Machine Learning Overview

Machine Learning

- It is finally time to dive deep into Machine Learning!
- This Machine Learning Overview section is designed to help get us in the correct frame of mind for the paradigm shift to Machine Learning.
- First, let’s quickly review where we are in the Machine Learning Pathway….

ML Pathway

Real World

Problem to Solve

Question to Answer

ML Pathway

Real World

Problem to Solve

How to fix or change X?

Question to Answer

How does a change in X affect Y?

ML Pathway

Real World

Problem to Solve

How to fix or change X?

Question to Answer

How does a change in X affect Y?

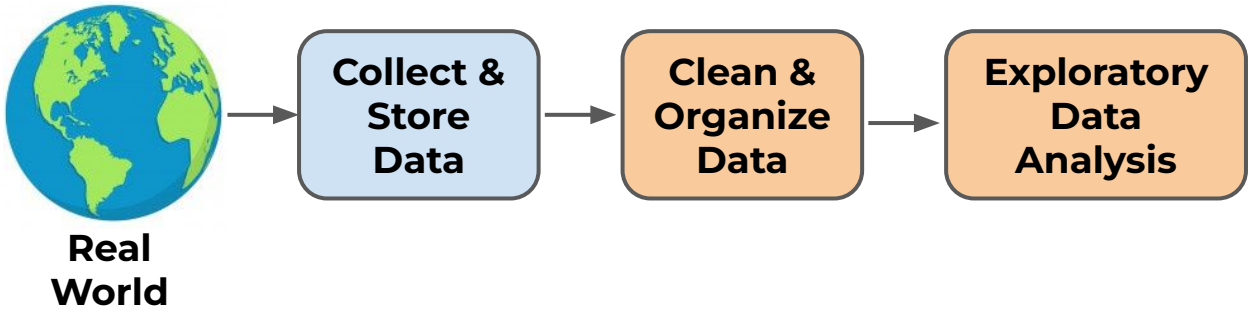
ML Pathway

Real World

Data Product

Data Analysis

ML Pathway


Real World
Collect & Store Data
Clean & Organize Data
Exploratory Data Analysis

ML Pathway

Real World

Collect & Store Data → **Clean & Organize Data** → **Exploratory Data Analysis** → **Machine Learning Models**

Supervised Learning:
Predict an Outcome
Unsupervised Learning:
Discover Patterns in Data

ML Pathway

Real World

Collect & Store Data → **Clean & Organize Data** → **Exploratory Data Analysis** → **Machine Learning Models**

Supervised Learning:
Predict an Outcome
Unsupervised Learning:
Discover Patterns in Data

Machine Learning

- Our main goals in ML Overview section:
  - Problems solved by Machine Learning
  - Types of Machine Learning
    - Supervised Learning
    - Unsupervised Learning
  - ML Process for Supervised Learning
  - Discussion on Companion Book

Machine Learning

- Our main goals in ML Overview section:
  - No coding in this section!
  - Purely a discussion on critically important ideas applied to ML problems.

Machine Learning

- Many other relevant topics will be discussed later in the course as we “discover” them, including:
  - Bias-Variance Trade-off
  - Cross-validation
  - Feature Engineering
  - Scikit-learn
  - Performance Metrics and much more!

Machine Learning

- Machine Learning Sections
  - Section for Type of Algorithm
    - Intuition and Mathematical Theory
    - Example code-along of application of Algorithm
    - Expansion of Algorithm
    - Project Exercise
    - Project Exercise Solution

Machine Learning

- Machine Learning Sections
  - Exception for Linear Regression
    - Intuition and Mathematical Theory
    - Simple Linear Regression
    - Scikit-learn and Linear Regression
    - Regularization
  - “Discovering” additional ML topics

Machine Learning

- Machine Learning Sections
  - “Discovering” additional ML topics
    - Performance Metrics
    - Feature Engineering
    - Cross-validation
  - Revisit Linear Regression to combine discovered ML ideas for Project Exercise.

Machine Learning

- Let’s continue by starting to understand why we use machine learning and the use cases for it!

Why Machine Learning?

Machine Learning

- Machine learning in general is the study of statistical computer algorithms that improve automatically through data.
- This means unlike typical computer algorithms that rely on human input for what approach to take, ML algorithms infer best approach from the data itself.

Machine Learning

- Machine learning is a subset of Artificial Intelligence.
- ML algorithms are not explicitly programmed on which decisions to make.
- Instead the algorithm is designed to infer from the data the most optimal choices to make.

Machine Learning

- What kinds of problems can ML solve?
  - Credit Scoring
  - Insurance Risk
  - Price Forecasting
  - Spam Filtering
  - Customer Segmentation
  - Much more!

Machine Learning

- Structure of ML Problem framing:
  - Given **features** from a data set **obtain** a desired **label**.
  - ML algorithms are often called “estimators” since they are estimating the desired **label** or output.

Machine Learning

- How can ML be so robust in solving all sorts of problems?
- Machine learning algorithms rely on data and a set of statistical methods to learn what features are important in data.

Machine Learning

- Simple Example:
  - Predict the price a house should sell at given its current features (Area,Bedrooms,Bathrooms,etc...)

Machine Learning

- House Price Prediction
  - Typical Algorithm
    - Human user defines an algorithm to manually set values of importance for each feature.

Machine Learning

- House Price Prediction
  - ML Algorithm
    - Algorithm automatically determines importance of each feature from existing data

Machine Learning

- Why machine learning?
  - Many complex problems are only solvable with machine learning techniques.
  - Problems such as spam email or handwriting identification require ML for an effective solution.

Machine Learning

- Why not just use machine learning for everything?
  - Major caveat to effective ML is good data.
  - Majority of development time is spent cleaning and organizing data, **not** implementing ML algorithms.

Machine Learning

- Do we develop our own ML algorithms?
  - Rare to have a need to manually develop and implement a new ML algorithm, since these techniques are well documented and developed.

Machine Learning

- Let’s continue this discussion by exploring the types of machine learning algorithms!

Types of Machine Learning

Machine Learning

- There are two main types of Machine Learning we will cover in upcoming sections:
    - Supervised Learning
    - Unsupervised Learning

Machine Learning

- Supervised Learning
  - Using **historical** and **labeled** data, the machine learning model predicts a value.
- Unsupervised Learning
  - Applied to **unlabeled** data, the machine learning model discovers possible patterns in the data.

Machine Learning

- Supervised Learning
  - Requires **historical labeled** data:
    - Historical
      - Known results and data from the past.
    - Labeled
      - The desired output is known.

Machine Learning

- Supervised Learning
  - Two main label types
    - Categorical Value to Predict
      - Classification Task
    - Continuous Value to Predict
      - Regression Task

Machine Learning

- Supervised Learning
  - Classification Tasks
    - Predict an assigned category
      - Cancerous vs. Benign Tumor
      - Fulfillment vs. Credit Default
      - Assigning Image Category
        - Handwriting Recognition

Machine Learning

- Supervised Learning
  - Regression Tasks
    - Predict a continuous value
      - Future prices
      - Electricity loads
      - Test scores

Machine Learning

- Unsupervised Learning
  - Group and interpret data without a label.
  - Example:
    - Clustering customers into separate groups based off their behaviour features.

Machine Learning

- Unsupervised Learning
  - Major downside is because there was no historical “correct” label, it is much harder to evaluate performance of an unsupervised learning algorithm.

Machine Learning

- Machine Learning Sections
  - We first focus on supervised learning to build an understanding of machine learning capabilities.
  - Then shift focus to unsupervised learning for clustering and dimensionality reduction.

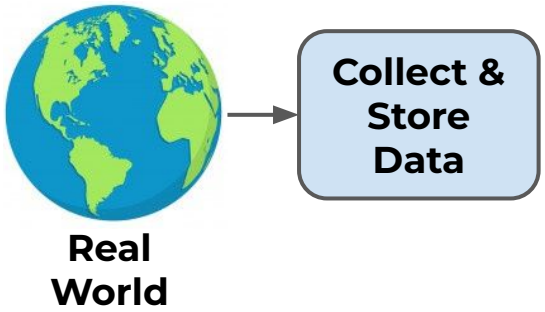
Machine Learning

- Finally, before we dive into coding and linear regression in the next section, let’s have a deep dive into the entire Supervised Machine Learning process to set ourselves up for success!

