

# Adversarial Networks for Data Generation and Domain Adaptation

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A gentle introduction

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# Outline

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- Learning Goals
- Introduction
- Generative Adversarial Networks (GANs)
- Domain Shift and Domain Adaptation
- Domain Adversarial Neural Networks
- Summary

# Learning Goals

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- Introduce Generative Adversarial Networks
  - What they do
  - How they work
- Introduce domain shift and domain adaptation concepts
  - Introduce domain adversarial models for domain adaptation

# Generative Adversarial Networks (GANs)

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# Introduction

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- GANs are unsupervised deep learning methods
- GANs are considered one of the greatest deep learning breakthroughs in recent years
- There are many types of GANs
  - Wasserstein GAN
  - Cycle-GAN
- They all operate under the same principle of having modules with adversarial (*i.e.*, competing objectives)

# What are GANs?

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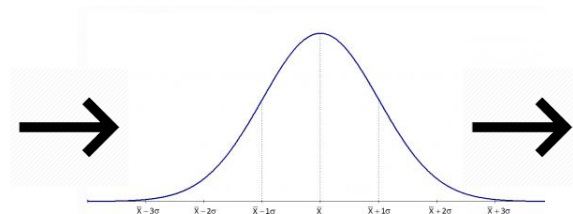
- GANs are generative models. What is a generative model?
- We have two different models in machine learning:
  - 1) Discriminative models



- 2) Generative models



- Dataset



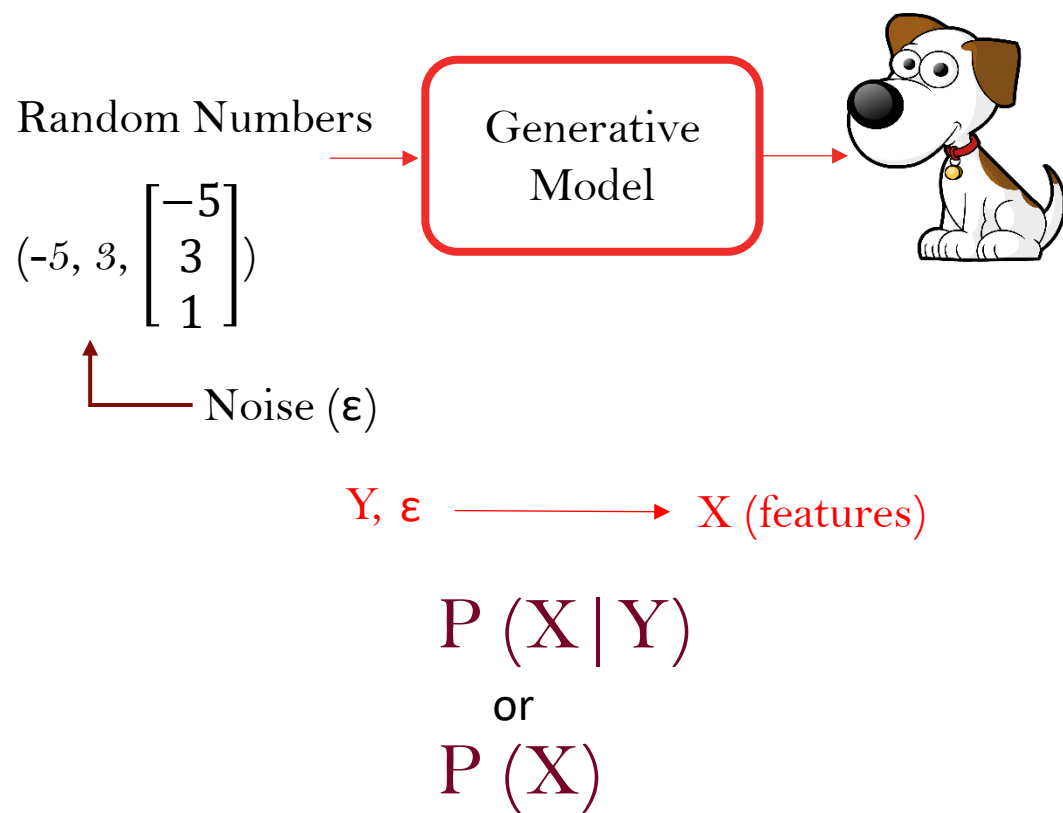
- Learning distribution



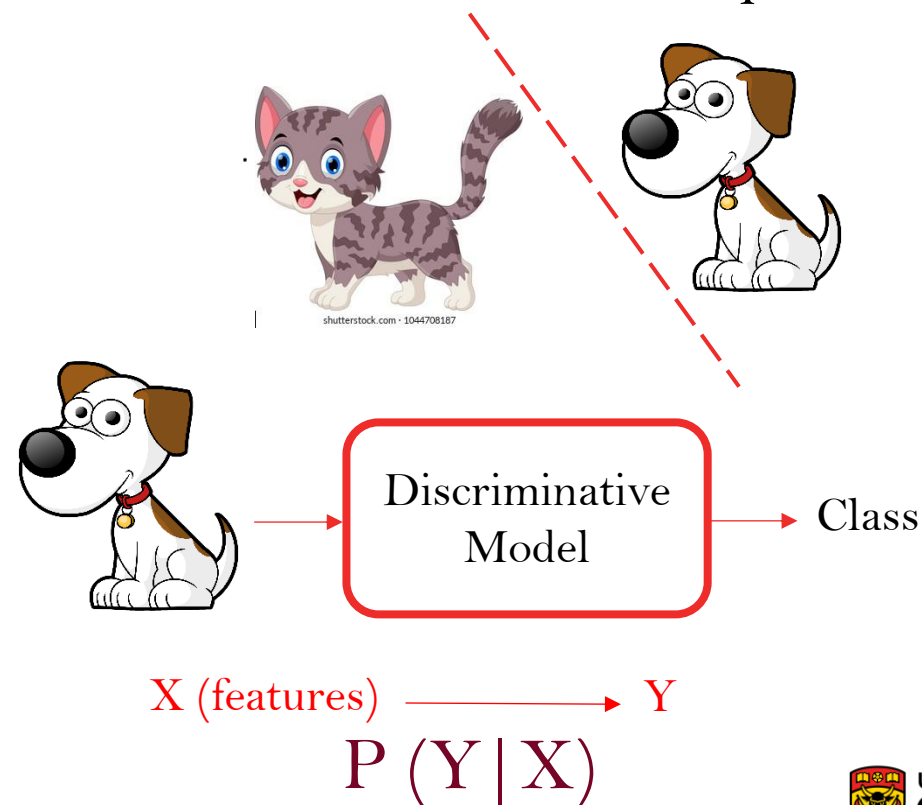
- New data

# Machine Learning Models

- Generative Models
  - Generate realistic representation for each class.



