Setup

```
In [4]:    # Import NumPy
           import numpy as np
           np.random.seed(42)   # Set random seed

           # Import scikit-learn DBN dependency modules
           from sklearn.datasets import load_digits
           from sklearn.model_selection import train_test_split
           from sklearn.metrics.classification import accuracy_score

           # Import deep-belief network
           # Found at https://github.com/albertbup/deep-belief-network
           from dbn.tensorflow import SupervisedDBNClassification

           # Graphs
           import matplotlib.pyplot as plt
```

Load and format dataset

```
In [11]:   # Load MNIST dataset
           from sklearn.datasets import fetch_openml
           mnist = fetch_openml("mnist_784")
```

```
In [12]:   # Create set of 1000 MNIST datapoints
           class_count = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
           X = []
           Y = []

           # Get 100 of each class
           for i in range(0, len(mnist.data)):
               target_value = int(mnist.target[i])
               if class_count[target_value] < 100:
                   X.append(mnist.data[i])
                   Y.append(target_value)
                   class_count[target_value] += 1
               if sum(class_count) == 1000:
                   break

           # Convert to NumPy
           X = np.array(X)
           Y = np.array(Y)

           # Scale data for MNIST
           X = (X / 256).astype(np.float32)
```

DBN function

```python
In [13]:  def deep_belief_net(hidden_layers_structure=[256, 256],
                              learning_rate_rbm=0.05,
                              learning_rate=0.1,
                              n_epochs_rbm=10,
                              n_iter_backprop=100,
                              batch_size=32,
                              activation_function='relu',
                              dropout_p=0.2):

              # Splitting data
              X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2,

              # Training
              classifier = SupervisedDBNClassification(hidden_layers_structure=hidden_la
                                                       learning_rate_rbm=learning_rate_
                                                       learning_rate=learning_rate,
                                                       n_epochs_rbm=n_epochs_rbm,
                                                       n_iter_backprop=n_iter_backprop,
                                                       batch_size=batch_size,
                                                       activation_function=activation_fu
                                                       dropout_p=dropout_p)
              classifier.fit(X_train, Y_train)

              # Save the model
              classifier.save('model.pkl')

              # Restore
              classifier = SupervisedDBNClassification.load('model.pkl')

              # Test
              Y_pred = classifier.predict(X_test)
              acc = accuracy_score(Y_test, Y_pred)
              print('Done.\nAccuracy: %f' % acc)
              return acc
```

Run DBN tests below:

Default setting (base performance)