Supervised Machine Learning Process

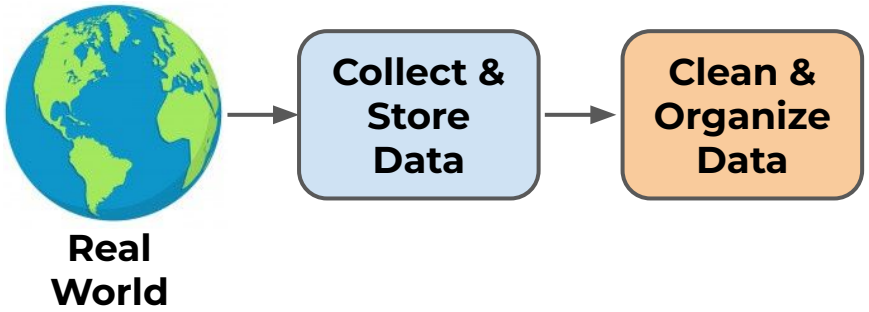
Machine Learning

- Machine Learning Pathway



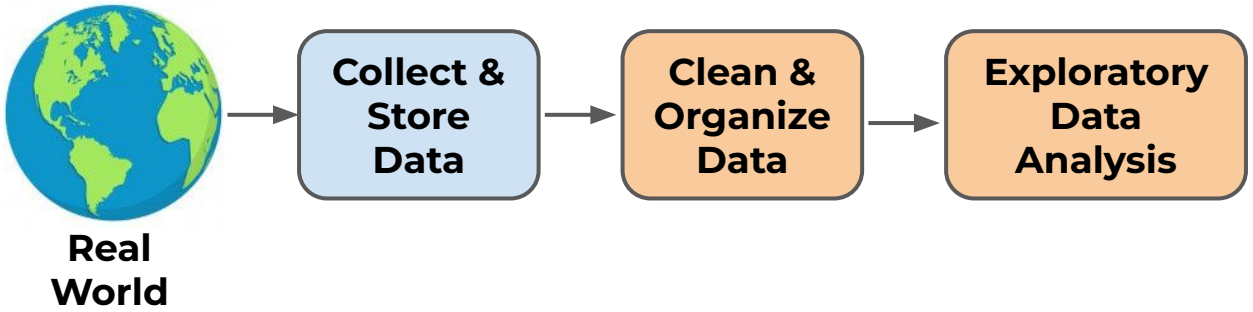
Machine Learning

- Machine Learning Pathway



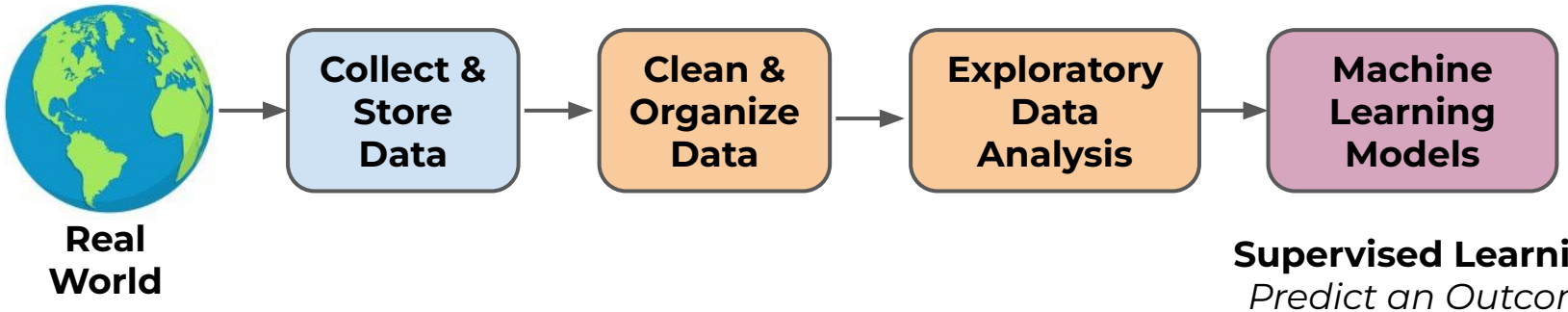
Machine Learning

- Machine Learning Pathway



Machine Learning

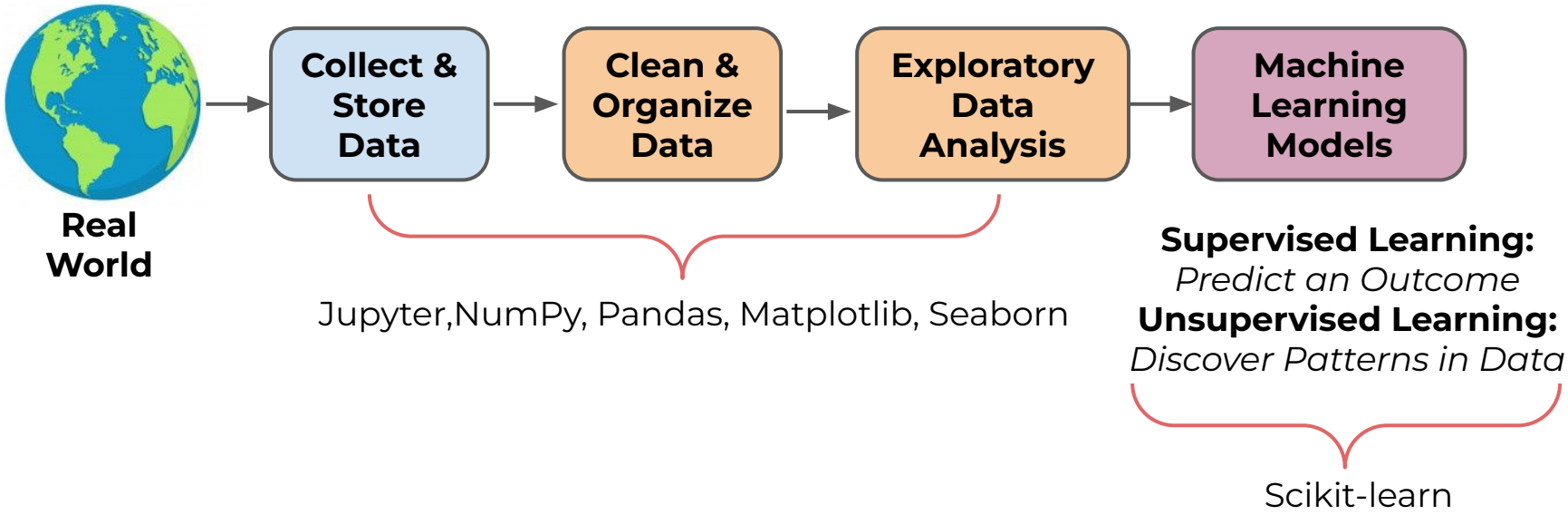
- Machine Learning Pathway



Supervised Learning:
Predict an Outcome
Unsupervised Learning:
Discover Patterns in Data

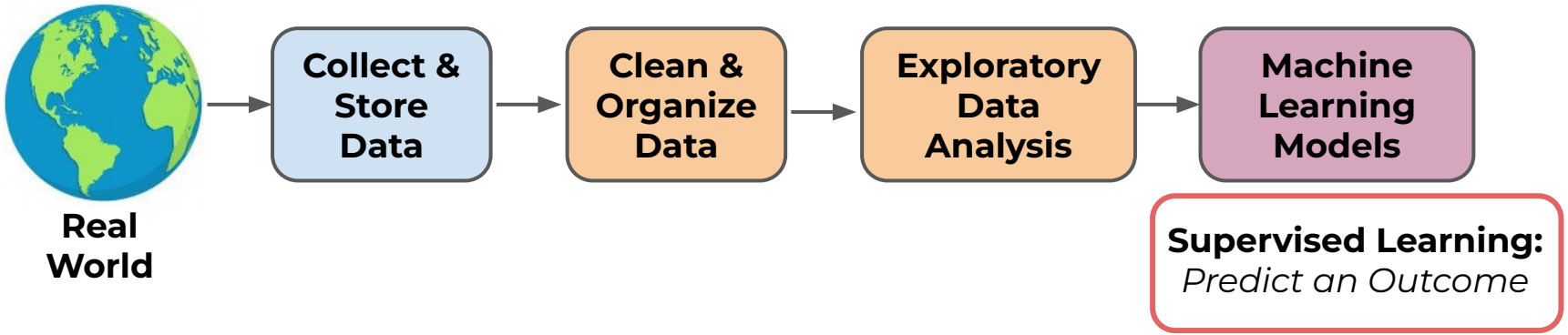
Machine Learning

- Machine Learning Pathway



Machine Learning

- ML Process : Supervised Learning Tasks



Machine Learning

- **Predict price a house should sell at.**

Real World

Collect & Store Data → **Clean & Organize Data** → **Exploratory Data Analysis** → **Machine Learning Models**

Supervised Learning:
Predict an Outcome

Machine Learning

- **Supervised** Machine Learning Process
- Start with collecting and organizing a data set based on history:

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Machine Learning

- **Historical labeled** data on previously sold houses.

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Machine Learning

- If a new house comes on the market with a known Area, Bedrooms, and Bathrooms: *Predict what price should it sell at.*

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Machine Learning

- Data Product:
  - Input house features
  - Output predicted selling price

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
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Machine Learning

- Using **historical, labeled** data predict a future outcome or result.