- Discriminative Models
  - Used for classification problem



# Generative Adversarial Networks

To produce Realistic Presentation of different classes

To distinguish real images from fake ones (produced by generator)

$$\begin{bmatrix} -5 \\ 3 \\ 1 \end{bmatrix}$$

Generative Model



Discriminative Model

Fake/ Real

There is a competition here !

Generator tries to make fakes that look real  
and fool the discriminator

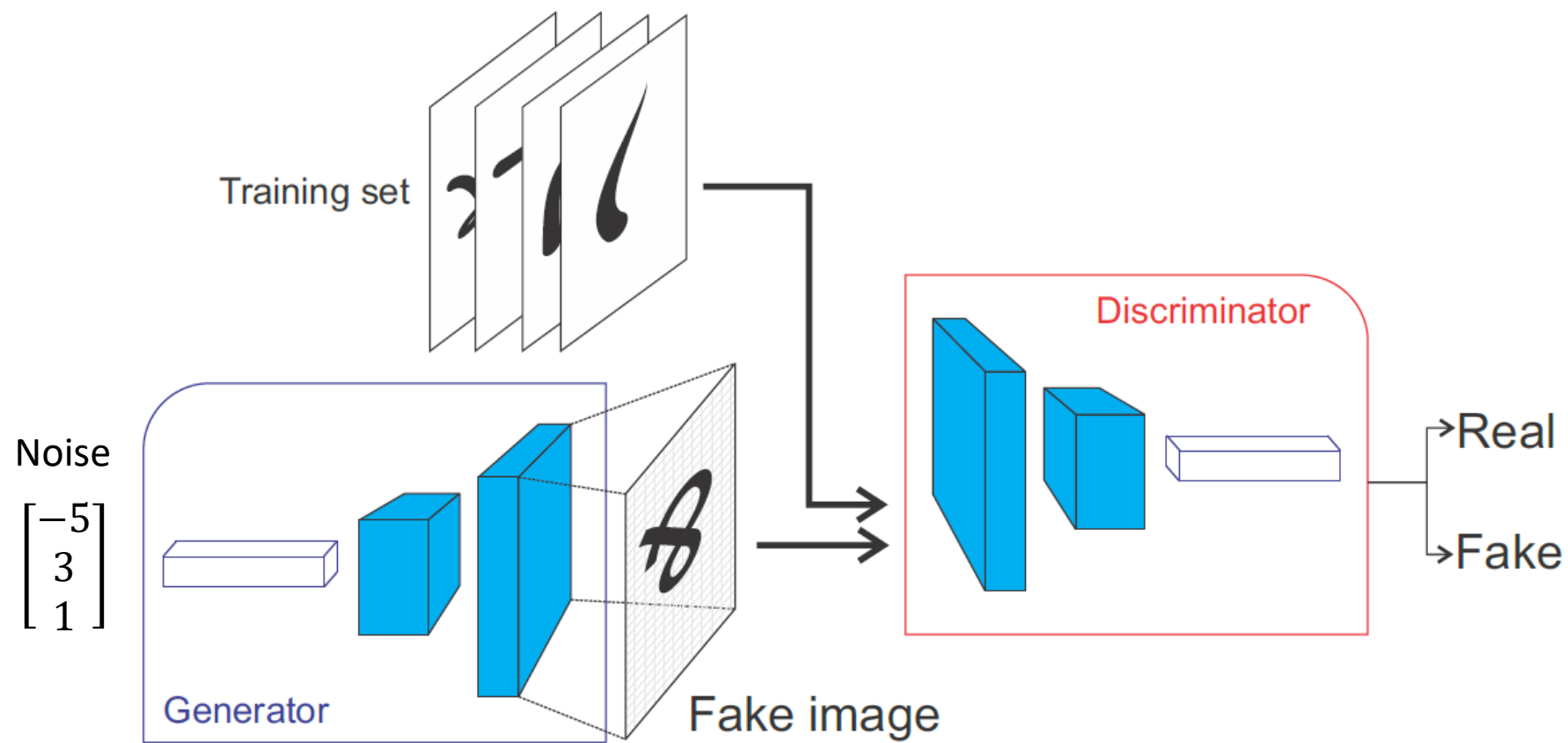
Discriminator learns how to distinguish  
reals from fakes



**GANs are generative  
models where the data  
distribution is learned  
implicitly!**

# GAN

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# GANs Problems

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- **Non-convergence:** the model parameters oscillate and the model does not converge
- **Mode collapse:** the generator collapses and produces a limited number of different samples
- **Diminished gradient:** the discriminator is too good that the generator gradient vanishes and learns nothing,
- **Highly sensitive** to the hyperparameter selections.

# Summary

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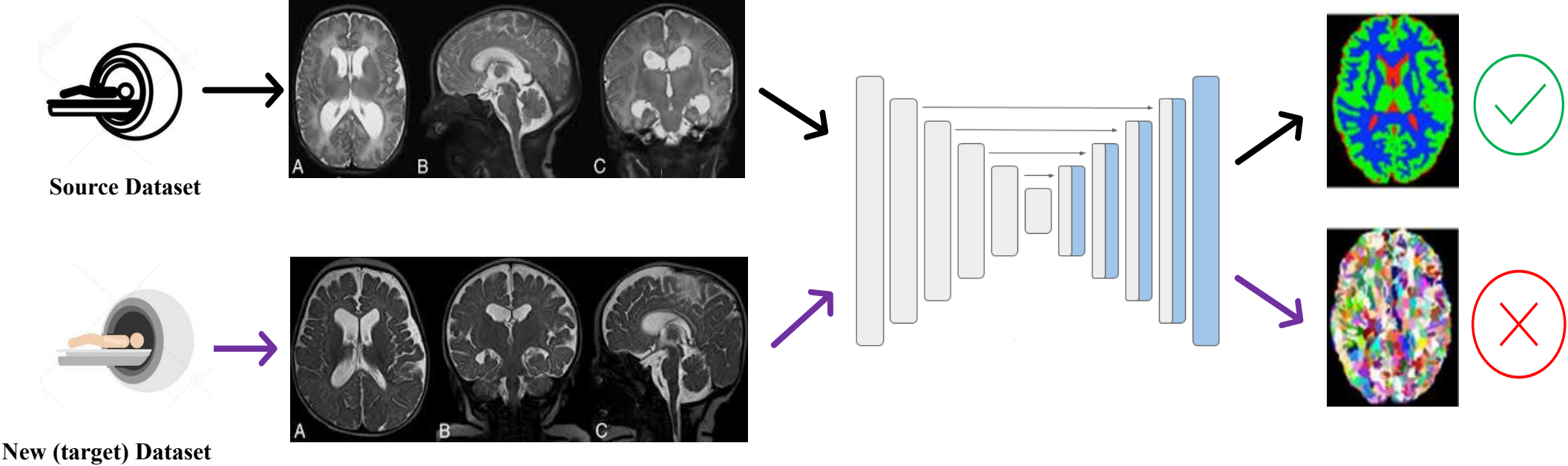
- GANs are unsupervised techniques
- They can be used to generate synthetic data that can potentially be used to train other deep learning models
- There are different GAN types, but they are all based on the principle of having two competing objectives
- GANs often face instabilities during training