hidden_layers_structure=[256, 256] learning_rate_rbm=0.05 learning_rate=0.1 n_epochs_rbm=10
n_iter_backprop=100 batch_size=32 activation_function='relu' dropout_p=0.2

```python
In [14]:  # Run DBN
          default_acc = deep_belief_net()
```

```
[START] Pre-training step:
WARNING:tensorflow:From C:\Users\ALIMI\Travail python2022\DBN_Mr_Yassine\dbn\t
ensorflow\models.py:151: to_float (from tensorflow.python.ops.math_ops) is dep
recated and will be removed in a future version.
Instructions for updating:
Use `tf.cast` instead.
>> Epoch 1 finished     RBM Reconstruction error 50.802662
>> Epoch 2 finished     RBM Reconstruction error 60.613663
>> Epoch 3 finished     RBM Reconstruction error 50.652267
>> Epoch 4 finished     RBM Reconstruction error 42.363338
>> Epoch 5 finished     RBM Reconstruction error 41.087261
```

```
                        >> Epoch 6 finished        RBM Reconstruction error 58.575821
                        >> Epoch 7 finished        RBM Reconstruction error 45.028019
                        >> Epoch 8 finished        RBM Reconstruction error 46.514248
                        >> Epoch 9 finished        RBM Reconstruction error 31.058884
                        >> Epoch 10 finished       RBM Reconstruction error 34.474251
                        >> Epoch 1 finished        RBM Reconstruction error 131.230072
                        >> Epoch 2 finished        RBM Reconstruction error 148.412552
                        >> Epoch 3 finished        RBM Reconstruction error 180.380722
                        >> Epoch 4 finished        RBM Reconstruction error 188.834381
                        >> Epoch 5 finished        RBM Reconstruction error 228.656799
                        >> Epoch 6 finished        RBM Reconstruction error 222.335159
                        >> Epoch 7 finished        RBM Reconstruction error 138.648148
                        >> Epoch 8 finished        RBM Reconstruction error 191.445023
                        >> Epoch 9 finished        RBM Reconstruction error 153.702499
                        >> Epoch 10 finished       RBM Reconstruction error 153.362122
                        [END] Pre-training step
                        WARNING:tensorflow:From C:\Users\ALIMI\Anaconda3\lib\site-packages\tensorflow\
                        python\util\dispatch.py:1096: calling dropout (from tensorflow.python.ops.nn_o
                        ps) with keep_prob is deprecated and will be removed in a future version.
                        Instructions for updating:
                        Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - ke
                        ep_prob`.
                        [START] Fine tuning step:
                        >> Epoch 0 finished        ANN training loss 0.740879
                        >> Epoch 1 finished        ANN training loss 0.453924
                        >> Epoch 2 finished        ANN training loss 0.376081
                        >> Epoch 3 finished        ANN training loss 0.350390
                        >> Epoch 4 finished        ANN training loss 0.287730
                        >> Epoch 5 finished        ANN training loss 0.240652
                        >> Epoch 6 finished        ANN training loss 0.220042
                        >> Epoch 7 finished        ANN training loss 0.203324
                        >> Epoch 8 finished        ANN training loss 0.177993
                        >> Epoch 9 finished        ANN training loss 0.158155
                        >> Epoch 10 finished       ANN training loss 0.141582
                        >> Epoch 11 finished       ANN training loss 0.131120
                        >> Epoch 12 finished       ANN training loss 0.121698
                        >> Epoch 13 finished       ANN training loss 0.100991
                        >> Epoch 14 finished       ANN training loss 0.091841
                        >> Epoch 15 finished       ANN training loss 0.093313
                        >> Epoch 16 finished       ANN training loss 0.076929
                        >> Epoch 17 finished       ANN training loss 0.080416
                        >> Epoch 18 finished       ANN training loss 0.067496
                        >> Epoch 19 finished       ANN training loss 0.061841
                        >> Epoch 20 finished       ANN training loss 0.051572
                        >> Epoch 21 finished       ANN training loss 0.051893
                        >> Epoch 22 finished       ANN training loss 0.046011
                        >> Epoch 23 finished       ANN training loss 0.042742