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
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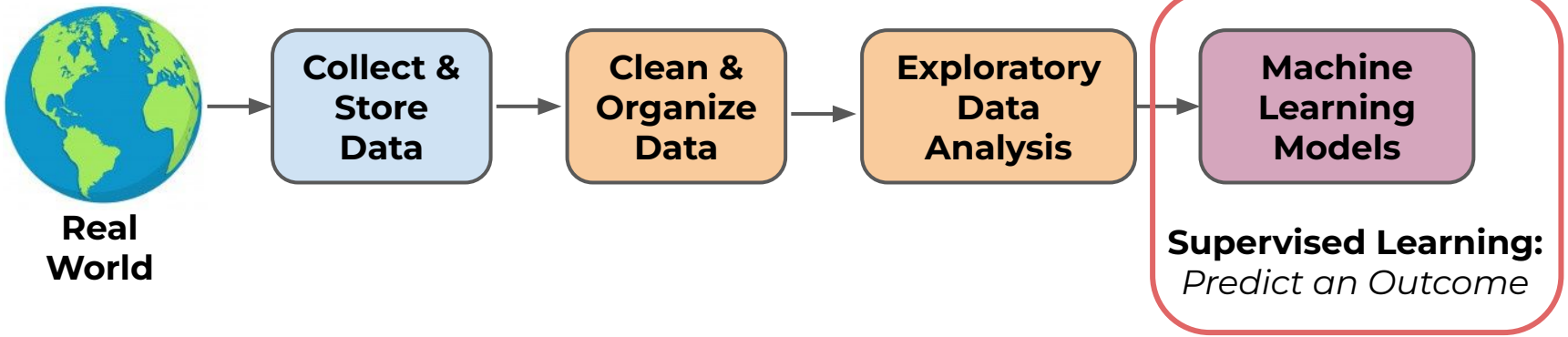
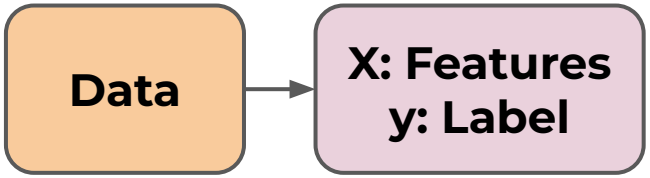
Machine Learning

- **Predict price a house should sell at.**



Machine Learning

- **Supervised** Machine Learning Process



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200	3	2	$500,000
190	2	1	$450,000
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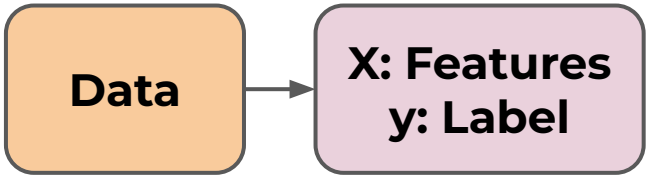
Machine Learning

- **Label** is what we are trying to predict



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190	2	1	$450,000
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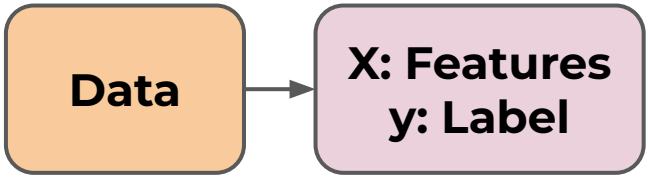
Machine Learning

- **Features** are known characteristics or components in the data



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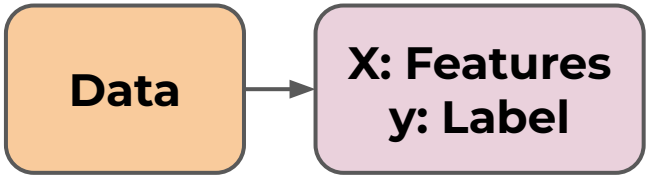
Machine Learning

- **Features** and **Label** are identified according to the problem being solved.



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200	3	2	$500,000
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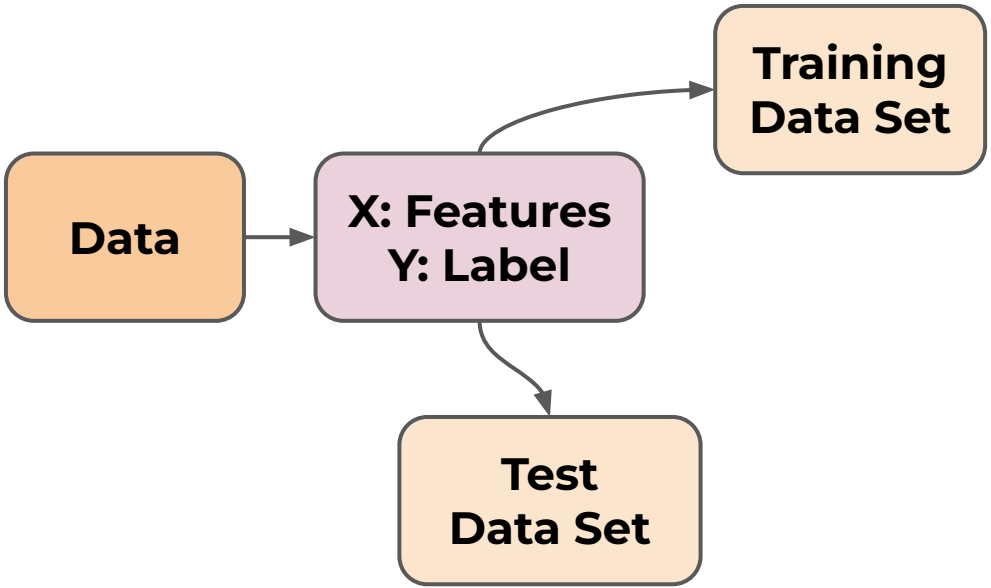
210	2	2	$550,000

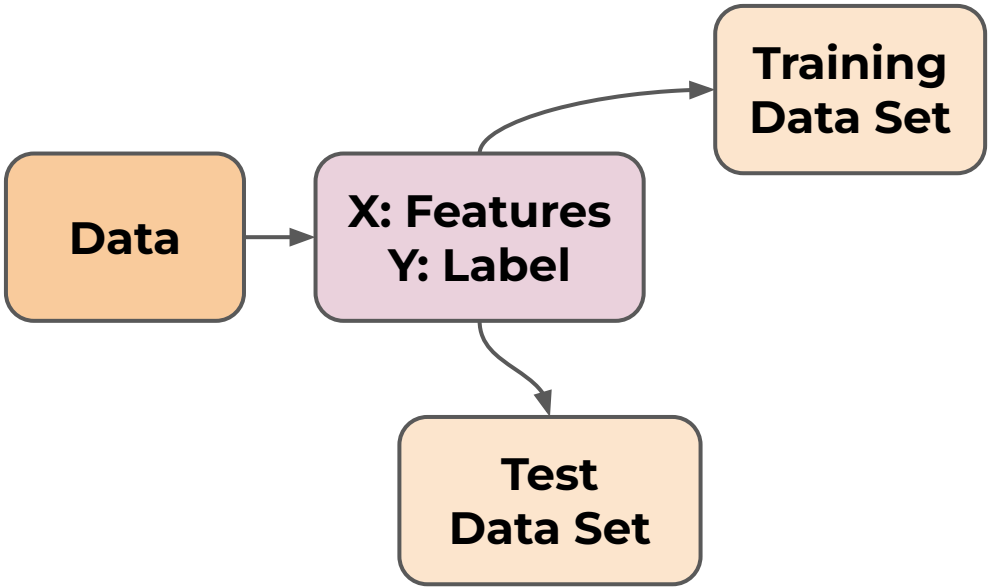
Supervised Machine Learning Process

- Split data into training set and test set



Supervised Machine Learning Process

- Later on we will discuss cross-validation



Supervised Machine Learning Process

- Why perform this split? How to split?

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- How would you judge a human realtor's performance?

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- Ask a human realtor to take a look at historical data...

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- Then give her the features of a house and ask her to predict a selling price.

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- But how would you measure how accurate her prediction is? What house should you choose to test on?

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- You can’t judge her based on a new house that hasn’t sold yet, you don’t know it’s true selling price!

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- You shouldn’t judge her on data she’s already seen, she could have **memorized** it!

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- Thus the need for a Train/Test split of the data, let's explore further...

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- We already organized the data into Features (X) and a Label (y)

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- Now we will split this into a training set and a test set:

	Area m^2	Bedrooms	Bathrooms	Price
TRAIN	200	3	2	$500,000
	190	2	1	$450,000
	230	3	3	$650,000
TEST	180	1	1	$400,000
	210	2	2	$550,000

Supervised Machine Learning Process

- Notice how we have 4 components

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

X TRAIN

Y TRAIN

X TEST

Y TEST

Supervised Machine Learning Process

- Let’s go back to fairly testing our human realtor….

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000
180	1	1	$400,000
210	2	2	$550,000

Supervised Machine Learning Process

- Let's go back to fairly testing our human realtor....

	Area m^2	Bedrooms	Bathrooms	Price
TRAIN	200	3	2	$500,000
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TEST	180	1	1	$400,000
	210	2	2	$550,000

Supervised Machine Learning Process

- Let her study and learn on the training set getting access to both X and y.

TRAIN

Area m^2	Bedrooms	Bathrooms	Price
200	3	2	$500,000
190	2	1	$450,000
230	3	3	$650,000

Supervised Machine Learning Process

- After she has “learned” about the data, we can test her skill on the test set.