# Domain Shift and Domain Adaptation

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# Motivation

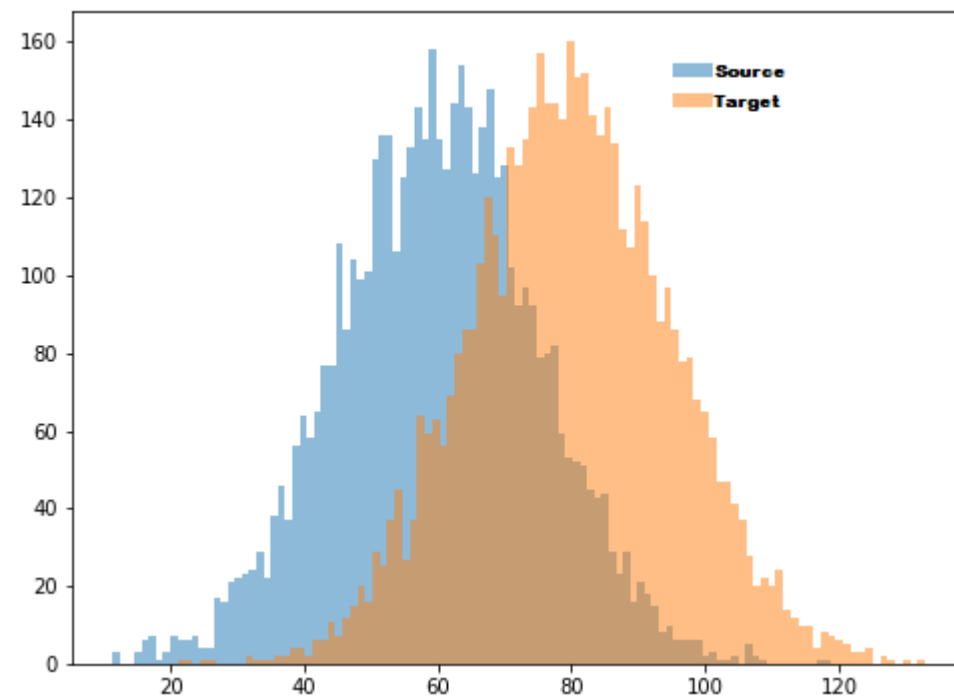


# Domain Shift

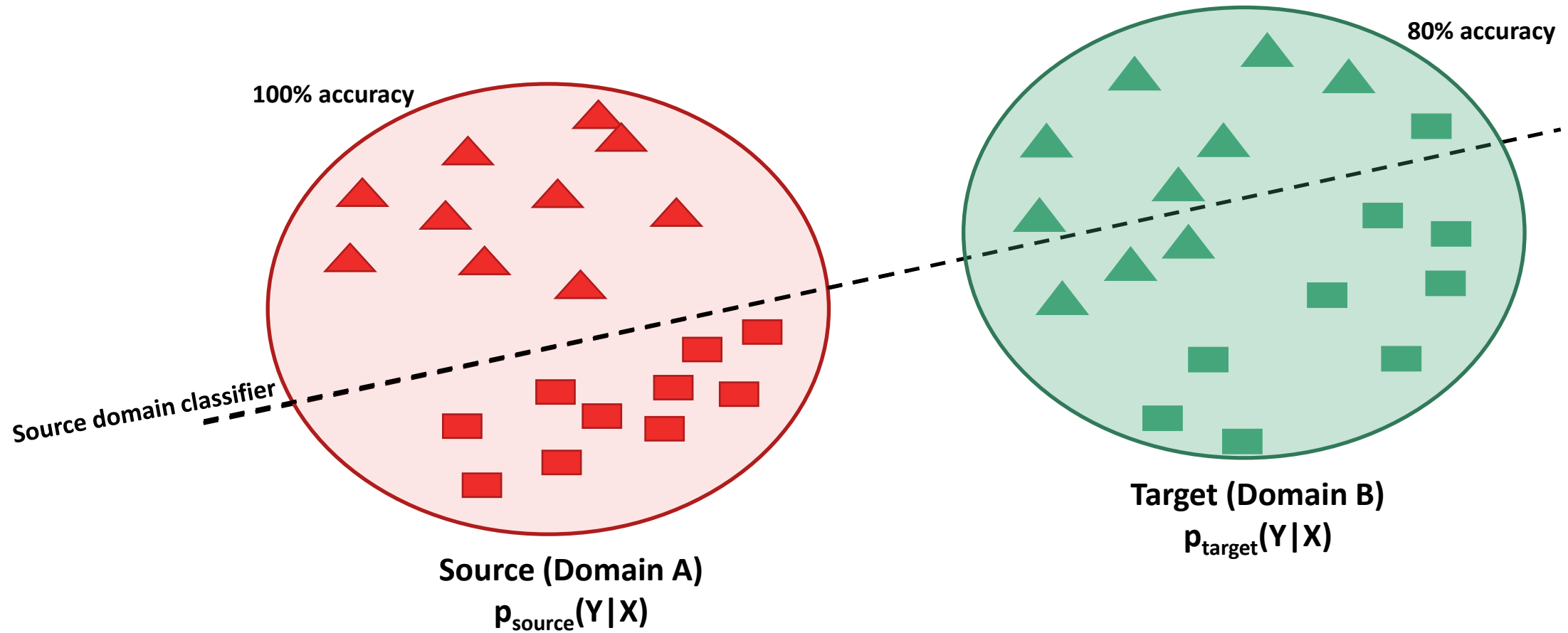
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- **Domain shift:** refers to the change of data distribution between one dataset (source/reference domain) and another dataset (target domain).

