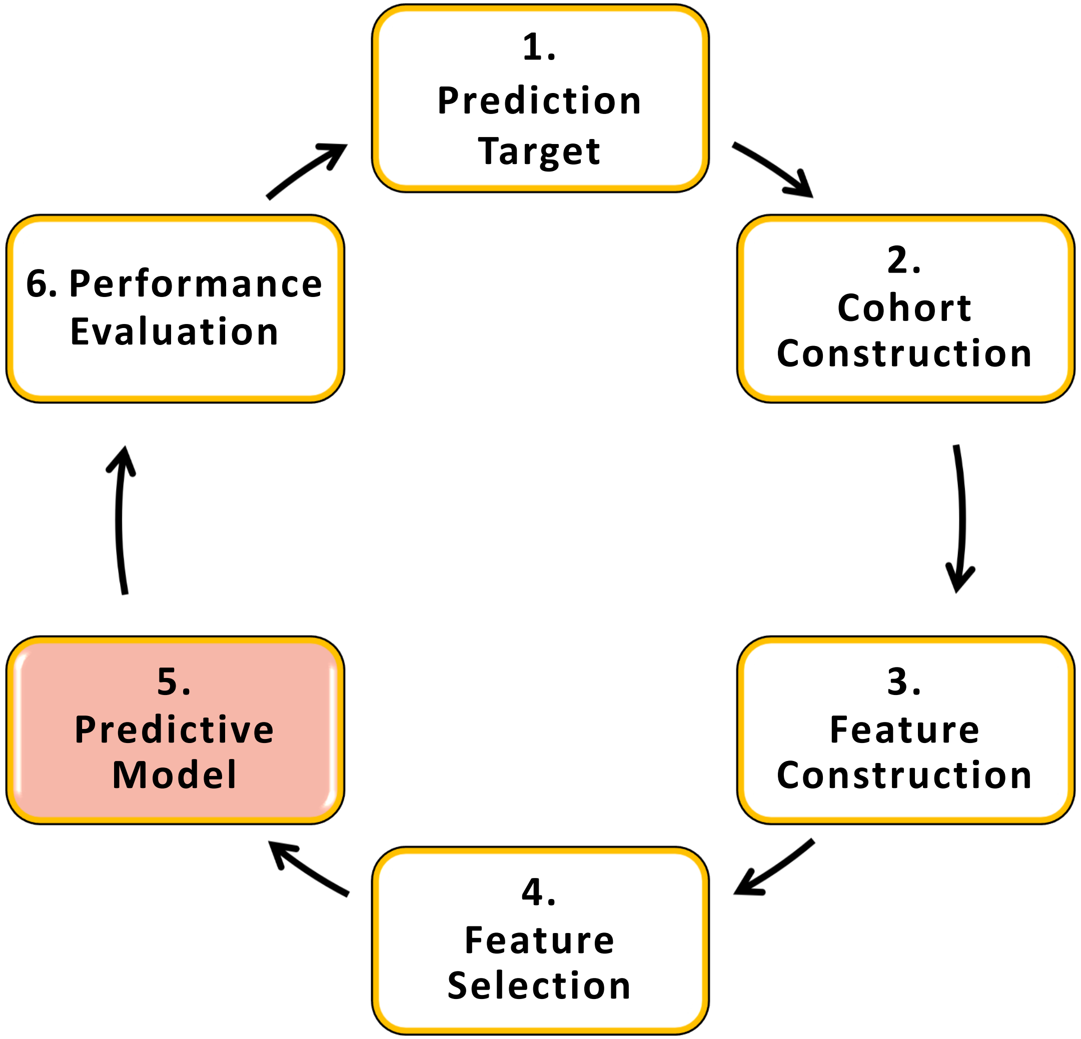

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Predictive Models

$$\overset{\text{Target}}{y} = f(\underset{\text{Features}}{x}) + \overset{\text{Error}}{e}$$

REGRESSION

- Target y is continuous
- Popular Methods
  - Linear Regression
  - Generalized Additive Models

