

# PSYC 430 Final Project - Simulating The Hippocampus

Run this first

```
In [ ]: # Import necessary libraries
import matplotlib.pyplot as plt
from keras.datasets import fashion_mnist
from tensorflow.keras.datasets import mnist
from tensorflow.keras.layers import Dense, Input, Flatten, ReLU, Activation, Reshape
from tensorflow.keras.models import Model, Sequential
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.optimizers import Adam, SGD
from keras import regularizers
import numpy as np
import random
```

Load in the Fashion MNIST data set, and split the data into a training and test set.

```
In [ ]: from tensorflow.keras.datasets import fashion_mnist as fmnist # Import Fashion MNIST data
(x_train, y_train), (x_test, y_test) = fmnist.load_data() # 60,000 -> training; 10,000 -> testing
x_train = x_train/255.0 # Normalize data to be between 0 - 1 (image data usually between 0 - 255)
x_test = x_test/255.0
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-labels-idx1-ubyte.gz
29515/29515 [=====] - 0s 1us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/train-images-idx3-ubyte.gz
26421880/26421880 [=====] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-labels-idx1-ubyte.gz
5148/5148 [=====] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/t10k-images-idx3-ubyte.gz
4422102/4422102 [=====] - 0s 0us/step
```

The data is made up of images of clothing. Here are some examples.

```
In [ ]: # Generate grid of images from a subset of a larger dataset
subset = x_train[np.random.randint(0, 10000, 20)]
fig, axs = plt.subplots(4, 5, figsize=(5,3))
for j, ax in enumerate(axs.flatten()):
    ax.imshow(subset[j], cmap="gray_r")
    ax.axis("off")
plt.tight_layout()
plt.show()
```



## Taking a Subset of the Fashion MNIST Dataset

We won't be using the entire dataset. Instead, we will be taking a subset of 4,000 stimuli, and varying the frequency by which they appear in order to understand the correlation between neuronal sparseness and image frequency. So,

- 1 stimulus will be repeated 1,000 times
- 10 stimuli will be repeated 100 times
- 100 stimuli will be repeated 10 times
- 1,000 stimuli will be repeated once

```
In [ ]: image_id = list(np.random.randint(0, 10000, 1111))

image_list = [image_id[0]] * 1000 + image_id[1:11] * 100 + image_id[11:111] * 10 + image_id[111:1111]
random.shuffle(image_list)

freq_train = x_train[np.array(image_list)]
```

## Creating the Autoencoder

The encoder represents the input coming into the medial temporal lobe from the temporal cortex, the entorhinal cortex, the DG, and the CA3. The decoder represents the information that was compressed from the encoder coming into the CA1, then back to the entorhinal cortex, and eventually is sent to the temporal cortex for further processing.

```
In [ ]: encoder = Sequential([
    Flatten(input_shape = (28, 28)), # Sensory neurons convert raw data into something preprocessed
    Dense(784), # Temporal Cortex
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(384), # Dentate Gyrus
    ReLU(),
    Dense(256), # CA3
    ReLU(),
])
decoder = Sequential([
    Dense(384, input_shape = (256,)), # CA1
```

```

        ReLU(),
        Dense(512), # Entorhinal Cortex
        ReLU(),
        Dense(784), # Temporal Cortex
        Activation("sigmoid"),
        Reshape((28, 28))
    ))
img = Input(shape = (28, 28))
latent_vector = encoder(img)
output = decoder(latent_vector)
model = Model(inputs = img, outputs = output)
model.compile("adam", loss = "mean_squared_error")

```

```

In [ ]: EPOCHS = 10
EXAMPLES = 8

# Pick a number of random images
rand = x_test[np.random.randint(0, 10000, EXAMPLES)].reshape((EXAMPLES, 1, 28, 28))

for epoch in range(EPOCHS):
    fig, axs = plt.subplots(2, EXAMPLES, figsize=(EXAMPLES, 2))

    for j in range(EXAMPLES):
        axs[0, j].imshow(rand[j][0], cmap="gray_r")
        axs[0, j].set_title("Input")
        axs[0, j].axis("off")
        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")
        axs[1, j].set_title("Output")
        axs[1, j].axis("off")

    fig.suptitle("Epoch %d" % (epoch+1))
    fig.tight_layout()
    plt.show()
    model.fit(freq_train, freq_train, verbose=0)

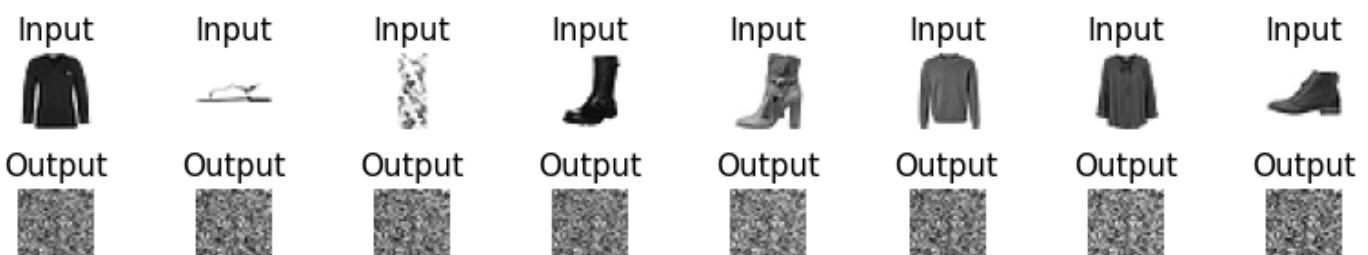
```

```

1/1 [=====] - 0s 110ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 25ms/step

```

Epoch 1

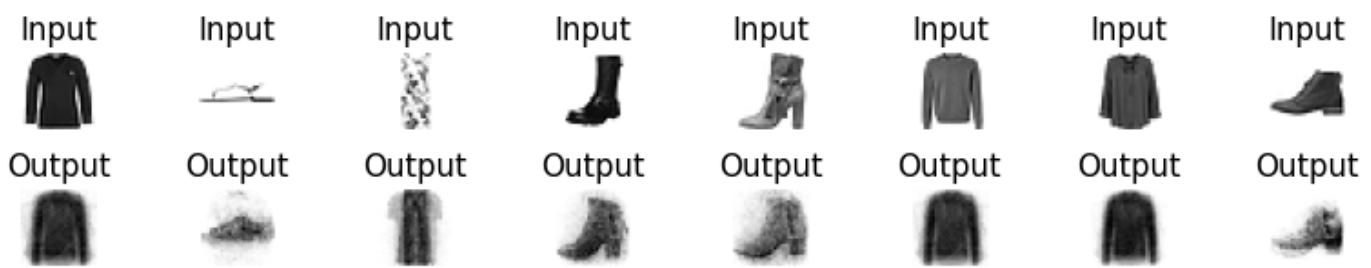


```

1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 21ms/step

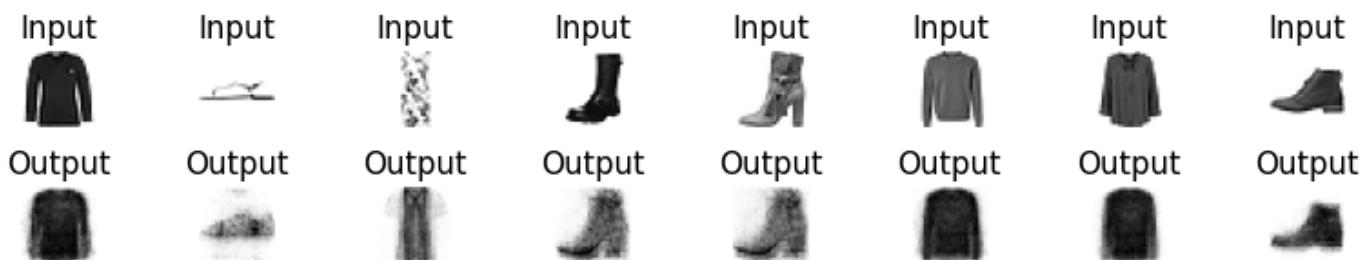
```

## Epoch 2



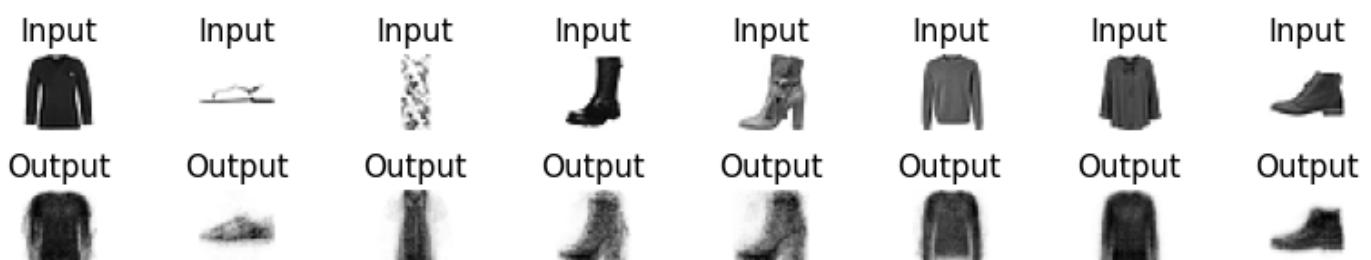
```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 30ms/step
```

## Epoch 3



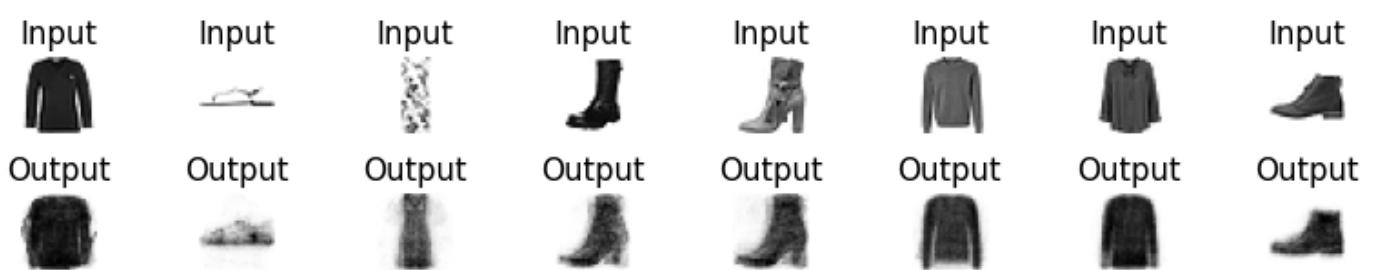
```
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 52ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 33ms/step
```

## Epoch 4



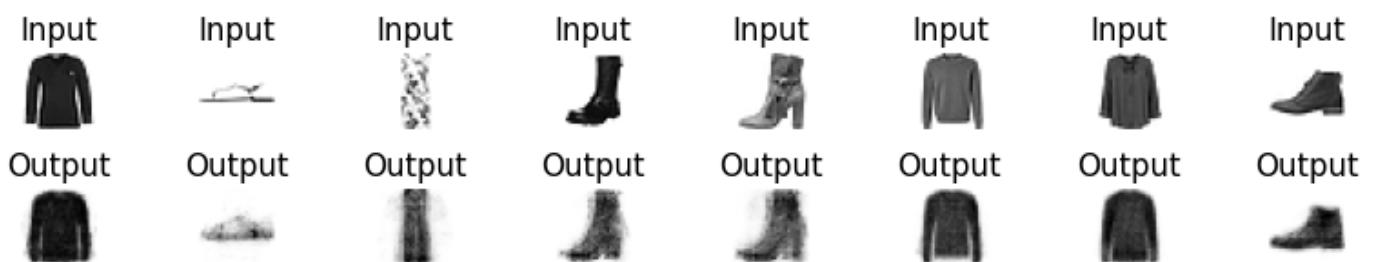
```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step
```

## Epoch 5



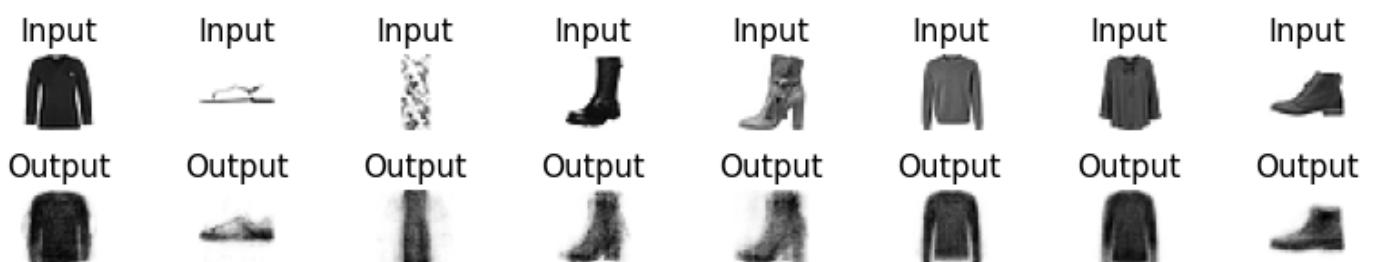
```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 28ms/step
```

## Epoch 6



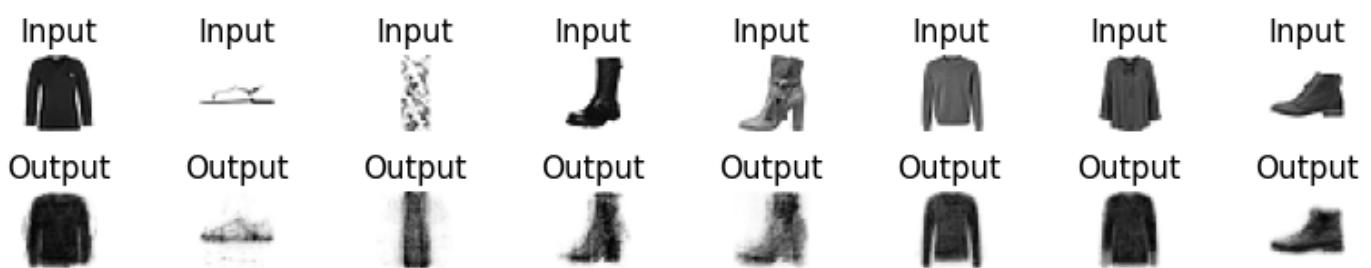
```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step
```

## Epoch 7



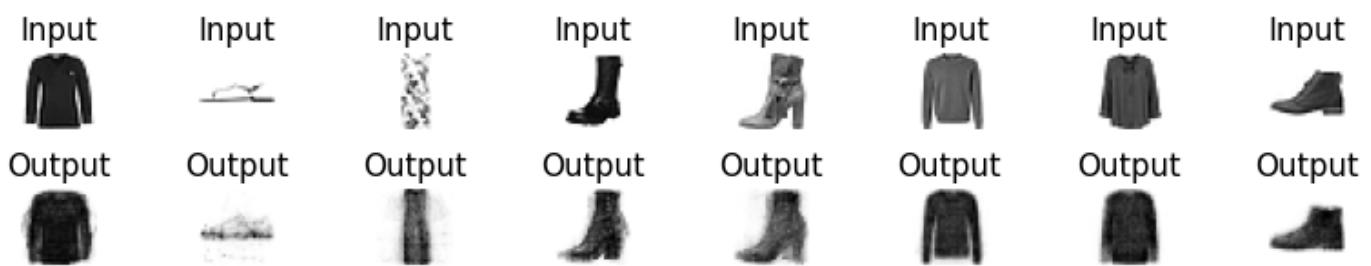
```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step
```

## Epoch 8



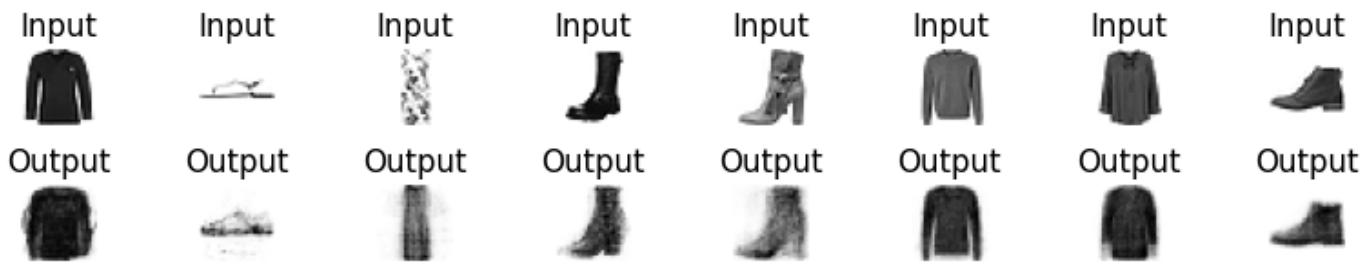
```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step
```

## Epoch 9



```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 25ms/step
```

## Epoch 10



## Convolutional Autoencoder

We can use convolutional layers, as well as max pooling and up sampling to better understand the most prominent features from each image.

As we see, there is a bias towards the shape of the object/item rather than its characteristics. In other words, there is a prioritization of getting the overall gist of the image rather than any specific details within the object.

```
In [ ]: from tensorflow.keras.layers import Conv2D, MaxPooling2D, UpSampling2D
```

```

# Encoder
encoder = Sequential([
    Input(shape=(28, 28, 1)), # Input layer
    Conv2D(256, (3, 3), activation='relu', padding='same'), # Temporal Cortex
    MaxPooling2D((2, 2), padding='same'),
    Conv2D(128, (3, 3), activation='relu', padding='same'), # Entorhinal Cortex
    MaxPooling2D((2, 2), padding='same'),
    Conv2D(64, (3, 3), activation='relu', padding='same'), # Dentate Gyrus
    MaxPooling2D((2, 2), padding='same'),
    Conv2D(32, (3, 3), activation='relu', padding='same'), # CA3
])

# Decoder
decoder = Sequential([
    Conv2D(64, (3, 3), activation='relu', padding='same', input_shape=(4, 4, 32)), # CA1
    UpSampling2D((2, 2)),
    Conv2D(128, (3, 3), activation='relu', padding='same'), # Entorhinal Cortex
    UpSampling2D((2, 2)),
    Conv2D(256, (3, 3), activation='relu'), # Temporal Cortex
    UpSampling2D((2, 2)),
    Conv2D(1, (3, 3), activation='sigmoid', padding='same'),
])

img = Input(shape = (28, 28, 1))
latent_vector = encoder(img)
output = decoder(latent_vector)
model = Model(inputs = img, outputs = output)
model.compile("adam", loss = "mean_squared_error")

```

In [ ]:

```

EPOCHS = 10
EXAMPLES = 8

# Pick a number of random images
rand = x_test[np.random.randint(0, 10000, EXAMPLES)].reshape((EXAMPLES, 1, 28, 28))

for epoch in range(EPOCHS):
    fig, axs = plt.subplots(2, EXAMPLES, figsize=(EXAMPLES, 2))

    for j in range(EXAMPLES):
        axs[0, j].imshow(rand[j][0], cmap="gray_r")
        axs[0,j].set_title("Input")
        axs[0,j].axis("off")
        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")
        axs[1,j].set_title("Output")
        axs[1,j].axis("off")

    fig.suptitle("Epoch %d" % (epoch+1))
    fig.tight_layout()
    plt.show()
    model.fit(freq_train, freq_train, verbose=0)

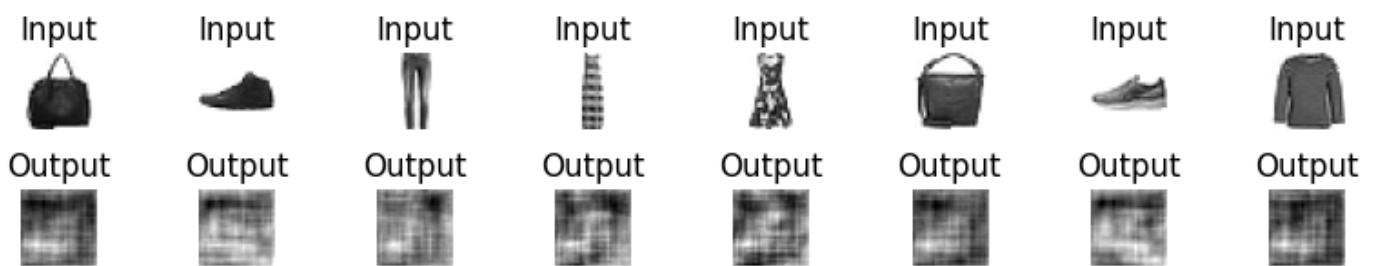
```

```

1/1 [=====] - 0s 151ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 30ms/step

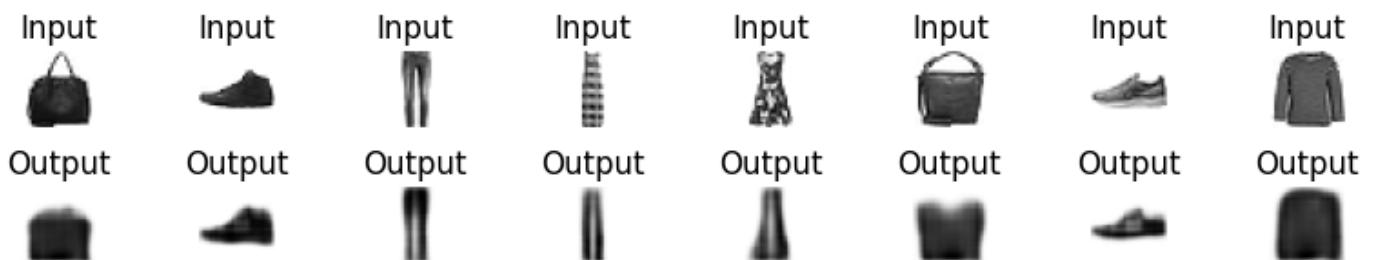
```

### Epoch 1



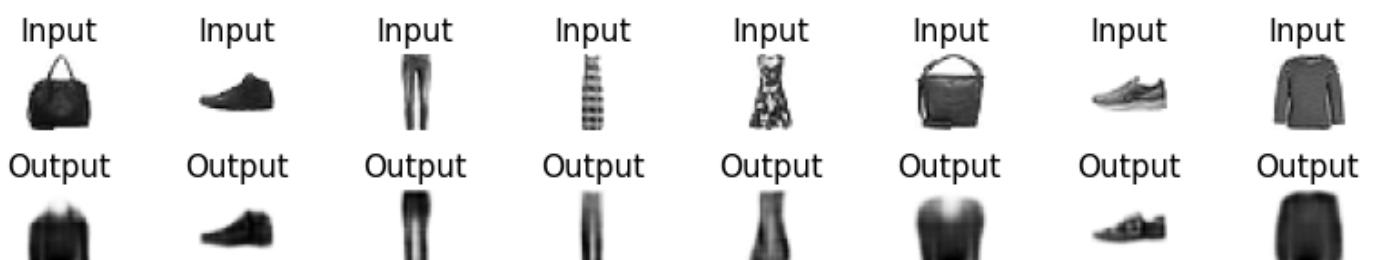
```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 28ms/step
```

### Epoch 2



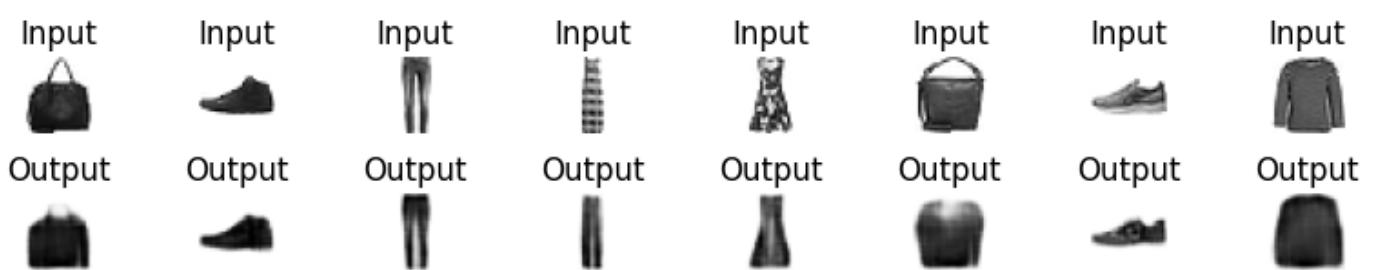
```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 27ms/step
```

### Epoch 3



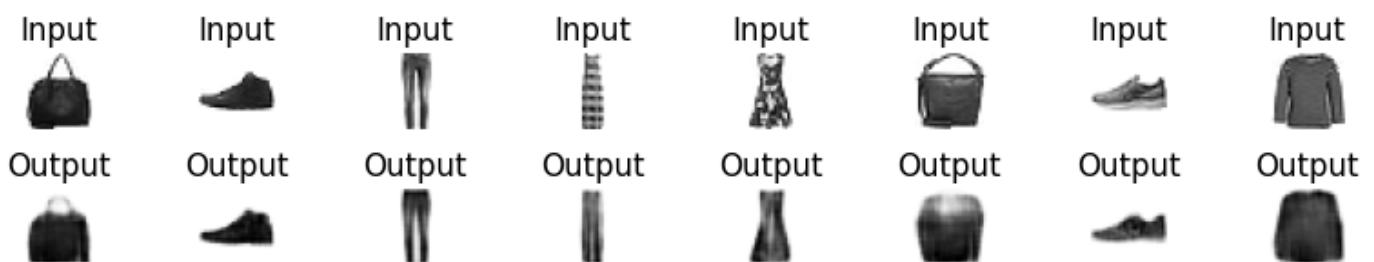
```
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step
```

## Epoch 4



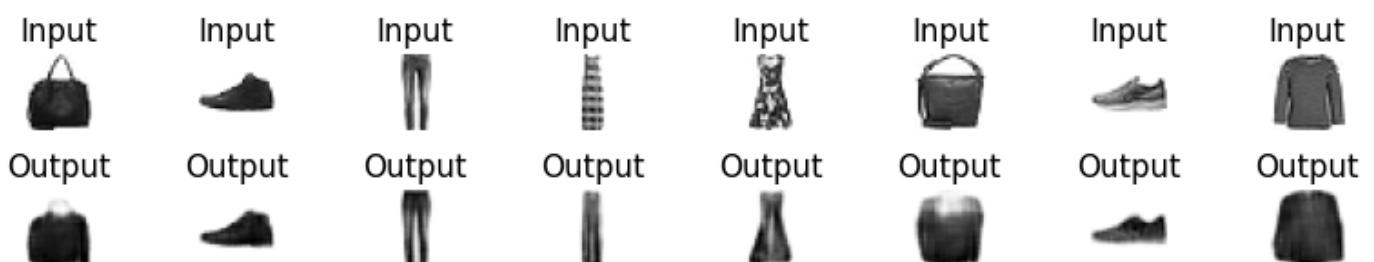
```
1/1 [=====] - 0s 44ms/step
1/1 [=====] - 0s 47ms/step
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 47ms/step
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 55ms/step
```

## Epoch 5



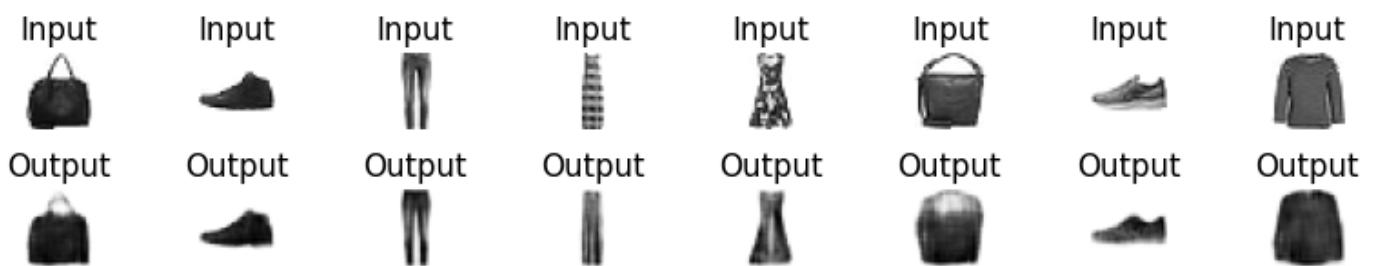
```
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 30ms/step
```

## Epoch 6



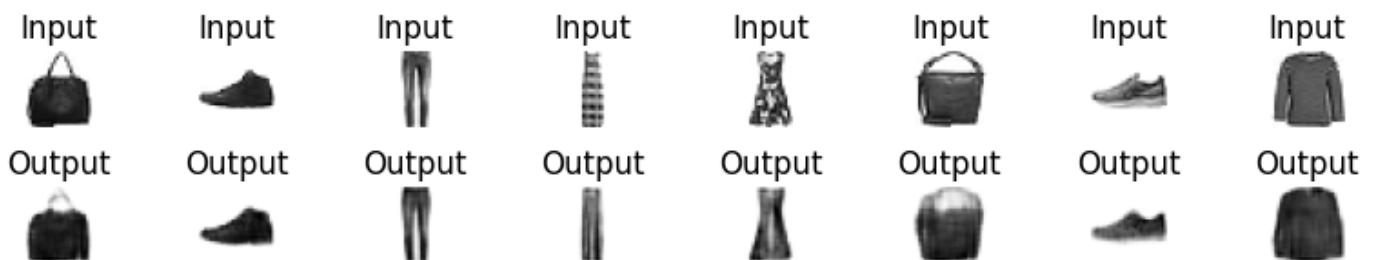
```
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 36ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 27ms/step
```

## Epoch 7



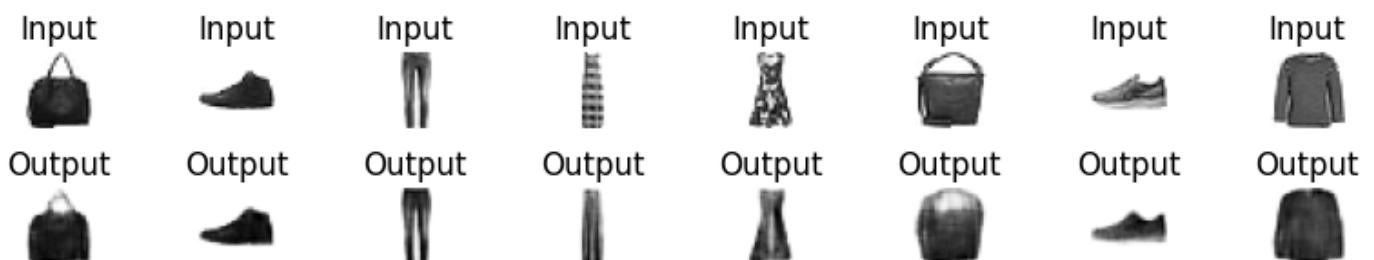
```
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 42ms/step
1/1 [=====] - 0s 42ms/step
1/1 [=====] - 0s 46ms/step
1/1 [=====] - 0s 43ms/step
1/1 [=====] - 0s 43ms/step
1/1 [=====] - 0s 51ms/step
1/1 [=====] - 0s 40ms/step
```

