

# Variational AutoEncoder (VAE)

CV Exercise - Generative Models

# Overview

- Task 1: Implement Variational Autoencoder (VAE)
- Task 2: Implement Conditional Variational Autoencoder (CVAE)

# Generative Model

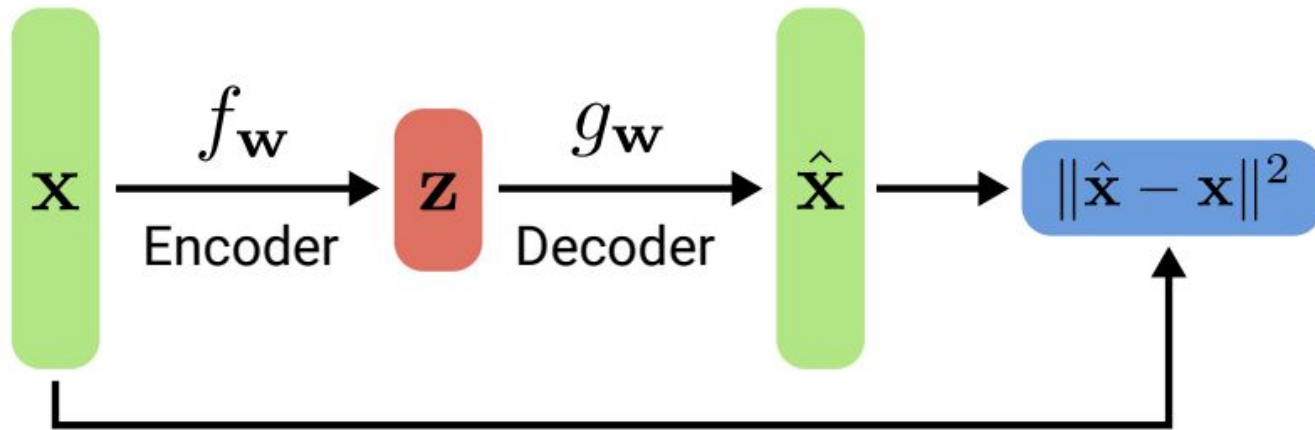
- A class of models that allows you to sample new output



["Diffusion Models Beat GANs on Image Synthesis"](#)  
[Dhariwal & Nichol, OpenAI, 2021](#)

# Variational Autoencoder (VAE)

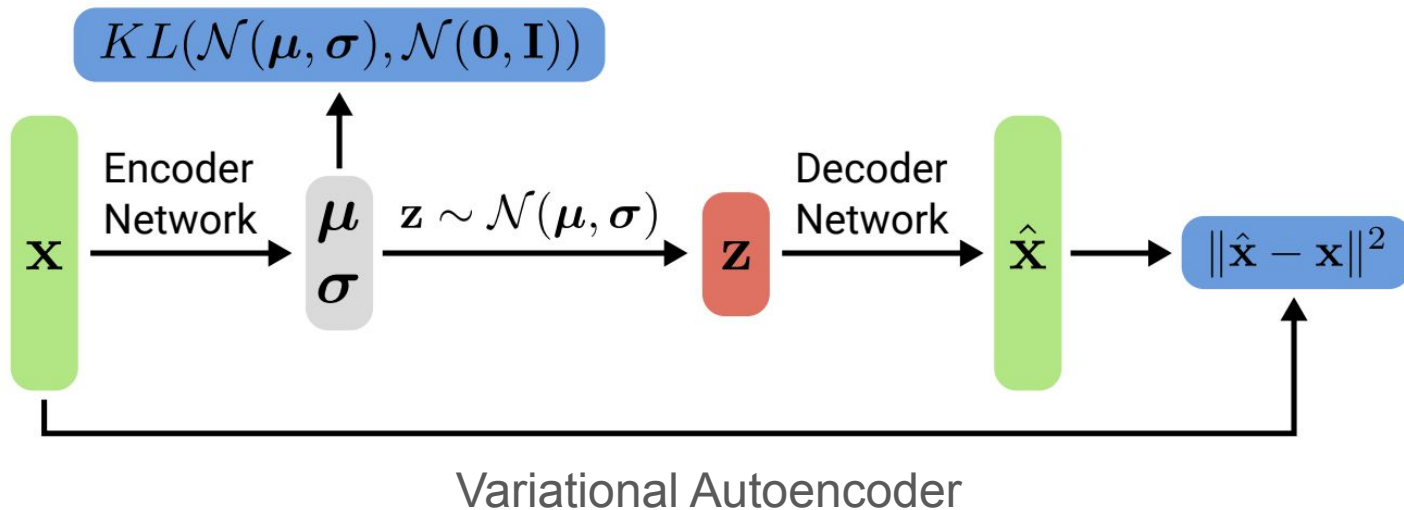
- An early version of a generative model that built on top of the Autoencoder (AE) concept.