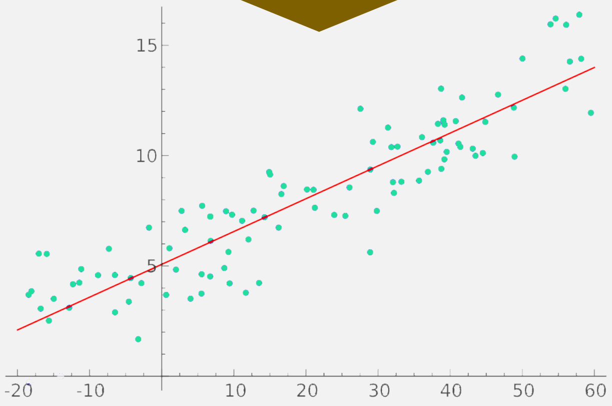
CLASSIFICATION

- Target y is categorical
- Popular Methods
  - Logistic regression
  - Support vector machine (SVM)
  - Decision tree, random forest
  - Neural networks

REGRESSION

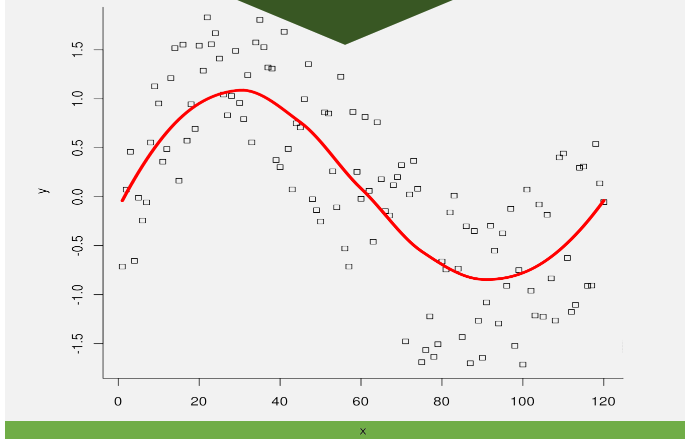
LINEAR REGRESSION

$$y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + e$$



GENERALIZED ADDITIVE MODEL

$$y = \beta_0 + \sum_{i=1}^{n} f_i(x_i) + e$$



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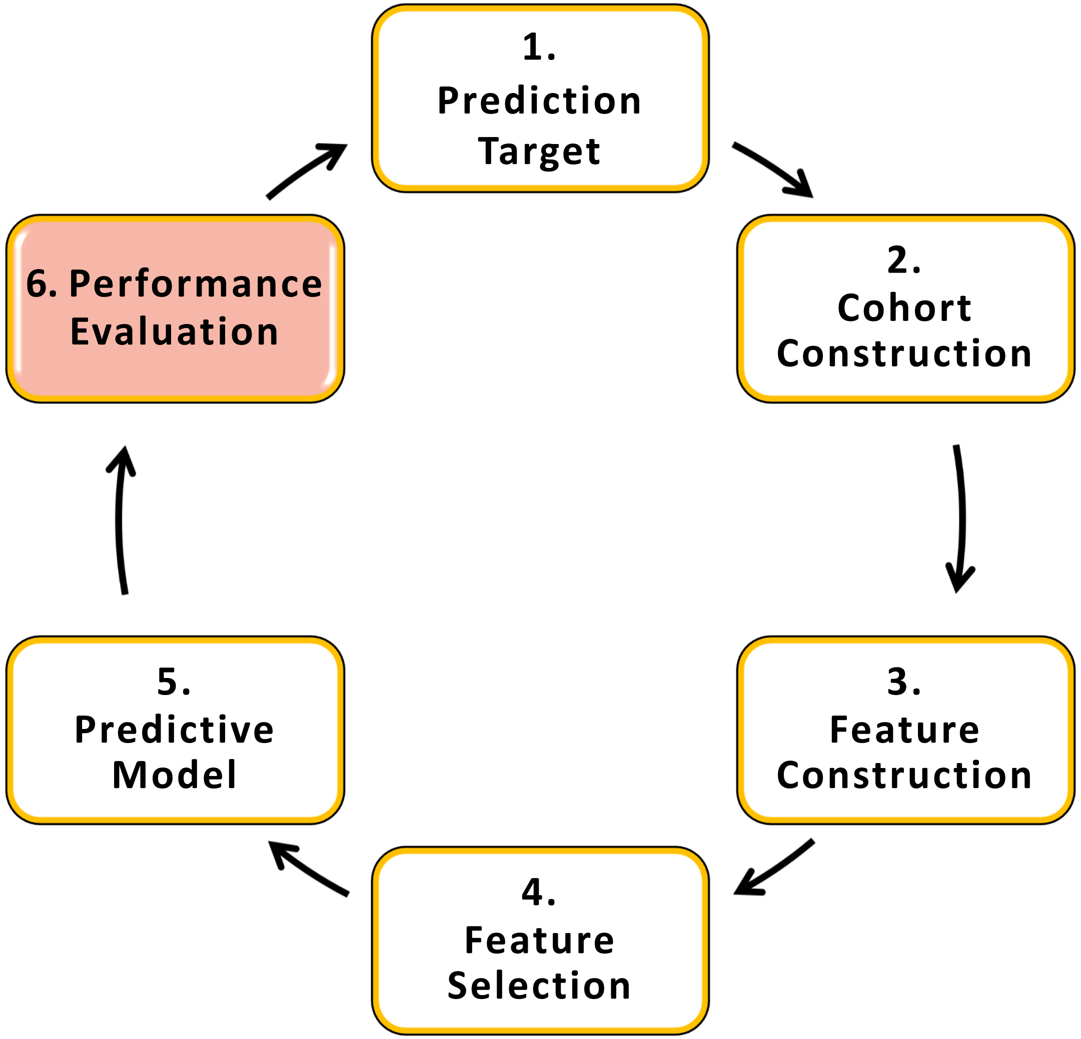