## Epoch 8

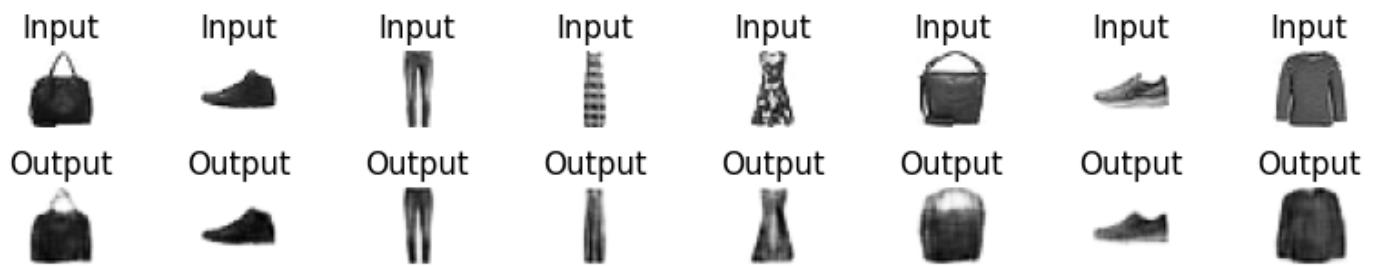


```
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 31ms/step
```

## Epoch 9



```
1/1 [=====] - 0s 52ms/step
1/1 [=====] - 0s 53ms/step
1/1 [=====] - 0s 42ms/step
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 51ms/step
1/1 [=====] - 0s 43ms/step
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 43ms/step
```



## Introducing Sparseness

We will use Lasso regression (L1 norm) regularization to encourage sparseness

```
In [ ]: from tensorflow.keras.layers import Layer
import tensorflow as tf
```

```
class Hippocampus(Activation):
    """Sparse hippocampus, includes an L1 penalty"""
    def __init__(self, l1 = 0.00001):
        super().__init__(activation='linear')
        self.l1 = l1

    def call(self, inputs):
        ysum = tf.math.reduce_sum(tf.math.abs(inputs))
        self.add_loss(ysum * self.l1)
        return inputs
```

```
In [ ]: encoder = Sequential([
    Flatten(input_shape = (28, 28)), # Sensory neurons convert raw data into something p
    Dense(784), # Temporal Cortex
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(384), # Dentate Gyrus
    ReLU(),
    Dense(256), # CA3
    ReLU(),
    Hippocampus() # Apply L1 penalty to the activations of the neurons; Encourages proce
])
decoder = Sequential([
    Dense(384, input_shape = (256,)), # CA1
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(784), # Temporal Cortex
    Activation("sigmoid"),
    Reshape((28, 28))
])
img = Input(shape = (28, 28))
latent_vector = encoder(img)
output = decoder(latent_vector)
model = Model(inputs = img, outputs = output)
model.compile(optimizer=Adam(), loss = "mean_squared_error")
```

```
In [ ]: EPOCHS = 10
EXAMPLES = 8

# Pick a number of random images
rand = x_test[np.random.randint(0, 10000, EXAMPLES)].reshape((EXAMPLES, 1, 28, 28))
```

```

for epoch in range(EPOCHS):
    fig, axs = plt.subplots(2, EXAMPLES, figsize=(EXAMPLES, 2))

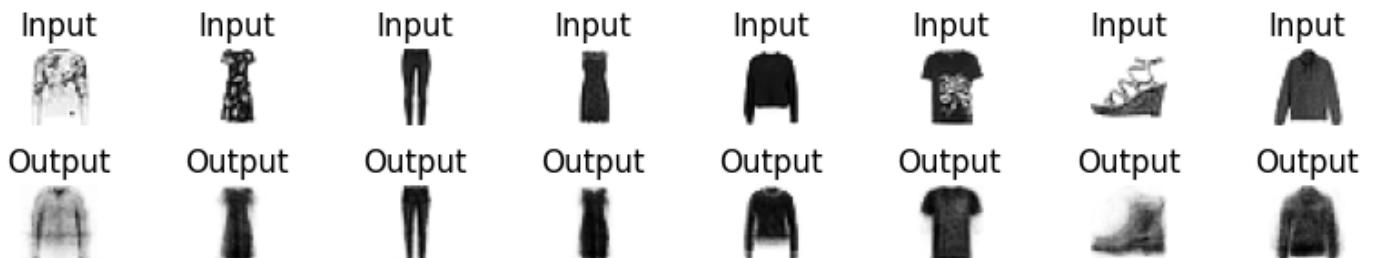
    for j in range(EXAMPLES):
        axs[0, j].imshow(rand[j][0], cmap="gray_r")
        axs[0,j].set_title("Input")
        axs[0,j].axis("off")
        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")
        axs[1,j].set_title("Output")
        axs[1,j].axis("off")

    fig.suptitle("Epoch %d" % (epoch+1))
    fig.tight_layout()
    plt.show()
    model.fit(freq_train, freq_train, verbose=0)

```

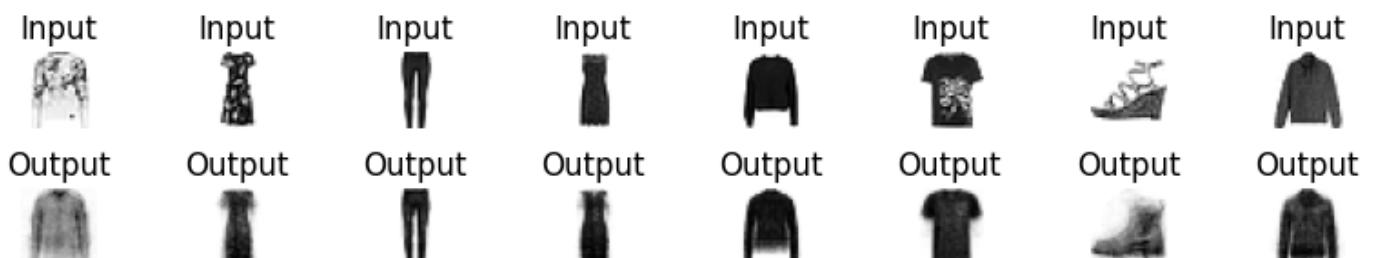
1/1 [=====] - 0s 26ms/step  
 1/1 [=====] - 0s 24ms/step  
 1/1 [=====] - 0s 24ms/step  
 1/1 [=====] - 0s 30ms/step  
 1/1 [=====] - 0s 25ms/step  
 1/1 [=====] - 0s 26ms/step  
 1/1 [=====] - 0s 36ms/step  
 1/1 [=====] - 0s 27ms/step

## Epoch 1



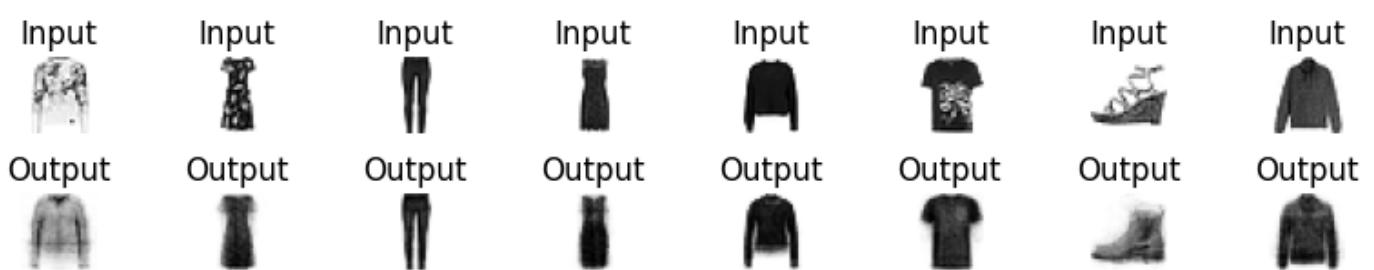
1/1 [=====] - 0s 38ms/step  
 1/1 [=====] - 0s 35ms/step  
 1/1 [=====] - 0s 37ms/step  
 1/1 [=====] - 0s 38ms/step  
 1/1 [=====] - 0s 37ms/step  
 1/1 [=====] - 0s 32ms/step  
 1/1 [=====] - 0s 33ms/step  
 1/1 [=====] - 0s 35ms/step

## Epoch 2



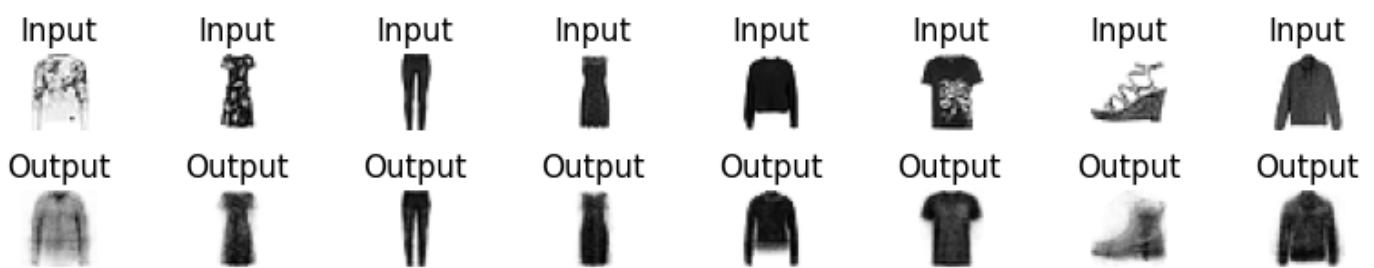
1/1 [=====] - 0s 27ms/step  
 1/1 [=====] - 0s 22ms/step  
 1/1 [=====] - 0s 21ms/step  
 1/1 [=====] - 0s 28ms/step  
 1/1 [=====] - 0s 23ms/step  
 1/1 [=====] - 0s 21ms/step  
 1/1 [=====] - 0s 23ms/step  
 1/1 [=====] - 0s 23ms/step

### Epoch 3



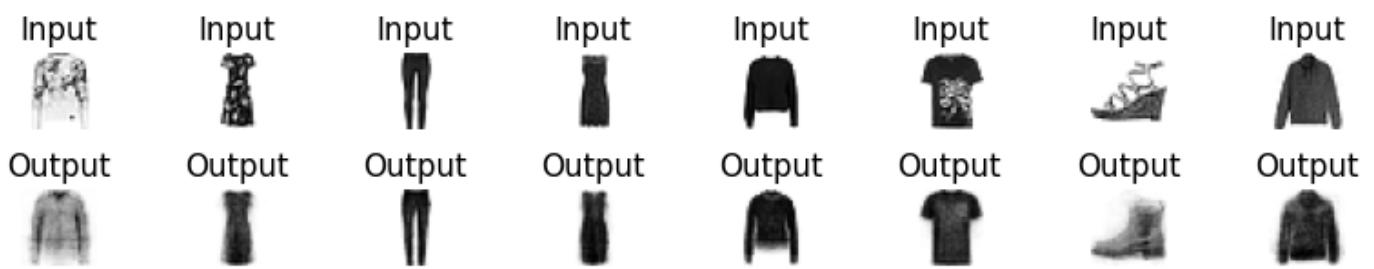
```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step
```

### Epoch 4



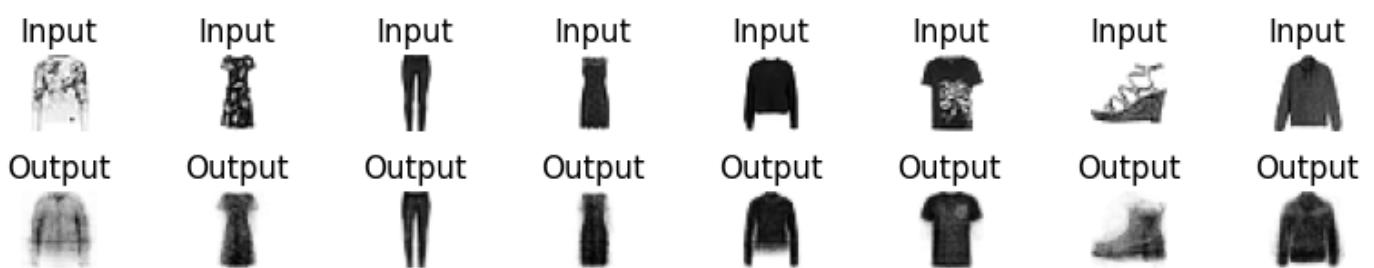
```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 23ms/step
```

### Epoch 5



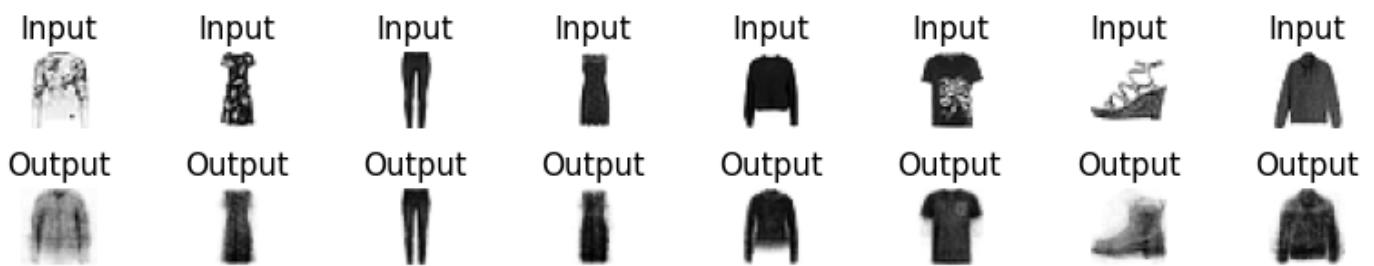
```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step
```

## Epoch 6



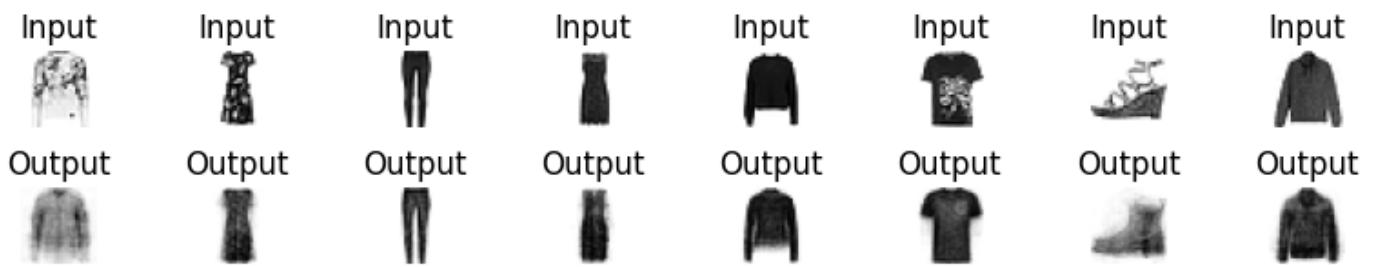
```
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step
```

## Epoch 7



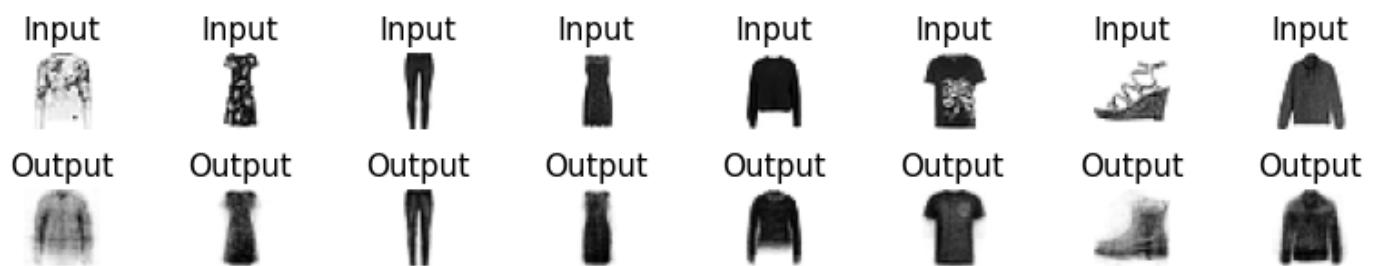
```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step
```

## Epoch 8



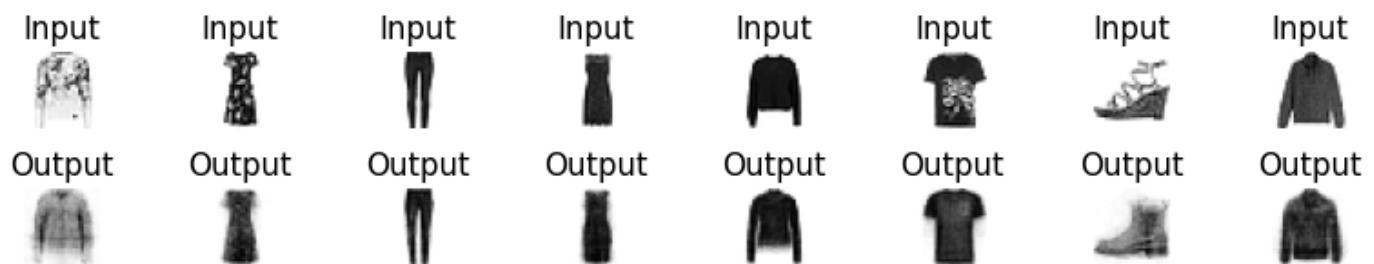
```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step
```

## Epoch 9



```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step
```

## Epoch 10



## What Is Lost?

We can see the exact details the neural network failed to reproduce.

```
In [ ]: fig, axs = plt.subplots(1, 3, figsize=(4, 1.5))  
err_test = x_test[np.random.randint(0, 10000, 1)]  
axs[0].imshow(err_test.reshape((28, 28)), cmap="gray_r")  
axs[0].set_title("Stimulus")  
axs[0].axis('off')  
  
# Intermediate representation in the hippocampus  
latent = encoder.predict(err_test)  
output = decoder.predict(latent)  
  
axs[1].imshow(output.reshape((28, 28)), cmap="gray_r")  
axs[1].set_title("Recall")  
axs[1].axis('off')  
  
err_img = (err_test - output)**2  
loss_val = np.sum(err_img)  
  
axs[2].imshow(err_img.reshape((28, 28)), cmap="gray_r")  
axs[2].set_title("Error$^2$")  
axs[2].axis('off')  
  
fig.suptitle("Total Loss = %.2f" % (loss_val,))  
fig.tight_layout()  
plt.show()
```

```
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 47ms/step
```

Total Loss = 15.82



## Taking Into Account Stimulus Frequency

Now, we will account for the frequency of each image as it goes through training after each epoch.

What we will see is a tendency for the model to generalize the lower frequency images and prioritize getting the overall gist of the image rather than grabbing any details.

```
In [ ]: EPOCHS = 100
EXAMPLES = 8

image_id = list(np.random.choice(range(10000), 1111, replace=False))

# Create a frequency dictionary
freq_dict = {img: 1000 for img in image_id[0:1]}
freq_dict.update({img: 100 for img in image_id[1:11]})
freq_dict.update({img: 10 for img in image_id[11:111]})
freq_dict.update({img: 1 for img in image_id[111:1111]})

# Separate image_ids based on their frequencies
image_ids_freq_1 = [image_id for image_id in image_id[111:1111]]
image_ids_freq_10 = [image_id for image_id in image_id[11:111]]
image_ids_freq_100 = [image_id for image_id in image_id[1:11]]
image_ids_freq_1000 = [image_id for image_id in image_id[0:1]]

# Create separate training sets for each frequency group
freq_train_1 = x_train[np.array([img for img in image_ids_freq_1])]
freq_train_10 = x_train[np.array([img for img in image_ids_freq_10])]
freq_train_100 = x_train[np.array([img for img in image_ids_freq_100])]
freq_train_1000 = x_train[np.array([img for img in image_ids_freq_1000])]

for epoch in range(EPOCHS):
    fig, axs = plt.subplots(3, EXAMPLES, figsize=(EXAMPLES * 2, 3)) # Change to 3 rows

    rand = x_test[rand_ids].reshape((EXAMPLES, 1, 28, 28))

    # Pick 2 random images from each frequency group
    rand_ids = np.concatenate([
        np.random.choice(image_ids_freq_1, 2),
        np.random.choice(image_ids_freq_10, 2),
        np.random.choice(image_ids_freq_100, 2),
        np.random.choice(image_ids_freq_1000, 2)
    ])

    for j in range(EXAMPLES):
        # Get the image ID and the frequency of the image from the dictionary
        image_id = rand_ids[j]
        freq = freq_dict[image_id]

        axs[0, j].imshow(rand[j][0], cmap="gray_r")
        axs[0, j].set_title("Input")
        axs[0, j].axis("off")
```

```

        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")
        axs[1,j].set_title("Output")
        axs[1,j].axis("off")

    # Display the frequency
    axs[2, j].text(0.5, 0.5, f"Frequency: {freq}", ha='center', va='center')
    axs[2,j].axis("off")

fig.suptitle("Epoch %d" % (epoch+1))
fig.tight_layout()
plt.show()

# Train the model separately on each frequency group
model.fit(freq_train_1, freq_train_1, verbose=0)
model.fit(freq_train_10, freq_train_10, verbose=0)
model.fit(freq_train_100, freq_train_100, verbose=0)
model.fit(freq_train_1000, freq_train_1000, verbose=0)

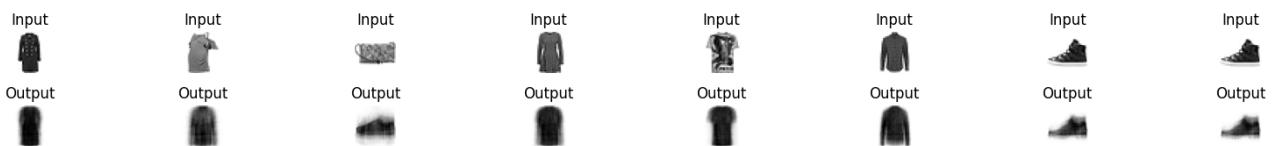
```

```

1/1 [=====] - 0s 67ms/step
1/1 [=====] - 0s 68ms/step
1/1 [=====] - 0s 62ms/step
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 46ms/step
1/1 [=====] - 0s 53ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 94ms/step

```

Epoch 1



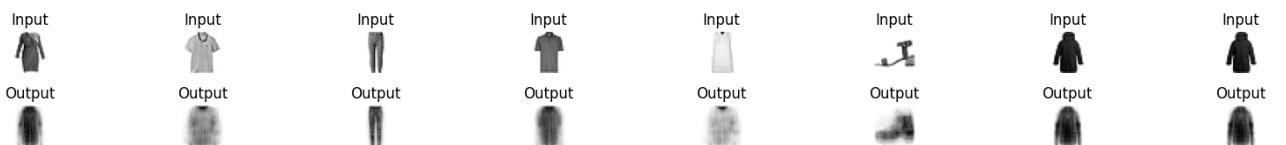
Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```

1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 28ms/step

```

Epoch 2



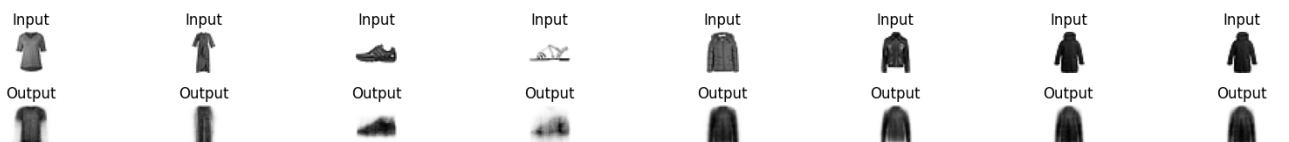
Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```

1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 38ms/step

```

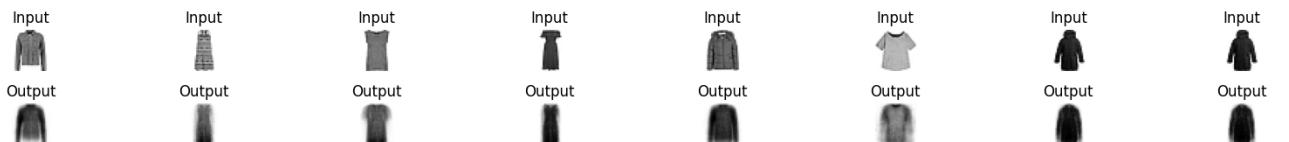
Epoch 3



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step
```

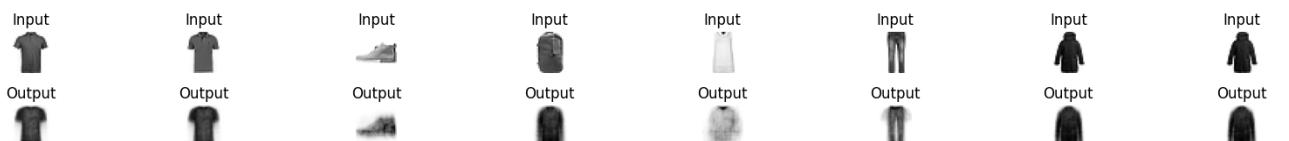
Epoch 4



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step
```

Epoch 5



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

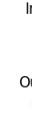
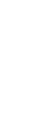
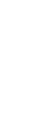
```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 33ms/step
```

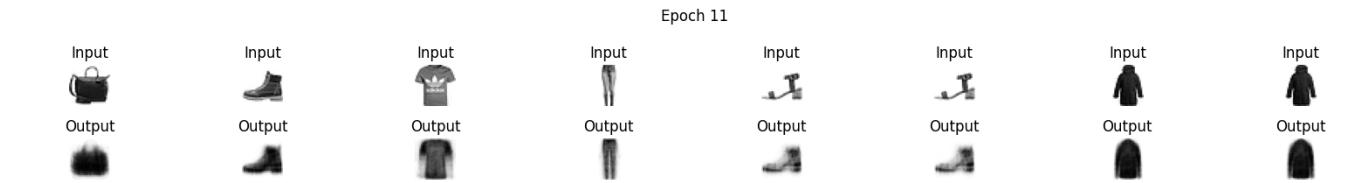
Epoch 6



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step
```

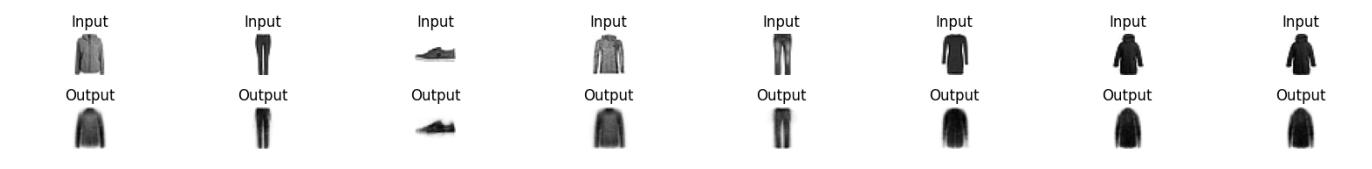
Epoch 7							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 28ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step			
Epoch 8							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 28ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 28ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 26ms/step
Epoch 9							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 31ms/step
Epoch 10							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 30ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 32ms/step
```

Epoch 12



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 40ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 38ms/step
1/1 [=====] - 0s 37ms/step
```

Epoch 13



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

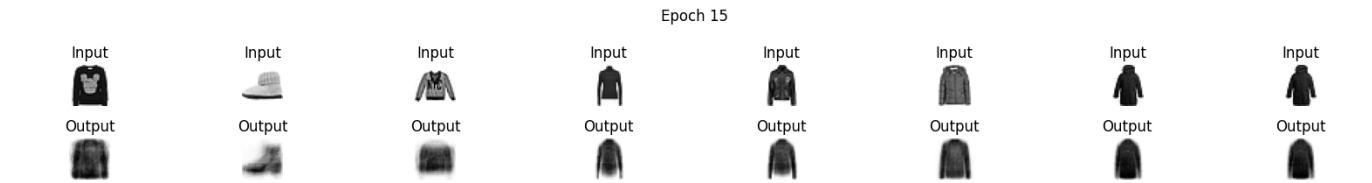
```
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 26ms/step
```

Epoch 14



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

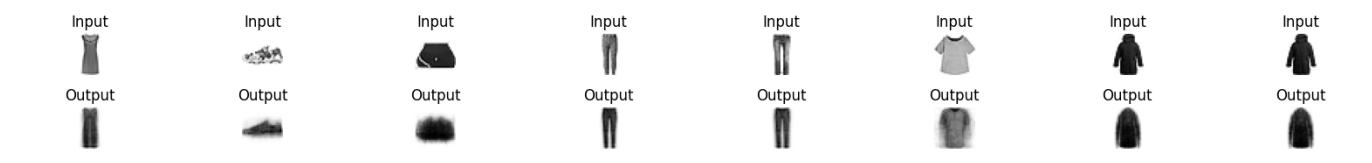
```
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 23ms/step
```



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 22ms/step
```

Epoch 16



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 43ms/step
```

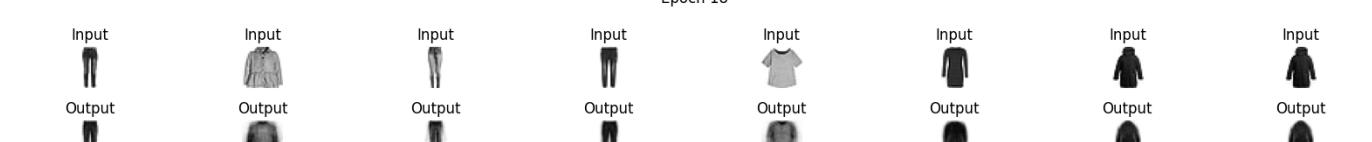
Epoch 17



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step
```