$$p_{\text{source}}(Y|X) \neq p_{\text{target}}(Y|X)$$



# Domain Shift Problem





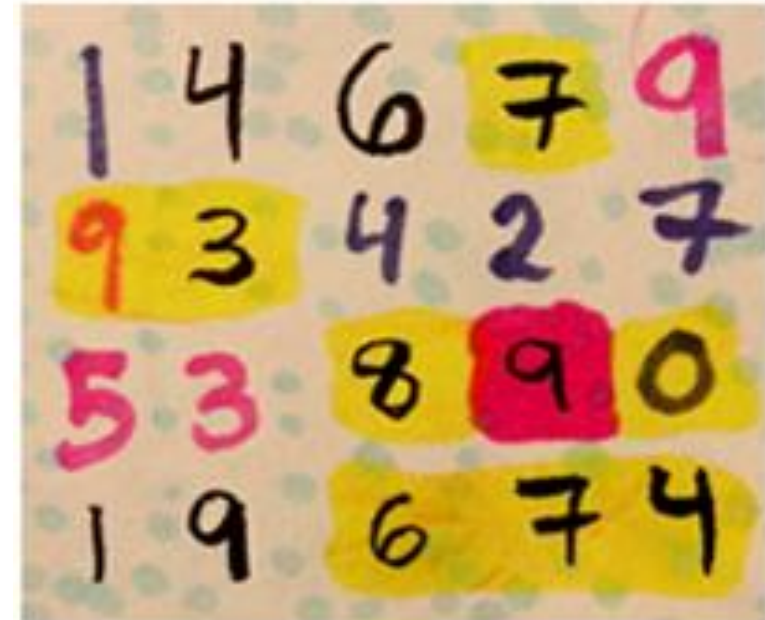
# Different Types of Images

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Domain A

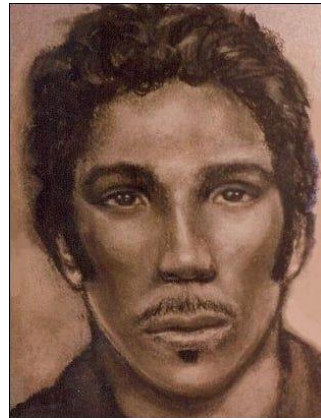


Domain B

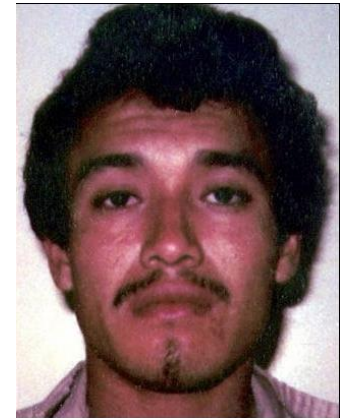


# Different Types of Images: Sketches and Photos

**Domain A: Sketches**

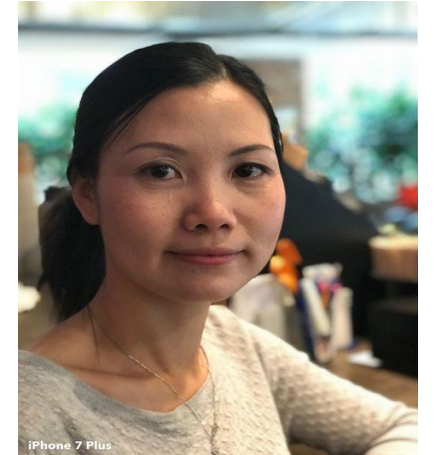
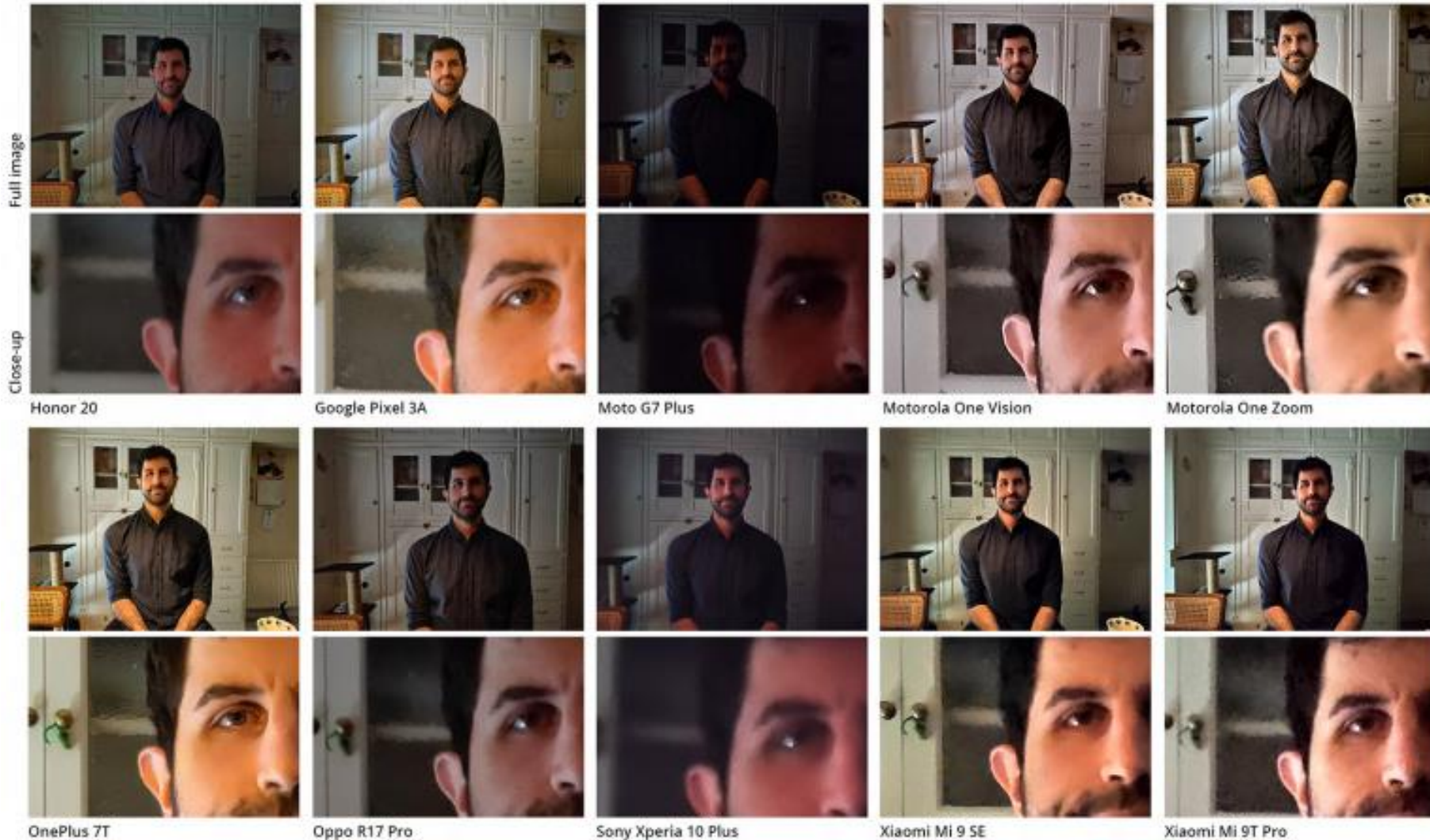