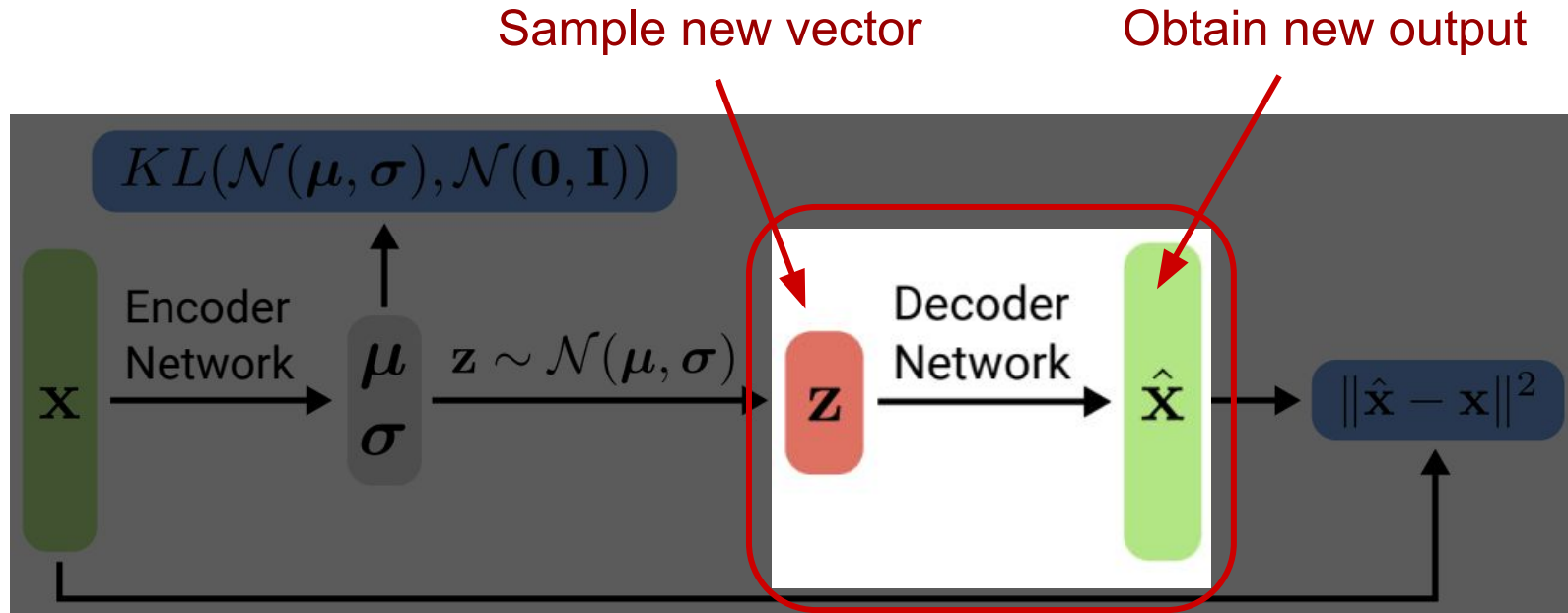
Autoencoder

# Variational Autoencoder (VAE) - Simplified

- Instead of having  $\mathbf{z}$  be any vector, we want it to be drawn from known distributions, which we assume to be Gaussian Distributions for VAE.
  - Why? So that during inference, we can sample a new  $\mathbf{z}$  from the distribution.