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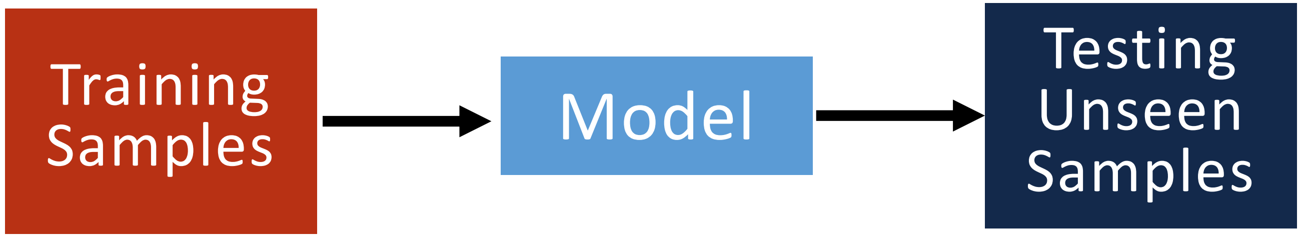
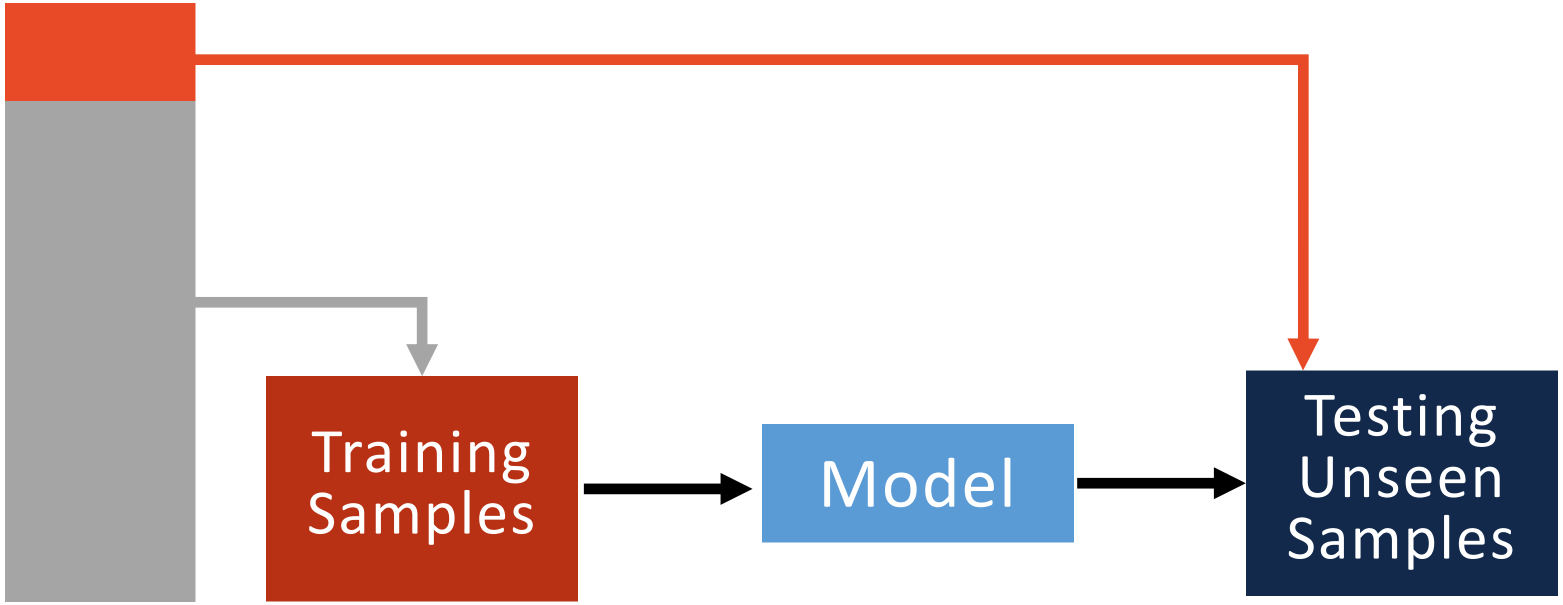
EVALUATION