**Domain B: Photos**



# Technology Differences and Evolution

Camera comparison images: Low light/night mode



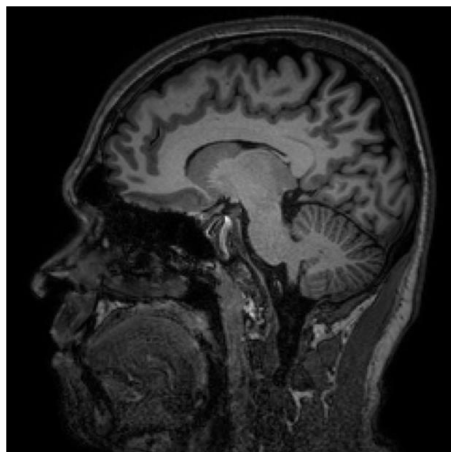


# Hardware and Software Differences

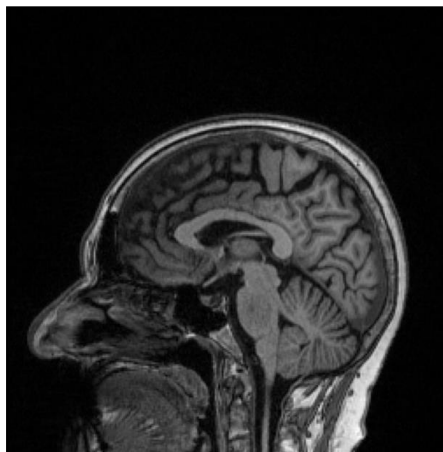
philips\_15



philips\_3



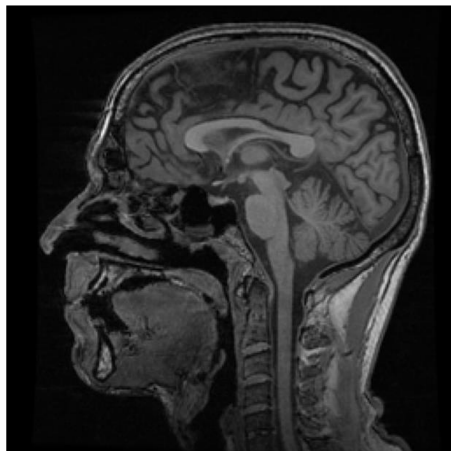
siemens\_15



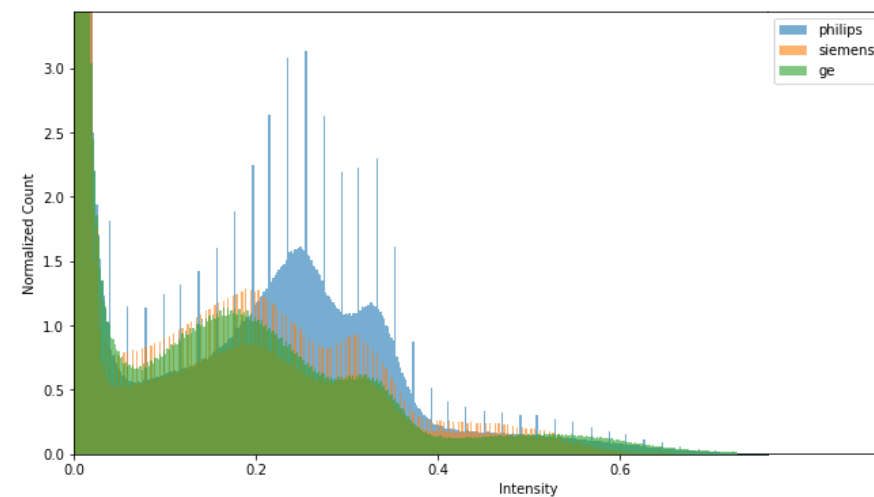
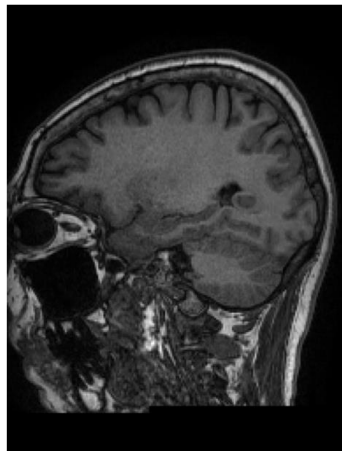
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ge\_3



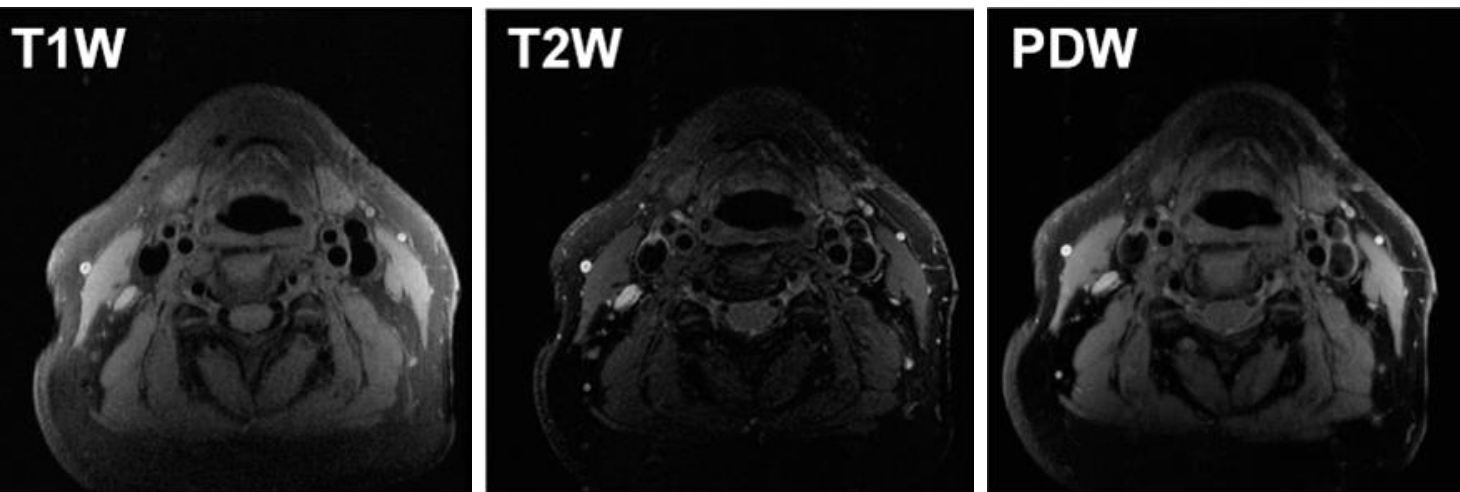
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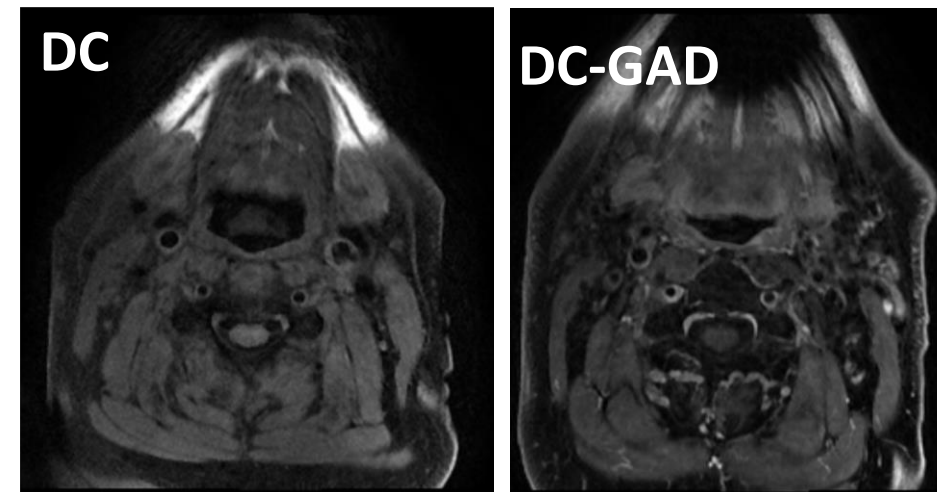
# Hardware and Software Differences