# Variational Autoencoder (VAE) - Inference

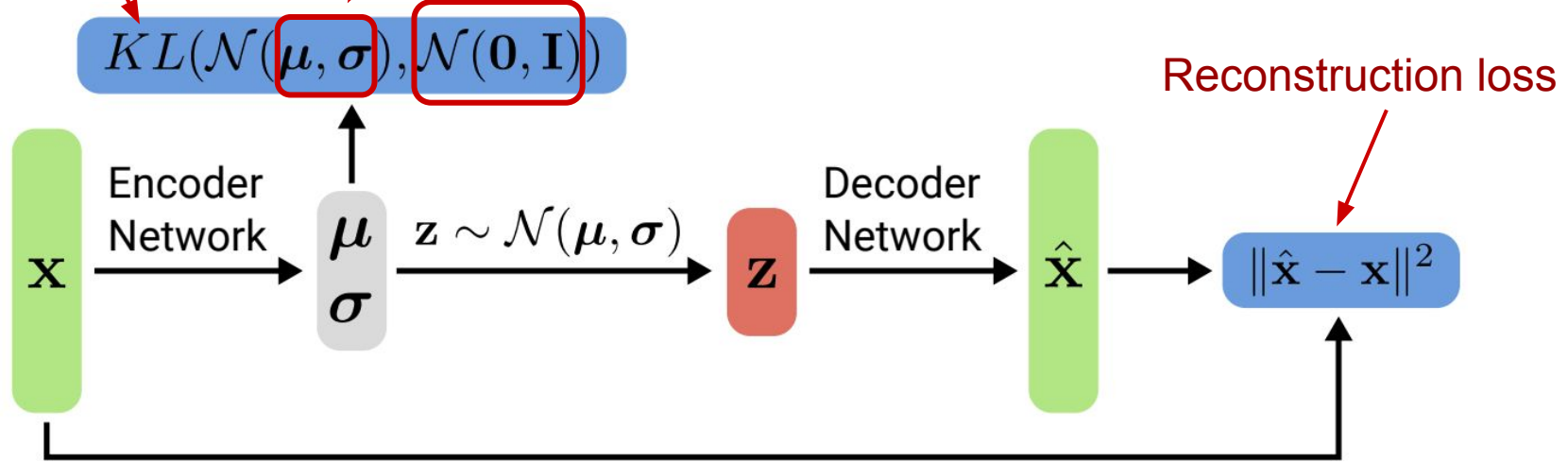


# Variational Autoencoder (VAE) - Training

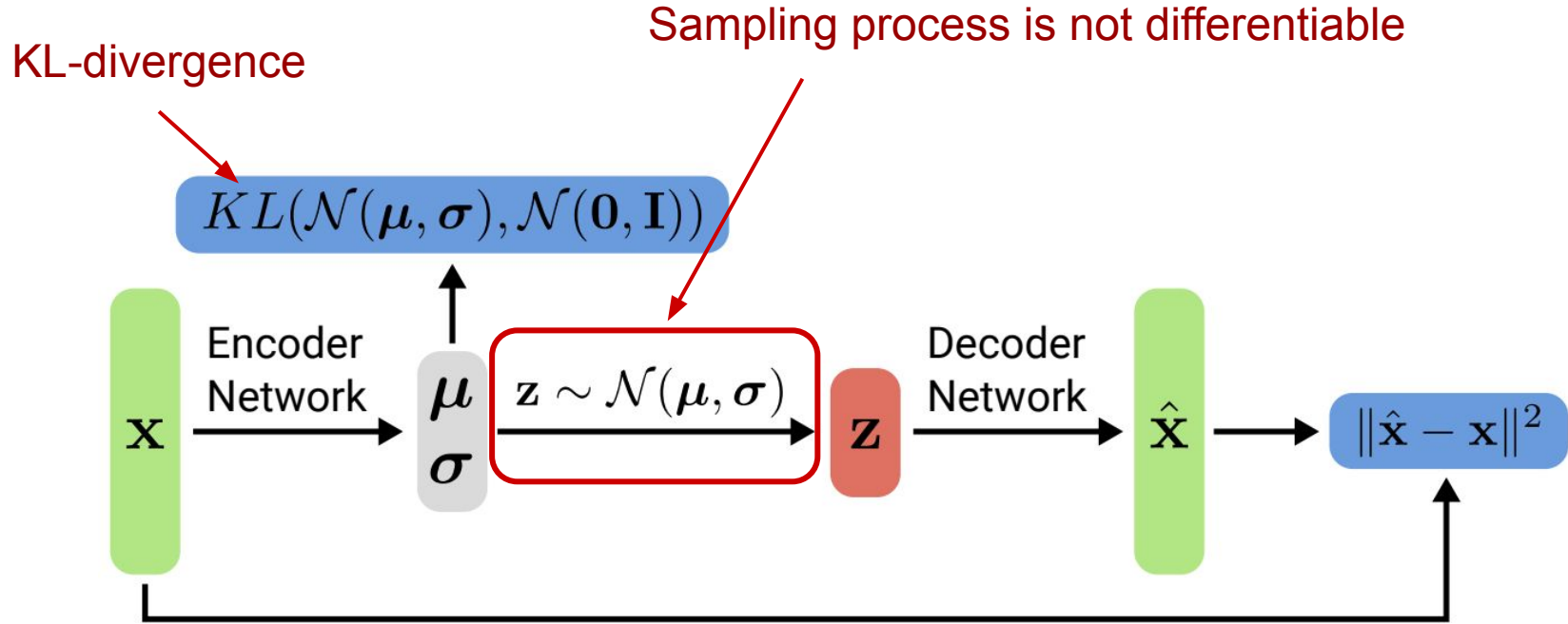
“Make distributions  
the same” loss

Prediction

Assume to be Gaussian

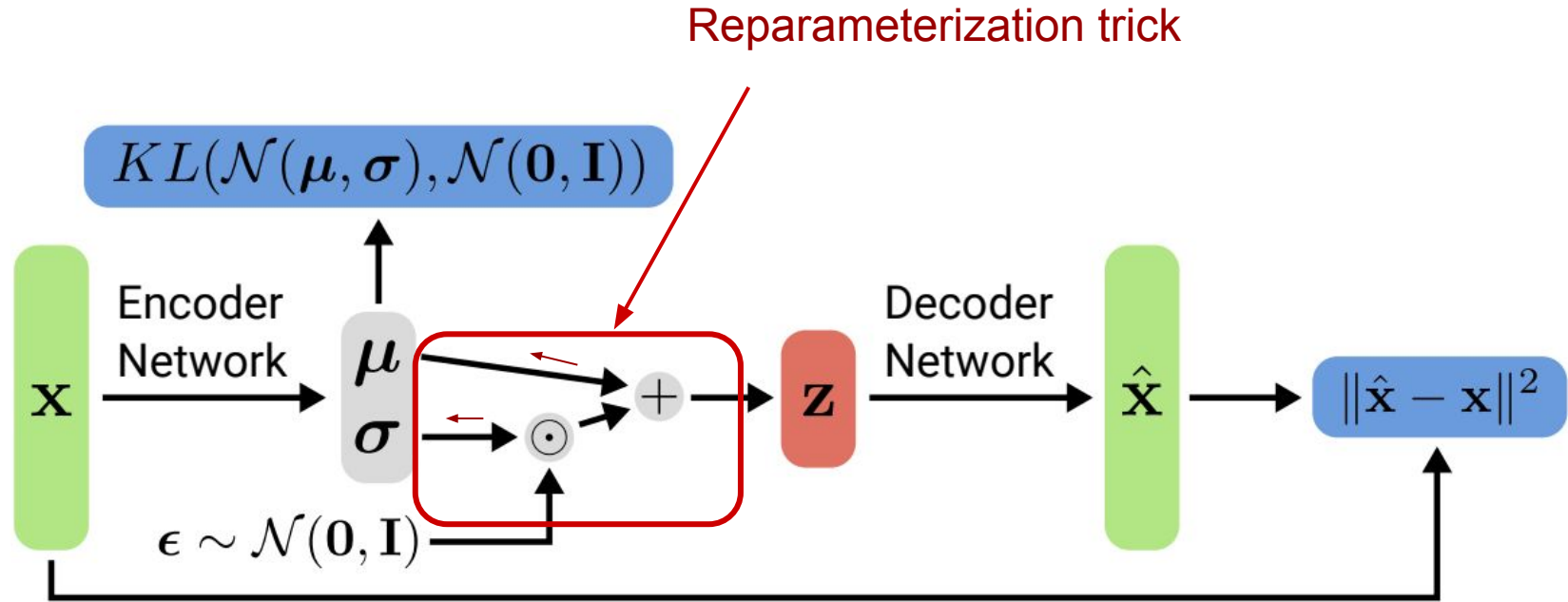