                        >> Epoch 24 finished       ANN training loss 0.038027
                        >> Epoch 25 finished       ANN training loss 0.034139
                        >> Epoch 26 finished       ANN training loss 0.029650
                        >> Epoch 27 finished       ANN training loss 0.028128
                        >> Epoch 28 finished       ANN training loss 0.029218
                        >> Epoch 29 finished       ANN training loss 0.023742
                        >> Epoch 30 finished       ANN training loss 0.024107
                        >> Epoch 31 finished       ANN training loss 0.020375
                        >> Epoch 32 finished       ANN training loss 0.019032
                        >> Epoch 33 finished       ANN training loss 0.019501
                        >> Epoch 34 finished       ANN training loss 0.016588
                        >> Epoch 35 finished       ANN training loss 0.016849
                        >> Epoch 36 finished       ANN training loss 0.013565
                        >> Epoch 37 finished       ANN training loss 0.015647
                        >> Epoch 38 finished       ANN training loss 0.013256
                        >> Epoch 39 finished       ANN training loss 0.012850
                        >> Epoch 40 finished       ANN training loss 0.011267
                        >> Epoch 41 finished       ANN training loss 0.010910
```

```
>> Epoch 42 finished      ANN training loss 0.010203
>> Epoch 43 finished      ANN training loss 0.009070
>> Epoch 44 finished      ANN training loss 0.008616
>> Epoch 45 finished      ANN training loss 0.008238
>> Epoch 46 finished      ANN training loss 0.008010
>> Epoch 47 finished      ANN training loss 0.007488
>> Epoch 48 finished      ANN training loss 0.007079
>> Epoch 49 finished      ANN training loss 0.006532
>> Epoch 50 finished      ANN training loss 0.006658
>> Epoch 51 finished      ANN training loss 0.005796
>> Epoch 52 finished      ANN training loss 0.005387
>> Epoch 53 finished      ANN training loss 0.004965
>> Epoch 54 finished      ANN training loss 0.005312
>> Epoch 55 finished      ANN training loss 0.006516
>> Epoch 56 finished      ANN training loss 0.005392
>> Epoch 57 finished      ANN training loss 0.004413
>> Epoch 58 finished      ANN training loss 0.003986
>> Epoch 59 finished      ANN training loss 0.003994
>> Epoch 60 finished      ANN training loss 0.004433
>> Epoch 61 finished      ANN training loss 0.003990
>> Epoch 62 finished      ANN training loss 0.003725
>> Epoch 63 finished      ANN training loss 0.003416
>> Epoch 64 finished      ANN training loss 0.003505
>> Epoch 65 finished      ANN training loss 0.003711
>> Epoch 66 finished      ANN training loss 0.003126
>> Epoch 67 finished      ANN training loss 0.002980
>> Epoch 68 finished      ANN training loss 0.003289
>> Epoch 69 finished      ANN training loss 0.002972
>> Epoch 70 finished      ANN training loss 0.002515
>> Epoch 71 finished      ANN training loss 0.004003
>> Epoch 72 finished      ANN training loss 0.002592
>> Epoch 73 finished      ANN training loss 0.002393
>> Epoch 74 finished      ANN training loss 0.002076
>> Epoch 75 finished      ANN training loss 0.002217
>> Epoch 76 finished      ANN training loss 0.001922
>> Epoch 77 finished      ANN training loss 0.002186
>> Epoch 78 finished      ANN training loss 0.001763
>> Epoch 79 finished      ANN training loss 0.001740
>> Epoch 80 finished      ANN training loss 0.001964
>> Epoch 81 finished      ANN training loss 0.001520
>> Epoch 82 finished      ANN training loss 0.001709
>> Epoch 83 finished      ANN training loss 0.001536
>> Epoch 84 finished      ANN training loss 0.001592
>> Epoch 85 finished      ANN training loss 0.001527
>> Epoch 86 finished      ANN training loss 0.001369
>> Epoch 87 finished      ANN training loss 0.001391
>> Epoch 88 finished      ANN training loss 0.001222
>> Epoch 89 finished      ANN training loss 0.001163
>> Epoch 90 finished      ANN training loss 0.001048
>> Epoch 91 finished      ANN training loss 0.001100
>> Epoch 92 finished      ANN training loss 0.001272
>> Epoch 93 finished      ANN training loss 0.001171
>> Epoch 94 finished      ANN training loss 0.001119
>> Epoch 95 finished      ANN training loss 0.001128
>> Epoch 96 finished      ANN training loss 0.001223
>> Epoch 97 finished      ANN training loss 0.001206
>> Epoch 98 finished      ANN training loss 0.001098
>> Epoch 99 finished      ANN training loss 0.001762
[END] Fine tuning step
Done.
```