AIM-HIGH Study



- The carotid arteries were manually annotated at the time of the study

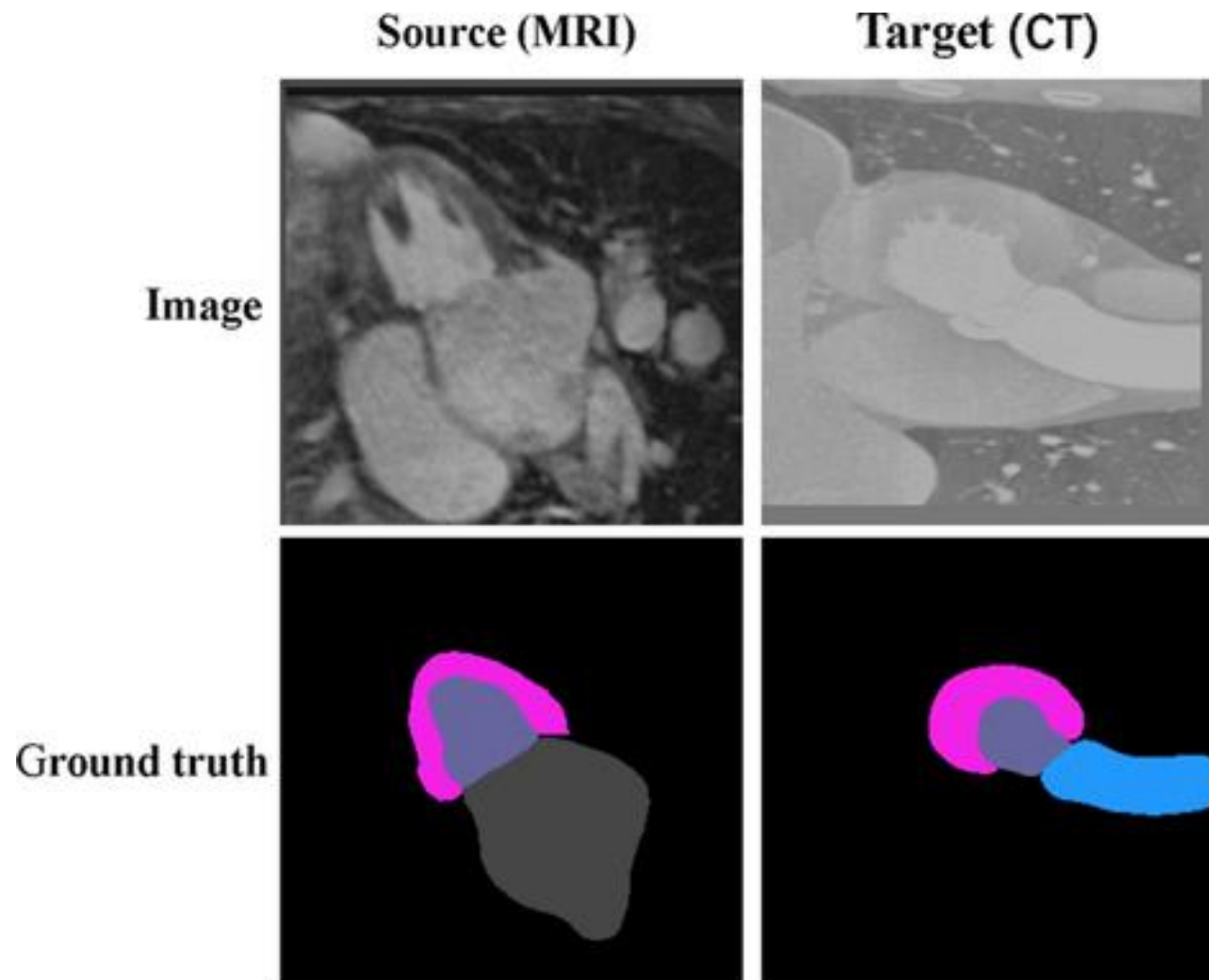
CARDIS Study



- Leverage AIM-HIGH annotated data to create a segmentation model for the data being collected at CARDIS study