# Variational Autoencoder (VAE) - Training



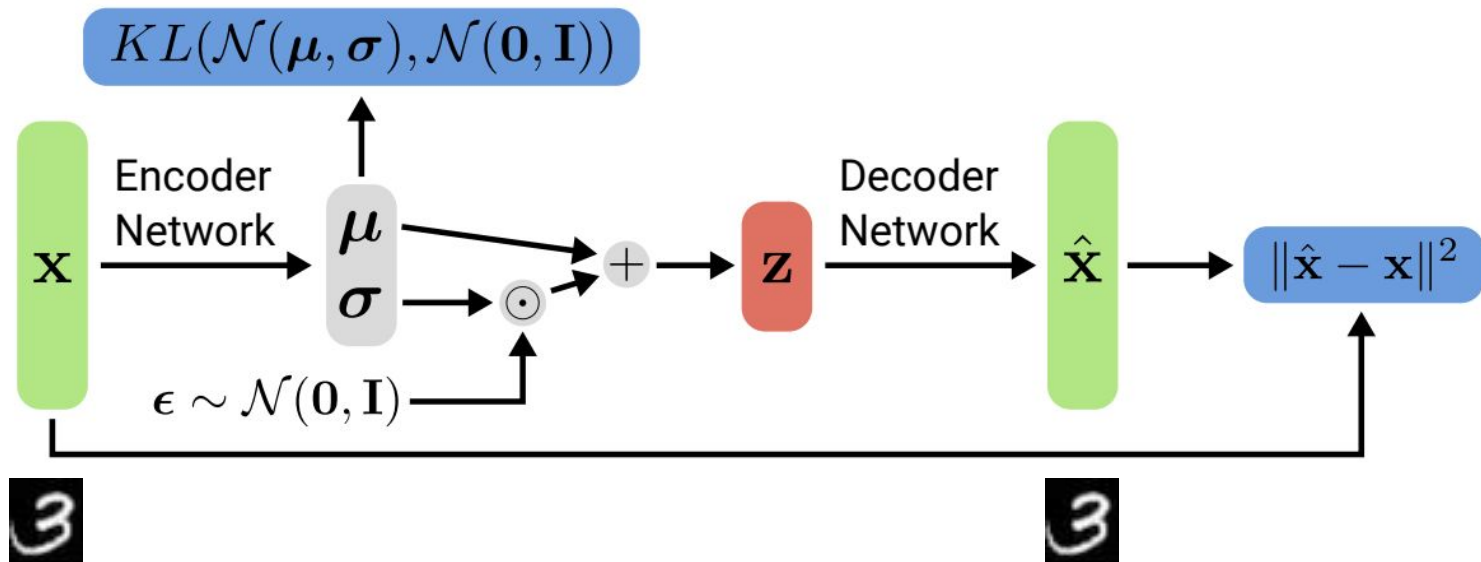


# Variational Autoencoder (VAE) - Training



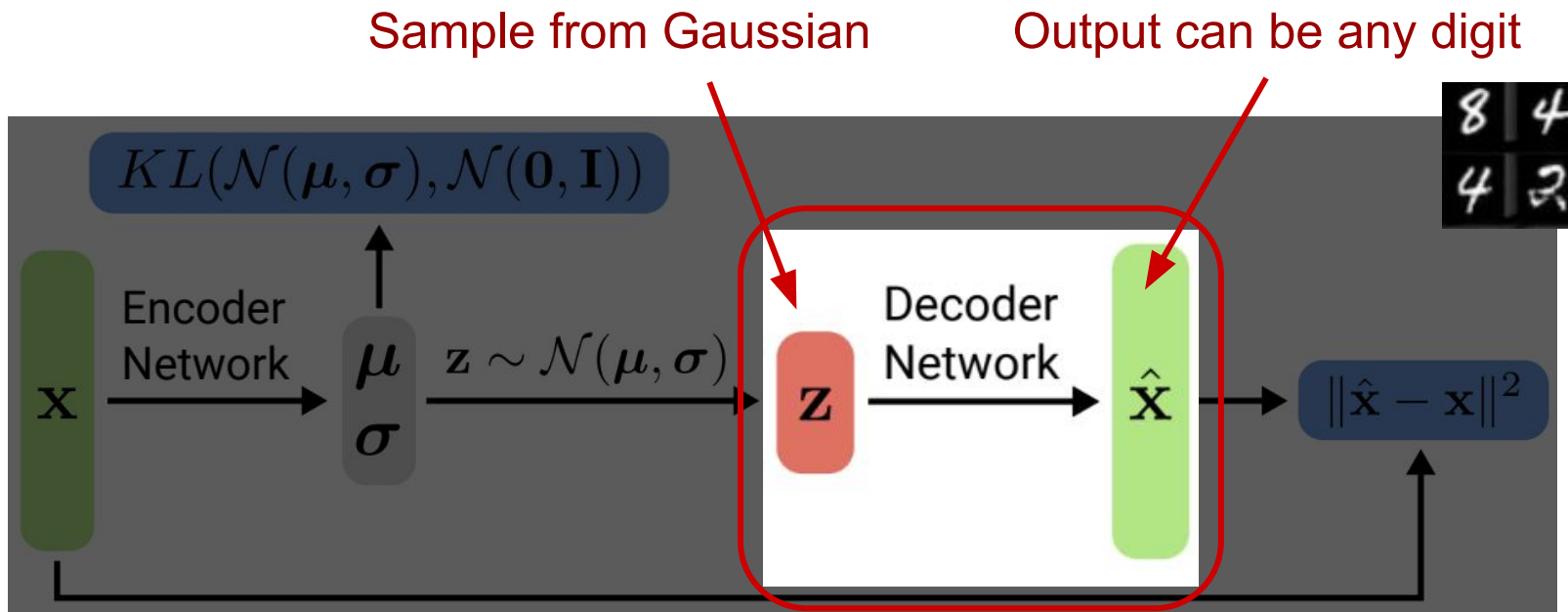
# Task 1: Train VAE on MNIST

0	8	2	7	6	4	6	9	7	2	1	5	1	4	6
0	1	2	3	4	4	6	2	9	3	0	1	2	3	4
0	1	2	3	4	5	6	7	0	1	2	3	4	5	0
7	4	2	0	9	1	2	8	9	1	4	0	9	5	0
0	2	7	8	4	8	0	7	7	1	1	2	9	3	6