In [15]:
```python
print('ACCURACY: ' + str(default_acc))
```

```
ACCURACY: 0.92
```

Different 1-layer structures

```
In [16]:   # Store accuracies
           onelayer_acc = [0, 0, 0, 0, 0]
```

Setting 1

hidden_layers_structure=[100]

```
In [17]:   onelayer_acc[0] = deep_belief_net(hidden_layers_structure=[100])
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 71.883064
>> Epoch 2 finished      RBM Reconstruction error 49.219536
>> Epoch 3 finished      RBM Reconstruction error 72.821922
>> Epoch 4 finished      RBM Reconstruction error 50.523182
>> Epoch 5 finished      RBM Reconstruction error 51.346024
>> Epoch 6 finished      RBM Reconstruction error 69.615524
>> Epoch 7 finished      RBM Reconstruction error 75.025543
>> Epoch 8 finished      RBM Reconstruction error 59.427540
>> Epoch 9 finished      RBM Reconstruction error 82.042488
>> Epoch 10 finished     RBM Reconstruction error 57.877441
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.799542
>> Epoch 1 finished      ANN training loss 0.587551
>> Epoch 2 finished      ANN training loss 0.490077
>> Epoch 3 finished      ANN training loss 0.431253
>> Epoch 4 finished      ANN training loss 0.405054
>> Epoch 5 finished      ANN training loss 0.342474
>> Epoch 6 finished      ANN training loss 0.318522
>> Epoch 7 finished      ANN training loss 0.304979
>> Epoch 8 finished      ANN training loss 0.272345
>> Epoch 9 finished      ANN training loss 0.248468
>> Epoch 10 finished     ANN training loss 0.227654
>> Epoch 11 finished     ANN training loss 0.217763
>> Epoch 12 finished     ANN training loss 0.198856
>> Epoch 13 finished     ANN training loss 0.190808
>> Epoch 14 finished     ANN training loss 0.174909
>> Epoch 15 finished     ANN training loss 0.166025
>> Epoch 16 finished     ANN training loss 0.148653
>> Epoch 17 finished     ANN training loss 0.143548
>> Epoch 18 finished     ANN training loss 0.131650
>> Epoch 19 finished     ANN training loss 0.123233
>> Epoch 20 finished     ANN training loss 0.116856
>> Epoch 21 finished     ANN training loss 0.106459
>> Epoch 22 finished     ANN training loss 0.097501
>> Epoch 23 finished     ANN training loss 0.095554
>> Epoch 24 finished     ANN training loss 0.087316
>> Epoch 25 finished     ANN training loss 0.083704
>> Epoch 26 finished     ANN training loss 0.077825
>> Epoch 27 finished     ANN training loss 0.072895
>> Epoch 28 finished     ANN training loss 0.066946
>> Epoch 29 finished     ANN training loss 0.069489
>> Epoch 30 finished     ANN training loss 0.061696
>> Epoch 31 finished     ANN training loss 0.056340
>> Epoch 32 finished     ANN training loss 0.054868
>> Epoch 33 finished     ANN training loss 0.050262
>> Epoch 34 finished     ANN training loss 0.048128
```

```
>> Epoch 35 finished     ANN training loss 0.046277
>> Epoch 36 finished     ANN training loss 0.043269
>> Epoch 37 finished     ANN training loss 0.041793
>> Epoch 38 finished     ANN training loss 0.039154
>> Epoch 39 finished     ANN training loss 0.035572
>> Epoch 40 finished     ANN training loss 0.034953