Epoch 18



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step
```

Epoch 19

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 38ms/step | 1/1 [=====] - 0s 37ms/step | 1/1 [=====] - 0s 46ms/step | 1/1 [=====] - 0s 34ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 36ms/step |

Epoch 20

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 23ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 26ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 26ms/step | 1/1 [=====] - 0s 26ms/step | 1/1 [=====] - 0s 24ms/step |

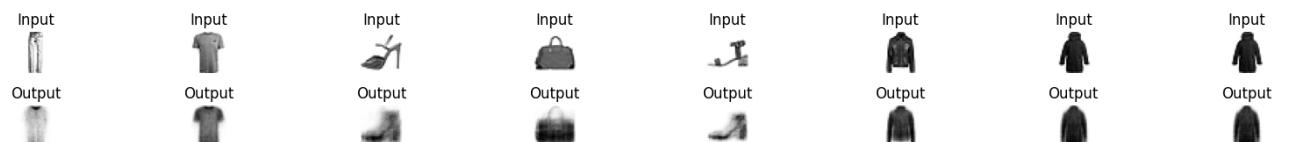
Epoch 21

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 25ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 25ms/step | 1/1 [=====] - 0s 24ms/step |

Epoch 22

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 46ms/step | 1/1 [=====] - 0s 52ms/step | 1/1 [=====] - 0s 45ms/step | 1/1 [=====] - 0s 39ms/step | 1/1 [=====] - 0s 43ms/step | 1/1 [=====] - 0s 40ms/step | 1/1 [=====] - 0s 50ms/step | 1/1 [=====] - 0s 48ms/step |

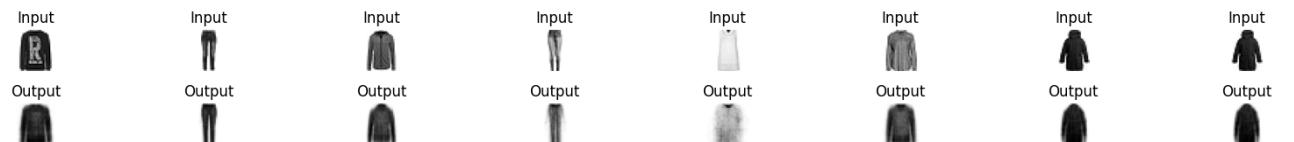
Epoch 23



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step
```

Epoch 24



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 29ms/step
```

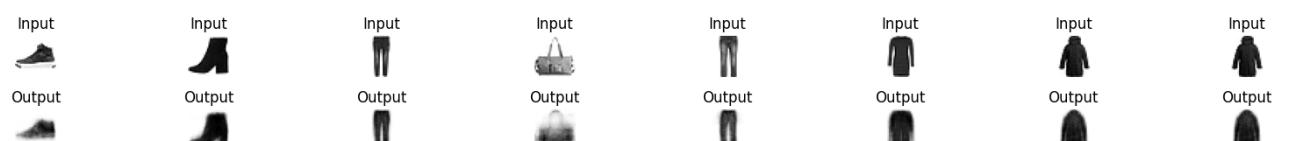
Epoch 25



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step
```

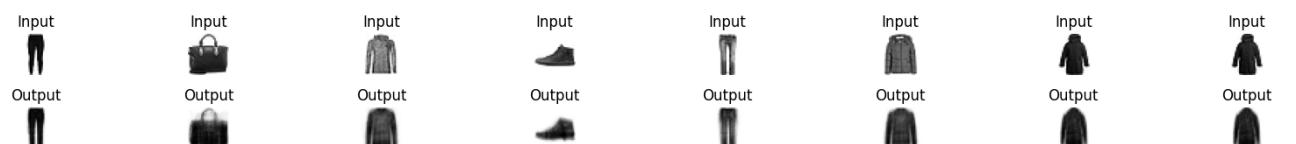
Epoch 26



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 45ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 27ms/step
```

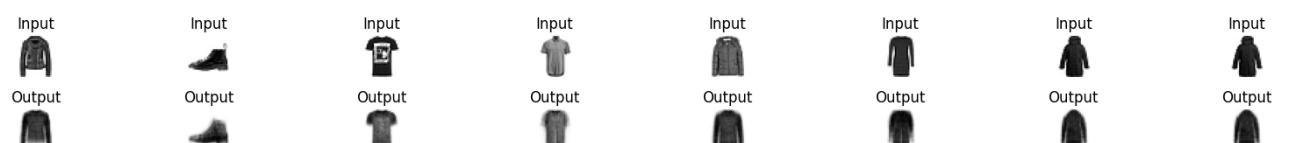
Epoch 27



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 24ms/step
```

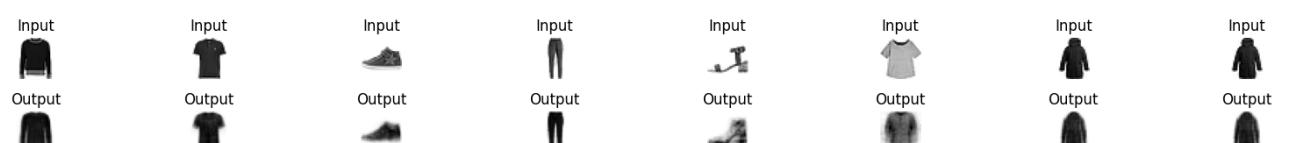
Epoch 28



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 26ms/step
```

Epoch 29



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

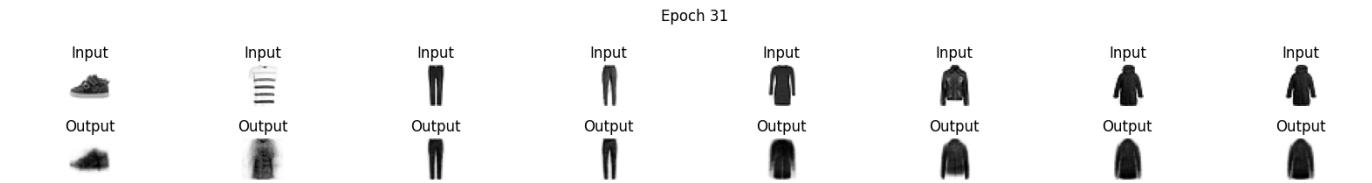
```
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 39ms/step
1/1 [=====] - 0s 37ms/step
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 40ms/step
1/1 [=====] - 0s 40ms/step
1/1 [=====] - 0s 37ms/step
```

Epoch 30



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

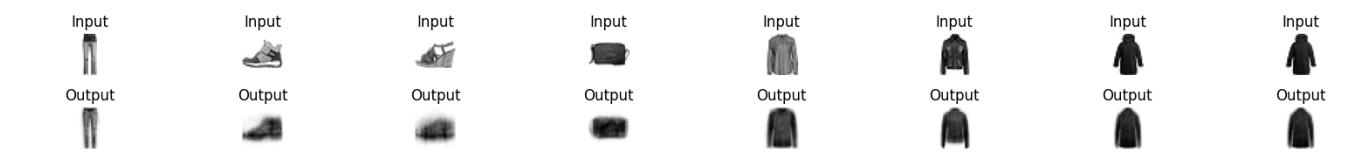
```
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 34ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 23ms/step
```



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 33ms/step
```

Epoch 32



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 28ms/step
```

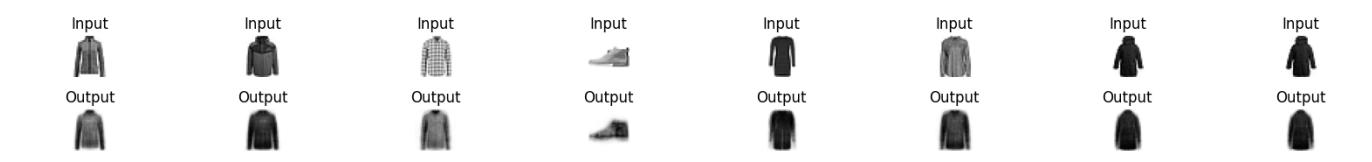
Epoch 33



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

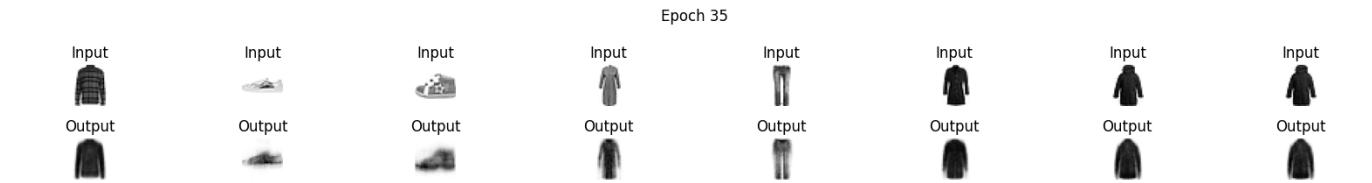
```
1/1 [=====] - 0s 38ms/step
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 53ms/step
1/1 [=====] - 0s 34ms/step
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 34ms/step
```

Epoch 34



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 38ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 27ms/step
```



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 30ms/step
```

Epoch 36



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step
```

Epoch 37



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step
```

Epoch 38



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step
```

Epoch 39



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

Frequency: 100

Frequency: 100

Frequency: 1000

Frequency: 1000

1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 70ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 58ms/step

Epoch 40



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

Frequency: 100

Frequency: 100

Frequency: 1000

Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 31ms/step

Epoch 41



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

Frequency: 100

Frequency: 100

Frequency: 1000

Frequency: 1000

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step

Epoch 42



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

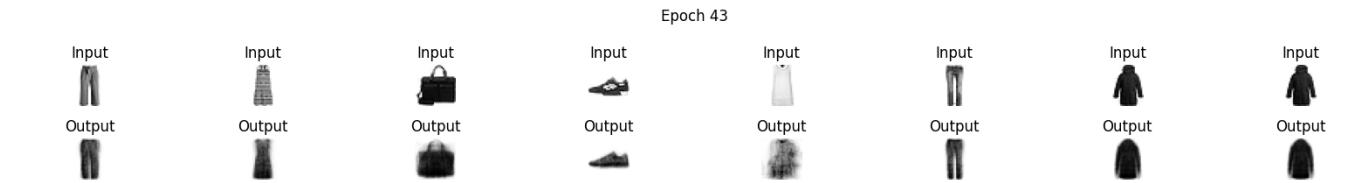
Frequency: 100

Frequency: 100

Frequency: 1000

Frequency: 1000

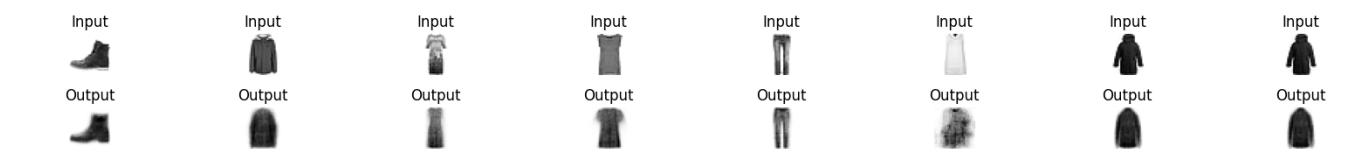
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 22ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 36ms/step
1/1 [=====] - 0s 49ms/step
1/1 [=====] - 0s 40ms/step
1/1 [=====] - 0s 47ms/step
1/1 [=====] - 0s 55ms/step
```

Epoch 44



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 28ms/step
```

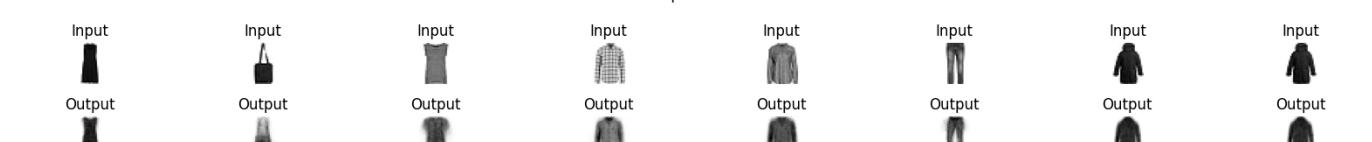
Epoch 45



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 29ms/step
1/1 [=====] - 0s 27ms/step
```

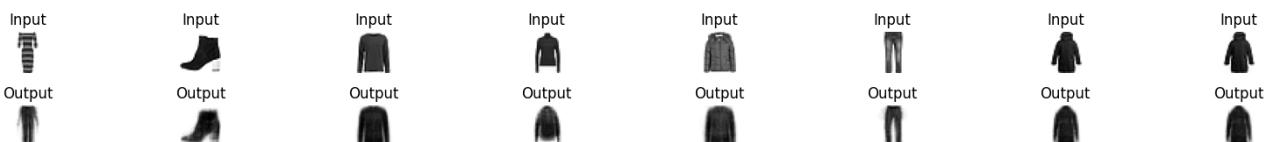
Epoch 46



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 38ms/step
```

Epoch 47



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 37ms/step
```

Epoch 48



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 45ms/step
```

Epoch 49



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 68ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 70ms/step  
1/1 [=====] - 0s 63ms/step
```

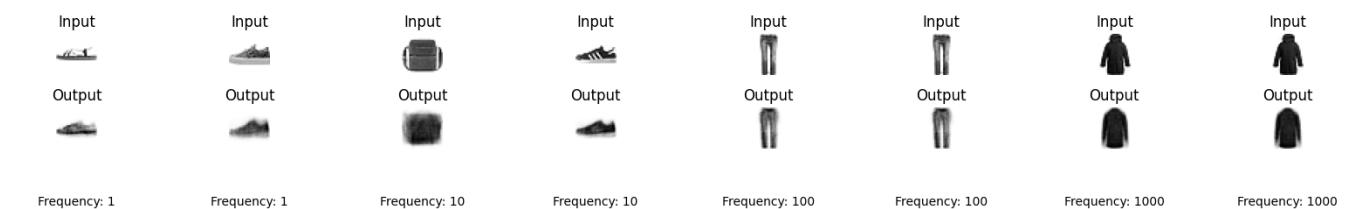
Epoch 50



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 35ms/step
```

Epoch 51



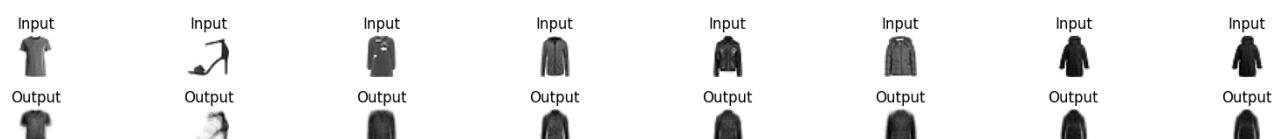
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step

Epoch 52



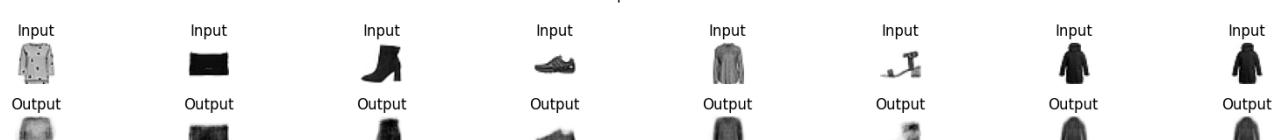
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 36ms/step

Epoch 53

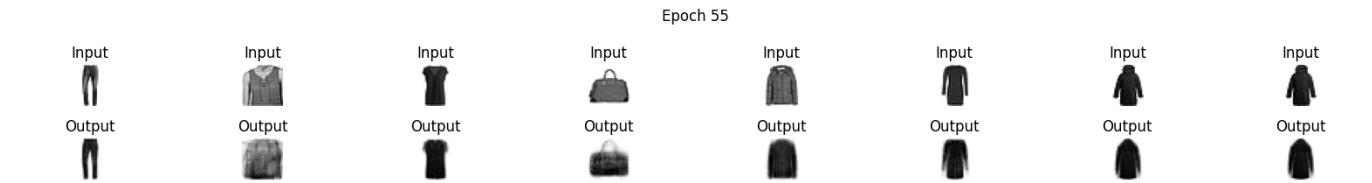


1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 66ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 32ms/step

Epoch 54



1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 43ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 36ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 35ms/step
```

Epoch 56



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 52ms/step  
1/1 [=====] - 0s 56ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 45ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 70ms/step
```

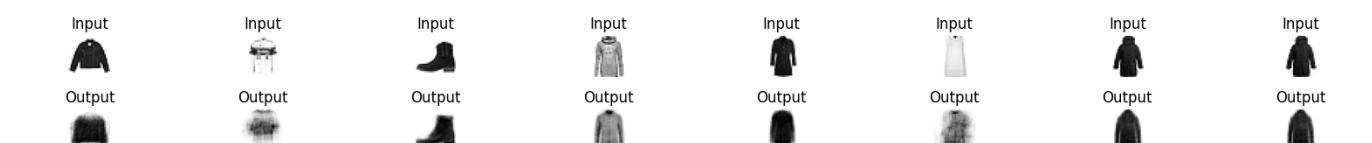
Epoch 57



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step
```

Epoch 58



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 34ms/step
```

Epoch 59

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 33ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 32ms/step |

Epoch 60

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 50ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 50ms/step

Epoch 61

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 35ms/step

Epoch 62

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 50ms/step  
1/1 [=====] - 0s 80ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 36ms/step

Epoch 63

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 42ms/step | 1/1 [=====] - 0s 33ms/step | 1/1 [=====] - 0s 34ms/step | 1/1 [=====] - 0s 34ms/step | 1/1 [=====] - 0s 33ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 35ms/step |

Epoch 64

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 60ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 34ms/step

Epoch 65

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 41ms/step

Epoch 66

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 36ms/step

Epoch 67

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 21ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 33ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 37ms/step | 1/1 [=====] - 0s 43ms/step |

Epoch 68

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 25ms/step | 1/1 [=====] - 0s 40ms/step | 1/1 [=====] - 0s 37ms/step | 1/1 [=====] - 0s 48ms/step | 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 33ms/step |

Epoch 69

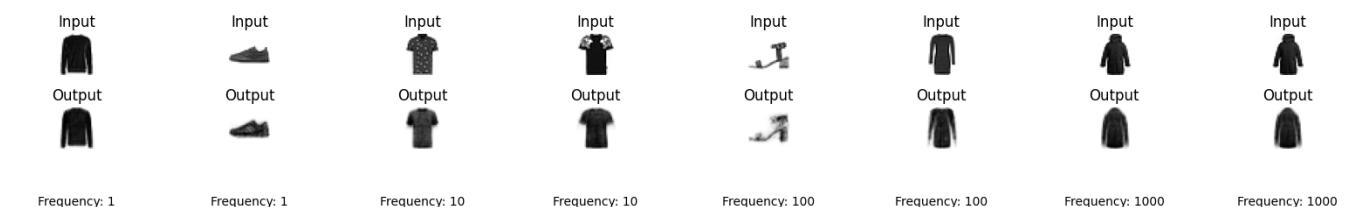
| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 29ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 46ms/step |

Epoch 70

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 34ms/step | 1/1 [=====] - 0s 39ms/step | 1/1 [=====] - 0s 39ms/step | 1/1 [=====] - 0s 41ms/step | 1/1 [=====] - 0s 38ms/step | 1/1 [=====] - 0s 35ms/step |

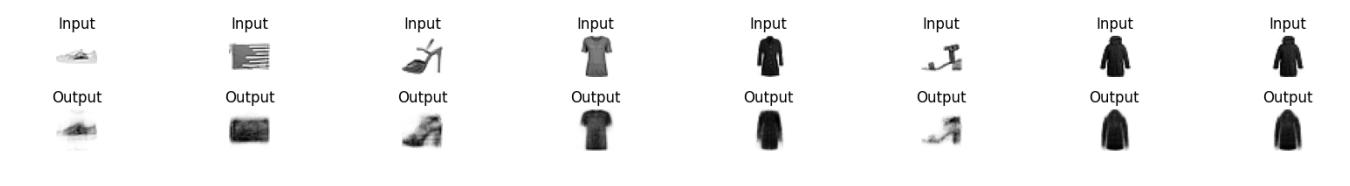
Epoch 71							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 42ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 33ms/step
Epoch 72							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 81ms/step	1/1 [=====] - 0s 57ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 53ms/step
Epoch 73							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 45ms/step	1/1 [=====] - 0s 43ms/step	1/1 [=====] - 0s 44ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 49ms/step	1/1 [=====] - 0s 50ms/step	1/1 [=====] - 0s 45ms/step	1/1 [=====] - 0s 41ms/step
Epoch 74							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 44ms/step	1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 43ms/step	1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 39ms/step

Epoch 75



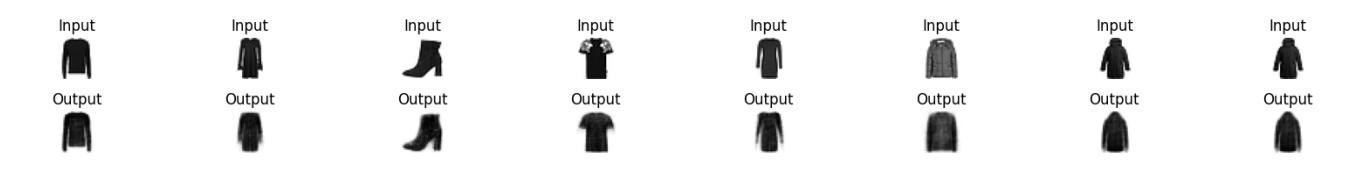
```
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 51ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 61ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 67ms/step  
1/1 [=====] - 0s 45ms/step
```

Epoch 76



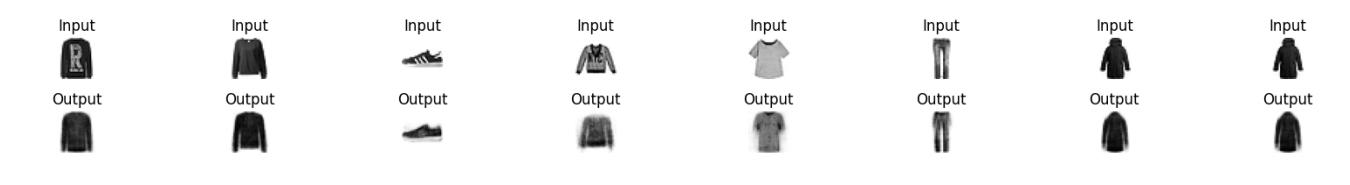
```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 56ms/step
```

Epoch 77



```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 39ms/step
```

Epoch 78



```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 55ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 39ms/step
```

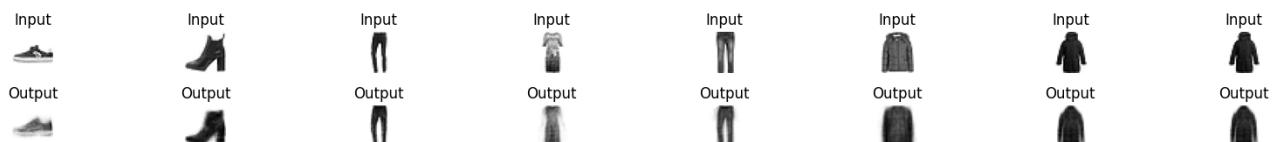
Epoch 79



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 34ms/step

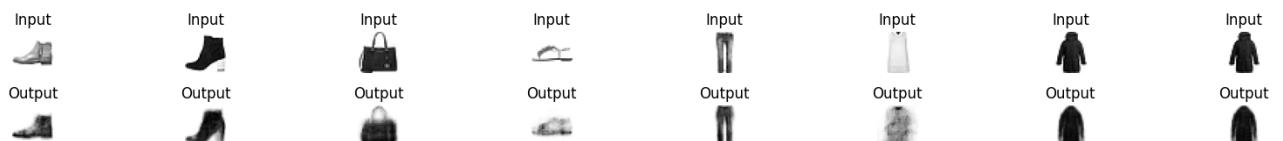
Epoch 80



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 33ms/step

Epoch 81



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 51ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 37ms/step

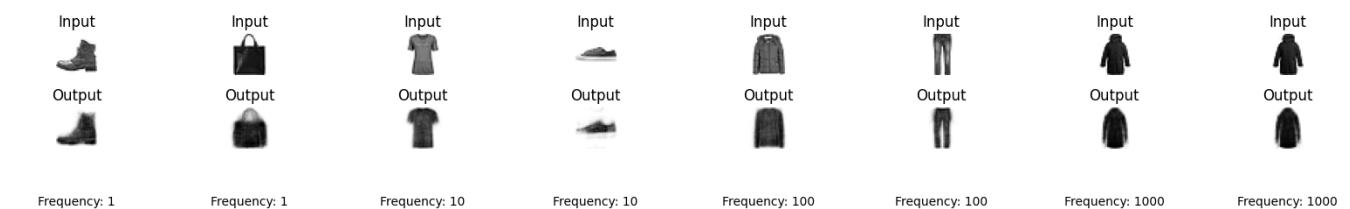
Epoch 82



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 63ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step

Epoch 83



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 36ms/step
```

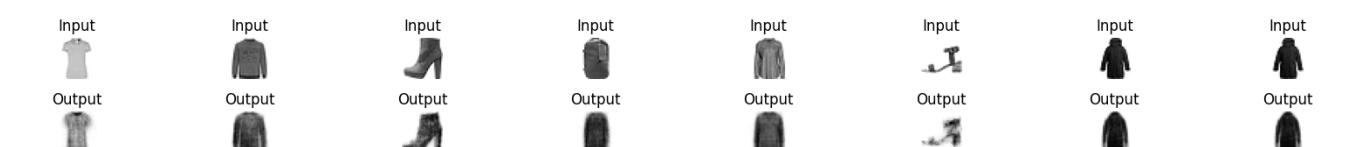
Epoch 84



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 35ms/step
```

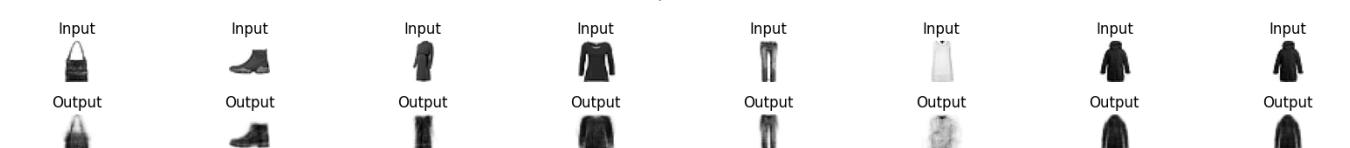
Epoch 85



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 52ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 81ms/step  
1/1 [=====] - 0s 50ms/step
```

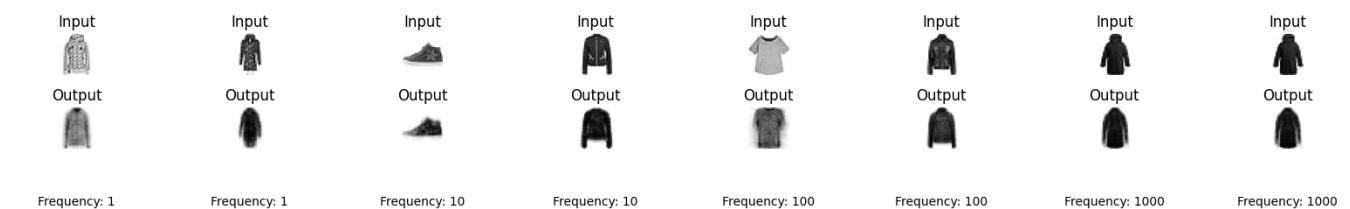
Epoch 86



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 50ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 49ms/step
```

Epoch 87



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 34ms/step

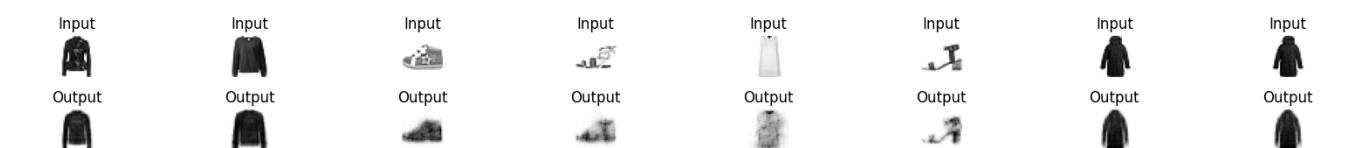
Epoch 88



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 59ms/step  
1/1 [=====] - 0s 54ms/step  
1/1 [=====] - 0s 98ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 69ms/step  
1/1 [=====] - 0s 91ms/step  
1/1 [=====] - 0s 62ms/step  
1/1 [=====] - 0s 39ms/step

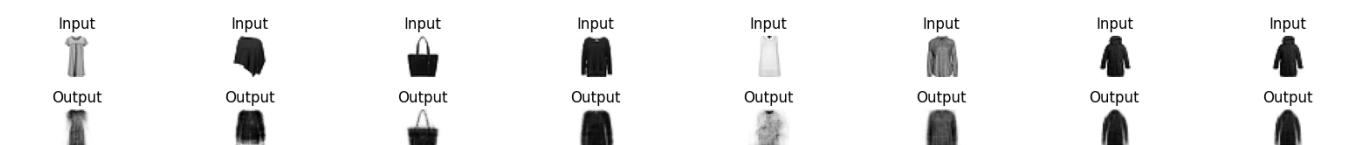
Epoch 89



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 52ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 43ms/step