- Training error is NOT very useful
- Testing error is the key metric
- Approach:
  - Cross-validation (CV)

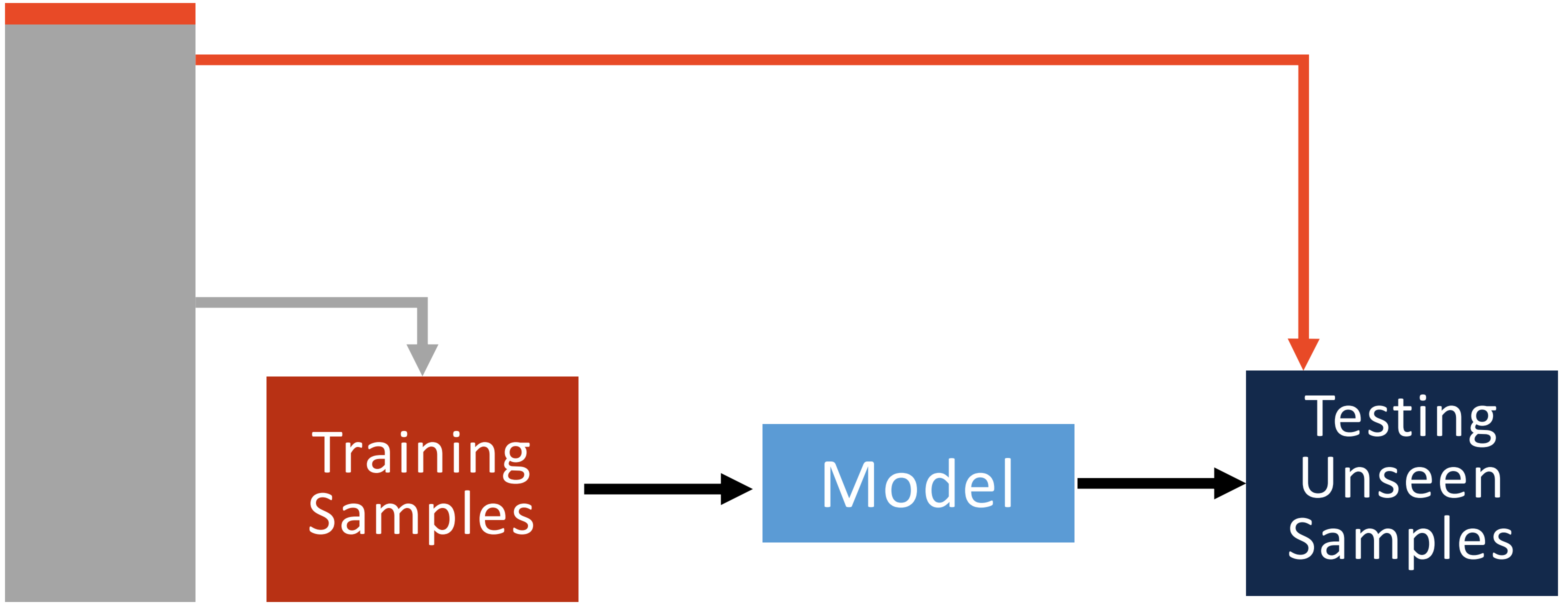


Cross-validation (Cv)