>> Epoch 41 finished     ANN training loss 0.032984
>> Epoch 42 finished     ANN training loss 0.030934
>> Epoch 43 finished     ANN training loss 0.031275
>> Epoch 44 finished     ANN training loss 0.030837
>> Epoch 45 finished     ANN training loss 0.028003
>> Epoch 46 finished     ANN training loss 0.026107
>> Epoch 47 finished     ANN training loss 0.025139
>> Epoch 48 finished     ANN training loss 0.025589
>> Epoch 49 finished     ANN training loss 0.022883
>> Epoch 50 finished     ANN training loss 0.021873
>> Epoch 51 finished     ANN training loss 0.021470
>> Epoch 52 finished     ANN training loss 0.020200
>> Epoch 53 finished     ANN training loss 0.019853
>> Epoch 54 finished     ANN training loss 0.021023
>> Epoch 55 finished     ANN training loss 0.020325
>> Epoch 56 finished     ANN training loss 0.018010
>> Epoch 57 finished     ANN training loss 0.018231
>> Epoch 58 finished     ANN training loss 0.016271
>> Epoch 59 finished     ANN training loss 0.016705
>> Epoch 60 finished     ANN training loss 0.015342
>> Epoch 61 finished     ANN training loss 0.014624
>> Epoch 62 finished     ANN training loss 0.014535
>> Epoch 63 finished     ANN training loss 0.013463
>> Epoch 64 finished     ANN training loss 0.012835
>> Epoch 65 finished     ANN training loss 0.012424
>> Epoch 66 finished     ANN training loss 0.013055
>> Epoch 67 finished     ANN training loss 0.012515
>> Epoch 68 finished     ANN training loss 0.012381
>> Epoch 69 finished     ANN training loss 0.011504
>> Epoch 70 finished     ANN training loss 0.011227
>> Epoch 71 finished     ANN training loss 0.011003
>> Epoch 72 finished     ANN training loss 0.010125
>> Epoch 73 finished     ANN training loss 0.011115
>> Epoch 74 finished     ANN training loss 0.010266
>> Epoch 75 finished     ANN training loss 0.009766
>> Epoch 76 finished     ANN training loss 0.009552
>> Epoch 77 finished     ANN training loss 0.009363
>> Epoch 78 finished     ANN training loss 0.009341
>> Epoch 79 finished     ANN training loss 0.008733
>> Epoch 80 finished     ANN training loss 0.008560
>> Epoch 81 finished     ANN training loss 0.008042
>> Epoch 82 finished     ANN training loss 0.007451
>> Epoch 83 finished     ANN training loss 0.007263
>> Epoch 84 finished     ANN training loss 0.007120
>> Epoch 85 finished     ANN training loss 0.006927
>> Epoch 86 finished     ANN training loss 0.006961
>> Epoch 87 finished     ANN training loss 0.007290
>> Epoch 88 finished     ANN training loss 0.007030
>> Epoch 89 finished     ANN training loss 0.006491
>> Epoch 90 finished     ANN training loss 0.006019
>> Epoch 91 finished     ANN training loss 0.006182
>> Epoch 92 finished     ANN training loss 0.006417
>> Epoch 93 finished     ANN training loss 0.006092
>> Epoch 94 finished     ANN training loss 0.005787
>> Epoch 95 finished     ANN training loss 0.005550
>> Epoch 96 finished     ANN training loss 0.006072
>> Epoch 97 finished     ANN training loss 0.005957
>> Epoch 98 finished     ANN training loss 0.005567
>> Epoch 99 finished     ANN training loss 0.005239
```

```
[END] Fine tuning step
Done.
```