TEST

Area m^2	Bedrooms	Bathrooms
180	1	1
210	2	2

Supervised Machine Learning Process

- Provide only the X test data and ask for her predictions for the sell price.

TEST

Area m^2	Bedrooms	Bathrooms
180	1	1
210	2	2

Supervised Machine Learning Process

- This is new data she has never seen before! She has also never seen the real sold price.

TEST

Area m^2	Bedrooms	Bathrooms
180	1	1
210	2	2

Supervised Machine Learning Process

- Ask for predictions per data point.

Predictions	Area m^2	Bedrooms	Bathrooms
$410,000	180	1	1
$540,000	210	2	2

Supervised Machine Learning Process

- Then bring back the original prices.

Predictions	Area m^2	Bedrooms	Bathrooms	Price
$410,000	180	1	1	$400,000
$540,000	210	2	2	$550,000

Supervised Machine Learning Process

- Finally compare predictions against true test price.

Predictions	Price
$410,000	$400,000
$540,000	$550,000

Supervised Machine Learning Process

- This is often labeled as **ŷ** compared again **y**

ŷ	**y**
Predictions	**Price**
$410,000	$400,000
$540,000	$550,000

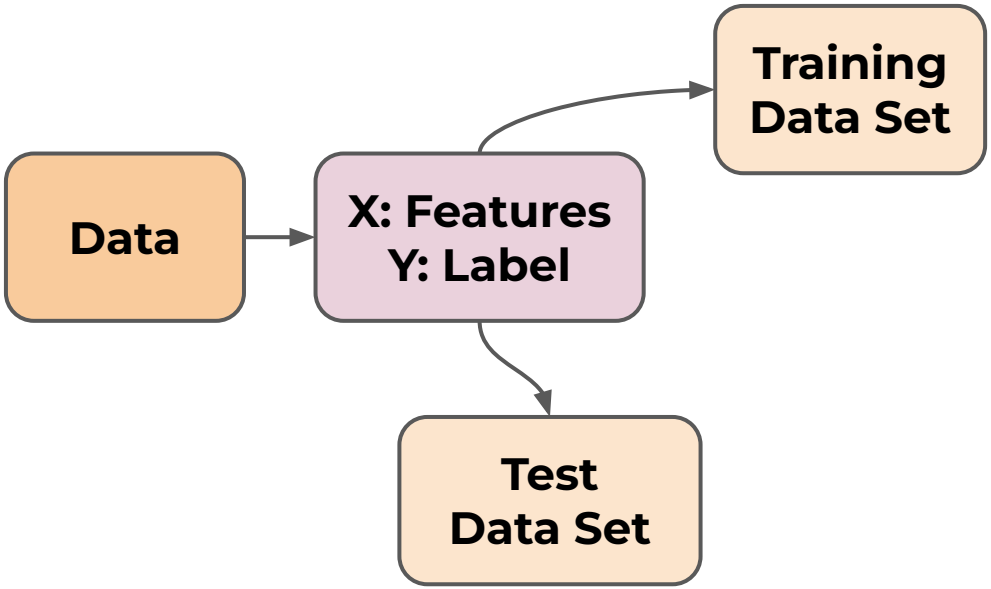
Supervised Machine Learning Process

- Later on we will discuss the many methods of evaluating this performance!