# Different Technologies

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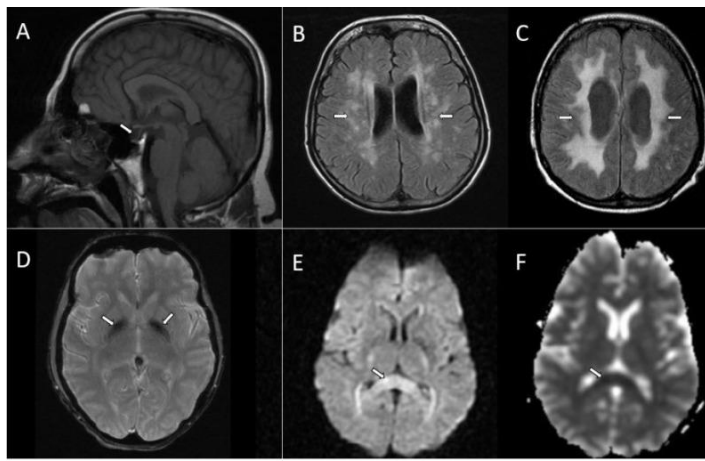
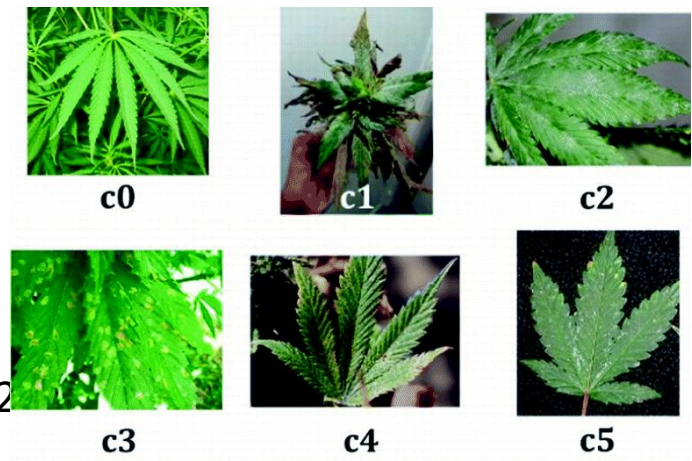
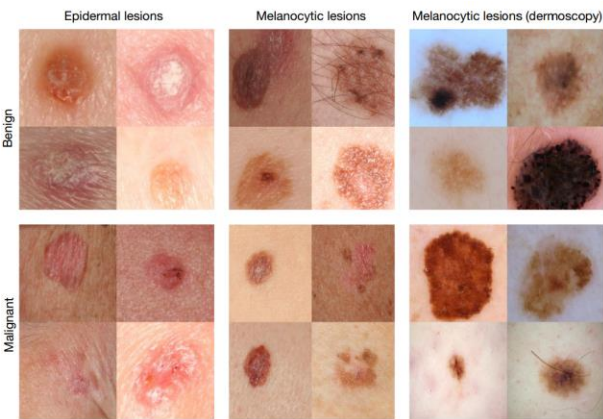
# Degree of Domain Shift

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- **Degree of domain shift** is a measure of how much the distributions of the source and target domains are different
- Previous studies have revealed that the test error generally increases in proportion to the degree of domain shift.

# Degree of Domain Shift

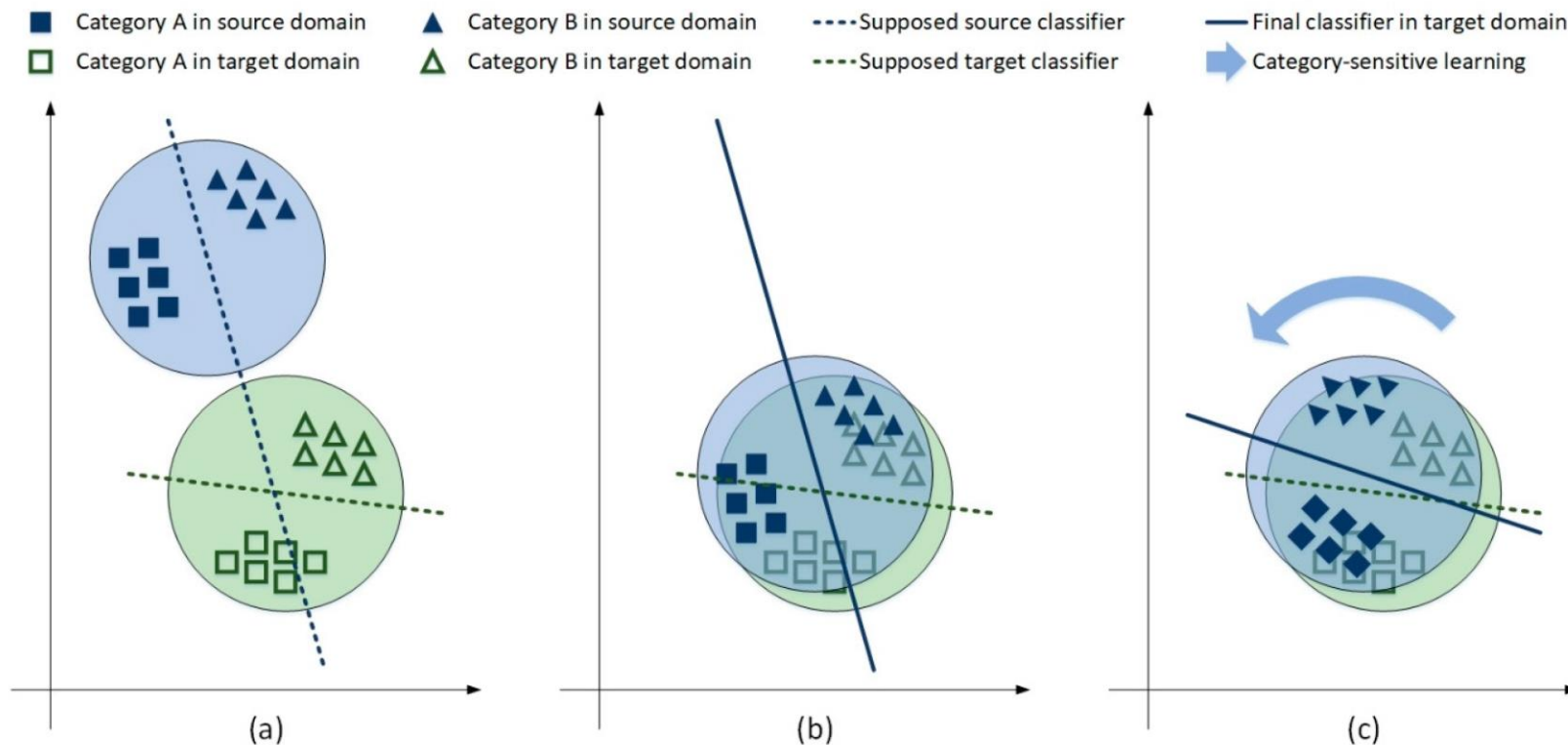
Small or large shift?