In [18]:
```python
print('ACCURACY: ' + str(onelayer_acc[0]))
```

```
ACCURACY: 0.91
```

Setting 2

hidden_layers_structure=[200]

In [19]:
```python
onelayer_acc[1] = deep_belief_net(hidden_layers_structure=[200])
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 45.414230
>> Epoch 2 finished     RBM Reconstruction error 36.285255
>> Epoch 3 finished     RBM Reconstruction error 43.517979
>> Epoch 4 finished     RBM Reconstruction error 53.830082
>> Epoch 5 finished     RBM Reconstruction error 38.417015
>> Epoch 6 finished     RBM Reconstruction error 42.754887
>> Epoch 7 finished     RBM Reconstruction error 61.840523
>> Epoch 8 finished     RBM Reconstruction error 28.709108
>> Epoch 9 finished     RBM Reconstruction error 43.236549
>> Epoch 10 finished    RBM Reconstruction error 41.682289
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.792403
>> Epoch 1 finished     ANN training loss 0.558377
>> Epoch 2 finished     ANN training loss 0.454259
>> Epoch 3 finished     ANN training loss 0.400325
>> Epoch 4 finished     ANN training loss 0.373724
>> Epoch 5 finished     ANN training loss 0.324249
>> Epoch 6 finished     ANN training loss 0.283223
>> Epoch 7 finished     ANN training loss 0.286118
>> Epoch 8 finished     ANN training loss 0.252217
>> Epoch 9 finished     ANN training loss 0.224174
>> Epoch 10 finished    ANN training loss 0.208734
>> Epoch 11 finished    ANN training loss 0.189222
>> Epoch 12 finished    ANN training loss 0.174400
>> Epoch 13 finished    ANN training loss 0.160516
>> Epoch 14 finished    ANN training loss 0.147868
>> Epoch 15 finished    ANN training loss 0.136332
>> Epoch 16 finished    ANN training loss 0.134410
>> Epoch 17 finished    ANN training loss 0.120683
>> Epoch 18 finished    ANN training loss 0.108563
>> Epoch 19 finished    ANN training loss 0.100035
>> Epoch 20 finished    ANN training loss 0.094514
>> Epoch 21 finished    ANN training loss 0.090196
>> Epoch 22 finished    ANN training loss 0.083452
>> Epoch 23 finished    ANN training loss 0.075955
>> Epoch 24 finished    ANN training loss 0.073228
>> Epoch 25 finished    ANN training loss 0.067497
>> Epoch 26 finished    ANN training loss 0.061881
>> Epoch 27 finished    ANN training loss 0.057142
>> Epoch 28 finished    ANN training loss 0.054623
>> Epoch 29 finished    ANN training loss 0.051979
>> Epoch 30 finished    ANN training loss 0.046972
>> Epoch 31 finished    ANN training loss 0.045256
>> Epoch 32 finished    ANN training loss 0.041754
>> Epoch 33 finished    ANN training loss 0.039661
>> Epoch 34 finished    ANN training loss 0.038830
>> Epoch 35 finished    ANN training loss 0.035795
```

```
>> Epoch 36 finished    ANN training loss 0.032724
>> Epoch 37 finished    ANN training loss 0.032022
>> Epoch 38 finished    ANN training loss 0.030272
>> Epoch 39 finished    ANN training loss 0.028746
>> Epoch 40 finished    ANN training loss 0.026873
>> Epoch 41 finished    ANN training loss 0.026083
>> Epoch 42 finished    ANN training loss 0.026594
>> Epoch 43 finished    ANN training loss 0.022998
>> Epoch 44 finished    ANN training loss 0.022573
>> Epoch 45 finished    ANN training loss 0.021450
>> Epoch 46 finished    ANN training loss 0.020896
>> Epoch 47 finished    ANN training loss 0.020846
>> Epoch 48 finished    ANN training loss 0.018584
>> Epoch 49 finished    ANN training loss 0.018938
>> Epoch 50 finished    ANN training loss 0.016996
>> Epoch 51 finished    ANN training loss 0.017308
>> Epoch 52 finished    ANN training loss 0.015784
>> Epoch 53 finished    ANN training loss 0.015339
>> Epoch 54 finished    ANN training loss 0.014552
>> Epoch 55 finished    ANN training loss 0.013740
>> Epoch 56 finished    ANN training loss 0.014268
>> Epoch 57 finished    ANN training loss 0.012771
>> Epoch 58 finished    ANN training loss 0.012065
>> Epoch 59 finished    ANN training loss 0.011734
>> Epoch 60 finished    ANN training loss 0.012192
>> Epoch 61 finished    ANN training loss 0.011301
>> Epoch 62 finished    ANN training loss 0.010572
>> Epoch 63 finished    ANN training loss 0.010339
>> Epoch 64 finished    ANN training loss 0.010474
>> Epoch 65 finished    ANN training loss 0.010081
>> Epoch 66 finished    ANN training loss 0.009656
>> Epoch 67 finished    ANN training loss 0.009271
>> Epoch 68 finished    ANN training loss 0.009088
>> Epoch 69 finished    ANN training loss 0.009002
>> Epoch 70 finished    ANN training loss 0.008970
>> Epoch 71 finished    ANN training loss 0.008535
>> Epoch 72 finished    ANN training loss 0.008833
>> Epoch 73 finished    ANN training loss 0.008431
>> Epoch 74 finished    ANN training loss 0.007508
>> Epoch 75 finished    ANN training loss 0.007415
>> Epoch 76 finished    ANN training loss 0.007602
>> Epoch 77 finished    ANN training loss 0.007047
>> Epoch 78 finished    ANN training loss 0.006930
>> Epoch 79 finished    ANN training loss 0.006668
>> Epoch 80 finished    ANN training loss 0.006308
>> Epoch 81 finished    ANN training loss 0.006420
>> Epoch 82 finished    ANN training loss 0.006179
>> Epoch 83 finished    ANN training loss 0.006544
>> Epoch 84 finished    ANN training loss 0.005859
>> Epoch 85 finished    ANN training loss 0.005690
>> Epoch 86 finished    ANN training loss 0.005678
>> Epoch 87 finished    ANN training loss 0.005546
>> Epoch 88 finished    ANN training loss 0.005765
>> Epoch 89 finished    ANN training loss 0.005562
>> Epoch 90 finished    ANN training loss 0.005201
>> Epoch 91 finished    ANN training loss 0.005090
>> Epoch 92 finished    ANN training loss 0.004959
>> Epoch 93 finished    ANN training loss 0.004830
>> Epoch 94 finished    ANN training loss 0.005204
>> Epoch 95 finished    ANN training loss 0.004768
>> Epoch 96 finished    ANN training loss 0.004679
>> Epoch 97 finished    ANN training loss 0.004691
>> Epoch 98 finished    ANN training loss 0.004748
>> Epoch 99 finished    ANN training loss 0.004642
[END] Fine tuning step
```

```
Done.
```