Predictions	Price
$410,000	$400,000
$540,000	$550,000

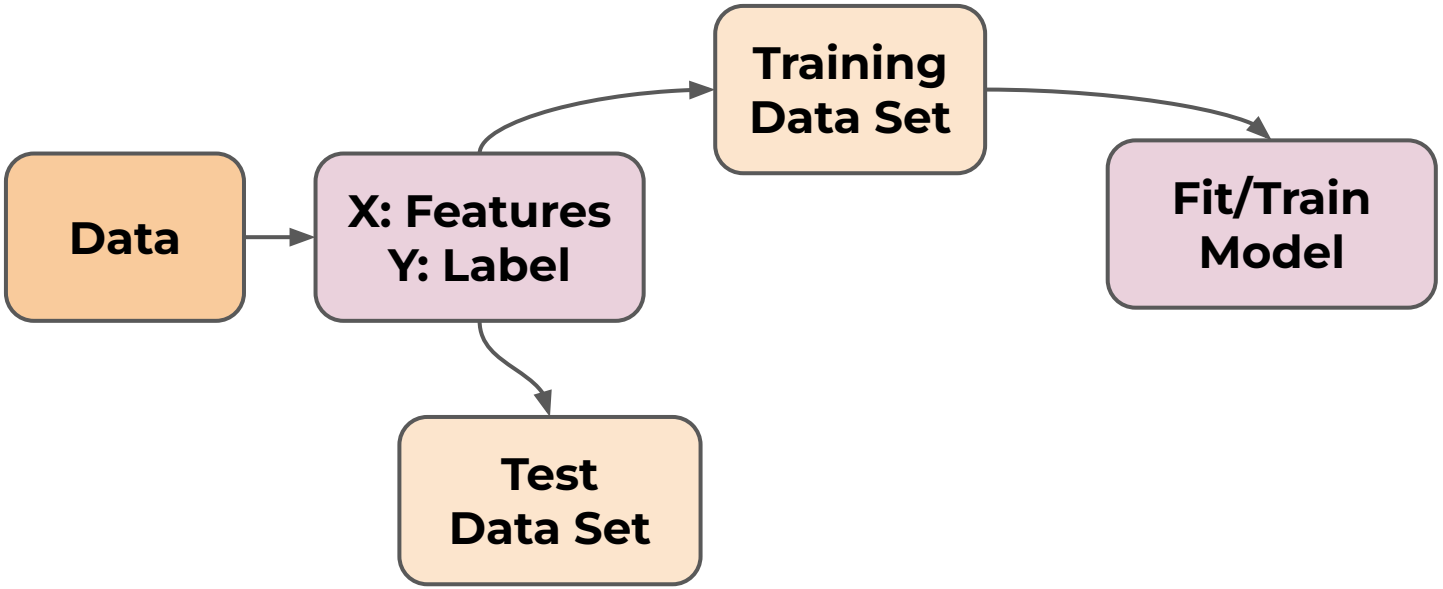
Supervised Machine Learning Process

- Split Data



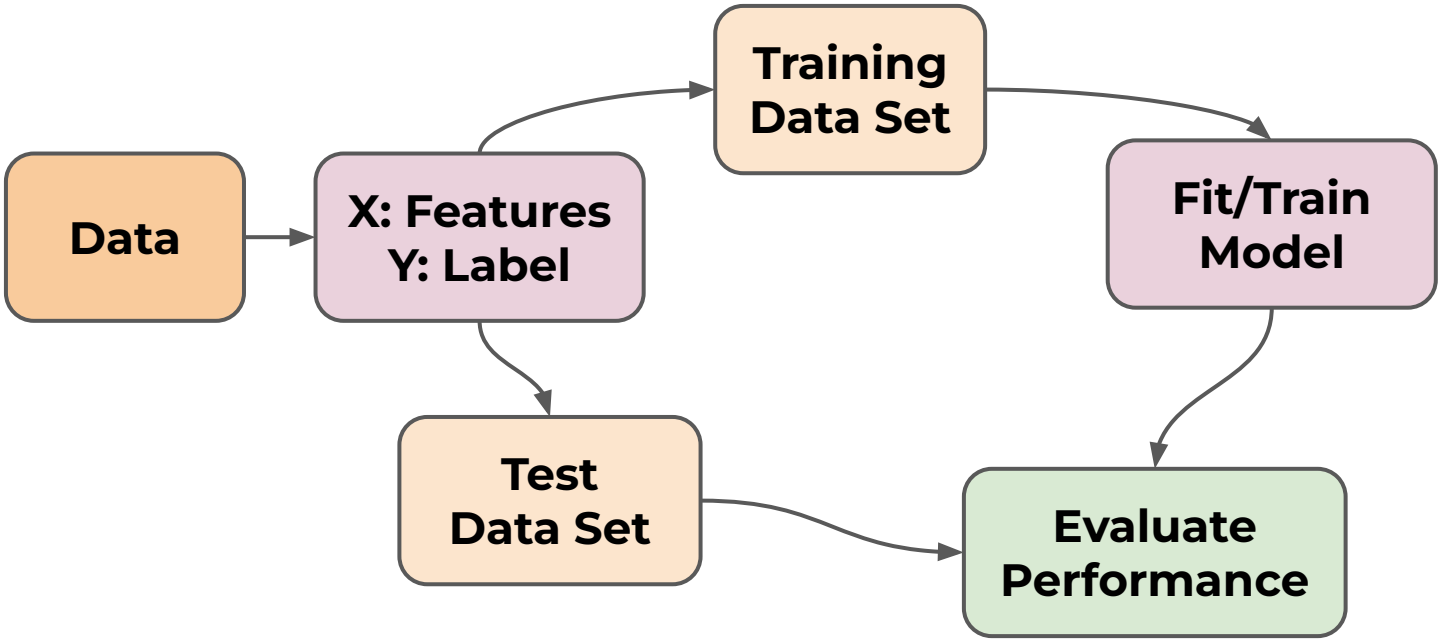
Supervised Machine Learning Process

- Split Data, Fit on Train Data



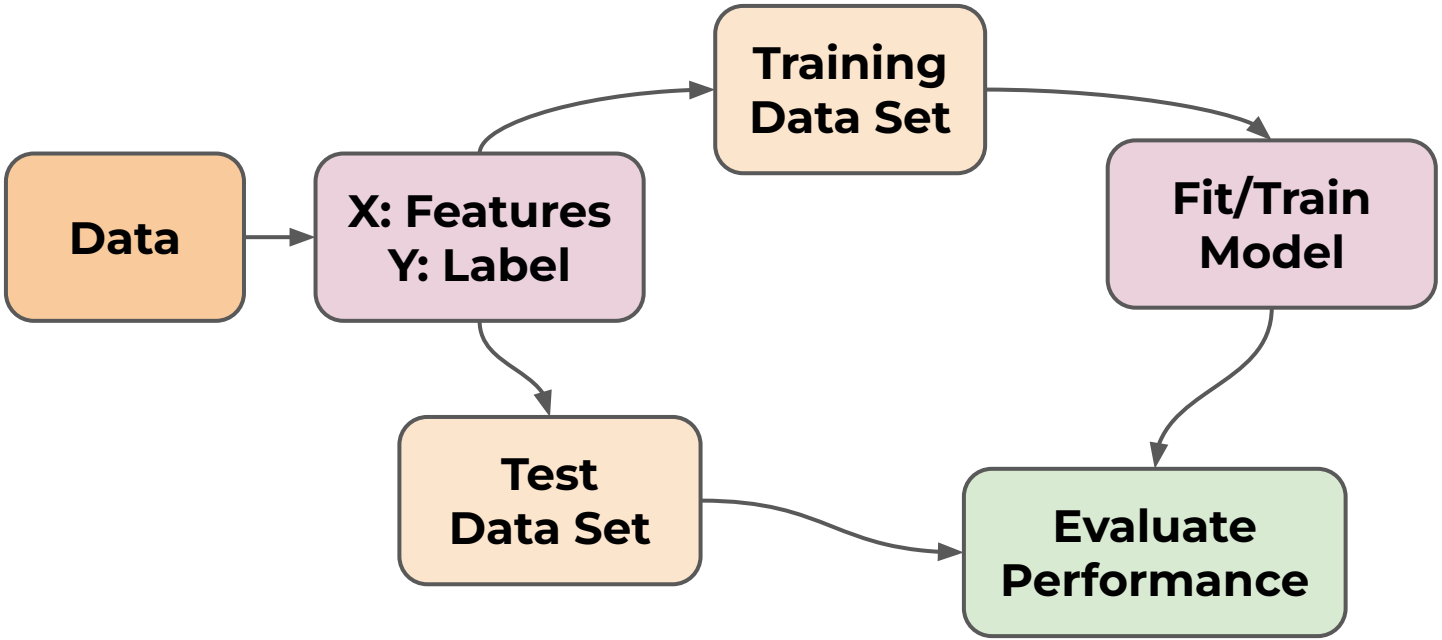
Supervised Machine Learning Process

- Split Data, Fit on Train Data,Evaluate Model



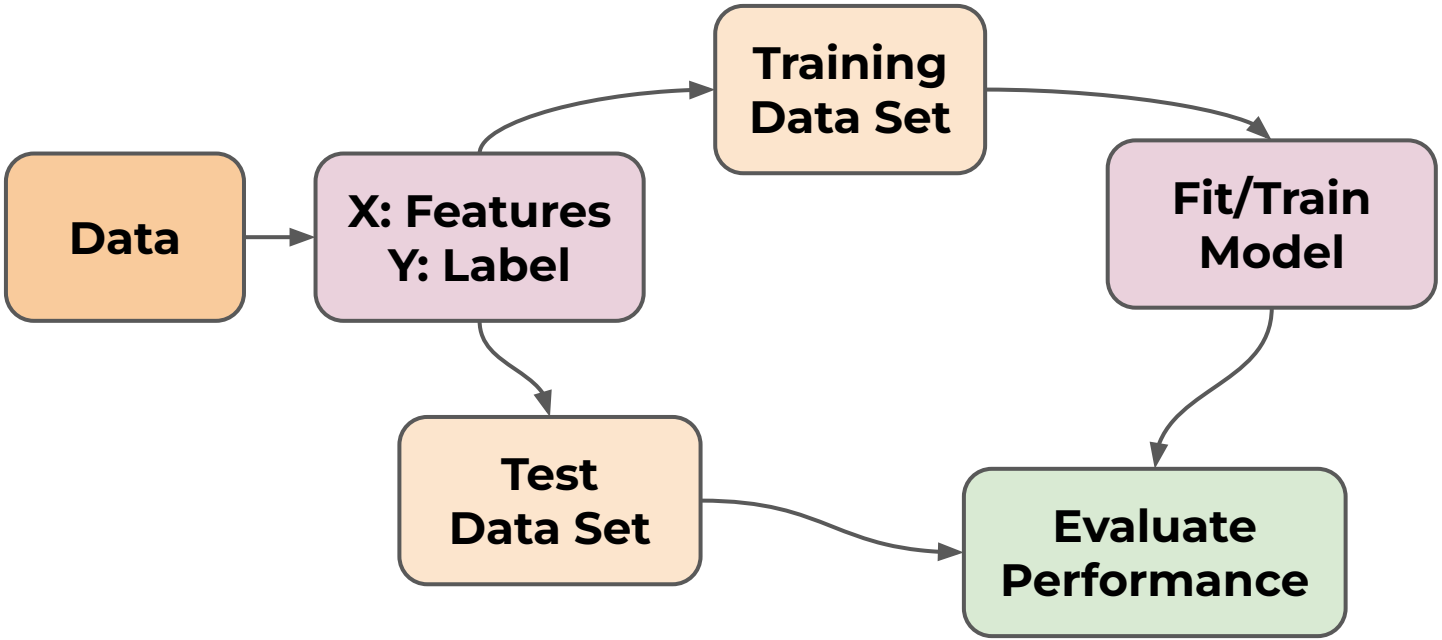
Supervised Machine Learning Process

- What happens if performance isn't great?