Epoch 90

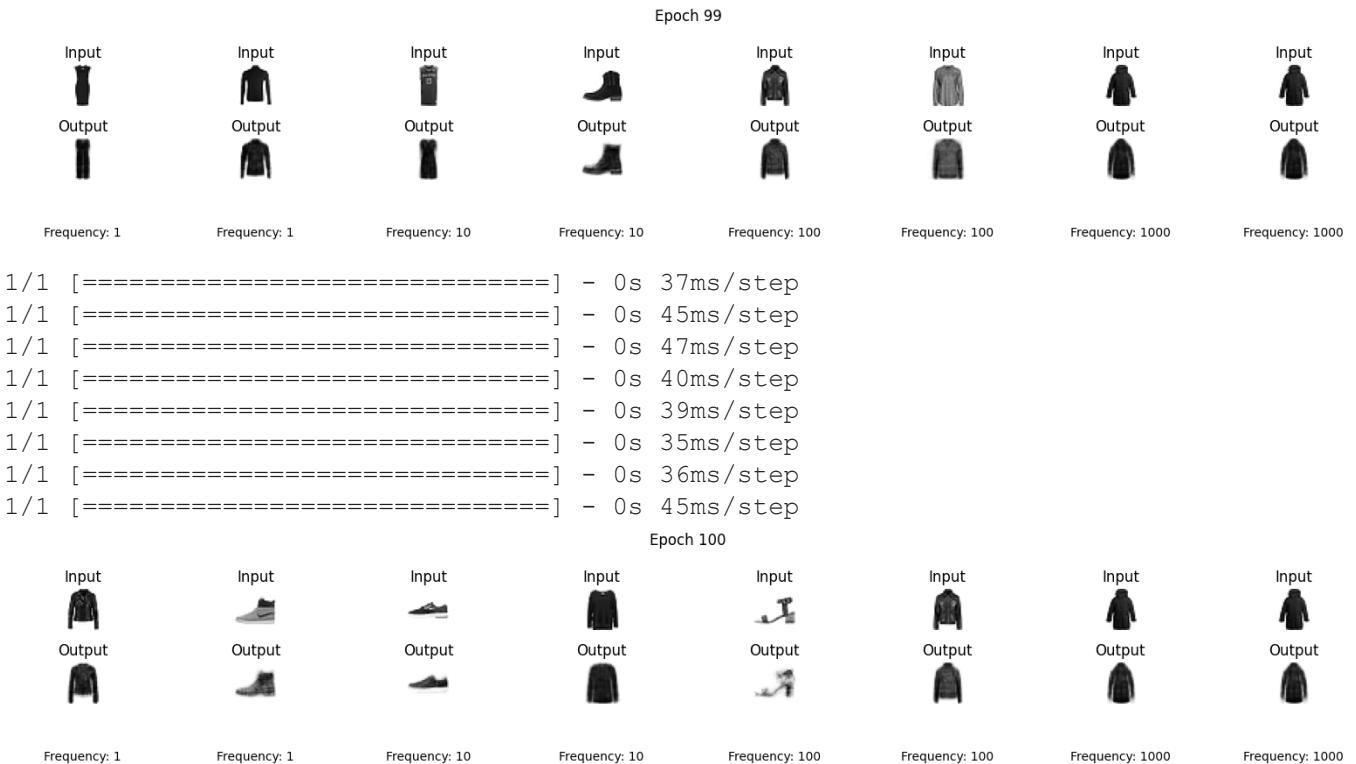


Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 34ms/step

Epoch 91							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 50ms/step	1/1 [=====] - 0s 36ms/step
Epoch 92							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 33ms/step
Epoch 93							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 36ms/step
Epoch 94							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 42ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 45ms/step	1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 46ms/step

Epoch 95							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 46ms/step	1/1 [=====] - 0s 60ms/step	1/1 [=====] - 0s 67ms/step	1/1 [=====] - 0s 59ms/step	1/1 [=====] - 0s 50ms/step	1/1 [=====] - 0s 50ms/step	1/1 [=====] - 0s 42ms/step	1/1 [=====] - 0s 36ms/step
Epoch 96							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 28ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 42ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 31ms/step
Epoch 97							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 35ms/step
Epoch 98							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 42ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 45ms/step	1/1 [=====] - 0s 41ms/step



## Lesioning the Hippocampus

To better understand how deficits look like those with hippocampal lesions, we will vary the number of neurons per layer, our L1 regularization value, as well as the learning rate of our optimizer, ADAM

We will start by damaging the input to the medial temporal lobe.

```
In [ ]: encoder = Sequential([
    Flatten(input_shape = (28, 28)), # Sensory neurons convert raw data into something p
    Dense(10), # Temporal Cortex
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(384), # Dentate Gyrus
    ReLU(),
    Dense(256), # CA3
    ReLU(),
    Hippocampus() # Apply L1 penalty to the activations of the neurons; Encourages proce
])
decoder = Sequential([
    Dense(384, input_shape = (256,)), # CA1
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(784), # Temporal Cortex
    Activation("sigmoid"),
    Reshape((28, 28))
])
img = Input(shape = (28, 28))
latent_vector = encoder(img)
output = decoder(latent_vector)
model = Model(inputs = img, outputs = output)
model.compile(optimizer=Adam(), loss = "mean_squared_error")
```

```
In [ ]: EPOCHS = 50
EXAMPLES = 8
```

```

image_id = list(np.random.choice(range(10000), 1111, replace=False))

# Create a frequency dictionary
freq_dict = {img: 1000 for img in image_id[0:1]}
freq_dict.update({img: 100 for img in image_id[1:11]})
freq_dict.update({img: 10 for img in image_id[11:111]})
freq_dict.update({img: 1 for img in image_id[111:1111]})

# Separate image_ids based on their frequencies
image_ids_freq_1 = [image_id for image_id in image_id[111:1111]]
image_ids_freq_10 = [image_id for image_id in image_id[11:111]]
image_ids_freq_100 = [image_id for image_id in image_id[1:11]]
image_ids_freq_1000 = [image_id for image_id in image_id[0:1]]

# Create separate training sets for each frequency group
freq_train_1 = x_train[np.array([img for img in image_ids_freq_1])]
freq_train_10 = x_train[np.array([img for img in image_ids_freq_10])]
freq_train_100 = x_train[np.array([img for img in image_ids_freq_100])]
freq_train_1000 = x_train[np.array([img for img in image_ids_freq_1000])]

for epoch in range(EPOCHS):
    fig, axs = plt.subplots(3, EXAMPLES, figsize=(EXAMPLES * 2, 3)) # Change to 3 rows

    # Pick 2 random images from each frequency group
    rand_ids = np.concatenate([
        np.random.choice(image_ids_freq_1, 2),
        np.random.choice(image_ids_freq_10, 2),
        np.random.choice(image_ids_freq_100, 2),
        np.random.choice(image_ids_freq_1000, 2)
    ])

    rand = x_test[rand_ids].reshape((EXAMPLES, 1, 28, 28))

    for j in range(EXAMPLES):
        # Get the image ID and the frequency of the image from the dictionary
        image_id = rand_ids[j]
        freq = freq_dict[image_id]

        axs[0, j].imshow(rand[j][0], cmap="gray_r")
        axs[0,j].set_title("Input")
        axs[0,j].axis("off")

        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")
        axs[1,j].set_title("Output")
        axs[1,j].axis("off")

        # Display the frequency
        axs[2, j].text(0.5, 0.5, f"Frequency: {freq}", ha='center', va='center')
        axs[2,j].axis("off")

    fig.suptitle("Epoch %d" % (epoch+1))
    fig.tight_layout()
    plt.show()

    # Train the model separately on each frequency group
    model.fit(freq_train_1, freq_train_1, verbose=0)
    model.fit(freq_train_10, freq_train_10, verbose=0)
    model.fit(freq_train_100, freq_train_100, verbose=0)
    model.fit(freq_train_1000, freq_train_1000, verbose=0)

```

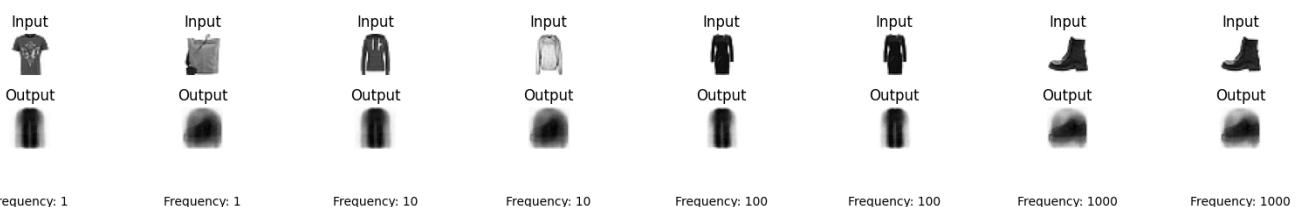
```

1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 23ms/step

```

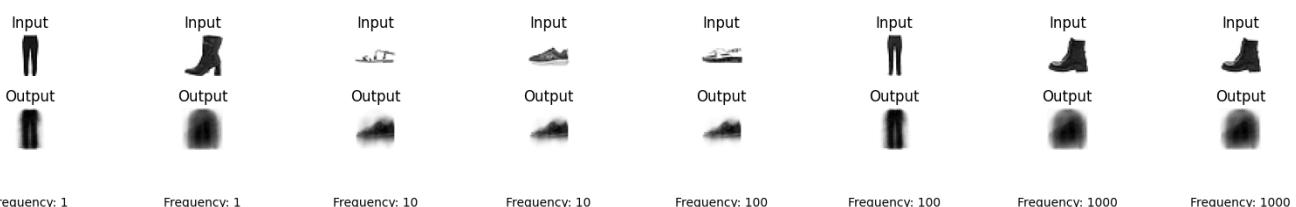
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step

Epoch 1



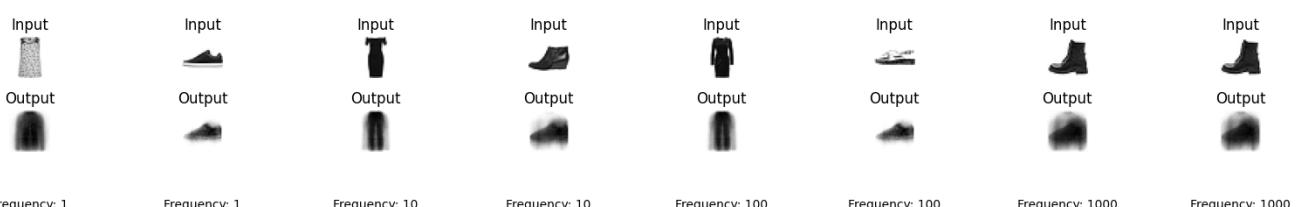
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 41ms/step

Epoch 2



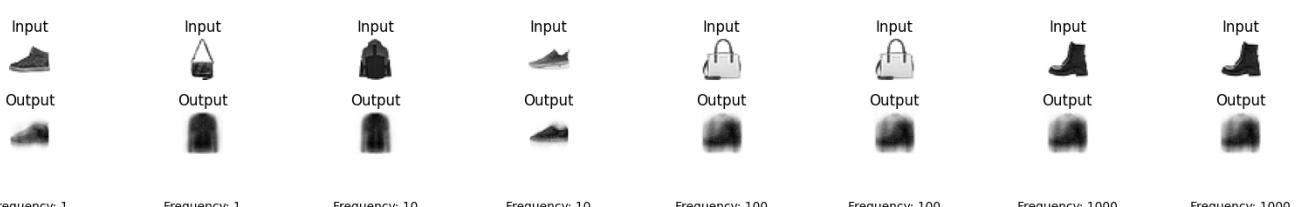
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 20ms/step

Epoch 3



1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step

Epoch 4



1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step

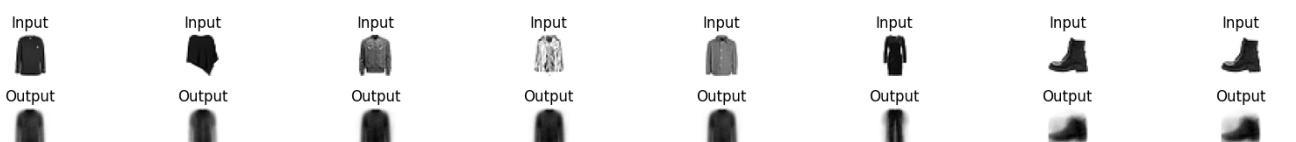
Epoch 5



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 20ms/step

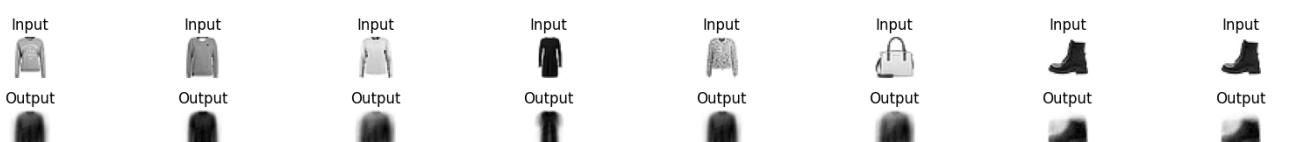
Epoch 6



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step

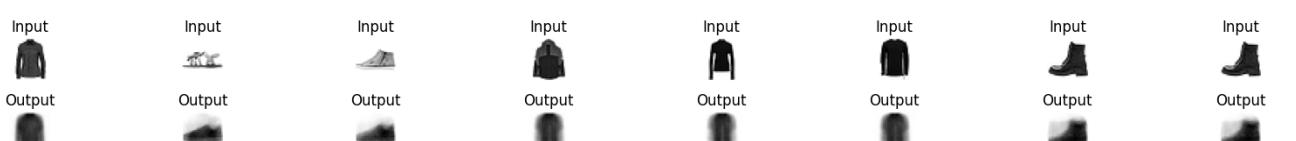
Epoch 7



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step

Epoch 8

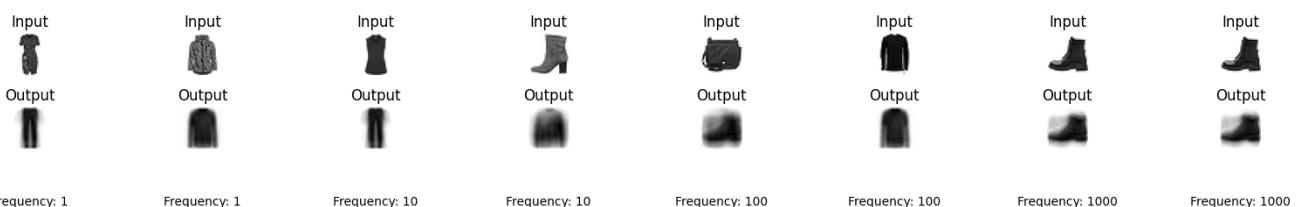


Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 22ms/step

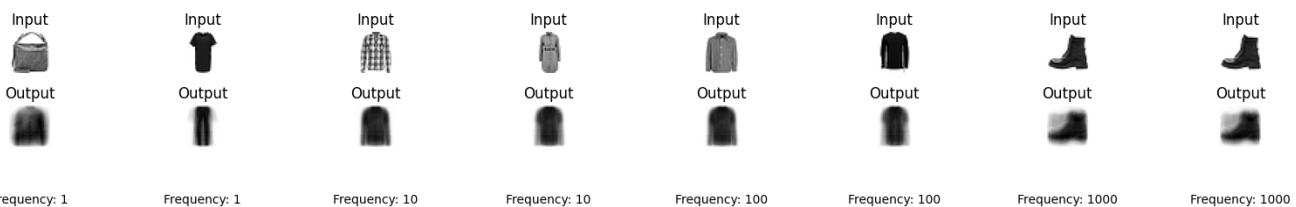
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 9



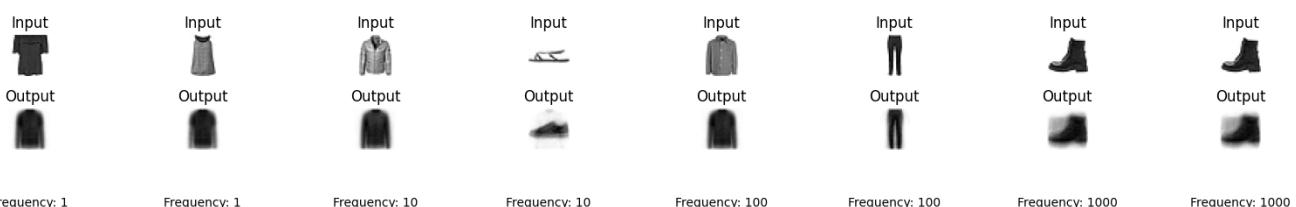
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 10



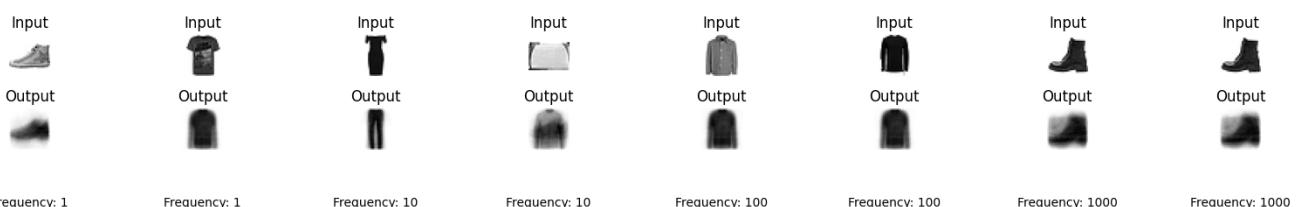
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 29ms/step

Epoch 11



1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step

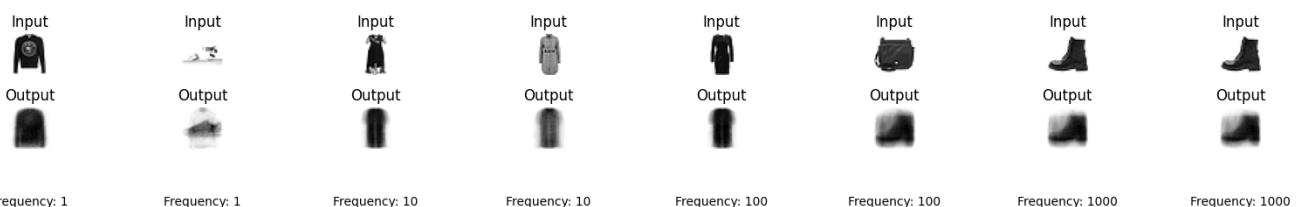
Epoch 12



1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 24ms/step

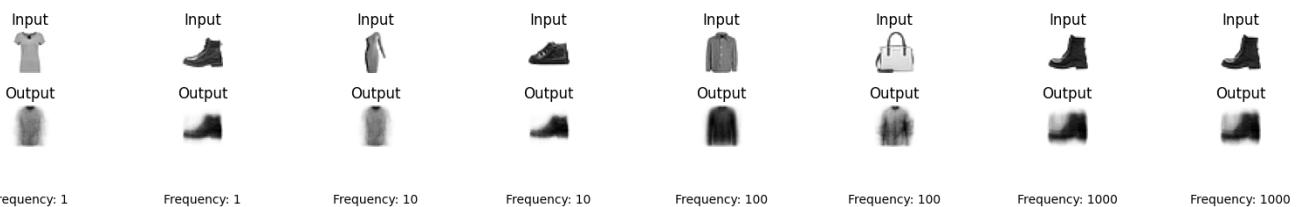
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 13



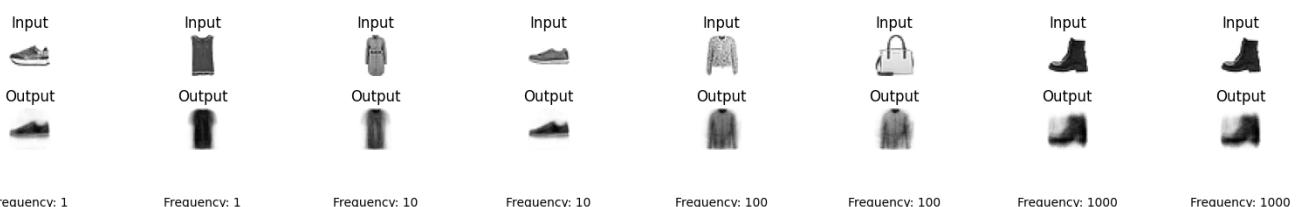
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step

Epoch 14



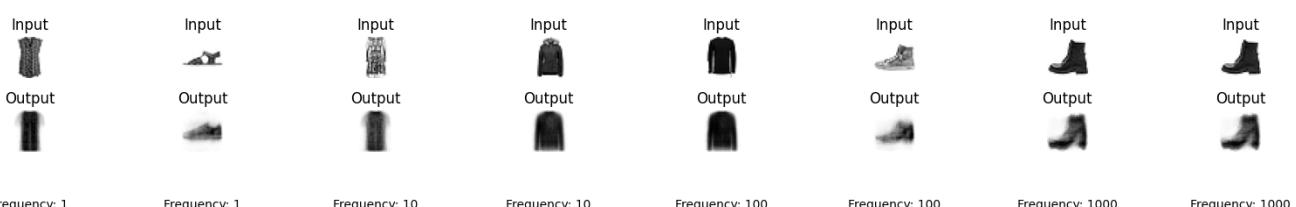
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step

Epoch 15



1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step

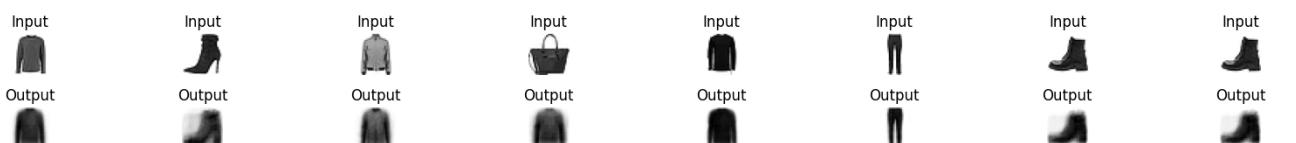
Epoch 16



1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step

1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 33ms/step

Epoch 17



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step

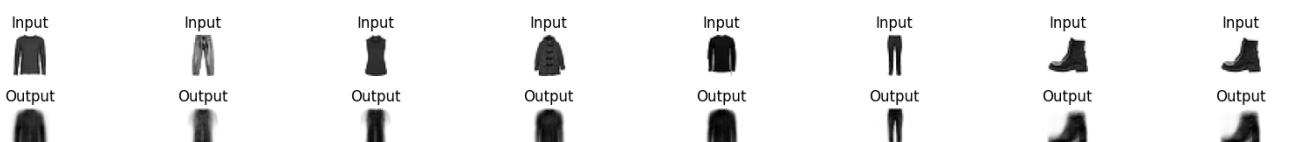
Epoch 18



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 43ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 37ms/step

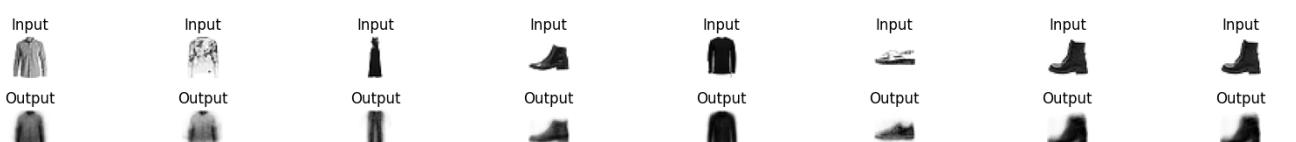
Epoch 19



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step

Epoch 20

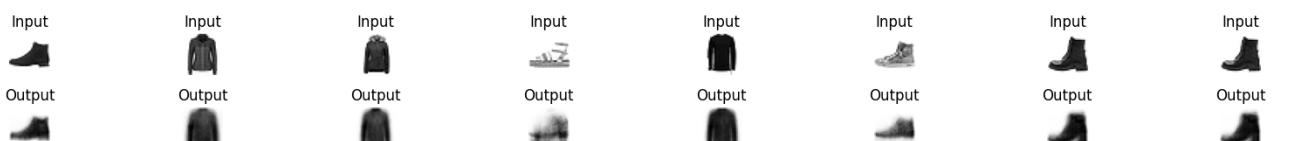


Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 21ms/step

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 21



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 29ms/step

Epoch 22



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 30ms/step

Epoch 23



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step

Epoch 24

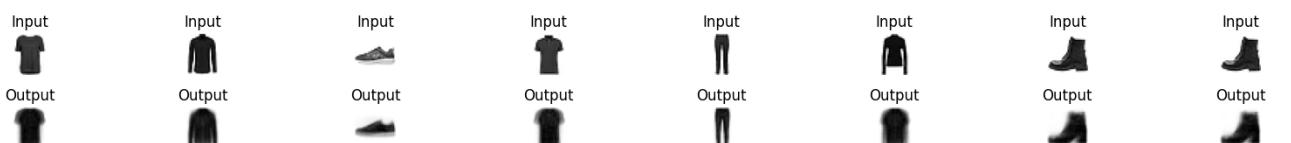


Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step

1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 25



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step

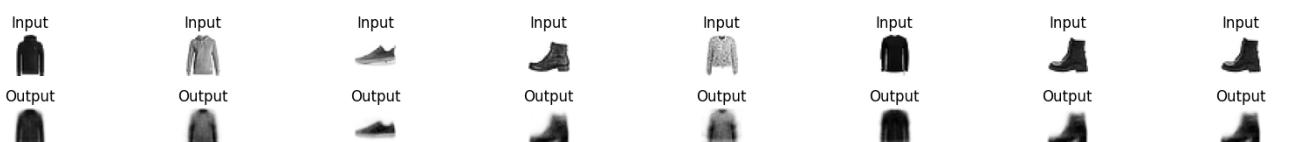
Epoch 26



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 50ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 32ms/step

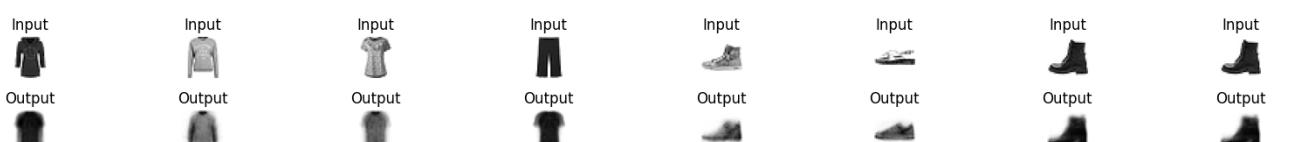
Epoch 27



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 28

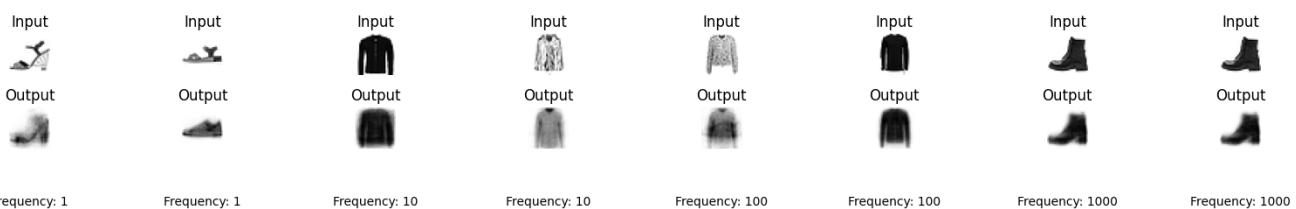


Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step

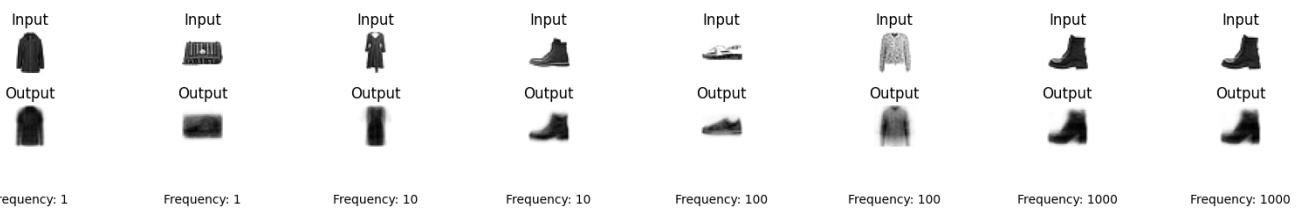
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 29



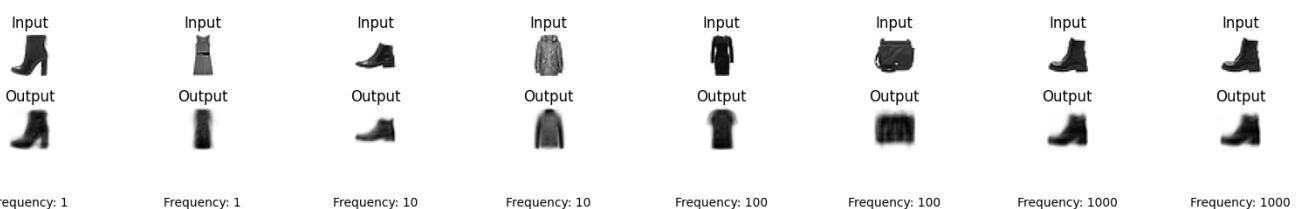
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step

Epoch 30



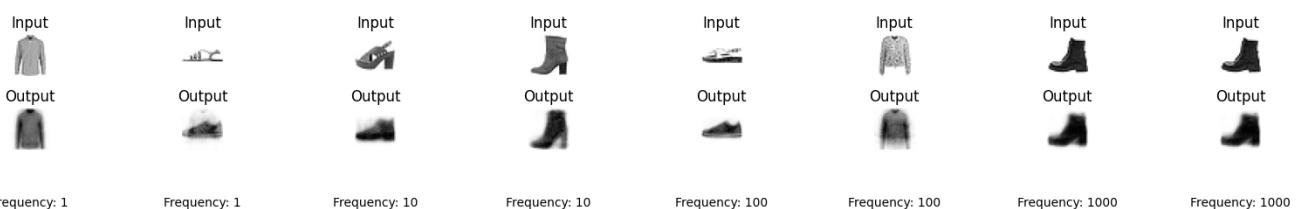
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 69ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 52ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 45ms/step