In [20]:
```python
print('ACCURACY: ' + str(onelayer_acc[1]))
```

```
ACCURACY: 0.915
```

Setting 3

hidden_layers_structure=[300]

In [21]:
```python
onelayer_acc[2] = deep_belief_net(hidden_layers_structure=[300])
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 77.476326
>> Epoch 2 finished     RBM Reconstruction error 94.029198
>> Epoch 3 finished     RBM Reconstruction error 40.229782
>> Epoch 4 finished     RBM Reconstruction error 43.480961
>> Epoch 5 finished     RBM Reconstruction error 65.467094
>> Epoch 6 finished     RBM Reconstruction error 40.833336
>> Epoch 7 finished     RBM Reconstruction error 31.919632
>> Epoch 8 finished     RBM Reconstruction error 41.051559
>> Epoch 9 finished     RBM Reconstruction error 38.219448
>> Epoch 10 finished    RBM Reconstruction error 46.930855
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.783310
>> Epoch 1 finished     ANN training loss 0.549260
>> Epoch 2 finished     ANN training loss 0.463997
>> Epoch 3 finished     ANN training loss 0.396184
>> Epoch 4 finished     ANN training loss 0.352683
>> Epoch 5 finished     ANN training loss 0.333062
>> Epoch 6 finished     ANN training loss 0.289539
>> Epoch 7 finished     ANN training loss 0.270611
>> Epoch 8 finished     ANN training loss 0.246243
>> Epoch 9 finished     ANN training loss 0.225119
>> Epoch 10 finished    ANN training loss 0.213675
>> Epoch 11 finished    ANN training loss 0.202141
>> Epoch 12 finished    ANN training loss 0.188057
>> Epoch 13 finished    ANN training loss 0.163305
>> Epoch 14 finished    ANN training loss 0.156307
>> Epoch 15 finished    ANN training loss 0.137869
>> Epoch 16 finished    ANN training loss 0.131596
>> Epoch 17 finished    ANN training loss 0.125882
>> Epoch 18 finished    ANN training loss 0.114390
>> Epoch 19 finished    ANN training loss 0.105198
>> Epoch 20 finished    ANN training loss 0.101032
>> Epoch 21 finished    ANN training loss 0.089239
>> Epoch 22 finished    ANN training loss 0.085690
>> Epoch 23 finished    ANN training loss 0.085752
>> Epoch 24 finished    ANN training loss 0.075805
>> Epoch 25 finished    ANN training loss 0.071583
>> Epoch 26 finished    ANN training loss 0.067185
>> Epoch 27 finished    ANN training loss 0.060088
>> Epoch 28 finished    ANN training loss 0.058456
>> Epoch 29 finished    ANN training loss 0.052903
>> Epoch 30 finished    ANN training loss 0.052745
>> Epoch 31 finished    ANN training loss 0.047205
>> Epoch 32 finished    ANN training loss 0.046610
>> Epoch 33 finished    ANN training loss 0.043999
>> Epoch 34 finished    ANN training loss 0.041643
>> Epoch 35 finished    ANN training loss 0.037786
>> Epoch 36 finished    ANN training loss 0.034954
```

```
>> Epoch 37 finished    ANN training loss 0.033461
>> Epoch 38 finished    ANN training loss 0.033022
>> Epoch 39 finished    ANN training loss 0.034786
>> Epoch 40 finished    ANN training loss 0.030337
>> Epoch 41 finished    ANN training loss 0.027136
>> Epoch 42 finished    ANN training loss 0.026427
>> Epoch 43 finished    ANN training loss 0.028217
>> Epoch 44 finished    ANN training loss 0.024056
>> Epoch 45 finished    ANN training loss 0.024212
>> Epoch 46 finished    ANN training loss 0.023414
>> Epoch 47 finished    ANN training loss 0.023089
>> Epoch 48 finished    ANN training loss 0.020701
>> Epoch 49 finished    ANN training loss 0.019389
>> Epoch 50 finished    ANN training loss 0.019352
>> Epoch 51 finished    ANN training loss 0.018409
>> Epoch 52 finished    ANN training loss 0.017390
>> Epoch 53 finished    ANN training loss 0.016837
>> Epoch 54 finished    ANN training loss 0.016487
>> Epoch 55 finished    ANN training loss 0.015638
>> Epoch 56 finished    ANN training loss 0.014420
>> Epoch 57 finished    ANN training loss 0.014166
>> Epoch 58 finished    ANN training loss 0.013992
>> Epoch 59 finished    ANN training loss 0.013447
>> Epoch 60 finished    ANN training loss 0.013118
>> Epoch 61 finished    ANN training loss 0.012236
>> Epoch 62 finished    ANN training loss 0.011784
>> Epoch 63 finished    ANN training loss 0.011592
>> Epoch 64 finished    ANN training loss 0.011207
>> Epoch 65 finished    ANN training loss 0.011314
>> Epoch 66 finished    ANN training loss 0.010311
>> Epoch 67 finished    ANN training loss 0.009886
>> Epoch 68 finished    ANN training loss 0.010130
>> Epoch 69 finished    ANN training loss 0.009324
>> Epoch 70 finished    ANN training loss 0.009377
>> Epoch 71 finished    ANN training loss 0.008784
>> Epoch 72 finished    ANN training loss 0.008783
>> Epoch 73 finished    ANN training loss 0.008712
>> Epoch 74 finished    ANN training loss 0.008220
>> Epoch 75 finished    ANN training loss 0.009286
>> Epoch 76 finished    ANN training loss 0.008008
>> Epoch 77 finished    ANN training loss 0.007511
>> Epoch 78 finished    ANN training loss 0.007517
>> Epoch 79 finished    ANN training loss 0.007242
>> Epoch 80 finished    ANN training loss 0.007096
>> Epoch 81 finished    ANN training loss 0.006769
>> Epoch 82 finished    ANN training loss 0.006714
>> Epoch 83 finished    ANN training loss 0.006599
>> Epoch 84 finished    ANN training loss 0.006354
>> Epoch 85 finished    ANN training loss 0.006042
>> Epoch 86 finished    ANN training loss 0.005984
>> Epoch 87 finished    ANN training loss 0.005717
>> Epoch 88 finished    ANN training loss 0.005882
>> Epoch 89 finished    ANN training loss 0.005977
>> Epoch 90 finished    ANN training loss 0.005671
>> Epoch 91 finished    ANN training loss 0.005543
>> Epoch 92 finished    ANN training loss 0.005214
>> Epoch 93 finished    ANN training loss 0.005137
>> Epoch 94 finished    ANN training loss 0.005082
>> Epoch 95 finished    ANN training loss 0.005186
>> Epoch 96 finished    ANN training loss 0.004884
>> Epoch 97 finished    ANN training loss 0.004751
>> Epoch 98 finished    ANN training loss 0.004773
>> Epoch 99 finished    ANN training loss 0.004624
[END] Fine tuning step
Done.
```