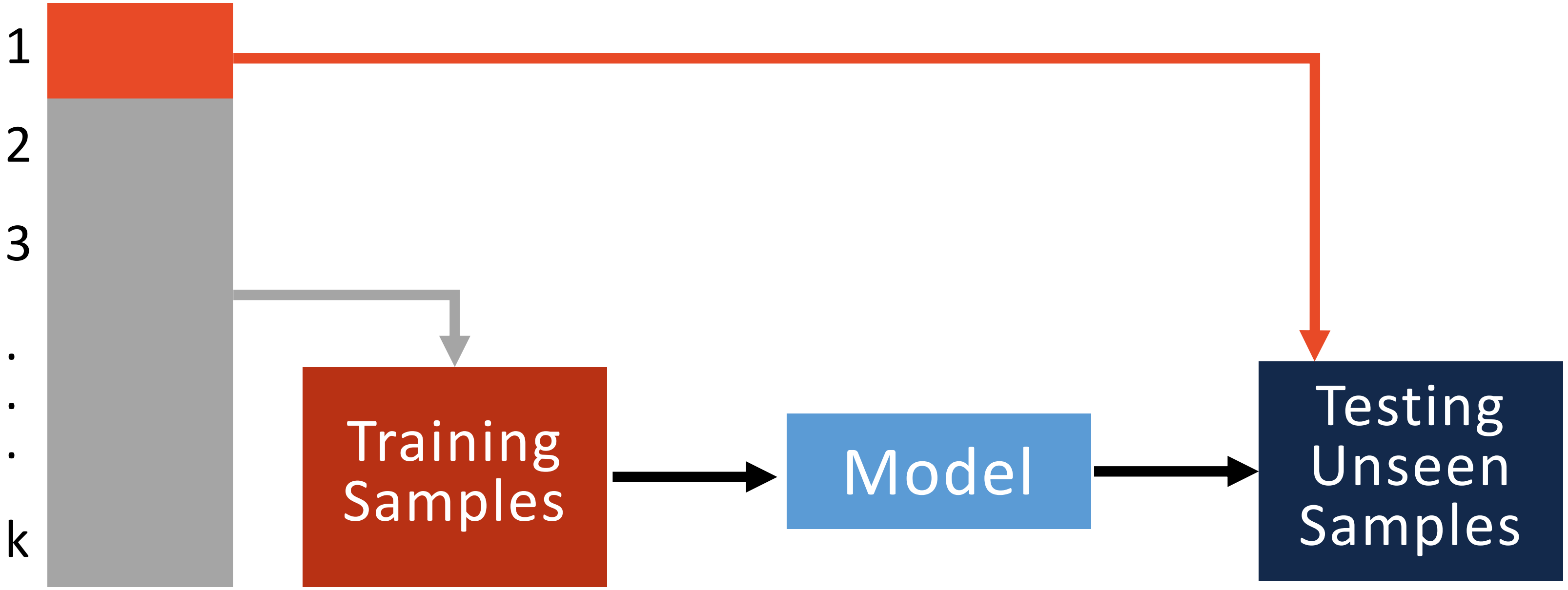
- Leave-1-out CV
- K-fold CV
- Randomized CV