Epoch 31



1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 32



1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 33



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step

Epoch 34



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 48ms/step

Epoch 35



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step

Epoch 36



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step

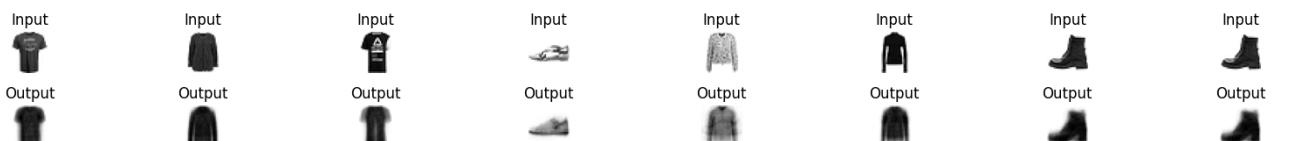
Epoch 37



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 38



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 32ms/step

Epoch 39



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 30ms/step

Epoch 40

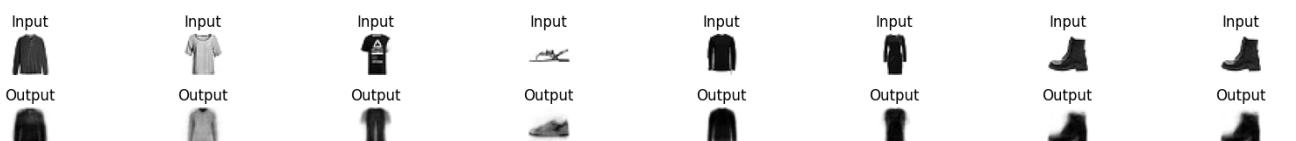


Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step

1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 28ms/step

Epoch 41



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 25ms/step

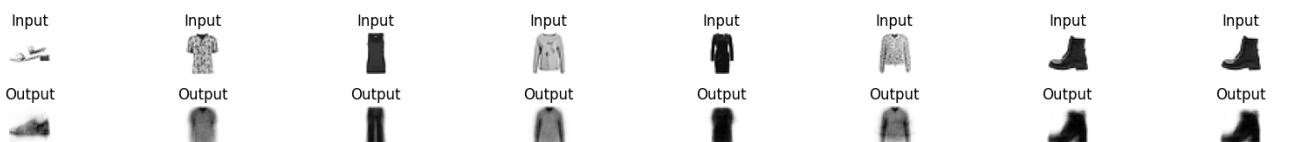
Epoch 42



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 86ms/step  
1/1 [=====] - 0s 46ms/step

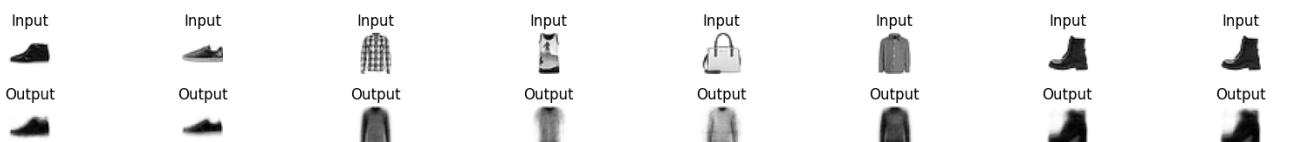
Epoch 43



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 31ms/step

Epoch 44

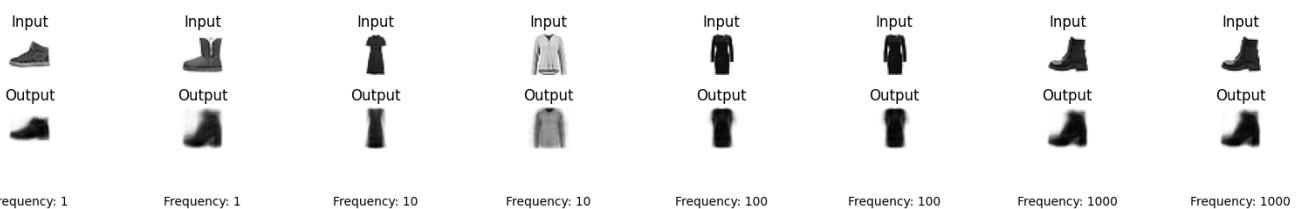


Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 34ms/step

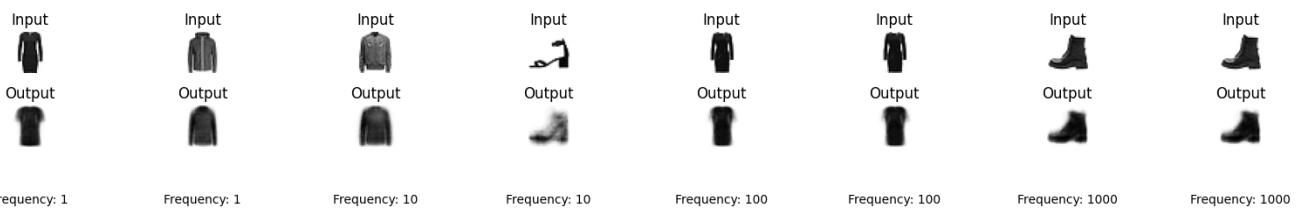
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step

Epoch 45



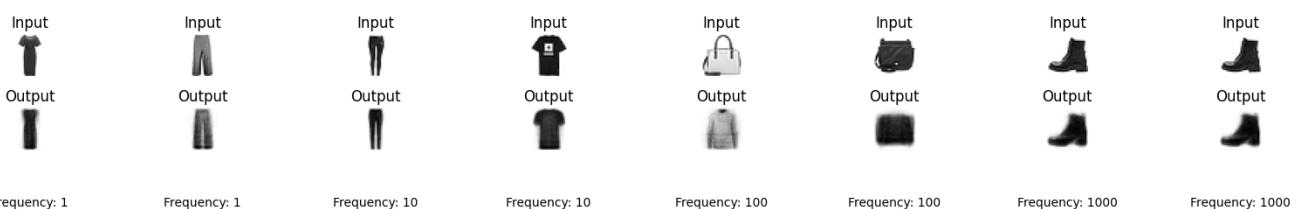
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step

Epoch 46



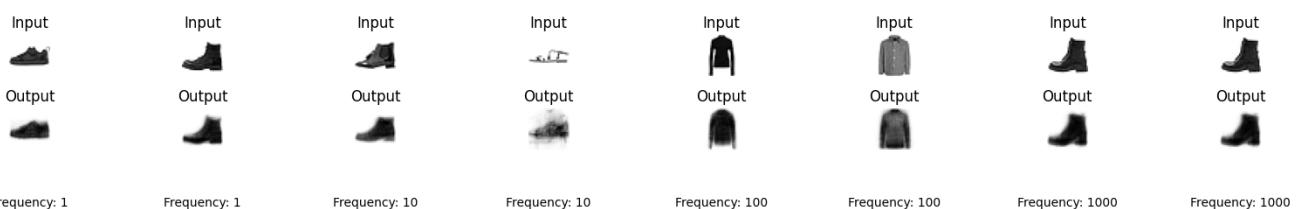
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 35ms/step

Epoch 47



1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 27ms/step

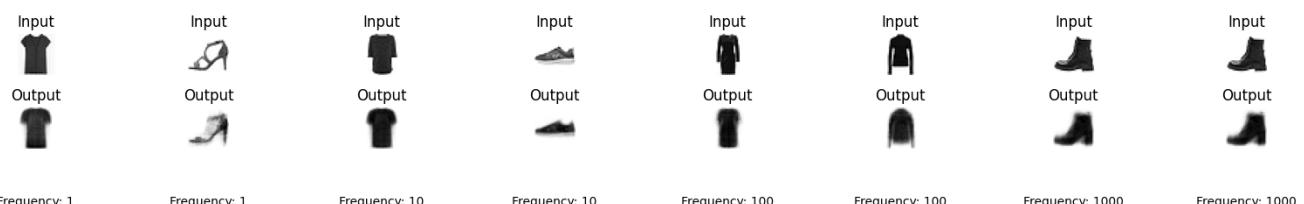
Epoch 48



1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 29ms/step

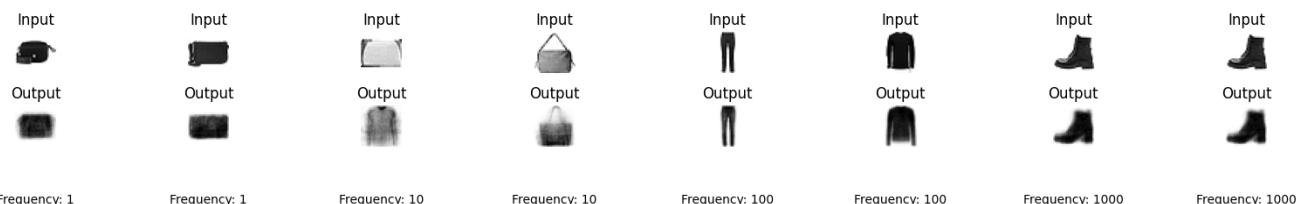
```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 29ms/step
```

Epoch 49



```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step
```

Epoch 50



## Damaging the DG of the hippocampus

```
In [ ]: encoder = Sequential([  
    Flatten(input_shape = (28, 28)), # Sensory neurons convert raw data into something p  
    Dense(784), # Temporal Cortex  
    ReLU(),  
    Dense(512), # Entorhinal Cortex  
    ReLU(),  
    Dense(50), # Dentate Gyrus  
    ReLU(),  
    Dense(256), # CA3  
    ReLU(),  
    Hippocampus() # Apply L1 penalty to the activations of the neurons; Encourages proce  
)  
decoder = Sequential([  
    Dense(384, input_shape = (256,)), # CA1  
    ReLU(),  
    Dense(512), # Entorhinal Cortex  
    ReLU(),  
    Dense(784), # Temporal Cortex  
    Activation("sigmoid"),  
    Reshape((28, 28))  
)  
img = Input(shape = (28, 28))  
latent_vector = encoder(img)  
output = decoder(latent_vector)  
model = Model(inputs = img, outputs = output)  
model.compile(optimizer=Adam(), loss = "mean_squared_error")
```

```
In [ ]: EPOCHS = 50  
EXAMPLES = 8  
  
image_id = list(np.random.choice(range(10000), 1111, replace=False))  
  
# Create a frequency dictionary  
freq_dict = {img: 1000 for img in image_id[0:1]}  
freq_dict.update({img: 100 for img in image_id[1:11]})
```

```

freq_dict.update({img: 10 for img in image_id[11:111]})  

freq_dict.update({img: 1 for img in image_id[111:1111]})  
  

# Separate image_ids based on their frequencies  

image_ids_freq_1 = [image_id for image_id in image_id[111:1111]]  

image_ids_freq_10 = [image_id for image_id in image_id[11:111]]  

image_ids_freq_100 = [image_id for image_id in image_id[1:11]]  

image_ids_freq_1000 = [image_id for image_id in image_id[0:1]]  
  

# Create separate training sets for each frequency group  

freq_train_1 = x_train[np.array([img for img in image_ids_freq_1])]  

freq_train_10 = x_train[np.array([img for img in image_ids_freq_10])]  

freq_train_100 = x_train[np.array([img for img in image_ids_freq_100])]  

freq_train_1000 = x_train[np.array([img for img in image_ids_freq_1000])]  
  

for epoch in range(EPOCHS):  

    fig, axs = plt.subplots(3, EXAMPLES, figsize=(EXAMPLES * 2, 3)) # Change to 3 rows  
  

    # Pick 2 random images from each frequency group  

    rand_ids = np.concatenate([  

        np.random.choice(image_ids_freq_1, 2),  

        np.random.choice(image_ids_freq_10, 2),  

        np.random.choice(image_ids_freq_100, 2),  

        np.random.choice(image_ids_freq_1000, 2)  

    ])  
  

    rand = x_test[rand_ids].reshape((EXAMPLES, 1, 28, 28))  
  

    for j in range(EXAMPLES):  

        # Get the image ID and the frequency of the image from the dictionary  

        image_id = rand_ids[j]  

        freq = freq_dict[image_id]  
  

        axs[0, j].imshow(rand[j][0], cmap="gray_r")  

        axs[0,j].set_title("Input")  

        axs[0,j].axis("off")  
  

        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")  

        axs[1,j].set_title("Output")  

        axs[1,j].axis("off")  
  

        # Display the frequency  

        axs[2, j].text(0.5, 0.5, f"Frequency: {freq}", ha='center', va='center')  

        axs[2,j].axis("off")  
  

    fig.suptitle("Epoch %d" % (epoch+1))  

    fig.tight_layout()  

    plt.show()  
  

    # Train the model separately on each frequency group  

model.fit(freq_train_1, freq_train_1, verbose=0)  

model.fit(freq_train_10, freq_train_10, verbose=0)  

model.fit(freq_train_100, freq_train_100, verbose=0)  

model.fit(freq_train_1000, freq_train_1000, verbose=0)

```

```

1/1 [=====] - 0s 449ms/step  

1/1 [=====] - 0s 106ms/step  

1/1 [=====] - 0s 123ms/step  

1/1 [=====] - 0s 119ms/step  

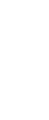
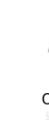
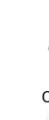
1/1 [=====] - 0s 109ms/step  

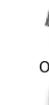
1/1 [=====] - 0s 96ms/step  

1/1 [=====] - 0s 72ms/step  

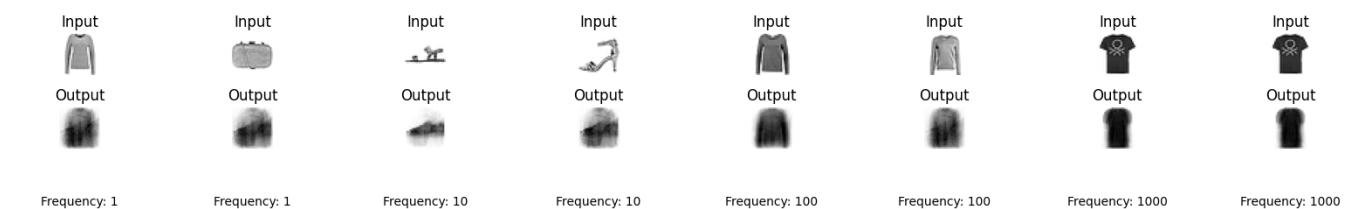
1/1 [=====] - 0s 81ms/step

```

Epoch 1							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 23ms/step
Epoch 2							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 34ms/step
Epoch 3							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 27ms/step
Epoch 4							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 23ms/step

Epoch 5							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 25ms/step
Epoch 6							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 31ms/step
Epoch 7							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step
Epoch 8							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 29ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 26ms/step

Epoch 9



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step
```

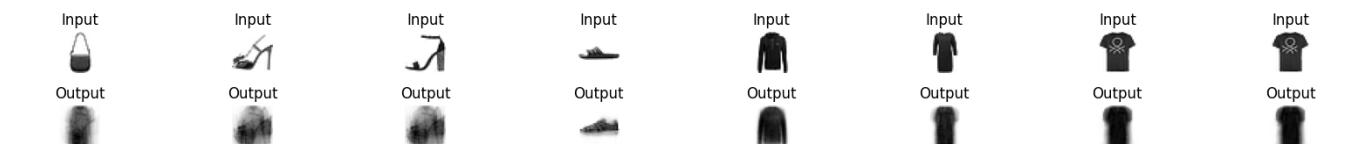
Epoch 10



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 32ms/step
```

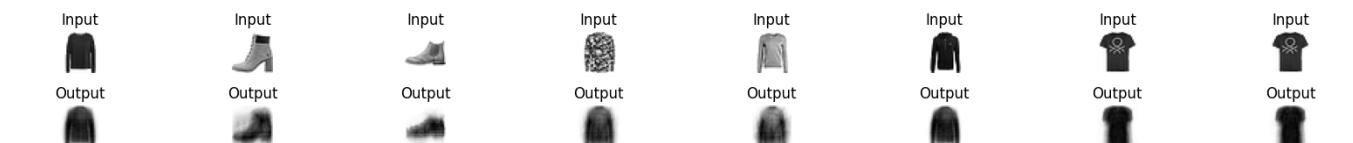
Epoch 11



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 23ms/step
```

Epoch 12

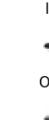
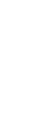


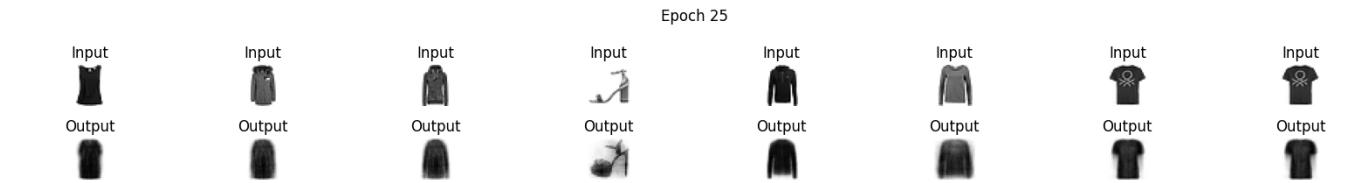
Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step
```

Epoch 13							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 27ms/step
Epoch 14							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 51ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 35ms/step
Epoch 15							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 26ms/step
Epoch 16							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 22ms/step

Epoch 17							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step
Epoch 18							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 35ms/step
Epoch 19							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 29ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 28ms/step
Epoch 20							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step

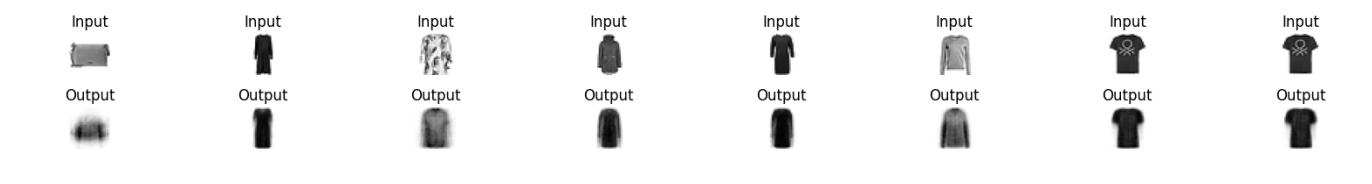
Epoch 21							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 23ms/step
Epoch 22							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 48ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 32ms/step
Epoch 23							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 26ms/step
Epoch 24							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 21ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step
```

Epoch 26



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 43ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 49ms/step
```

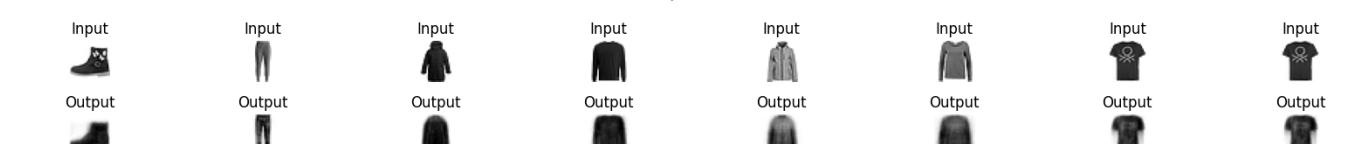
Epoch 27



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

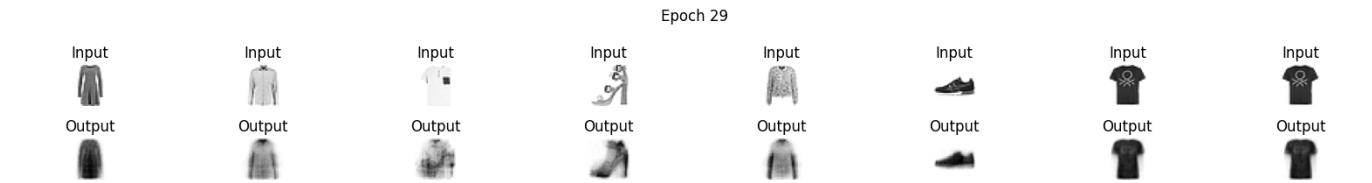
```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step
```

Epoch 28



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 20ms/step
```



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step
```

Epoch 30



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 32ms/step
```

Epoch 31



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

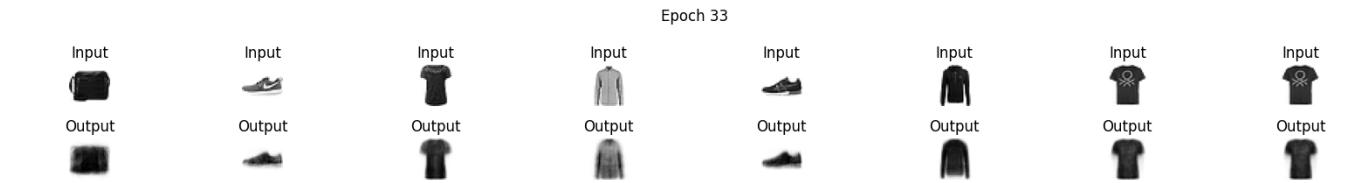
```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step
```

Epoch 32



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

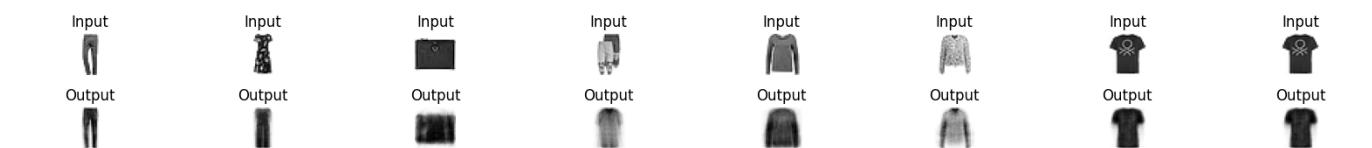
```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 28ms/step
```



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 52ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 51ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 37ms/step
```

Epoch 34



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 58ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 37ms/step
```

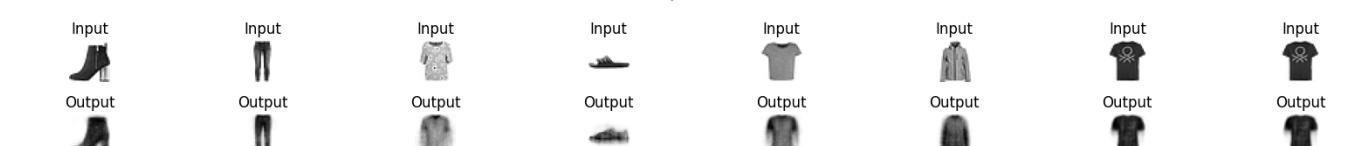
Epoch 35



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step
```

Epoch 36



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 22ms/step
```

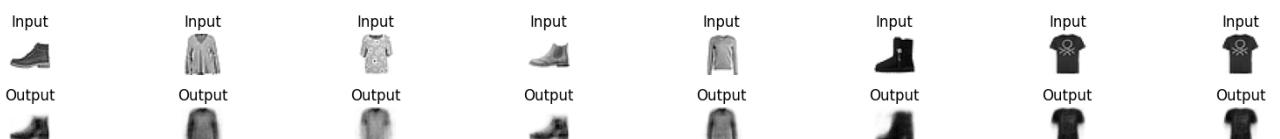
Epoch 37



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step

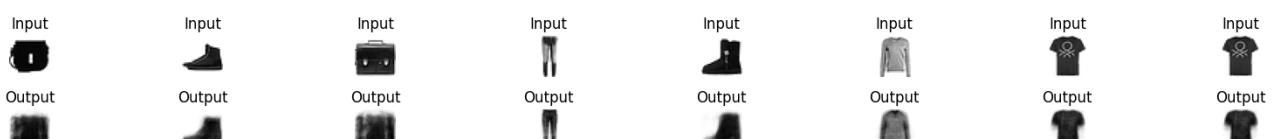
Epoch 38



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 25ms/step

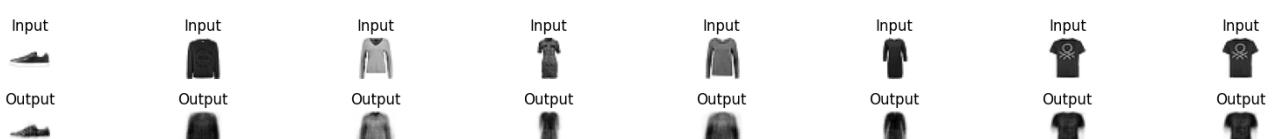
Epoch 39



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 30ms/step

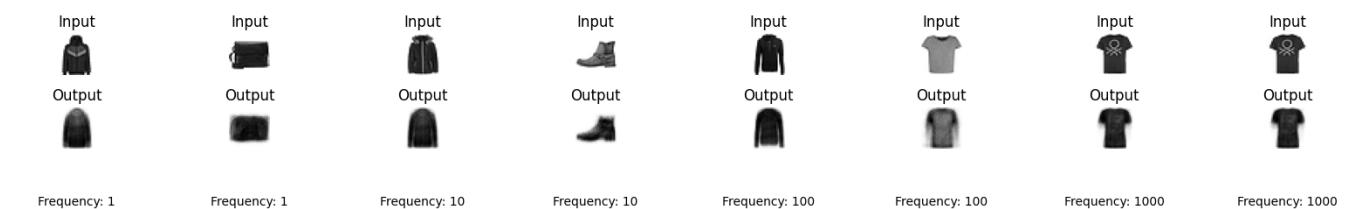
Epoch 40



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 30ms/step

Epoch 41



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 74ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 54ms/step  
1/1 [=====] - 0s 43ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 39ms/step
```

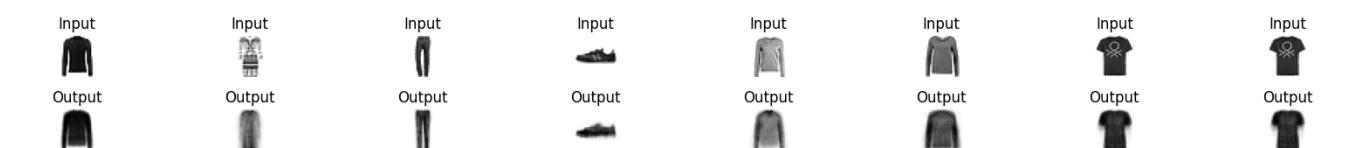
Epoch 42



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 29ms/step
```

Epoch 43



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step
```

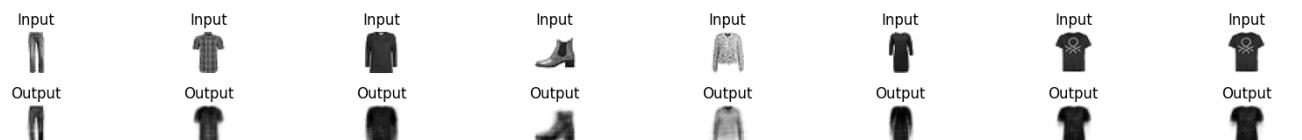
Epoch 44



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 53ms/step  
1/1 [=====] - 0s 78ms/step  
1/1 [=====] - 0s 44ms/step
```

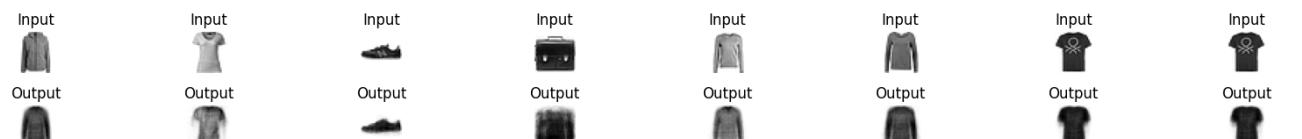
Epoch 45



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 29ms/step
```

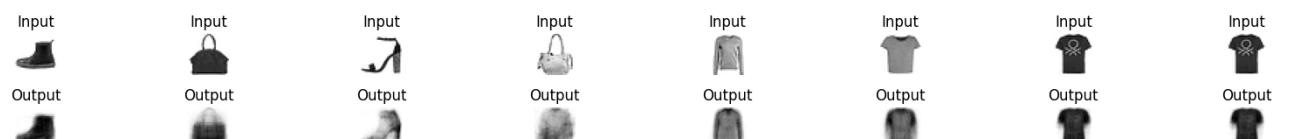
Epoch 46



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step
```

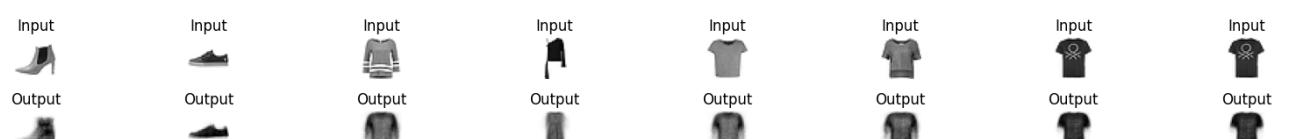
Epoch 47



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

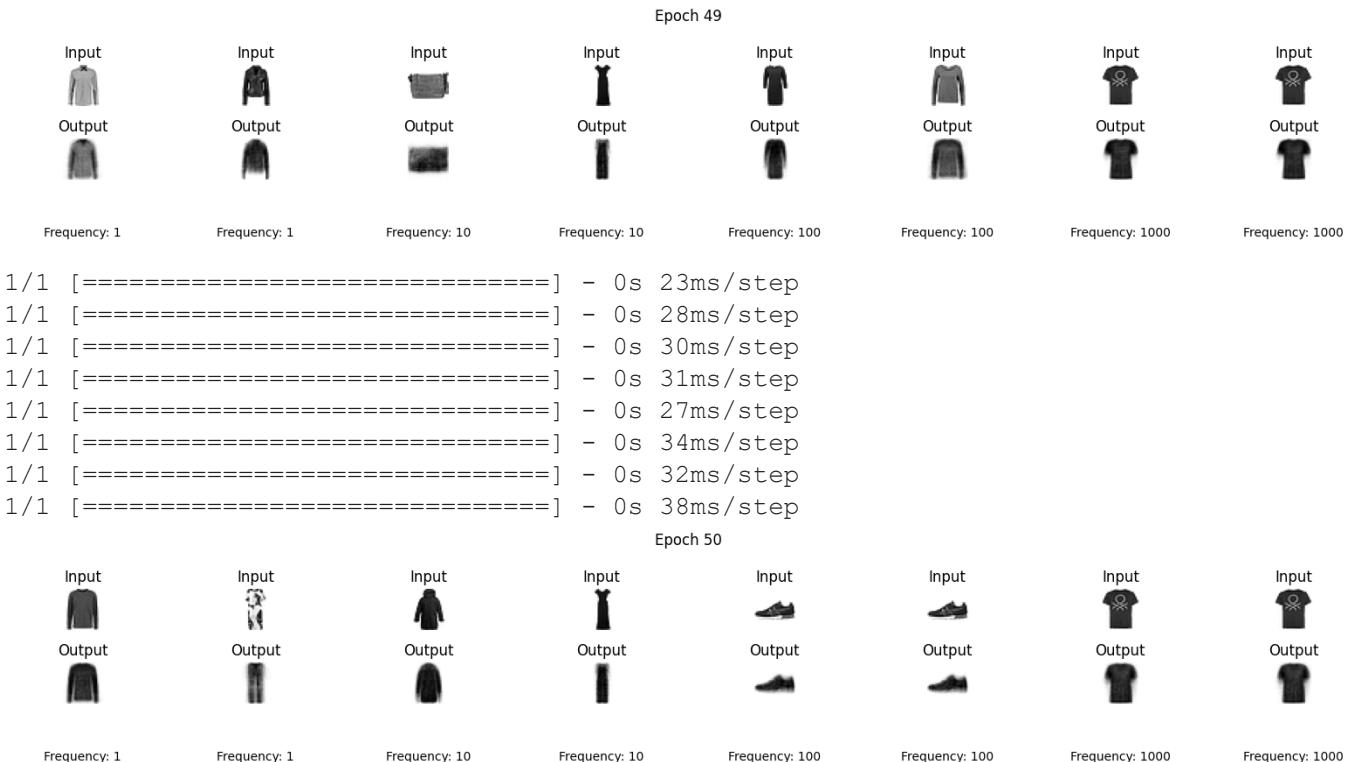
```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 33ms/step
```

Epoch 48



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 55ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 64ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 44ms/step
```