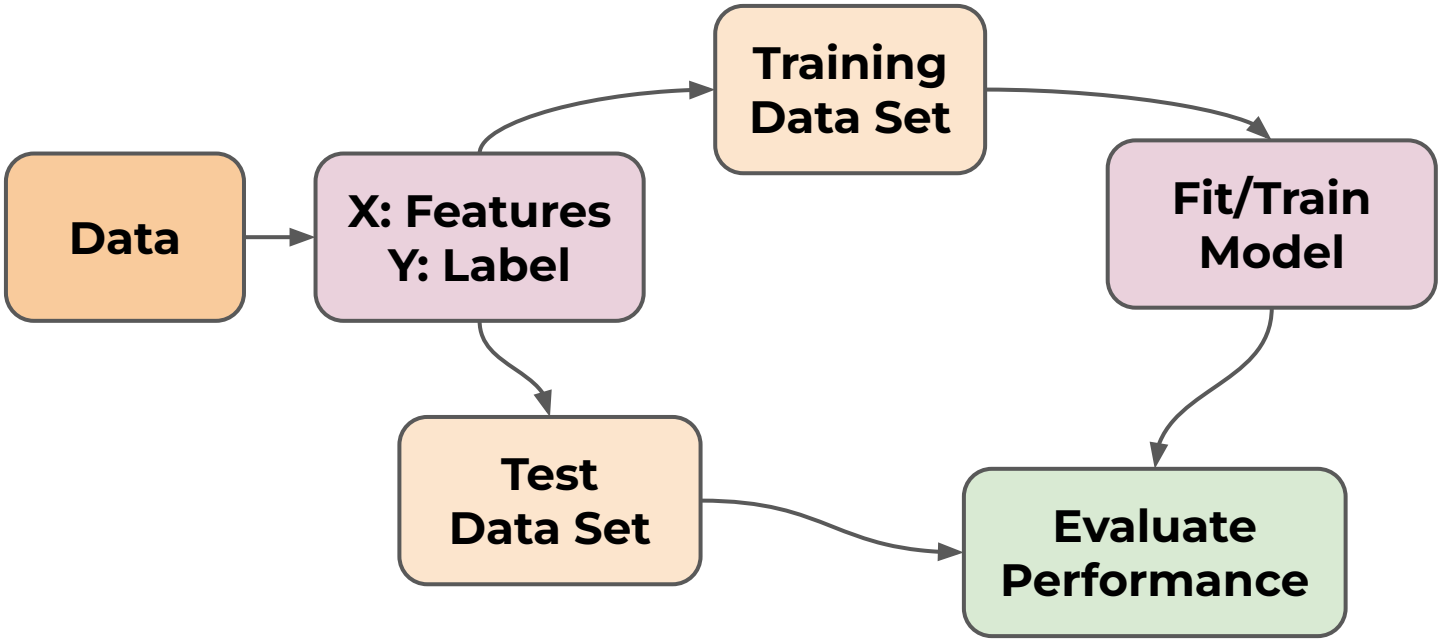
Supervised Machine Learning Process

- We can adjust model **hyperparameters**



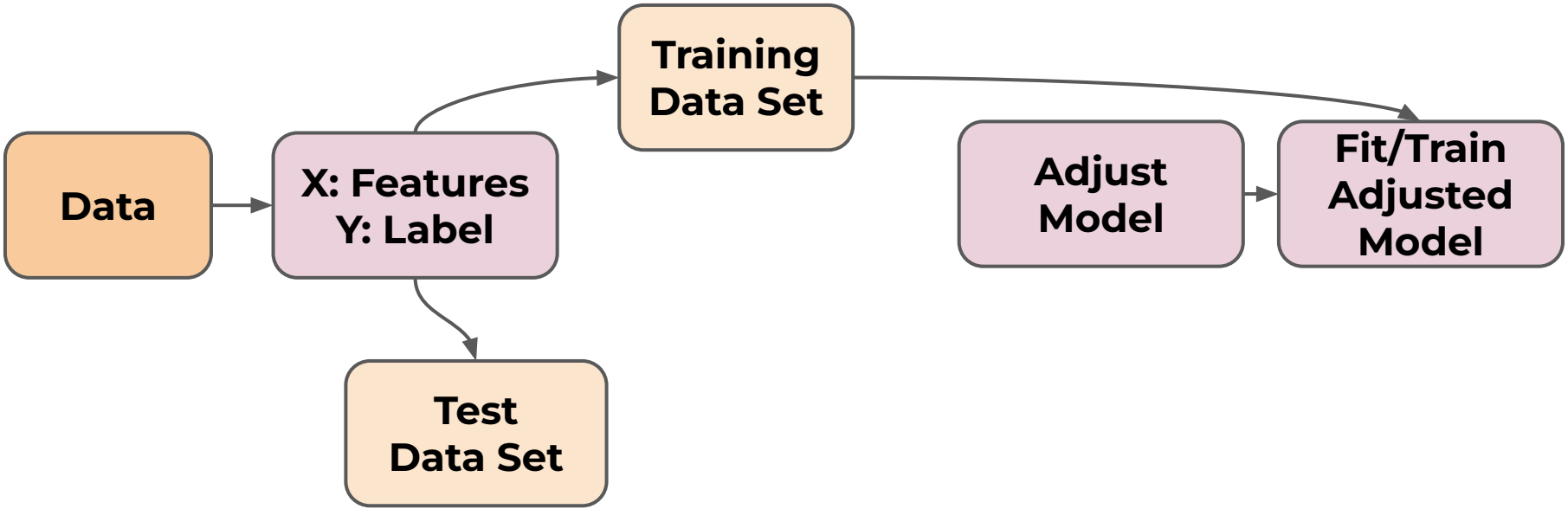
Supervised Machine Learning Process

- Many algorithms have adjustable values



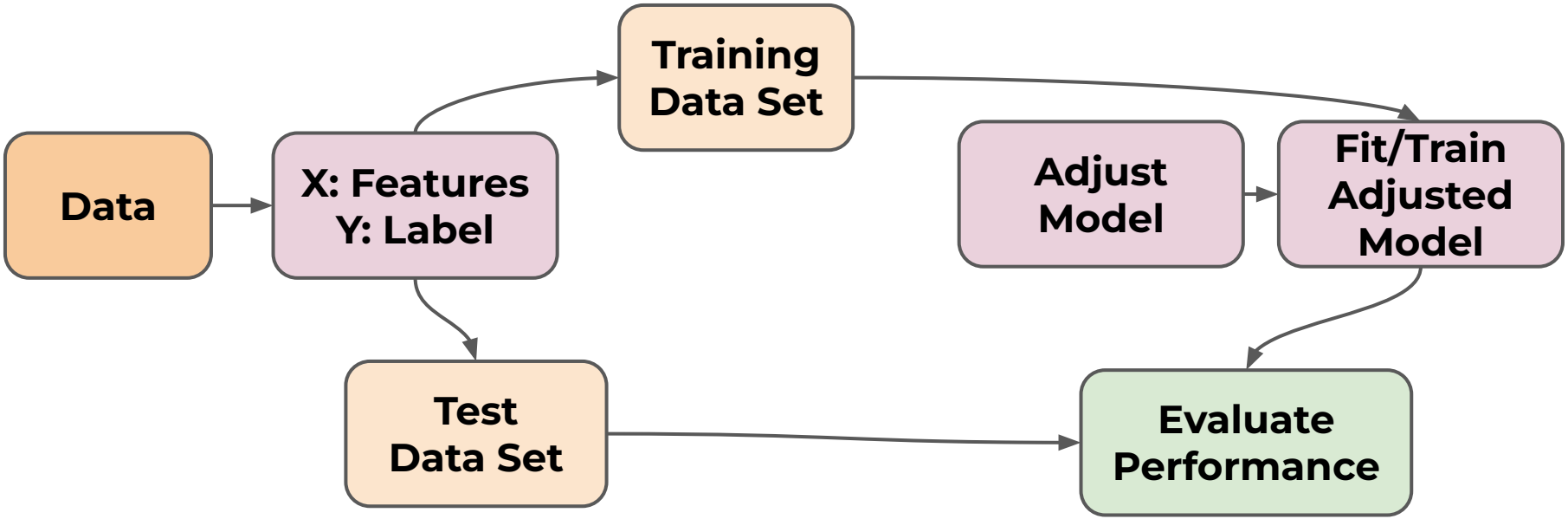
Supervised Machine Learning Process

- Many algorithms have adjustable values



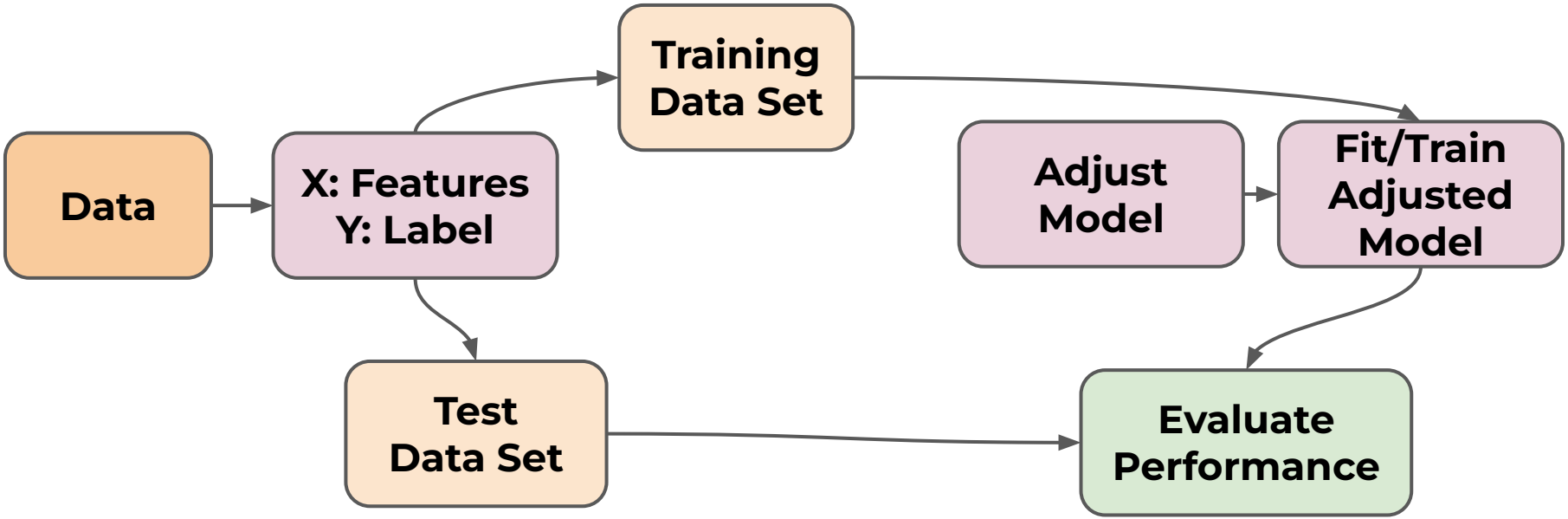
Supervised Machine Learning Process

- Evaluate adjusted model



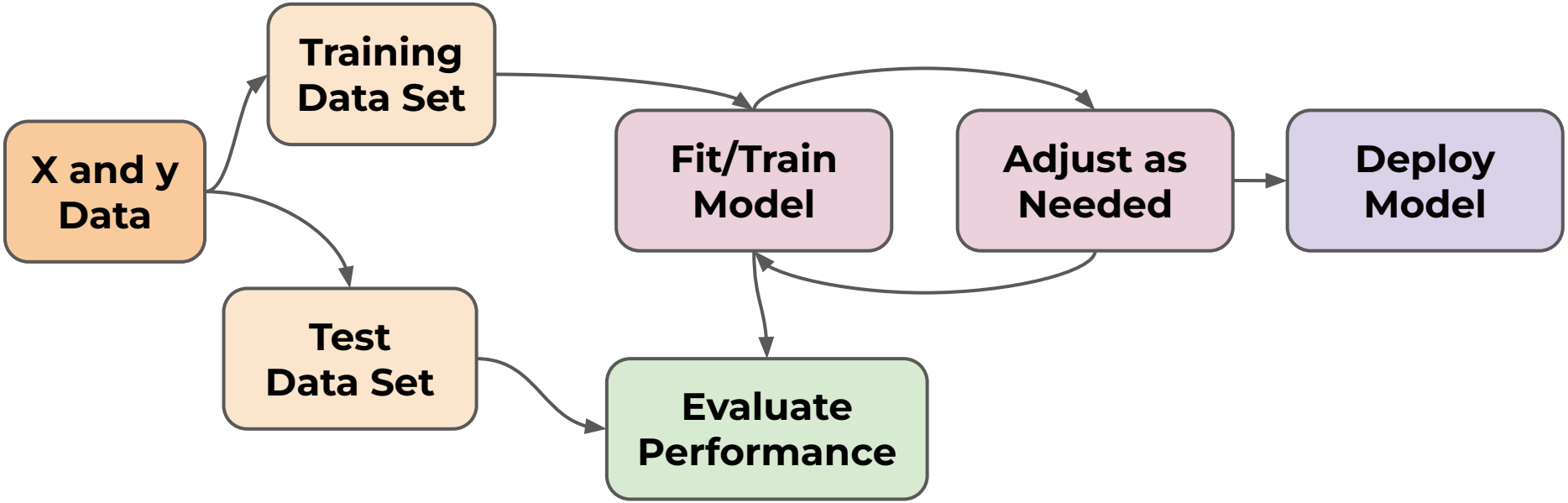
Supervised Machine Learning Process

- Can repeat this process as necessary



Supervised Machine Learning Process

- Full and Simplified Process



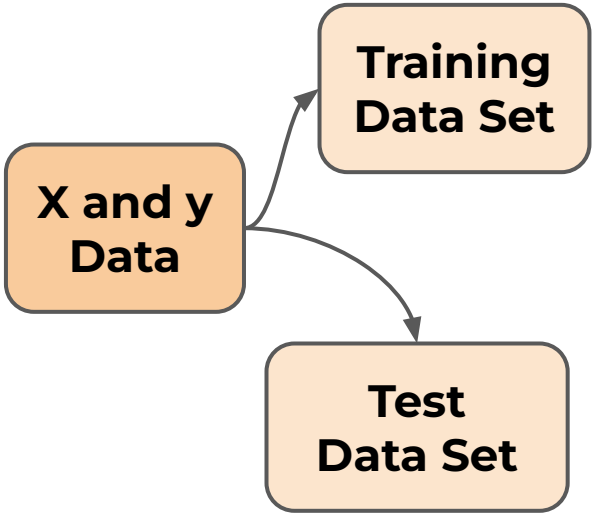