5	3	9	4	2	7	2	3	8	1	2	9	8	8	7
2	9	1	6	0	1	7	1	1	0	3	4	2	6	4
7	7	6	3	6	7	4	2	7	4	9	1	0	6	8
2	4	1	8	3	5	5	5	3	5	9	7	4	8	5



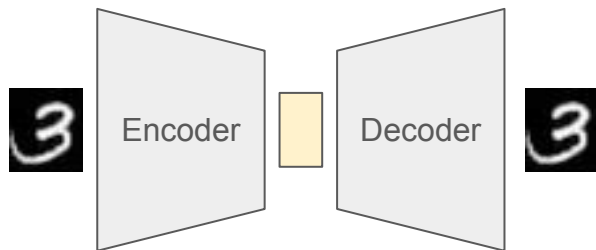
# Conditional Variational Autoencoder (CVAE)

- Normal VAE does not accept conditioning signals.
  - What if we want to sample only digit 3?



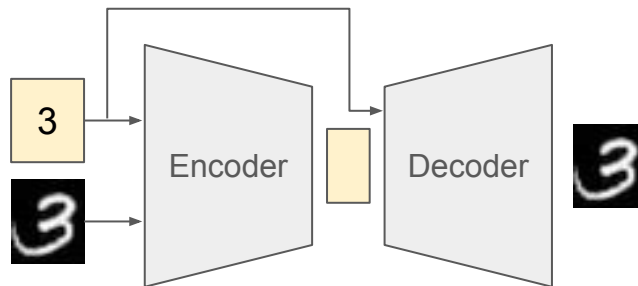