## Damaging the CA3 and CA1

```
In [ ]:
encoder = Sequential([
    Flatten(input_shape = (28, 28)), # Sensory neurons convert raw data into something p
    Dense(784), # Temporal Cortex
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(384), # Dentate Gyrus
    ReLU(),
    Dense(10), # CA3
    ReLU(),
    Hippocampus() # Apply L1 penalty to the activations of the neurons; Encourages proce
])
decoder = Sequential([
    Dense(10, input_shape = (10,)), # CA1
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(784), # Temporal Cortex
    Activation("sigmoid"),
    Reshape((28, 28))
])
img = Input(shape = (28, 28))
latent_vector = encoder(img)
output = decoder(latent_vector)
model = Model(inputs = img, outputs = output)
model.compile(optimizer=Adam(), loss = "mean_squared_error")
```

```
In [ ]:
EPOCHS = 50
EXAMPLES = 8

image_id = list(np.random.choice(range(10000), 1111, replace=False))

# Create a frequency dictionary
freq_dict = {img: 1000 for img in image_id[0:1]}
freq_dict.update({img: 100 for img in image_id[1:11]})
freq_dict.update({img: 10 for img in image_id[11:111]})
freq_dict.update({img: 1 for img in image_id[111:1111]})
```

```

# Separate image_ids based on their frequencies
image_ids_freq_1 = [image_id for image_id in image_id[111:1111]]
image_ids_freq_10 = [image_id for image_id in image_id[11:111]]
image_ids_freq_100 = [image_id for image_id in image_id[1:11]]
image_ids_freq_1000 = [image_id for image_id in image_id[0:1]]

# Create separate training sets for each frequency group
freq_train_1 = x_train[np.array([img for img in image_ids_freq_1])]
freq_train_10 = x_train[np.array([img for img in image_ids_freq_10])]
freq_train_100 = x_train[np.array([img for img in image_ids_freq_100])]
freq_train_1000 = x_train[np.array([img for img in image_ids_freq_1000])]

for epoch in range(EPOCHS):
    fig, axs = plt.subplots(3, EXAMPLES, figsize=(EXAMPLES * 2, 3)) # Change to 3 rows

    # Pick 2 random images from each frequency group
    rand_ids = np.concatenate([
        np.random.choice(image_ids_freq_1, 2),
        np.random.choice(image_ids_freq_10, 2),
        np.random.choice(image_ids_freq_100, 2),
        np.random.choice(image_ids_freq_1000, 2)
    ])

    rand = x_test[rand_ids].reshape((EXAMPLES, 1, 28, 28))

    for j in range(EXAMPLES):
        # Get the image ID and the frequency of the image from the dictionary
        image_id = rand_ids[j]
        freq = freq_dict[image_id]

        axs[0, j].imshow(rand[j][0], cmap="gray_r")
        axs[0, j].set_title("Input")
        axs[0, j].axis("off")

        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")
        axs[1, j].set_title("Output")
        axs[1, j].axis("off")

        # Display the frequency
        axs[2, j].text(0.5, 0.5, f"Frequency: {freq}", ha='center', va='center')
        axs[2, j].axis("off")

    fig.suptitle("Epoch %d" % (epoch+1))
    fig.tight_layout()
    plt.show()

    # Train the model separately on each frequency group
    model.fit(freq_train_1, freq_train_1, verbose=0)
    model.fit(freq_train_10, freq_train_10, verbose=0)
    model.fit(freq_train_100, freq_train_100, verbose=0)
    model.fit(freq_train_1000, freq_train_1000, verbose=0)

```

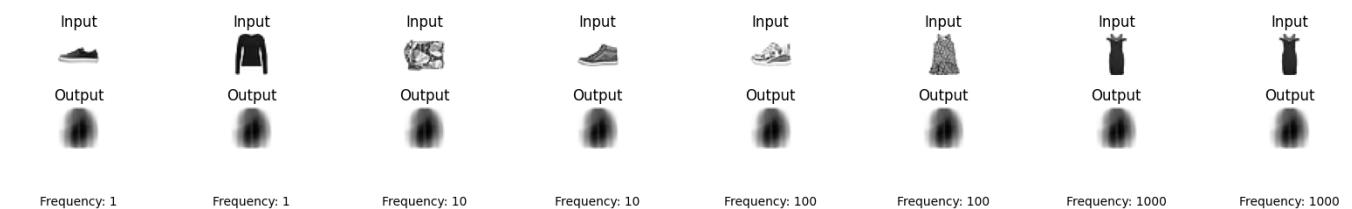
```

1/1 [=====] - 0s 119ms/step
1/1 [=====] - 0s 36ms/step
1/1 [=====] - 0s 38ms/step
1/1 [=====] - 0s 45ms/step
1/1 [=====] - 0s 46ms/step
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 64ms/step
1/1 [=====] - 0s 67ms/step

```

Epoch 1							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 44ms/step	1/1 [=====] - 0s 72ms/step	1/1 [=====] - 0s 100ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step
Epoch 2							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 21ms/step
Epoch 3							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 21ms/step
Epoch 4							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 36ms/step

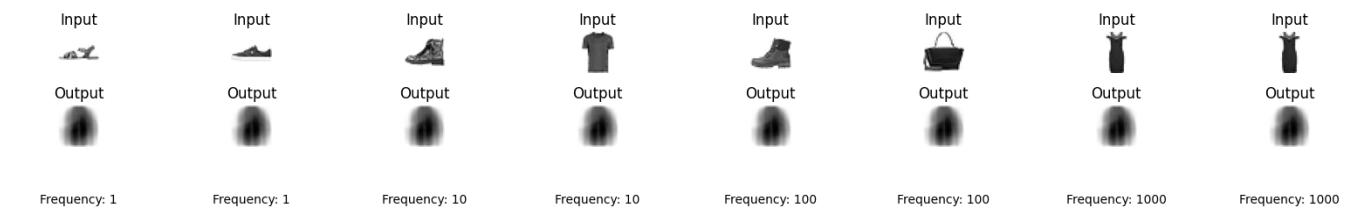
Epoch 5



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 40ms/step
1/1 [=====] - 0s 38ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 33ms/step
```

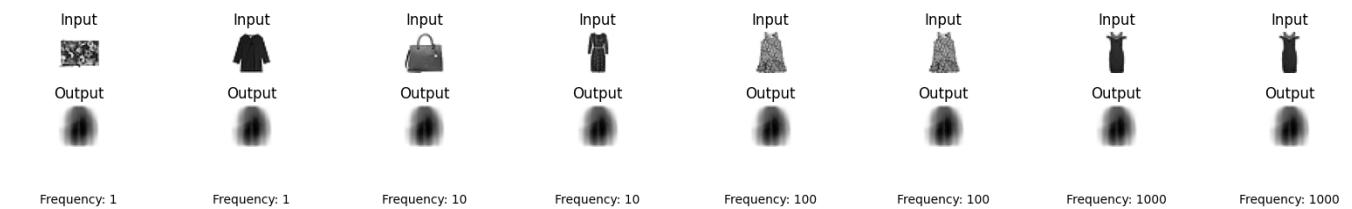
Epoch 6



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 20ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
```

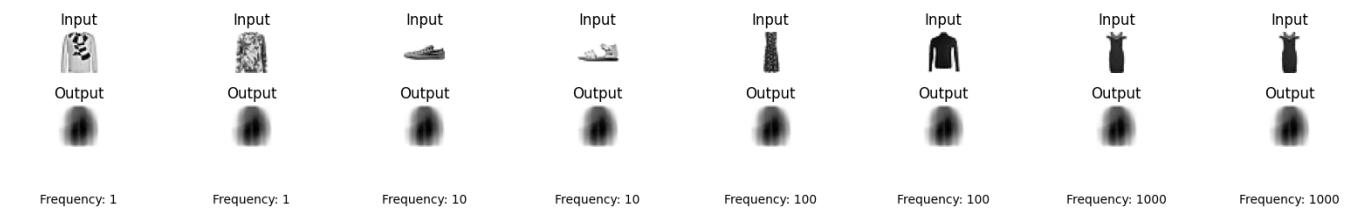
Epoch 7



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

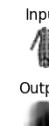
```
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 24ms/step
```

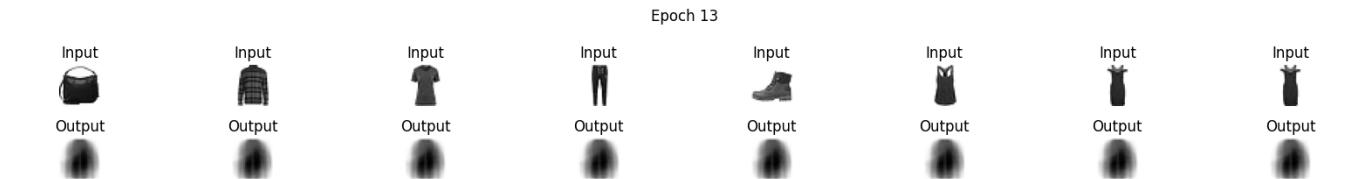
Epoch 8



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 20ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 21ms/step
```

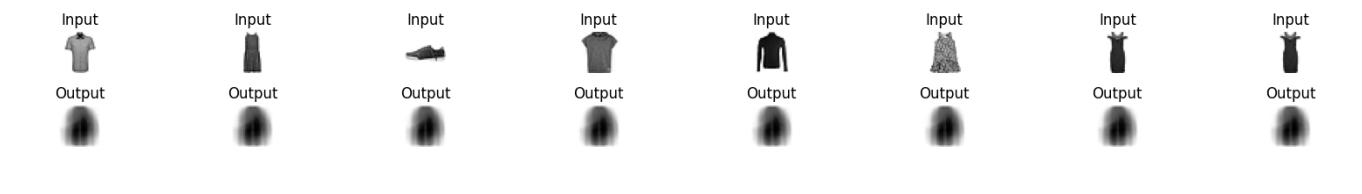
Epoch 9							
 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 36ms/step					
Epoch 10							
 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 32ms/step
Epoch 11							
 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 32ms/step
Epoch 12							
 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output	 Input  Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 50ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 34ms/step
```

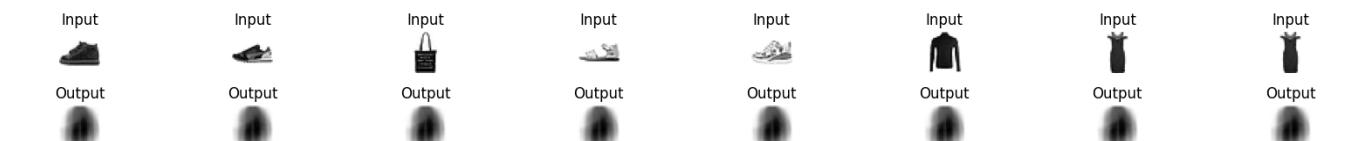
Epoch 14



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 97ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step
```

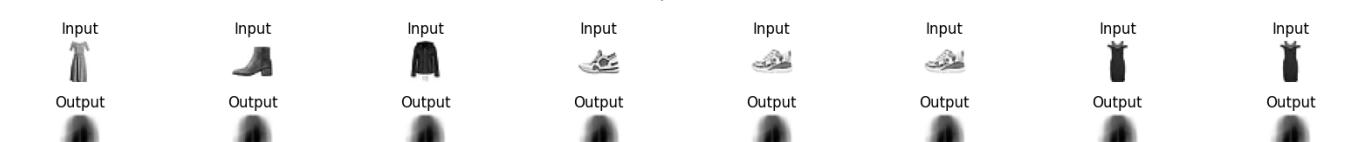
Epoch 15



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

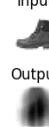
```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 24ms/step
```

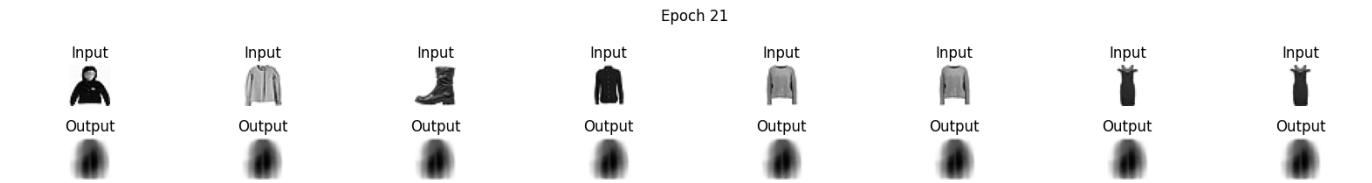
Epoch 16



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 51ms/step  
1/1 [=====] - 0s 44ms/step
```

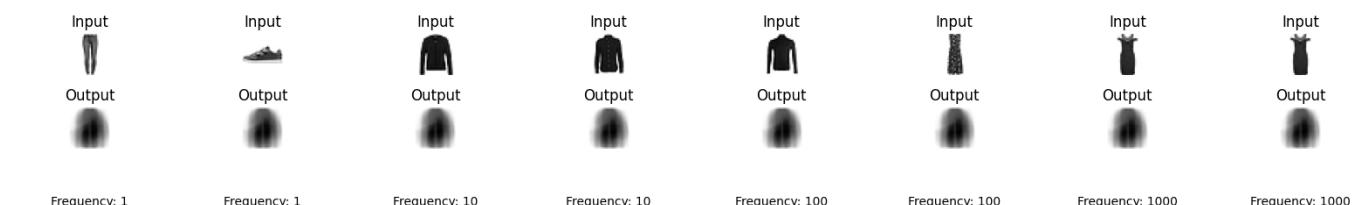
Epoch 17							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 28ms/step	1/1 [=====] - 0s 21ms/step
Epoch 18							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step			
Epoch 19							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 39ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step
Epoch 20							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 31ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step
```

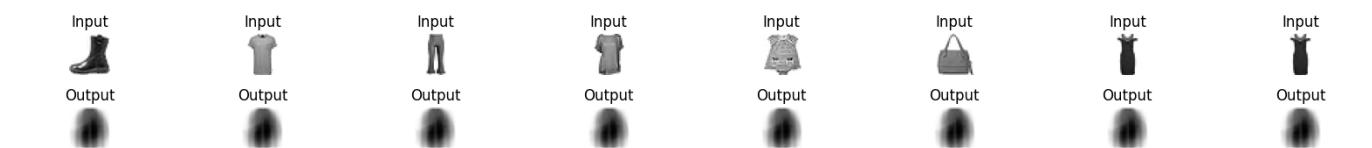
Epoch 22



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step
```

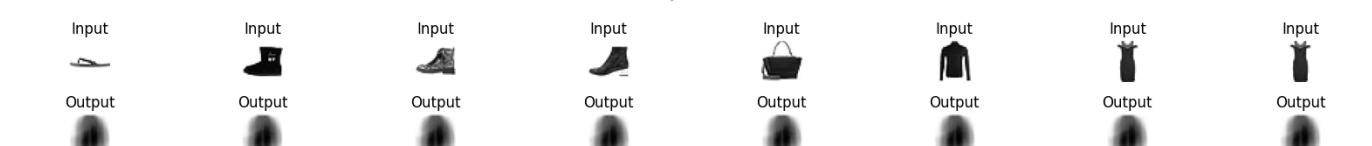
Epoch 23



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step
```

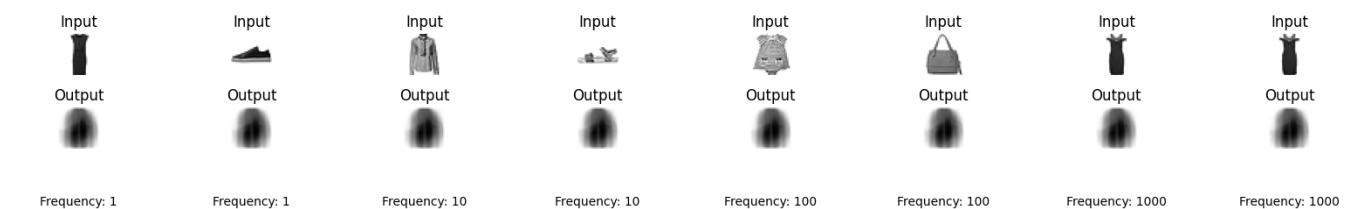
Epoch 24



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

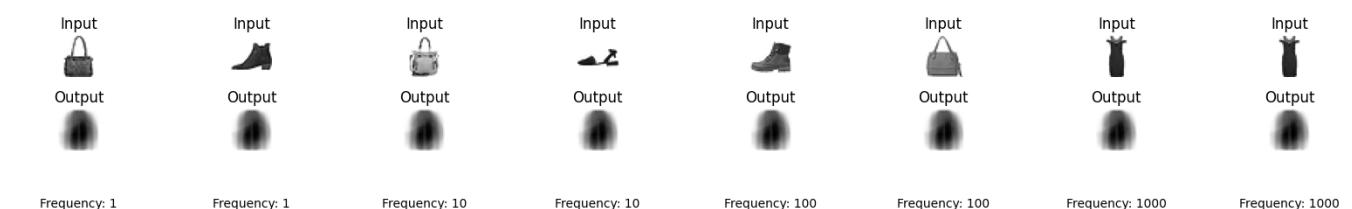
```
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 50ms/step
```

Epoch 25



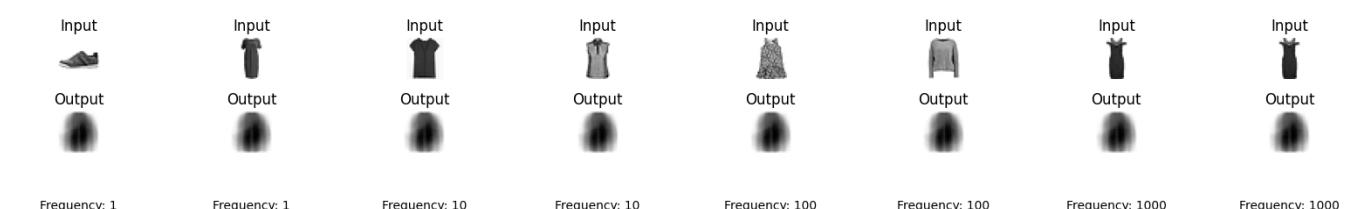
```
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step
```

Epoch 26



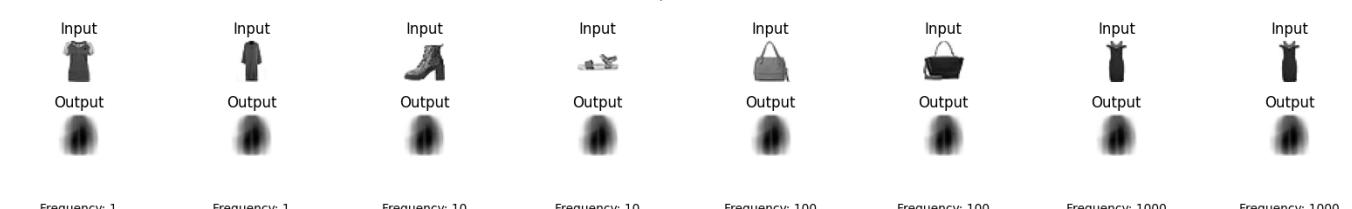
```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step
```

Epoch 27



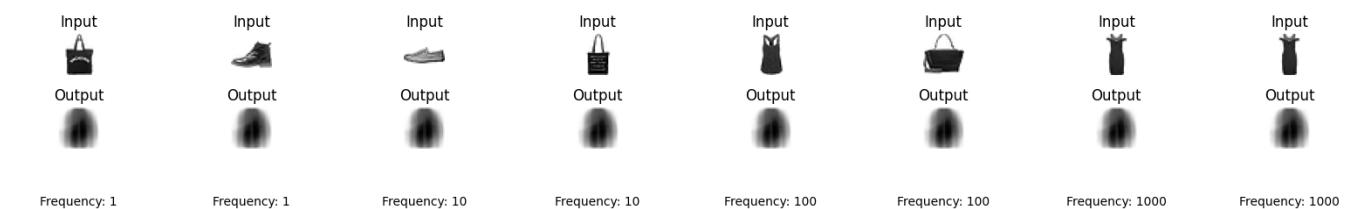
```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step
```

Epoch 28



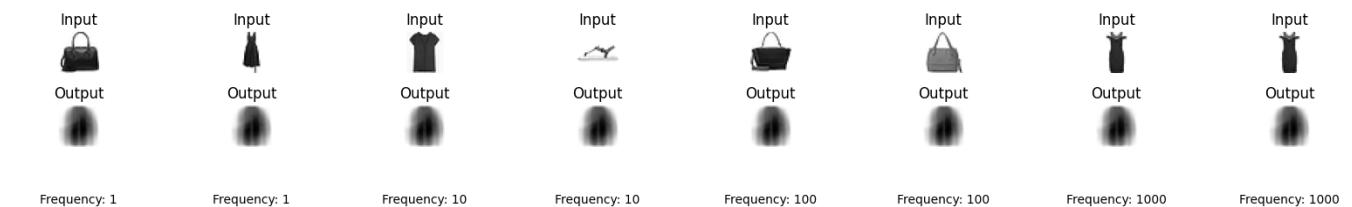
```
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 33ms/step
```

Epoch 29



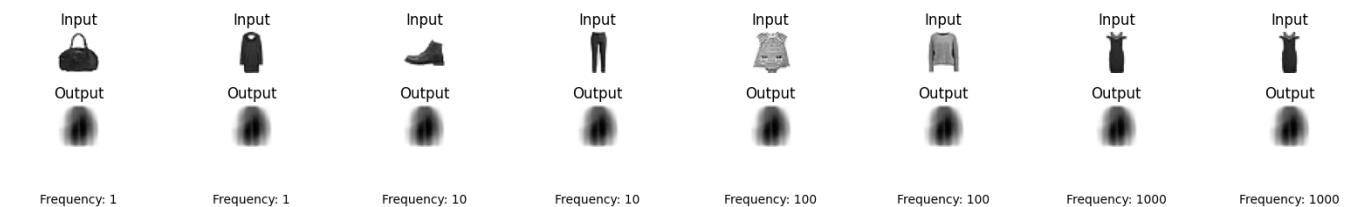
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step

Epoch 30



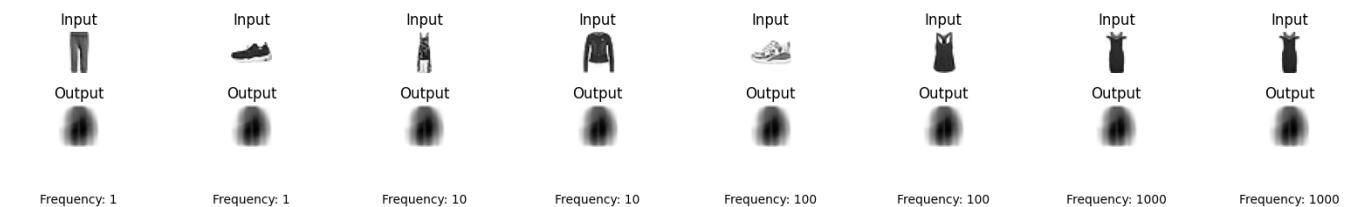
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 20ms/step

Epoch 31



1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step

Epoch 32



1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step

Epoch 33



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 23ms/step
```

Epoch 34



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 24ms/step
```

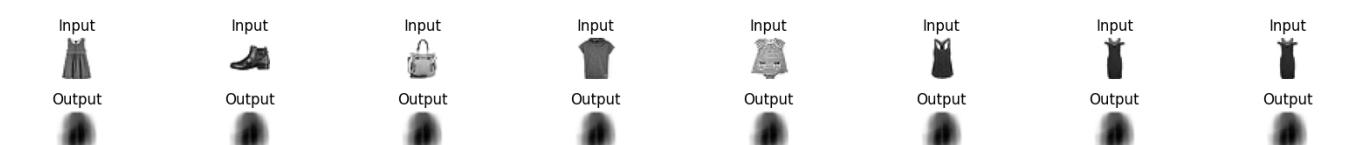
Epoch 35



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 34ms/step
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 31ms/step
```

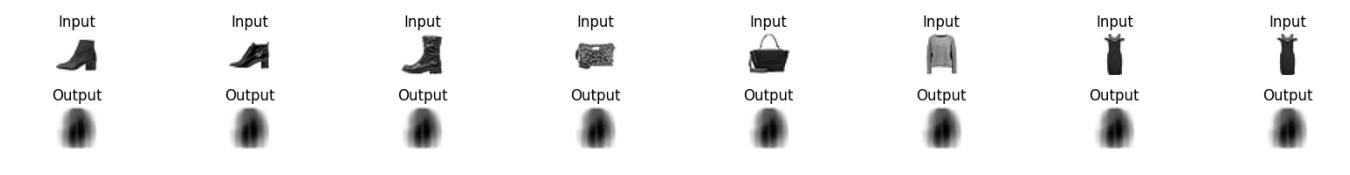
Epoch 36



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 22ms/step
```

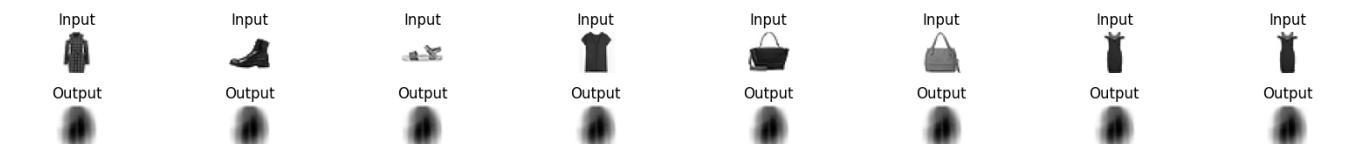
Epoch 37



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 22ms/step

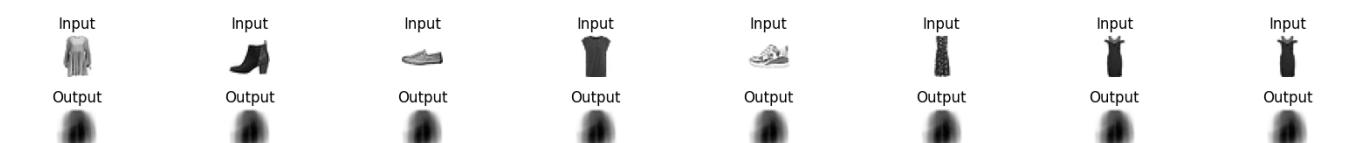
Epoch 38



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step

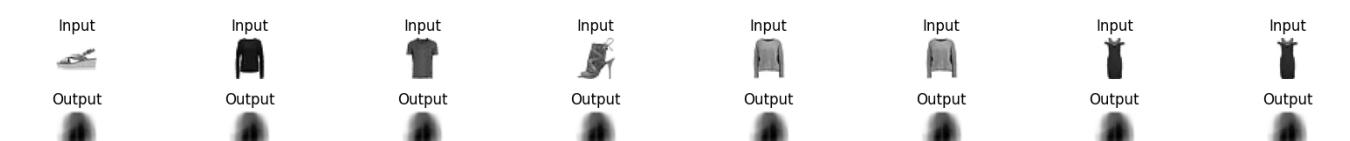
Epoch 39



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 29ms/step

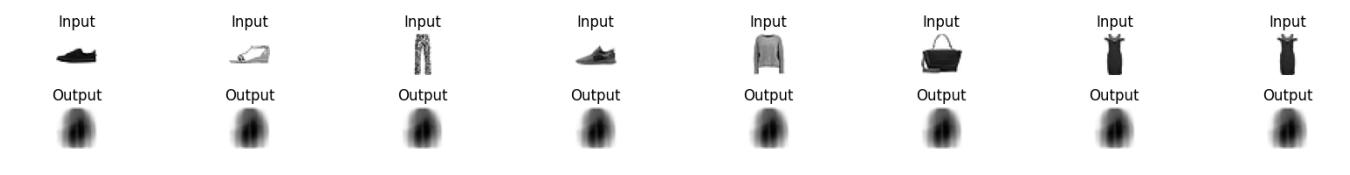
Epoch 40



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step

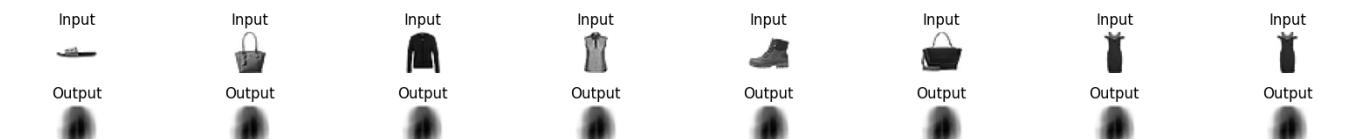
Epoch 41



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step

Epoch 42



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step

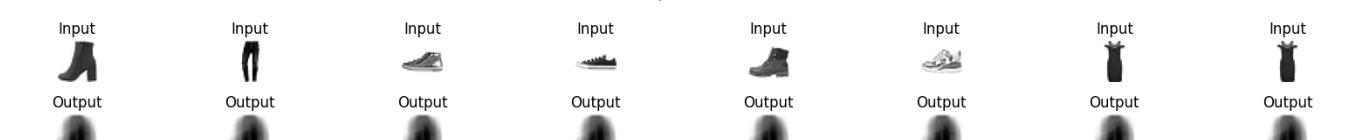
Epoch 43



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

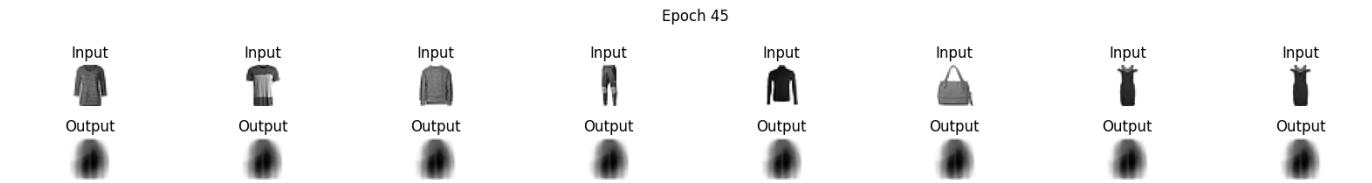
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 44



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

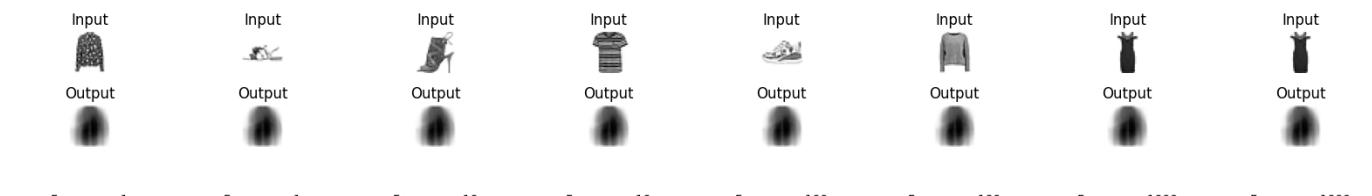
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step
```