Supervised Machine Learning Process

- Get X and y data

X and y Data

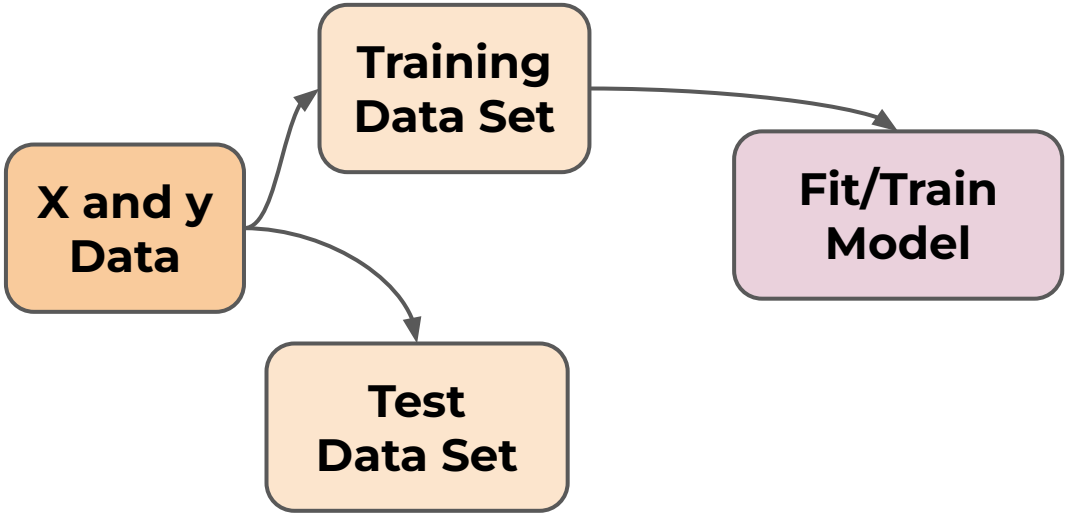
Supervised Machine Learning Process

- Split data for evaluation purposes



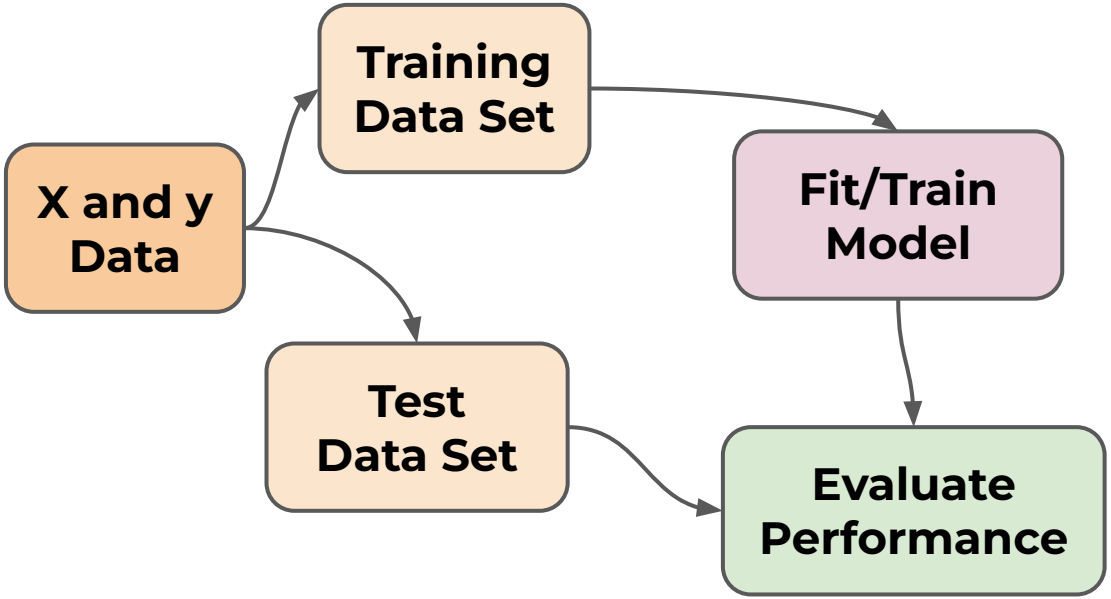
Supervised Machine Learning Process

- Fit ML Model on Training Data Set



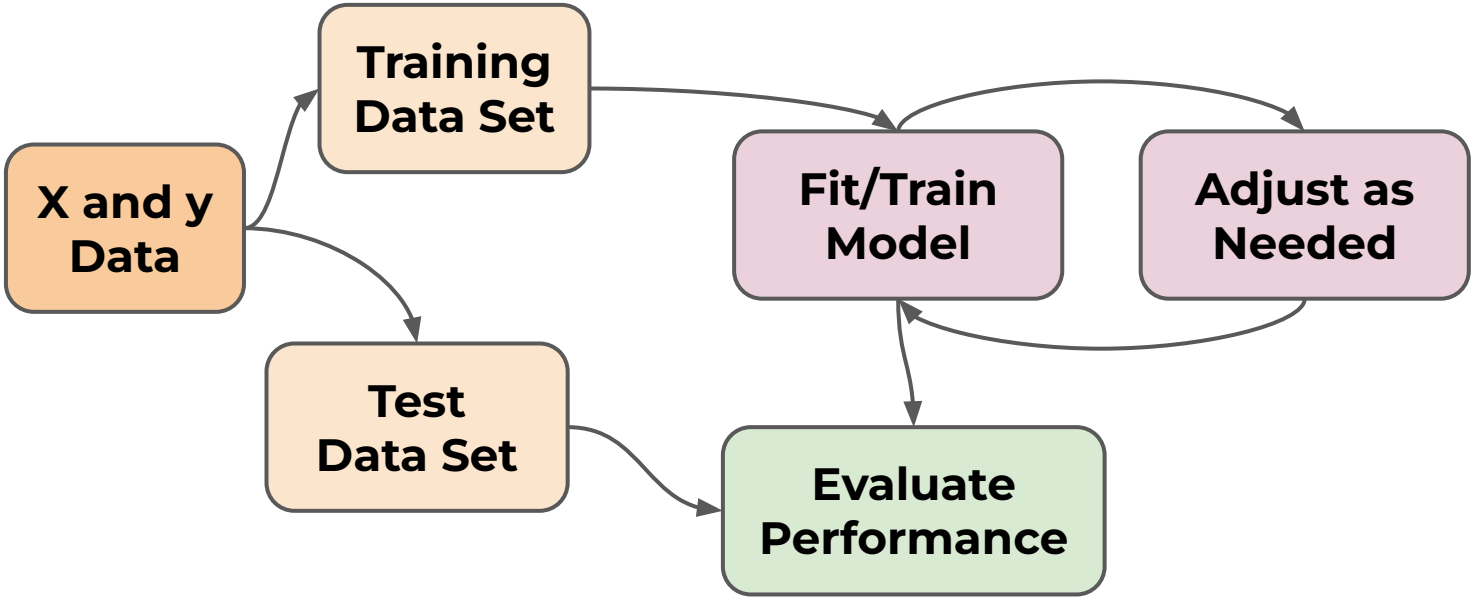
Supervised Machine Learning Process

- Evaluate Model Performance



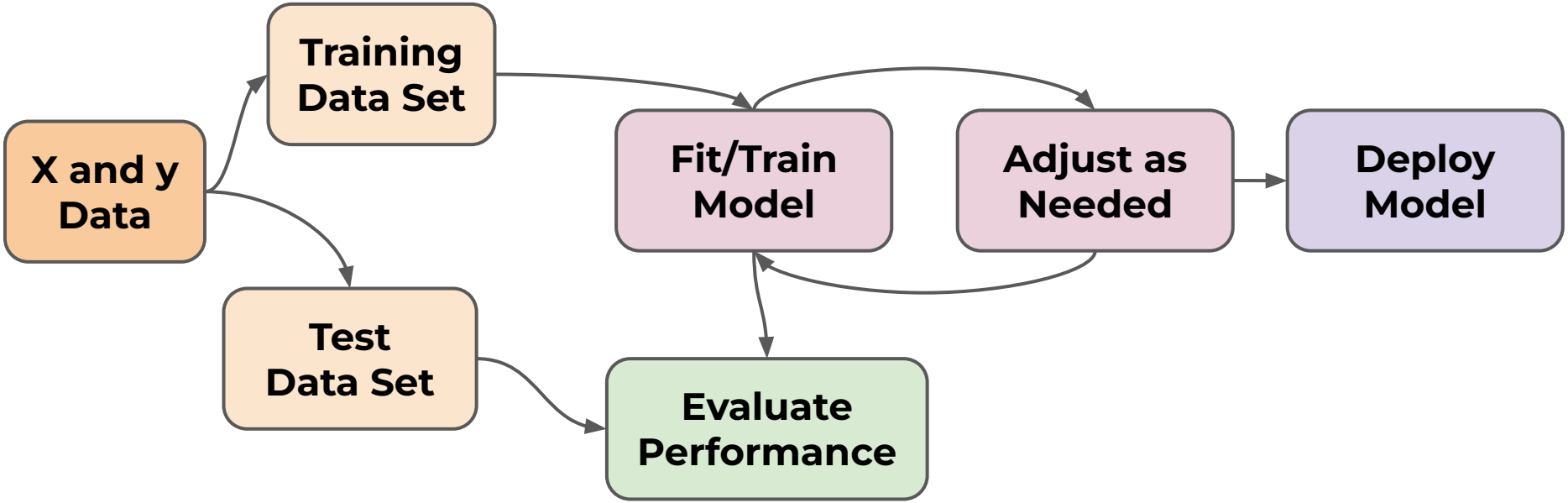
Supervised Machine Learning Process

- Adjust model hyperparameters as needed



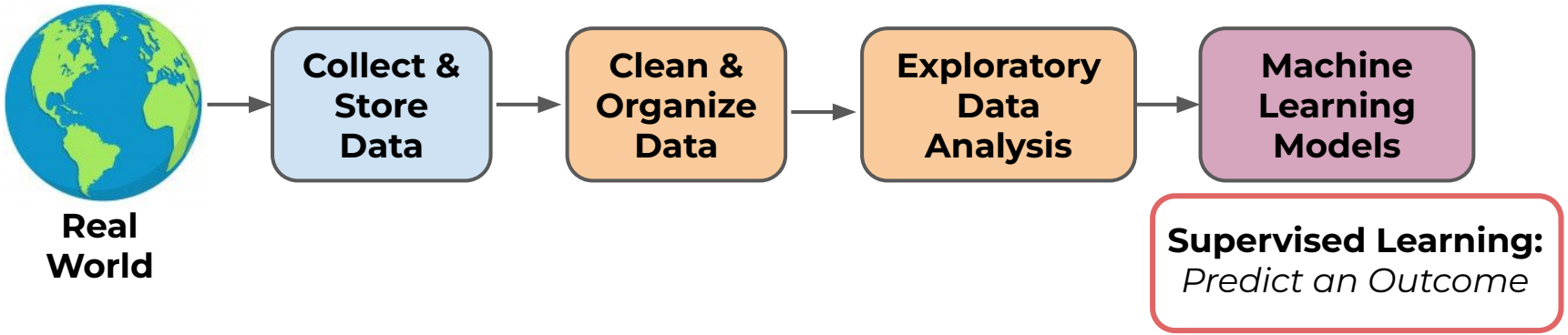
Supervised Machine Learning Process

- Deploy model to real world

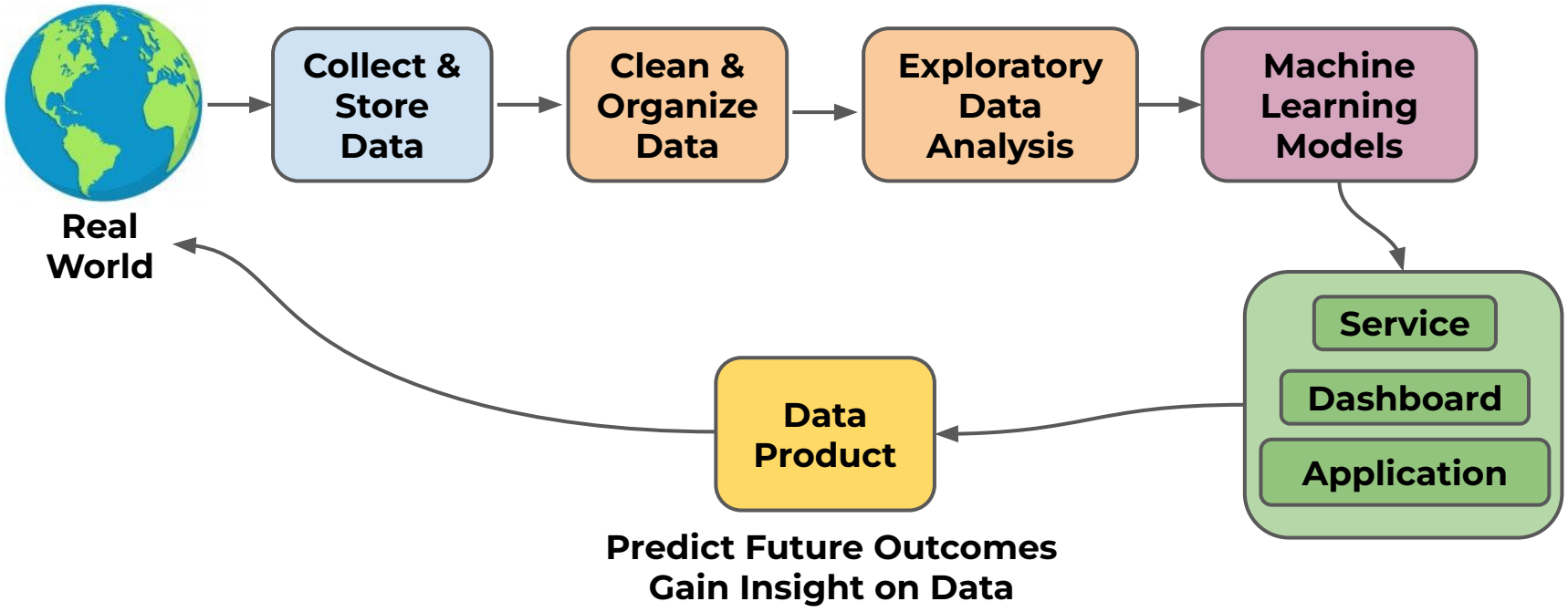


Machine Learning

- ML Process : Supervised Learning Tasks



ML Pathway


Real World
Collect & Store Data
Clean & Organize Data
Exploratory Data Analysis
Machine Learning Models
Service
Dashboard
Application
Data Product
Predict Future Outcomes
Gain Insight on Data

Companion Book

Machine Learning

- ISLR - Introduction to Statistical Learning
  - Freely available book that gives a fantastic overview of many of the ML algorithms we discuss in the course.

Machine Learning

- We will refer to the book for optional reading assignments.
- A few examples will line up nicely with the book content.
- Book is freely available, simply google search for relevant links:
  - ISLR + Pdf