# Conditional Variational Autoencoder (CVAE)

- Add conditional signal as part of the input
  - Let the model learn conditional distribution (on the class label).



VAE

One-hot label

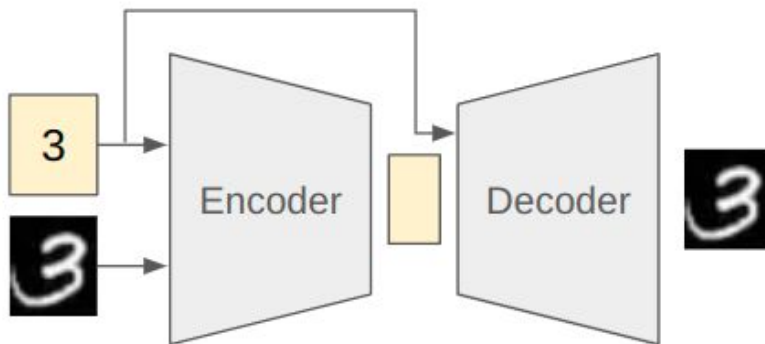


CVAE

0	8	2	7	6	4	6	9	7	2	1	5	1	4	6
0	1	2	3	4	4	6	2	9	3	0	1	2	3	4
0	1	2	3	4	5	6	7	0	1	2	3	4	5	6
7	4	2	0	9	1	2	8	9	1	4	0	9	5	0
0	2	7	8	4	8	0	7	7	1	1	2	9	3	6
5	3	9	4	2	7	2	3	8	1	2	9	8	8	7
2	9	1	6	0	1	7	1	1	0	3	4	2	6	4
7	7	6	3	6	7	4	2	7	4	9	1	0	6	8
2	4	1	8	3	5	5	5	3	5	9	7	4	8	5

## Task 2: Train CVAE on MNIST with Class Label

- Mostly the same as the base VAE but with additional input for encoder and decoder



Question?