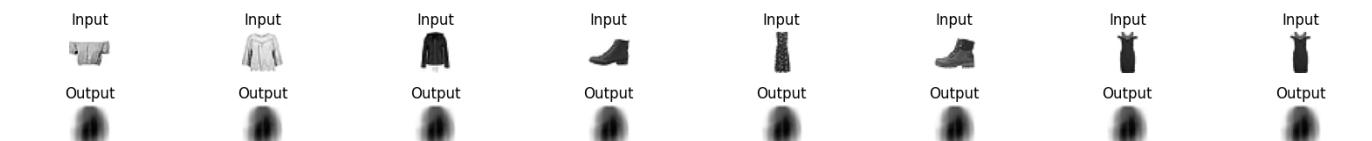
Epoch 46



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 51ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 50ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 47ms/step
```

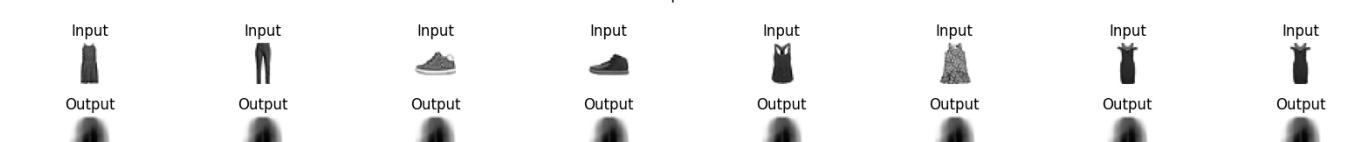
Epoch 47



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step
```

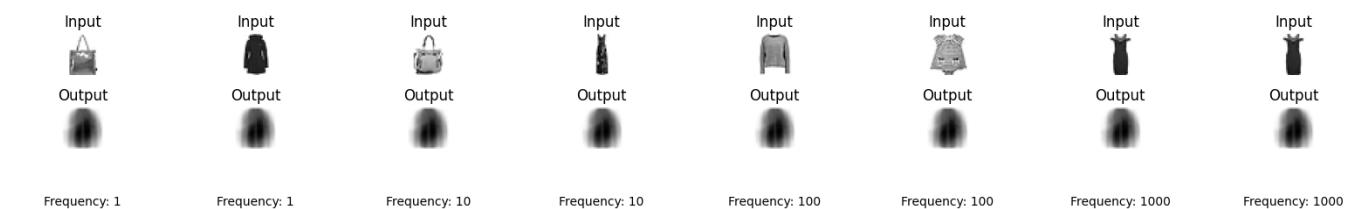
Epoch 48



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

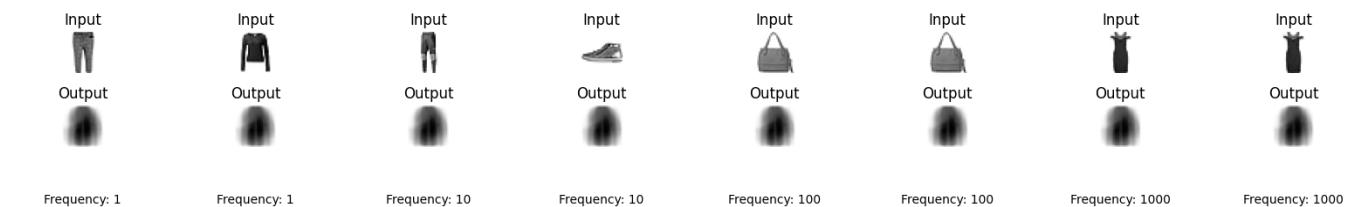
```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step
```

Epoch 49



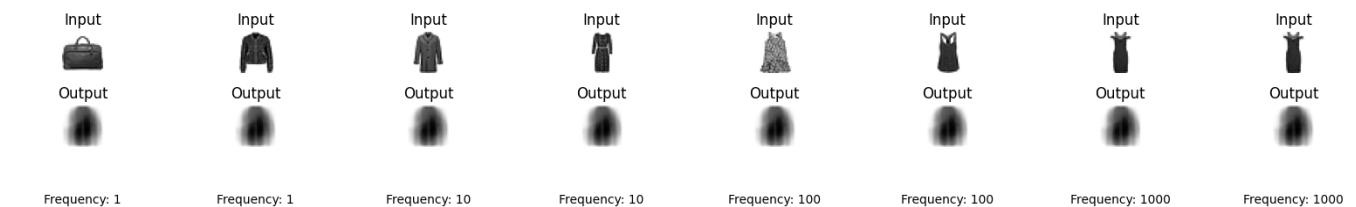
```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 28ms/step
```

Epoch 50



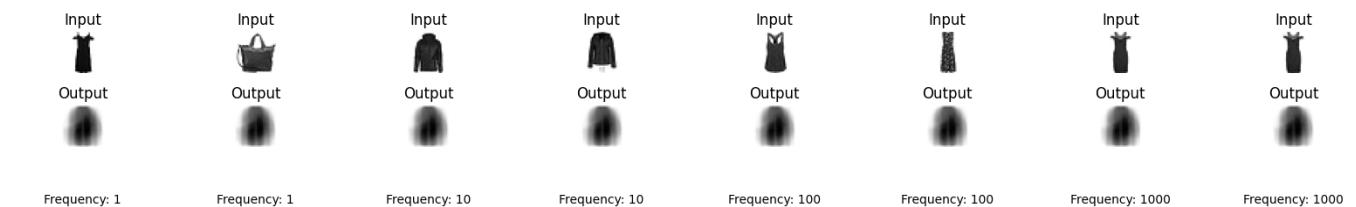
```
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 56ms/step
```

Epoch 51



```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 28ms/step
```

Epoch 52



```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step
```

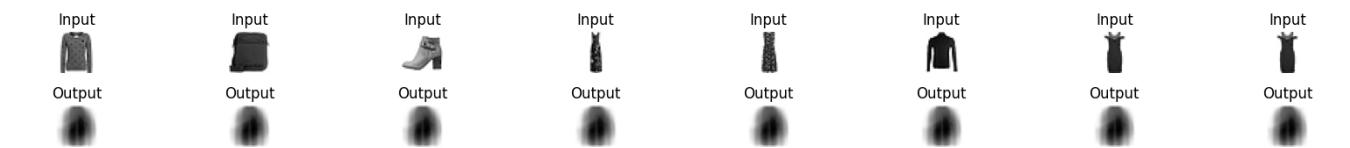
Epoch 53



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 25ms/step
```

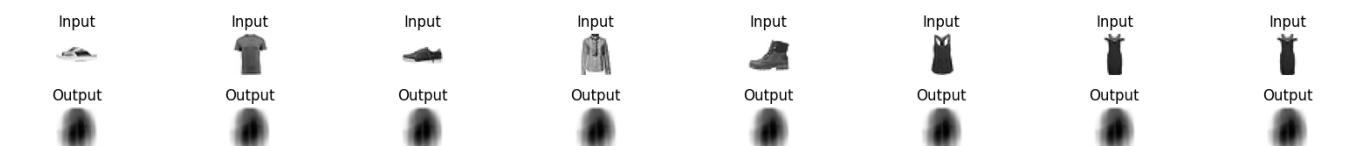
Epoch 54



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 37ms/step
```

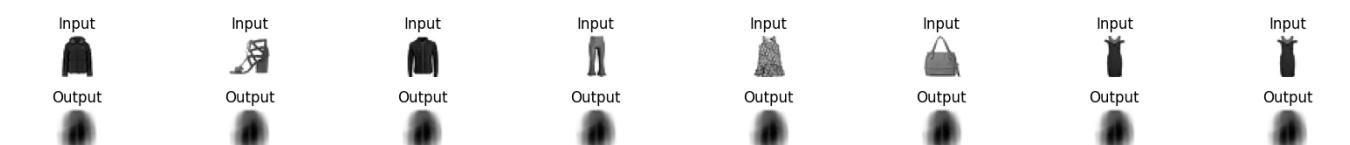
Epoch 55



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step
```

Epoch 56



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 28ms/step
```

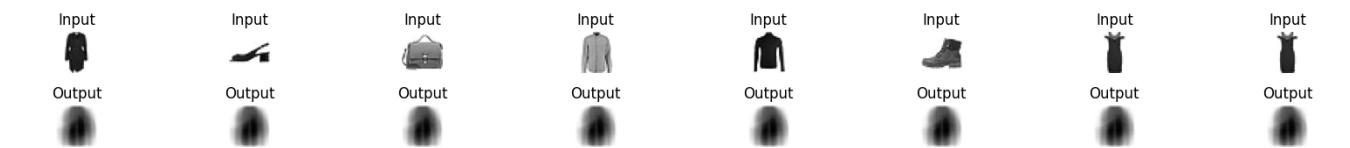
Epoch 57



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 26ms/step

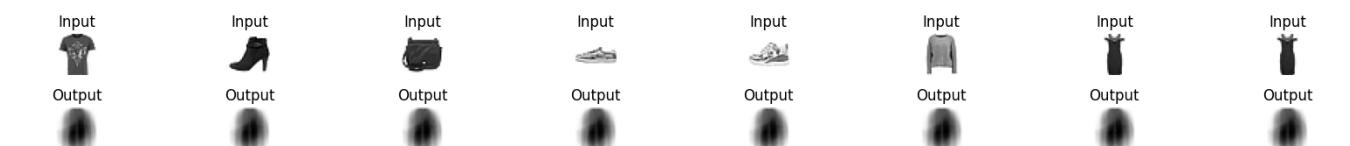
Epoch 58



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 25ms/step

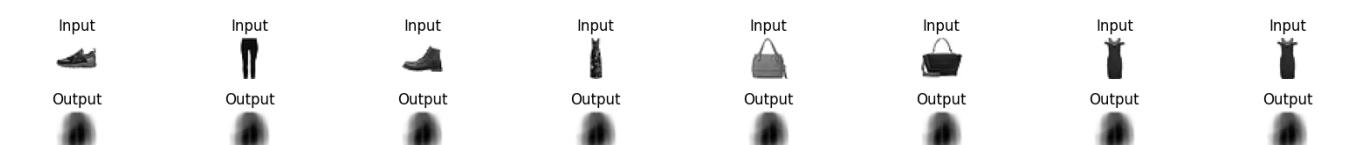
Epoch 59



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step

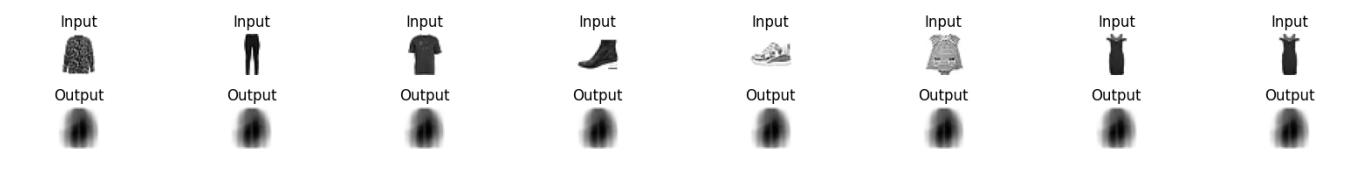
Epoch 60



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 27ms/step

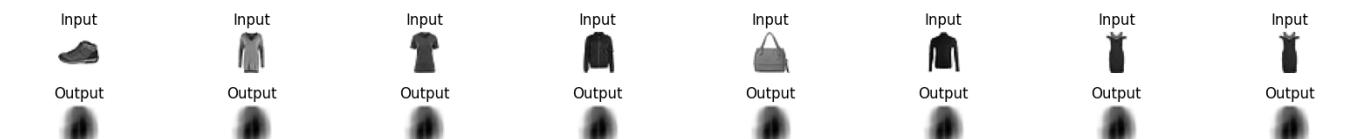
Epoch 61



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 43ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 67ms/step  
1/1 [=====] - 0s 31ms/step
```

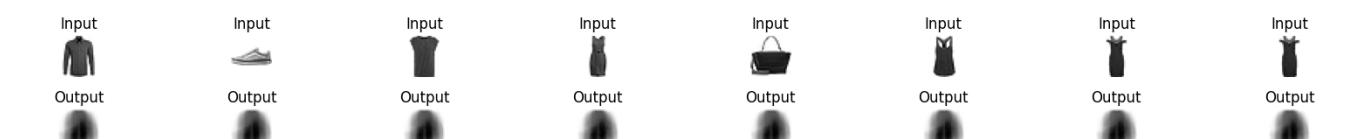
Epoch 62



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 29ms/step
```

Epoch 63



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 29ms/step
```

Epoch 64



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 25ms/step
```

Epoch 65

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 33ms/step | 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 64ms/step | 1/1 [=====] - 0s 55ms/step | 1/1 [=====] - 0s 57ms/step | 1/1 [=====] - 0s 38ms/step |

Epoch 66

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 28ms/step | 1/1 [=====] - 0s 27ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 34ms/step | 1/1 [=====] - 0s 33ms/step | 1/1 [=====] - 0s 26ms/step | 1/1 [=====] - 0s 28ms/step |

Epoch 67

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 52ms/step | 1/1 [=====] - 0s 56ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 39ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 26ms/step |

Epoch 68

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 79ms/step | 1/1 [=====] - 0s 48ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 38ms/step | 1/1 [=====] - 0s 37ms/step | 1/1 [=====] - 0s 71ms/step | 1/1 [=====] - 0s 35ms/step |

Epoch 69



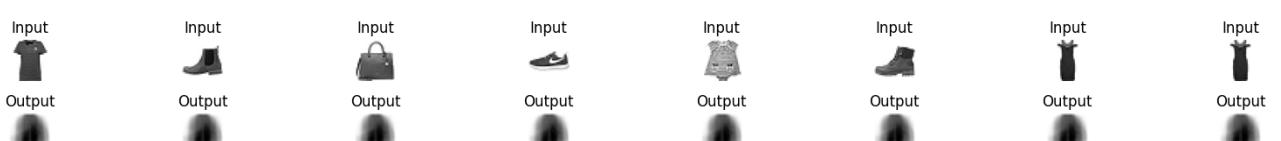
```
Frequency: 1           Frequency: 1           Frequency: 10          Frequency: 10          Frequency: 100         Frequency: 100         Frequency: 1000        Frequency: 1000
'/1 [=====] - 0s 23ms/step
'/1 [=====] - 0s 28ms/step
'/1 [=====] - 0s 29ms/step
'/1 [=====] - 0s 30ms/step
'/1 [=====] - 0s 28ms/step
'/1 [=====] - 0s 29ms/step
'/1 [=====] - 0s 37ms/step
'/1 [=====] - 0s 28ms/step
```

Epoch 70



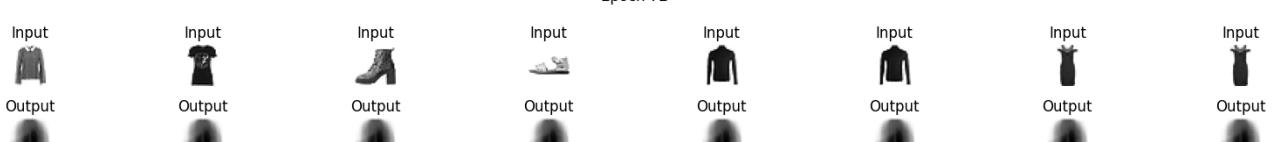
```
Frequency: 1           Frequency: 1           Frequency: 10          Frequency: 10          Frequency: 100         Frequency: 100         Frequency: 1000        Frequency: 1000
'/1 [=====] - 0s 30ms/step
'/1 [=====] - 0s 29ms/step
'/1 [=====] - 0s 30ms/step
'/1 [=====] - 0s 28ms/step
'/1 [=====] - 0s 32ms/step
'/1 [=====] - 0s 30ms/step
'/1 [=====] - 0s 33ms/step
'/1 [=====] - 0s 27ms/step
```

Epoch 71



```
Frequency: 1           Frequency: 1           Frequency: 10          Frequency: 10          Frequency: 100         Frequency: 100         Frequency: 1000        Frequency: 1000
'/1 [=====] - 0s 21ms/step
'/1 [=====] - 0s 29ms/step
'/1 [=====] - 0s 34ms/step
'/1 [=====] - 0s 32ms/step
'/1 [=====] - 0s 29ms/step
'/1 [=====] - 0s 27ms/step
'/1 [=====] - 0s 29ms/step
'/1 [=====] - 0s 31ms/step
```

Enseb 72



```
Frequency: 1           Frequency: 1           Frequency: 10          Frequency: 10          Frequency: 100         Frequency: 100        Frequency: 1000        Frequency: 1000
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 31ms/step
```

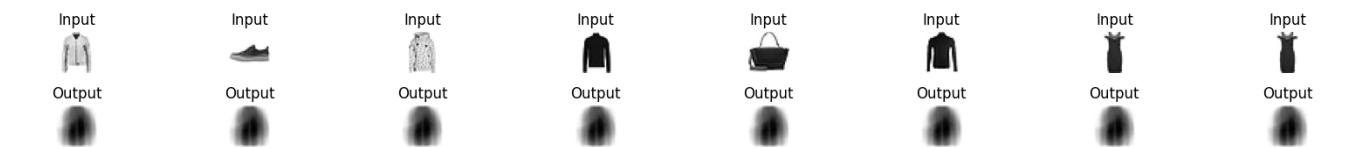
Epoch 73



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 30ms/step
```

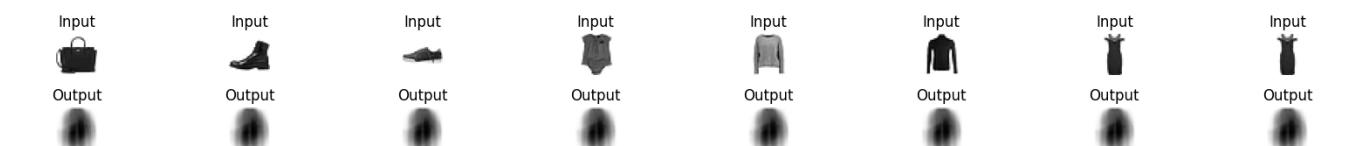
Epoch 74



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 47ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 30ms/step
```

Epoch 75



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 56ms/step  
1/1 [=====] - 0s 51ms/step  
1/1 [=====] - 0s 70ms/step  
1/1 [=====] - 0s 43ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 33ms/step
```

Epoch 76



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 32ms/step
```

Epoch 77

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 23ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 35ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 34ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 29ms/step |

Epoch 78

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 30ms/step

Epoch 79

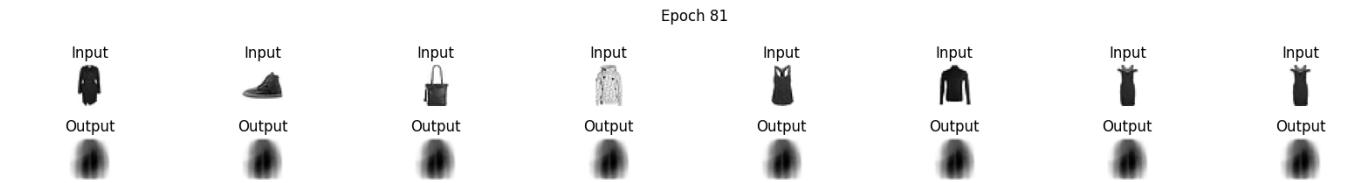
Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 45ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 48ms/step

Epoch 80

Input	Input	Input	Input	Input	Input	Input	Input
Output	Output	Output	Output	Output	Output	Output	Output
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

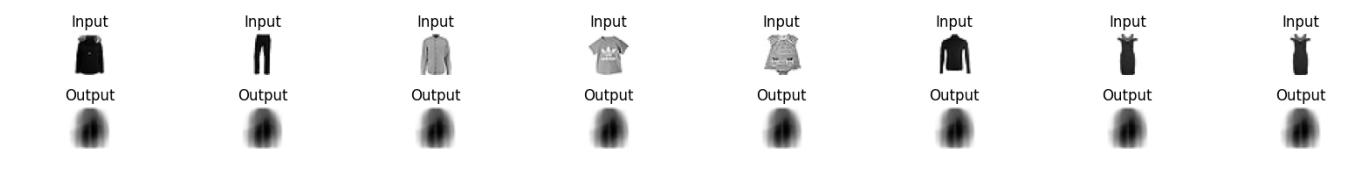
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 32ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 34ms/step
```

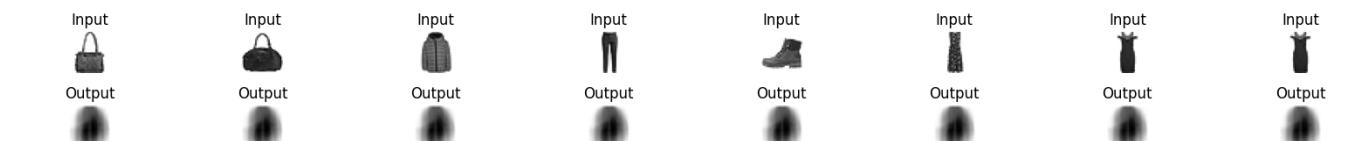
Epoch 82



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 54ms/step  
1/1 [=====] - 0s 37ms/step
```

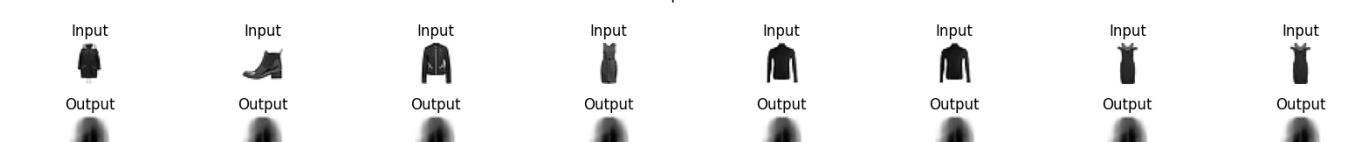
Epoch 83



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

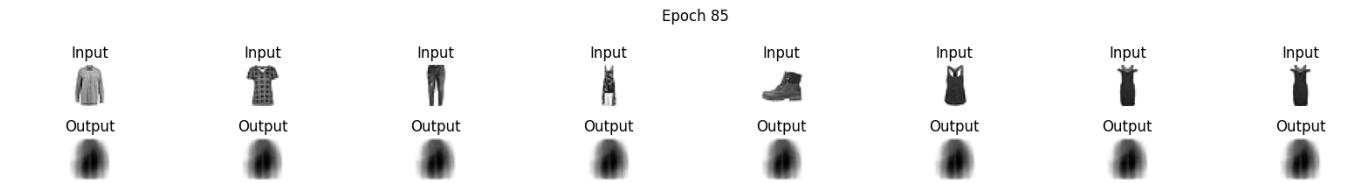
```
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 32ms/step
```

Epoch 84



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

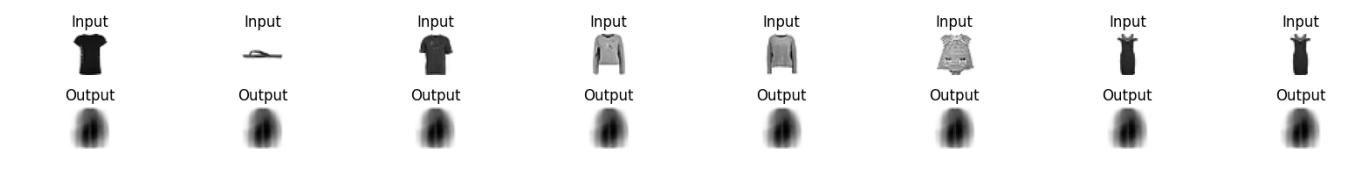
```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step
```



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 37ms/step
```

Epoch 86



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 52ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 40ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 43ms/step  
1/1 [=====] - 0s 52ms/step
```

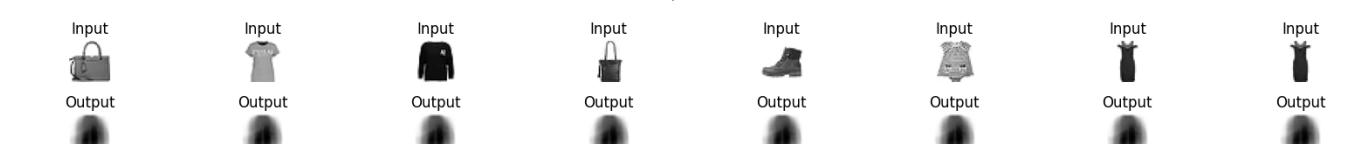
Epoch 87



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step
```

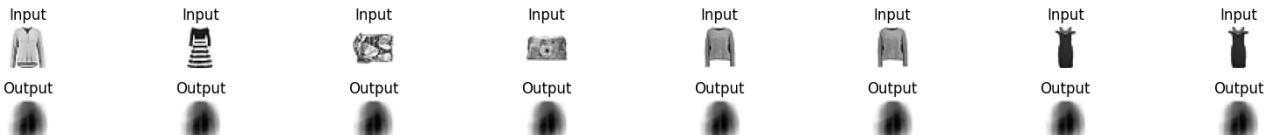
Epoch 88



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 45ms/step
```

Epoch 89



```
Frequency: 1           Frequency: 1           Frequency: 10          Frequency: 10          Frequency: 100         Frequency: 100         Frequency: 1000        Frequency: 1000
'/1 [=====] - 0s 24ms/step
'/1 [=====] - 0s 34ms/step
'/1 [=====] - 0s 33ms/step
'/1 [=====] - 0s 33ms/step
'/1 [=====] - 0s 45ms/step
'/1 [=====] - 0s 34ms/step
'/1 [=====] - 0s 47ms/step
'/1 [=====] - 0s 44ms/step
```

Epoch 90



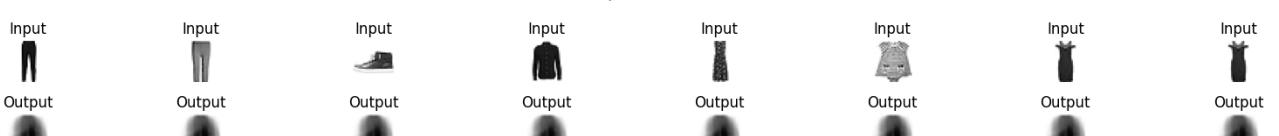
```
Frequency: 1           Frequency: 1           Frequency: 10          Frequency: 10          Frequency: 100         Frequency: 100         Frequency: 1000        Frequency: 1000
'/1 [=====] - 0s 23ms/step
'/1 [-----] - 0s 31ms/step
'/1 [=====] - 0s 38ms/step
'/1 [=====] - 0s 33ms/step
'/1 [-----] - 0s 32ms/step
'/1 [=====] - 0s 31ms/step
'/1 [=====] - 0s 32ms/step
'/1 [-----] - 0s 33ms/step
```

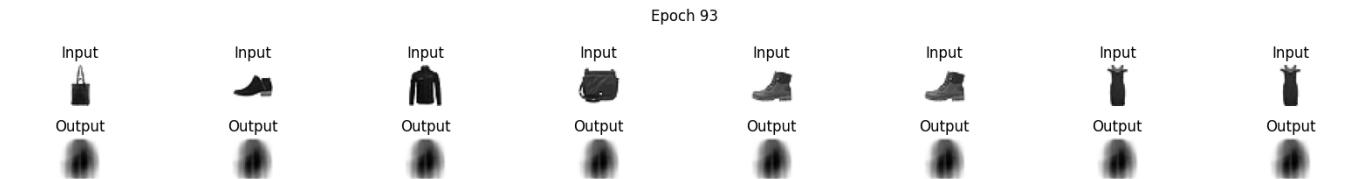
Epoch 91



```
Frequency: 1           Frequency: 1           Frequency: 10          Frequency: 10          Frequency: 100         Frequency: 100        Frequency: 1000        Frequency: 1000
'1 [ ===== ] - 0s 21ms/step
'1 [ ===== ] - 0s 31ms/step
'1 [ ===== ] - 0s 31ms/step
'1 [ ===== ] - 0s 35ms/step
'1 [ ===== ] - 0s 33ms/step
'1 [ ===== ] - 0s 34ms/step
'1 [ ===== ] - 0s 31ms/step
'1 [ ===== ] - 0s 38ms/step
```

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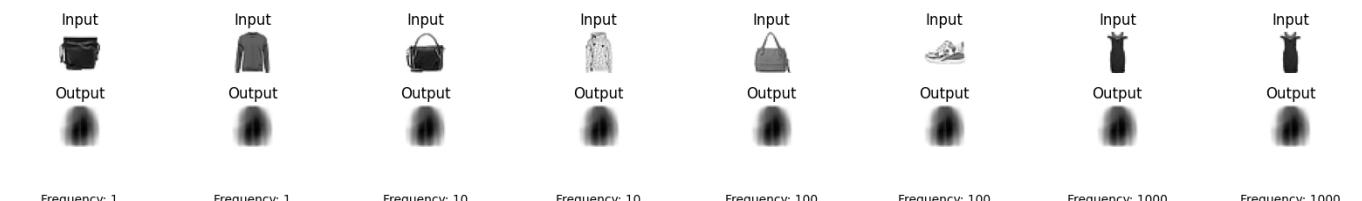




Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 34ms/step
```

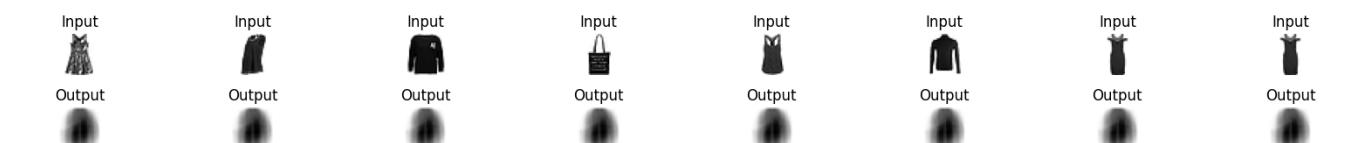
Epoch 94



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 46ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 39ms/step  
1/1 [=====] - 0s 32ms/step
```

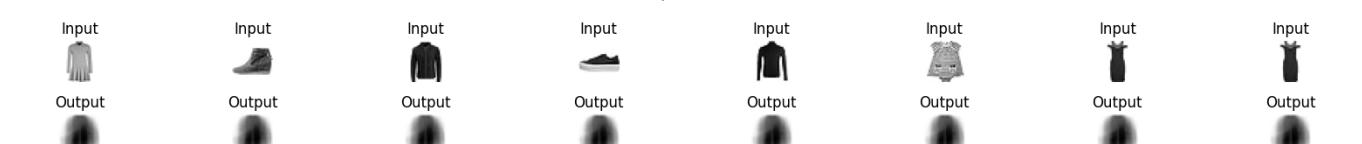
Epoch 95



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

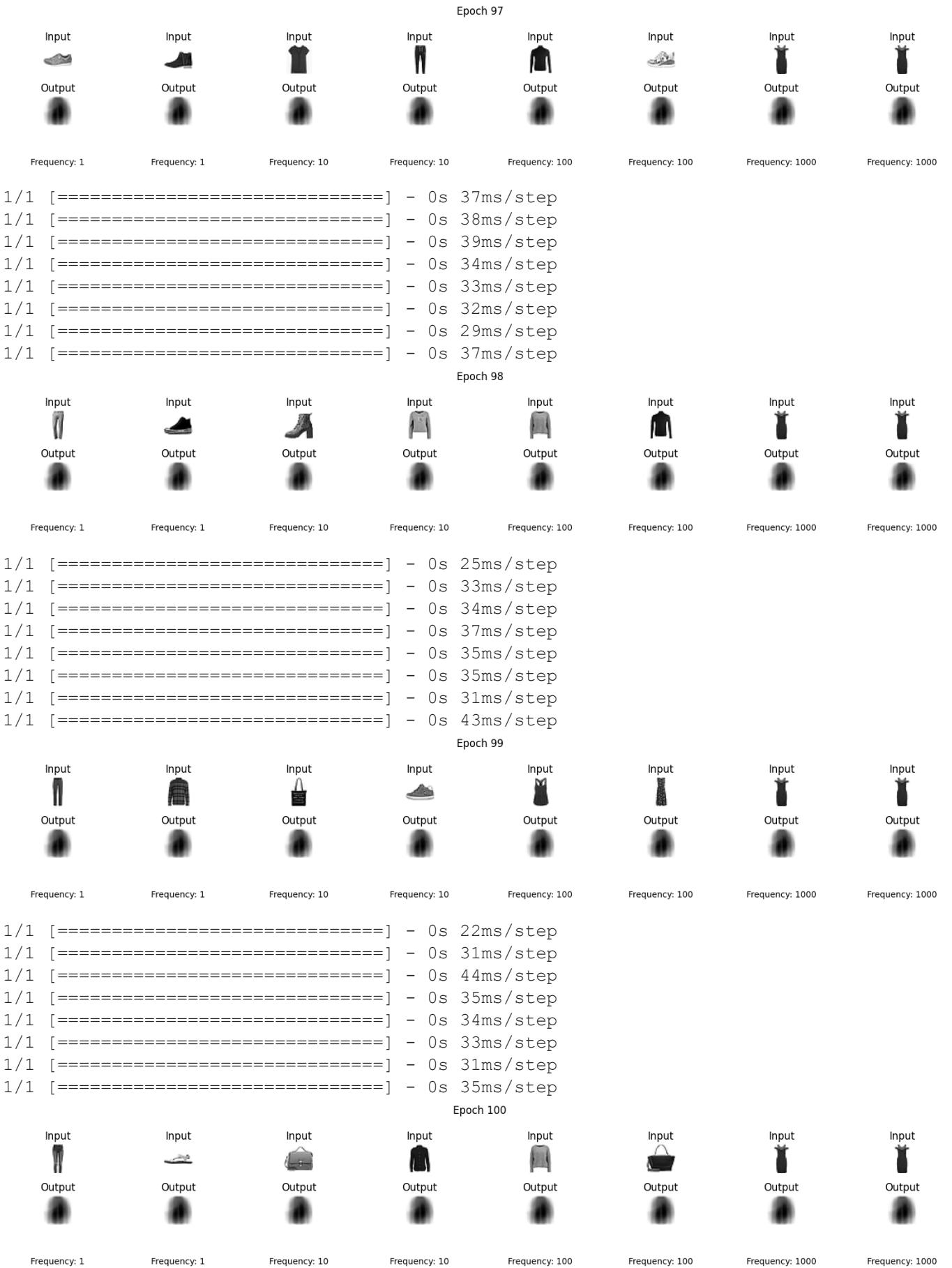
```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 41ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 34ms/step
```

Epoch 96



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 35ms/step
```



## Damaging the CA3

```
In [ ]: encoder = Sequential([
    Flatten(input_shape = (28, 28)), # Sensory neurons convert raw data into something p
    Dense(784), # Temporal Cortex
    ReLU(),
```

```

Dense(512), # Entorhinal Cortex
ReLU(),
Dense(384), # Dentate Gyrus
ReLU(),
Dense(10), # CA3
ReLU(),
Hippocampus() # Apply L1 penalty to the activations of the neurons; Encourages proce
])
decoder = Sequential([
    Dense(384, input_shape = (10,)), # CA1
    ReLU(),
    Dense(512), # Entorhinal Cortex
    ReLU(),
    Dense(784), # Temporal Cortex
    Activation("sigmoid"),
    Reshape((28, 28))
])
img = Input(shape = (28, 28))
latent_vector = encoder(img)
output = decoder(latent_vector)
model = Model(inputs = img, outputs = output)
model.compile(optimizer=Adam(), loss = "mean_squared_error")

```

```

In [ ]: EPOCHS = 50
EXAMPLES = 8

image_id = list(np.random.choice(range(10000), 1111, replace=False))

# Create a frequency dictionary
freq_dict = {img: 1000 for img in image_id[0:1]}
freq_dict.update({img: 100 for img in image_id[1:11]})
freq_dict.update({img: 10 for img in image_id[11:111]})
freq_dict.update({img: 1 for img in image_id[111:1111]})

# Separate image_ids based on their frequencies
image_ids_freq_1 = [image_id for image_id in image_id[111:1111]]
image_ids_freq_10 = [image_id for image_id in image_id[11:111]]
image_ids_freq_100 = [image_id for image_id in image_id[1:11]]
image_ids_freq_1000 = [image_id for image_id in image_id[0:1]]

# Create separate training sets for each frequency group
freq_train_1 = x_train[np.array([img for img in image_ids_freq_1])]
freq_train_10 = x_train[np.array([img for img in image_ids_freq_10])]
freq_train_100 = x_train[np.array([img for img in image_ids_freq_100])]
freq_train_1000 = x_train[np.array([img for img in image_ids_freq_1000])]

for epoch in range(EPOCHS):
    fig, axs = plt.subplots(3, EXAMPLES, figsize=(EXAMPLES * 2, 3)) # Change to 3 rows

    # Pick 2 random images from each frequency group
    rand_ids = np.concatenate([
        np.random.choice(image_ids_freq_1, 2),
        np.random.choice(image_ids_freq_10, 2),
        np.random.choice(image_ids_freq_100, 2),
        np.random.choice(image_ids_freq_1000, 2)
    ])

    rand = x_test[rand_ids].reshape((EXAMPLES, 1, 28, 28))

    for j in range(EXAMPLES):
        # Get the image ID and the frequency of the image from the dictionary
        image_id = rand_ids[j]
        freq = freq_dict[image_id]

        axs[0, j].imshow(rand[j][0], cmap="gray_r")

```

```

        axs[0,j].set_title("Input")
        axs[0,j].axis("off")

        axs[1, j].imshow(model.predict(rand[j])[0], cmap="gray_r")
        axs[1,j].set_title("Output")
        axs[1,j].axis("off")

        # Display the frequency
        axs[2, j].text(0.5, 0.5, f"Frequency: {freq}", ha='center', va='center')
        axs[2,j].axis("off")

fig.suptitle("Epoch %d" % (epoch+1))
fig.tight_layout()
plt.show()

```

```

# Train the model separately on each frequency group
model.fit(freq_train_1, freq_train_1, verbose=0)
model.fit(freq_train_10, freq_train_10, verbose=0)
model.fit(freq_train_100, freq_train_100, verbose=0)
model.fit(freq_train_1000, freq_train_1000, verbose=0)

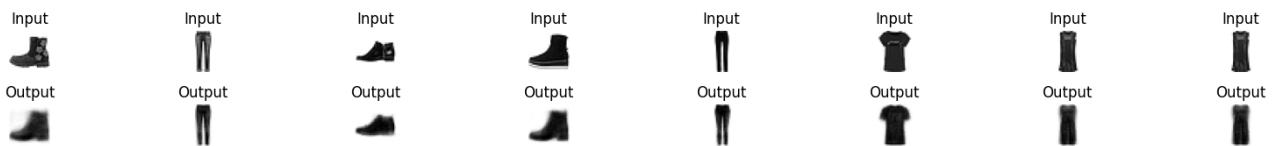
```

```

1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 23ms/step

```

Epoch 1



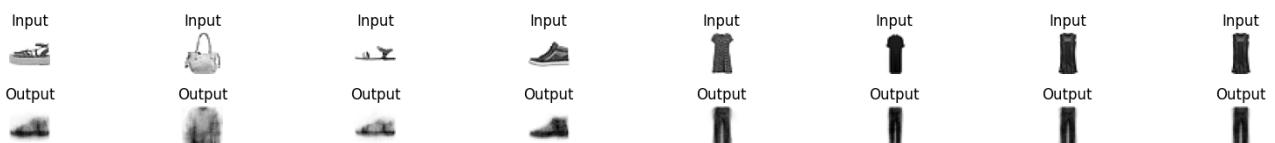
Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```

1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 30ms/step
1/1 [=====] - 0s 35ms/step
1/1 [=====] - 0s 32ms/step

```

Epoch 2

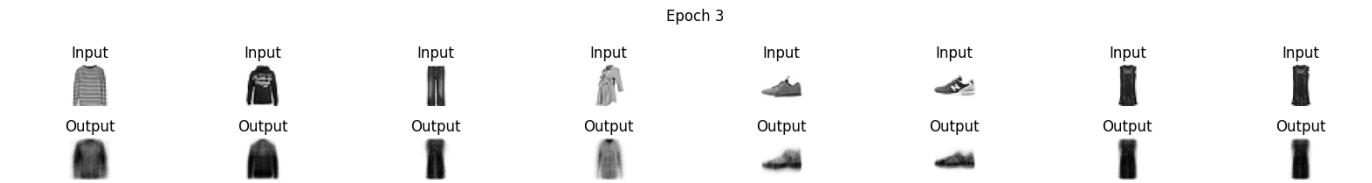


Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```

1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 22ms/step

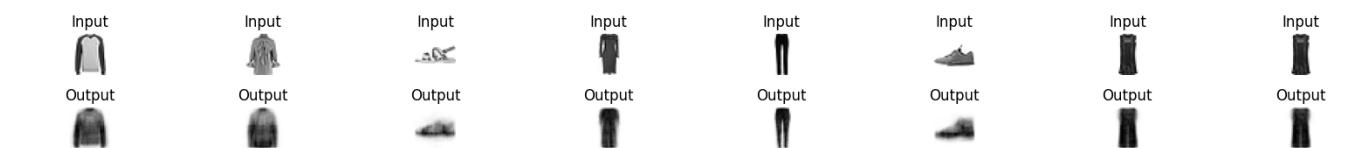
```



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 27ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 28ms/step
1/1 [=====] - 0s 33ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 25ms/step
1/1 [=====] - 0s 24ms/step
```

Epoch 4



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 21ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 24ms/step
```

Epoch 5



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

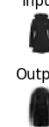
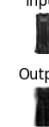
```
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 41ms/step
1/1 [=====] - 0s 34ms/step
1/1 [=====] - 0s 31ms/step
1/1 [=====] - 0s 32ms/step
1/1 [=====] - 0s 36ms/step
1/1 [=====] - 0s 36ms/step
```

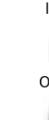
Epoch 6

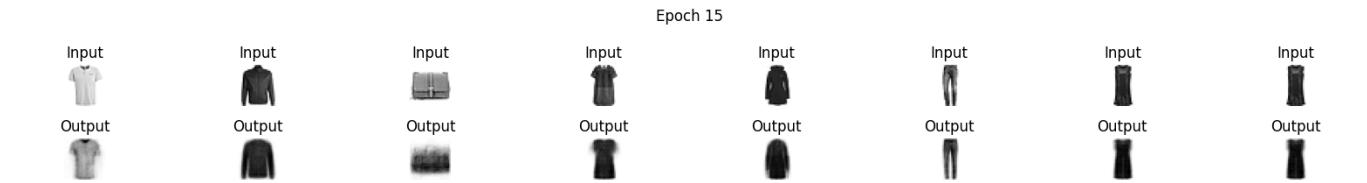


Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 26ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 24ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 23ms/step
1/1 [=====] - 0s 22ms/step
1/1 [=====] - 0s 22ms/step
```

Epoch 7							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step
Epoch 8							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 27ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step
Epoch 9							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 32ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 31ms/step
Epoch 10							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 22ms/step

Epoch 11							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step
Epoch 12							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 28ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 24ms/step	1/1 [=====] - 0s 22ms/step
Epoch 13							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 33ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 31ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 34ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 45ms/step	1/1 [=====] - 0s 35ms/step
Epoch 14							
Input 	Input 	Input 	Input 	Input 	Input 	Input 	Input 
Output 	Output 	Output 	Output 	Output 	Output 	Output 	Output 
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 29ms/step
```

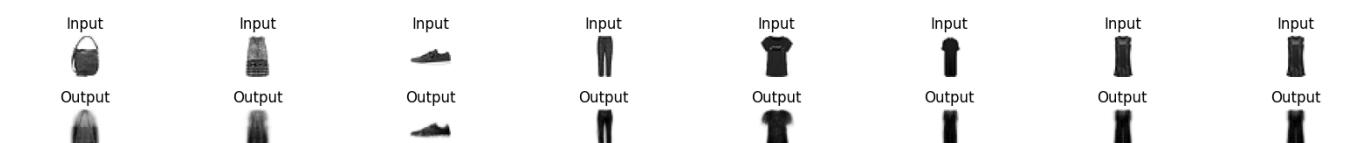
Epoch 16



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step
```

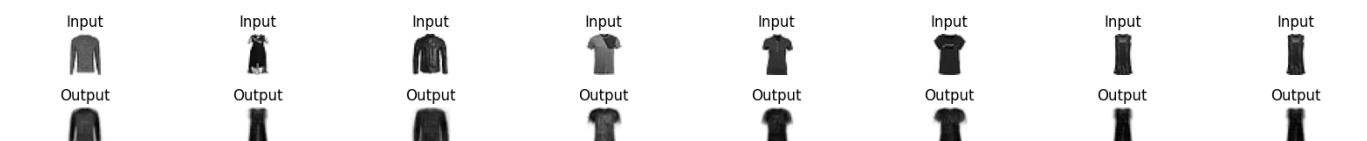
Epoch 17



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 30ms/step
```

Epoch 18



Frequency: 1      Frequency: 1      Frequency: 10      Frequency: 10      Frequency: 100      Frequency: 100      Frequency: 1000      Frequency: 1000

```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step
```

Epoch 19



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

Frequency: 100

Frequency: 100

Frequency: 1000

Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 20



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

Frequency: 100

Frequency: 100

Frequency: 1000

Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 21



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

Frequency: 100

Frequency: 100

Frequency: 1000

Frequency: 1000

1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 26ms/step

Epoch 22



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output



Input

Output

Frequency: 1

Frequency: 1

Frequency: 10

Frequency: 10

Frequency: 100

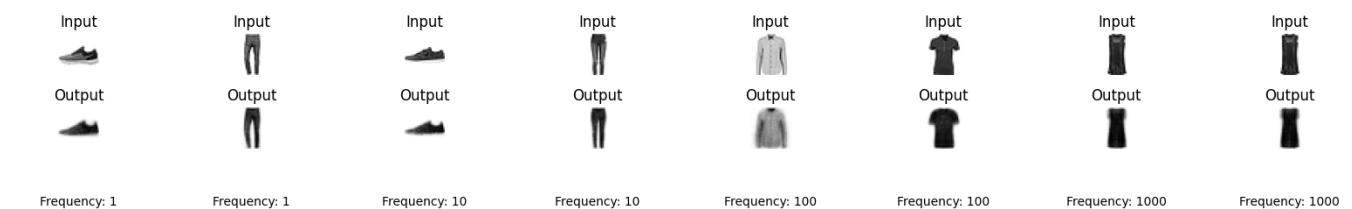
Frequency: 100

Frequency: 1000

Frequency: 1000

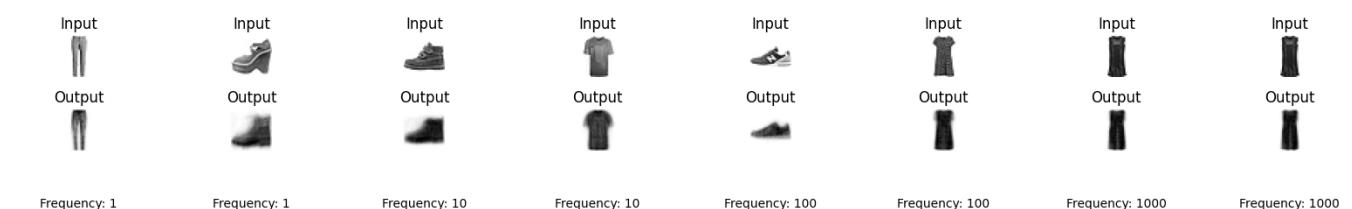
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 23



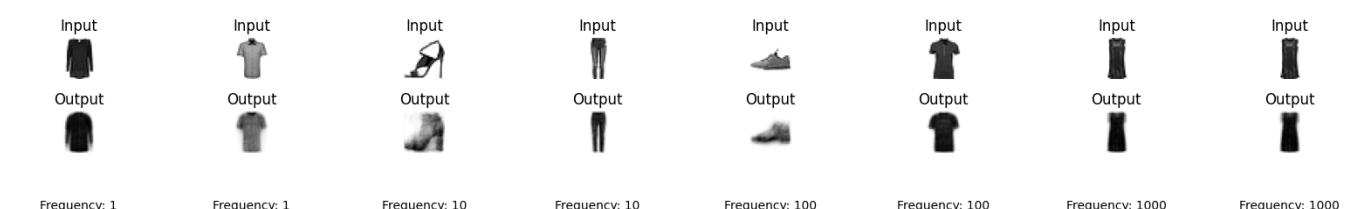
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 24



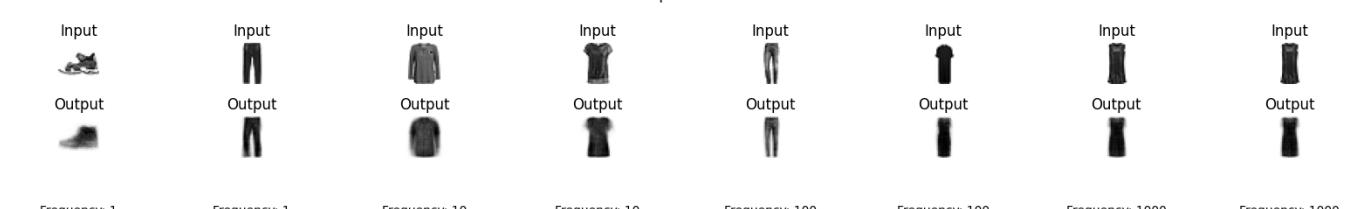
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 44ms/step

Epoch 25



1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step

Epoch 26



1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 27

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 27ms/step | 1/1 [=====] - 0s 25ms/step | 1/1 [=====] - 0s 27ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 26ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 25ms/step |

Epoch 28

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 32ms/step | 1/1 [=====] - 0s 40ms/step | 1/1 [=====] - 0s 30ms/step | 1/1 [=====] - 0s 31ms/step | 1/1 [=====] - 0s 36ms/step | 1/1 [=====] - 0s 51ms/step |

Epoch 29

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 23ms/step | 1/1 [=====] - 0s 28ms/step | 1/1 [=====] - 0s 21ms/step | 1/1 [=====] - 0s 21ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 23ms/step |

Epoch 30

| Input                      |
|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Output                     |
| Frequency: 1               | Frequency: 1               | Frequency: 10              | Frequency: 10              | Frequency: 100             | Frequency: 100             | Frequency: 1000            | Frequency: 1000            |
| 1/1 [=====] - 0s 24ms/step | 1/1 [=====] - 0s 23ms/step | 1/1 [=====] - 0s 25ms/step | 1/1 [=====] - 0s 23ms/step | 1/1 [=====] - 0s 22ms/step | 1/1 [=====] - 0s 21ms/step | 1/1 [=====] - 0s 21ms/step | 1/1 [=====] - 0s 27ms/step |

Epoch 31

 Input	 Input	 Input	 Input	 Input	 Input	 Input	 Input
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 32

 Input	 Input	 Input	 Input	 Input	 Input	 Input	 Input
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 20ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 35ms/step

Epoch 33

 Input	 Input	 Input	 Input	 Input	 Input	 Input	 Input
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 23ms/step

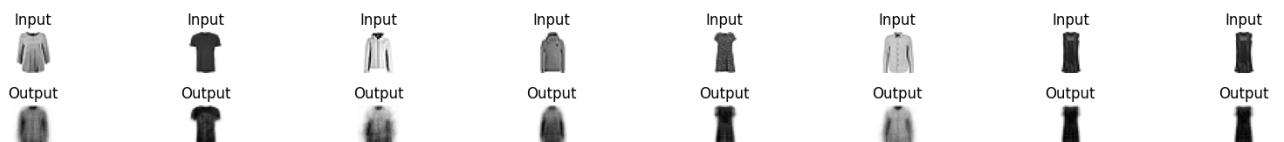
Epoch 34

 Input	 Input	 Input	 Input	 Input	 Input	 Input	 Input
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000

1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step

Epoch 35							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 30ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 21ms/step
Epoch 36							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 36ms/step	1/1 [=====] - 0s 40ms/step	1/1 [=====] - 0s 44ms/step	1/1 [=====] - 0s 38ms/step	1/1 [=====] - 0s 47ms/step	1/1 [=====] - 0s 37ms/step	1/1 [=====] - 0s 38ms/step
Epoch 37							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 22ms/step	1/1 [=====] - 0s 29ms/step	1/1 [=====] - 0s 26ms/step
Epoch 38							
Input 							
Output 							
Frequency: 1	Frequency: 1	Frequency: 10	Frequency: 10	Frequency: 100	Frequency: 100	Frequency: 1000	Frequency: 1000
1/1 [=====] - 0s 21ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 35ms/step	1/1 [=====] - 0s 20ms/step	1/1 [=====] - 0s 23ms/step	1/1 [=====] - 0s 25ms/step	1/1 [=====] - 0s 26ms/step	1/1 [=====] - 0s 22ms/step

Epoch 39



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 30ms/step
```

Epoch 40



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 50ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 55ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 73ms/step  
1/1 [=====] - 0s 38ms/step
```

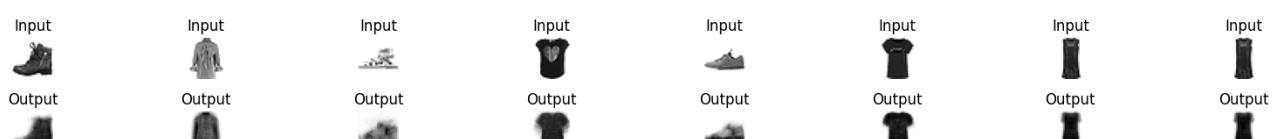
Epoch 41



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 31ms/step
```

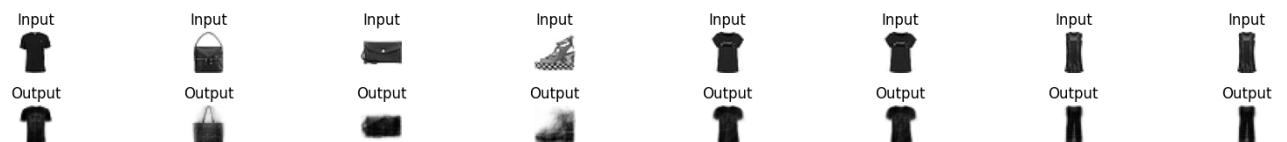
Epoch 42



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 23ms/step
```

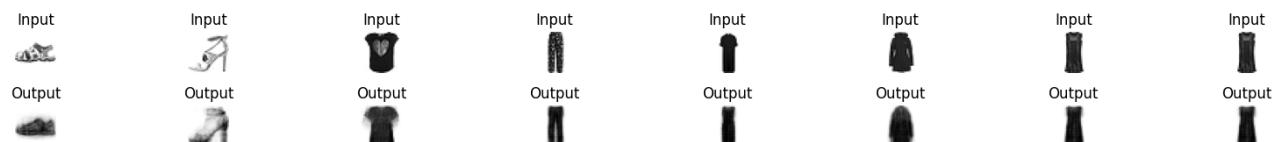
Epoch 43



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 23ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 34ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 28ms/step
```

Epoch 44



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 35ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 48ms/step  
1/1 [=====] - 0s 45ms/step  
1/1 [=====] - 0s 31ms/step  
1/1 [=====] - 0s 30ms/step  
1/1 [=====] - 0s 34ms/step
```

Epoch 45



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

```
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 37ms/step  
1/1 [=====] - 0s 23ms/step
```

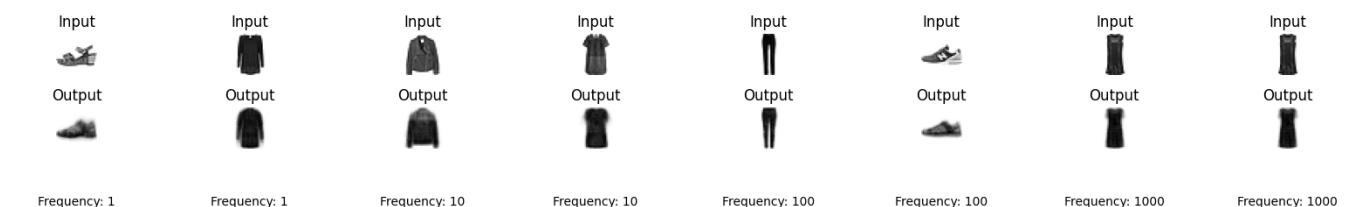
Epoch 46



Frequency: 1 Frequency: 1 Frequency: 10 Frequency: 10 Frequency: 100 Frequency: 100 Frequency: 1000 Frequency: 1000

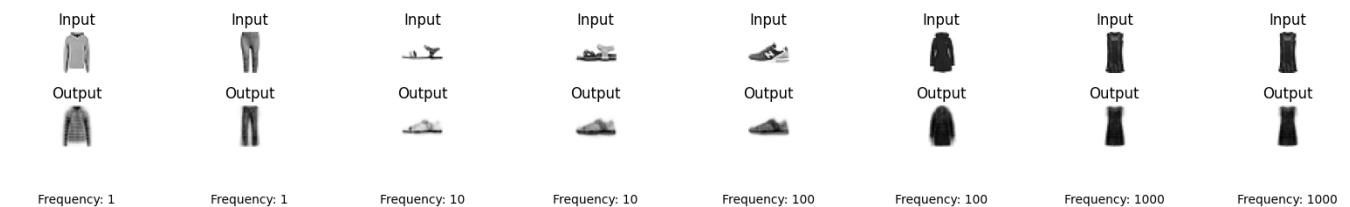
```
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 55ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 71ms/step  
1/1 [=====] - 0s 55ms/step  
1/1 [=====] - 0s 44ms/step  
1/1 [=====] - 0s 49ms/step  
1/1 [=====] - 0s 31ms/step
```

Epoch 47



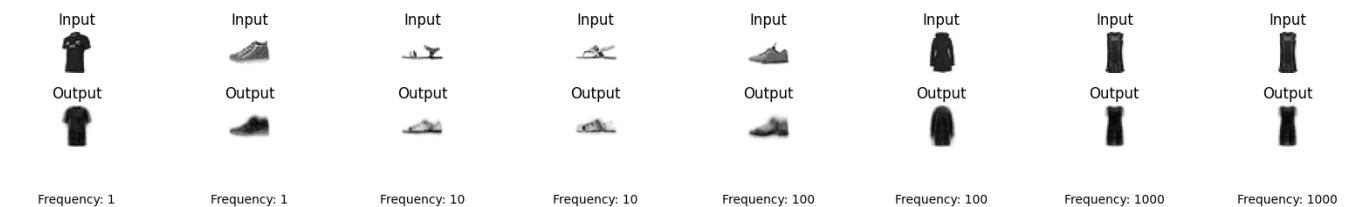
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 26ms/step  
1/1 [=====] - 0s 29ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 22ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 24ms/step  
1/1 [=====] - 0s 28ms/step

Epoch 48



1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 45ms/step  
1/1 [=====] - 0s 36ms/step  
1/1 [=====] - 0s 64ms/step  
1/1 [=====] - 0s 38ms/step  
1/1 [=====] - 0s 42ms/step  
1/1 [=====] - 0s 53ms/step  
1/1 [=====] - 0s 38ms/step

Epoch 49



1/1 [=====] - 0s 21ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 33ms/step  
1/1 [=====] - 0s 25ms/step  
1/1 [=====] - 0s 27ms/step  
1/1 [=====] - 0s 32ms/step  
1/1 [=====] - 0s 28ms/step  
1/1 [=====] - 0s 23ms/step

Epoch 50