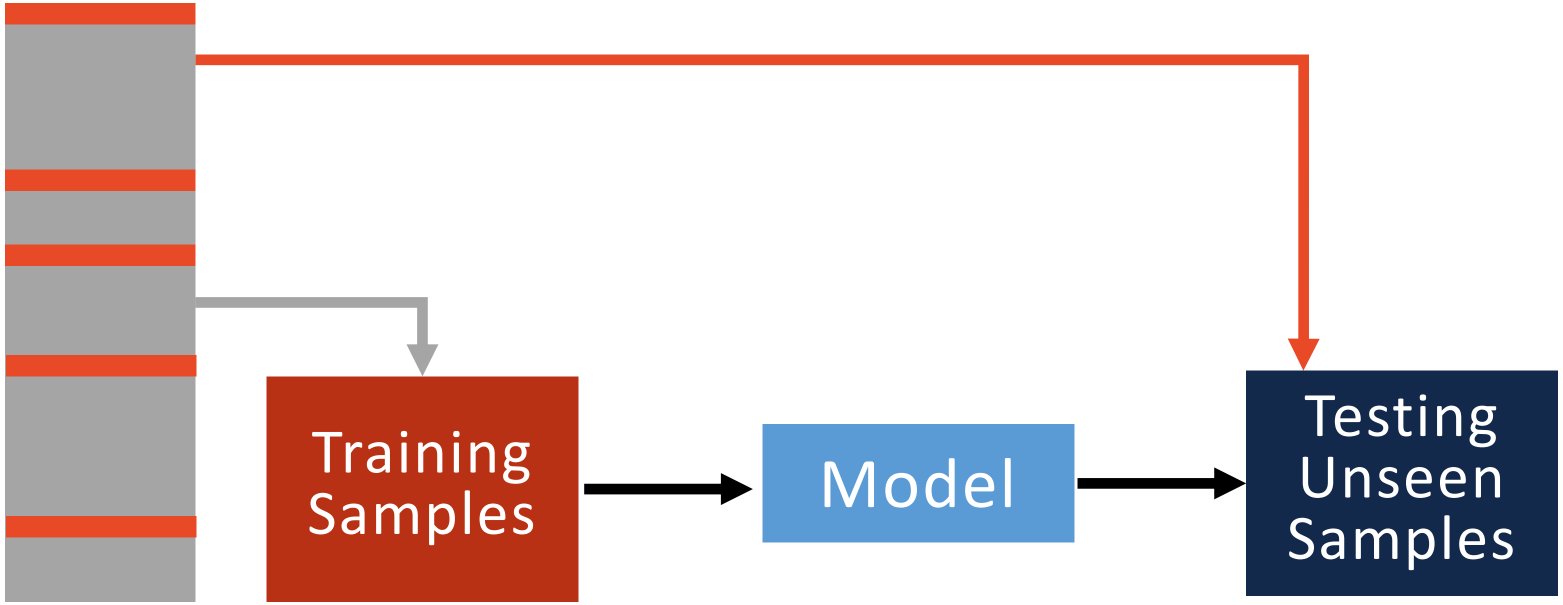
Leave-1-out Cv



K-fold Cv



Randomized Cv



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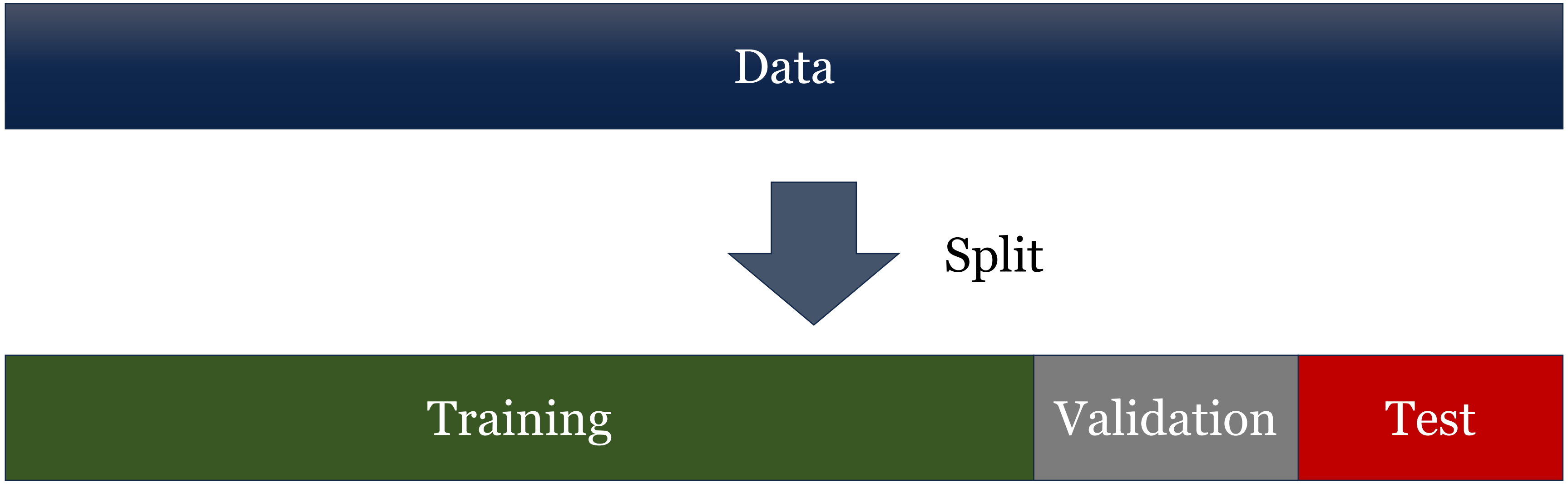
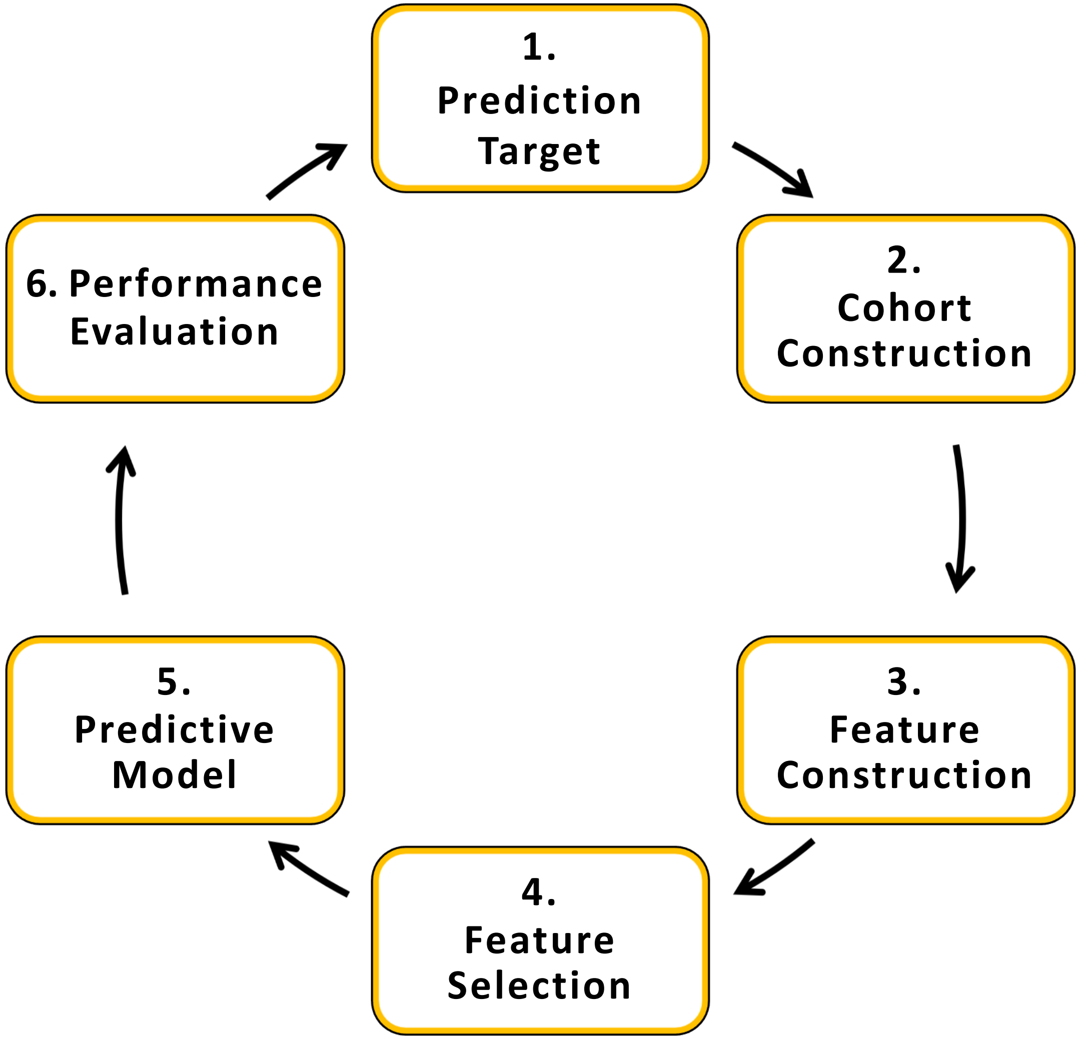
Best practice of predictive modeling evaluation



- Validation and test sets can be small,
  - but should be similar to each other
- Training data can be flexible
  - High volume is preferred
  - Some low quality data can be allowed

Predictive Modeling Pipeline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