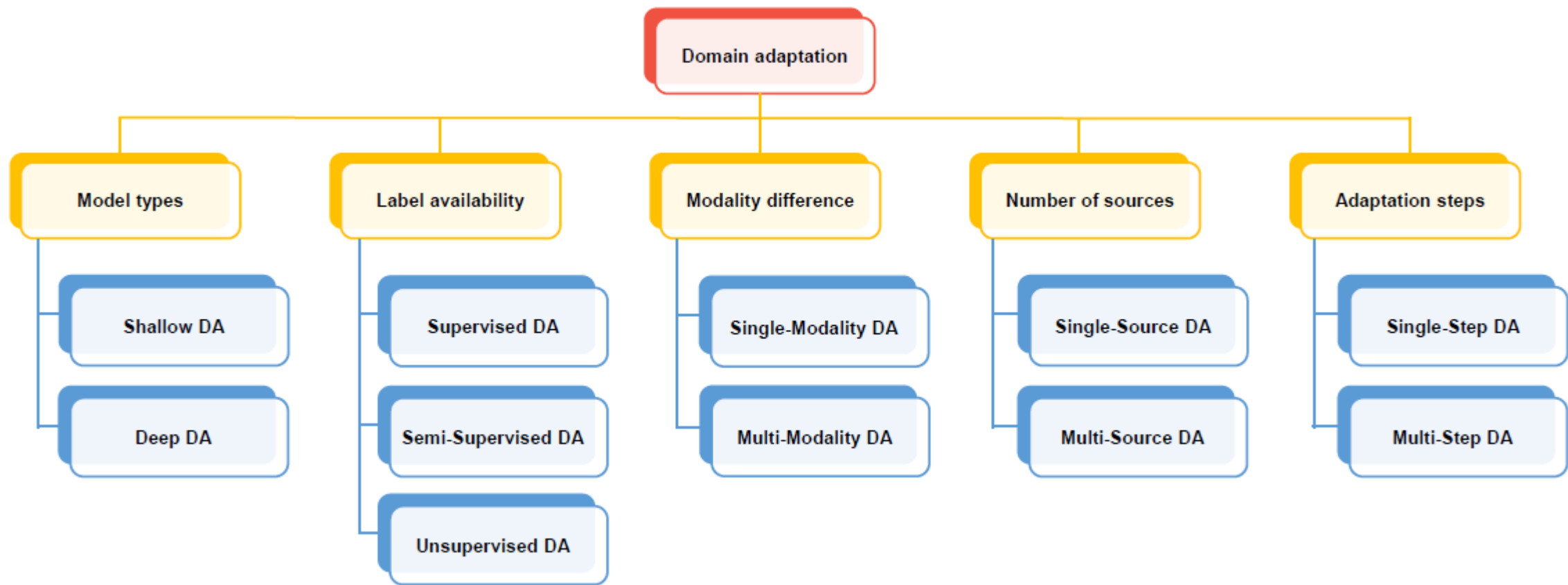


# Domain Adaptation

- **Domain adaptation:** domain adaptation refers to adapting a model trained in one or more source domains to a different one or more target domains.



# Domain Adaptation Categories

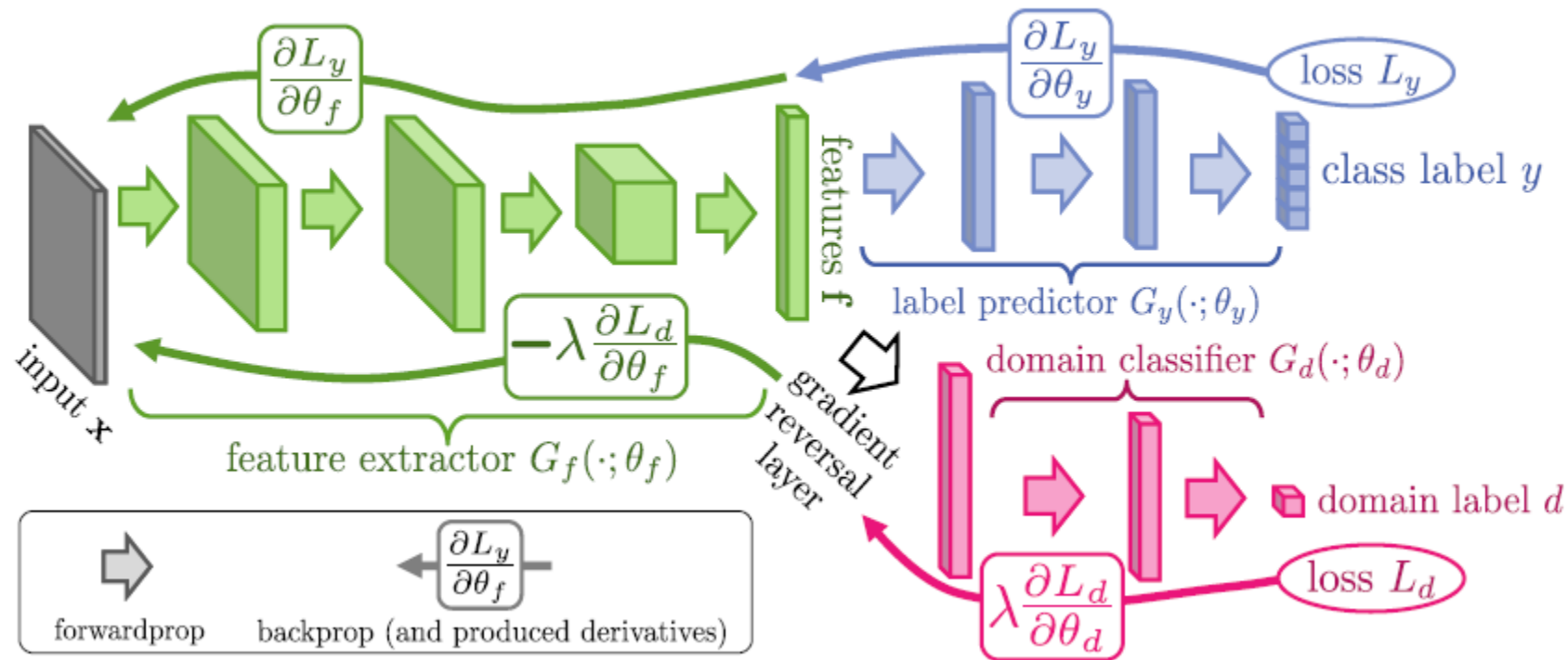


# Supervised Domain Adaptation

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- Essentially transfer learning
  - Fine-tune all layers
  - Fine-tune initial layers
  - Fine-tune final layers

# Domain-Adversarial Training of Neural Networks (Unsupervised)



\*Ganin et al., JMLR, 2016

$$E(\theta_f, \theta_y, \theta_d) = \frac{1}{n} \sum_{i=1}^n \mathcal{L}_y^i(\theta_f, \theta_y) - \lambda \left( \frac{1}{n} \sum_{i=1}^n \mathcal{L}_d^i(\theta_f, \theta_d) + \frac{1}{n'} \sum_{i=n+1}^N \mathcal{L}_d^i(\theta_f, \theta_d) \right)$$

# Summary

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- Domain shift is a problem in machine learning that can make model performance decrease when there is a distribution shift in the test data
- Domain adaptation techniques can be used to make models more robust to data domain shifts

# Thank you!

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