In [22]:
```python
print('ACCURACY: ' + str(onelayer_acc[2]))
```
ACCURACY: 0.91

Setting 4

hidden_layers_structure=[400]

In [23]:
```python
onelayer_acc[3] = deep_belief_net(hidden_layers_structure=[400])
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 76.508209
>> Epoch 2 finished     RBM Reconstruction error 55.080544
>> Epoch 3 finished     RBM Reconstruction error 38.907104
>> Epoch 4 finished     RBM Reconstruction error 47.255497
>> Epoch 5 finished     RBM Reconstruction error 56.742077
>> Epoch 6 finished     RBM Reconstruction error 38.577198
>> Epoch 7 finished     RBM Reconstruction error 55.470825
>> Epoch 8 finished     RBM Reconstruction error 46.093624
>> Epoch 9 finished     RBM Reconstruction error 36.421066
>> Epoch 10 finished    RBM Reconstruction error 32.891293
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.829531
>> Epoch 1 finished     ANN training loss 0.570312
>> Epoch 2 finished     ANN training loss 0.475225
>> Epoch 3 finished     ANN training loss 0.415622
>> Epoch 4 finished     ANN training loss 0.361415
>> Epoch 5 finished     ANN training loss 0.324670
>> Epoch 6 finished     ANN training loss 0.295907
>> Epoch 7 finished     ANN training loss 0.275827
>> Epoch 8 finished     ANN training loss 0.254593
>> Epoch 9 finished     ANN training loss 0.235754
>> Epoch 10 finished    ANN training loss 0.222178
>> Epoch 11 finished    ANN training loss 0.200712
>> Epoch 12 finished    ANN training loss 0.179394
>> Epoch 13 finished    ANN training loss 0.167557
>> Epoch 14 finished    ANN training loss 0.157992
>> Epoch 15 finished    ANN training loss 0.152153
>> Epoch 16 finished    ANN training loss 0.139974
>> Epoch 17 finished    ANN training loss 0.122666
>> Epoch 18 finished    ANN training loss 0.115121
>> Epoch 19 finished    ANN training loss 0.105786
>> Epoch 20 finished    ANN training loss 0.097660
>> Epoch 21 finished    ANN training loss 0.091725
>> Epoch 22 finished    ANN training loss 0.084845
>> Epoch 23 finished    ANN training loss 0.081502
>> Epoch 24 finished    ANN training loss 0.074462
>> Epoch 25 finished    ANN training loss 0.069918
>> Epoch 26 finished    ANN training loss 0.064744
>> Epoch 27 finished    ANN training loss 0.061617
>> Epoch 28 finished    ANN training loss 0.056188
>> Epoch 29 finished    ANN training loss 0.055571
>> Epoch 30 finished    ANN training loss 0.051942
>> Epoch 31 finished    ANN training loss 0.049073
>> Epoch 32 finished    ANN training loss 0.043022
>> Epoch 33 finished    ANN training loss 0.041094
>> Epoch 34 finished    ANN training loss 0.038909
>> Epoch 35 finished    ANN training loss 0.036306
>> Epoch 36 finished    ANN training loss 0.035280
>> Epoch 37 finished    ANN training loss 0.033102
>> Epoch 38 finished    ANN training loss 0.031871
```

```
              >> Epoch 39 finished    ANN training loss 0.029242
              >> Epoch 40 finished    ANN training loss 0.028371
              >> Epoch 41 finished    ANN training loss 0.026208
              >> Epoch 42 finished    ANN training loss 0.025588
              >> Epoch 43 finished    ANN training loss 0.024393
              >> Epoch 44 finished    ANN training loss 0.023542
              >> Epoch 45 finished    ANN training loss 0.023028
              >> Epoch 46 finished    ANN training loss 0.021649
              >> Epoch 47 finished    ANN training loss 0.020691
              >> Epoch 48 finished    ANN training loss 0.019979
              >> Epoch 49 finished    ANN training loss 0.018928
              >> Epoch 50 finished    ANN training loss 0.017665
              >> Epoch 51 finished    ANN training loss 0.017382
              >> Epoch 52 finished    ANN training loss 0.016298
              >> Epoch 53 finished    ANN training loss 0.015319
              >> Epoch 54 finished    ANN training loss 0.014617
              >> Epoch 55 finished    ANN training loss 0.014130
              >> Epoch 56 finished    ANN training loss 0.013414
              >> Epoch 57 finished    ANN training loss 0.013307
              >> Epoch 58 finished    ANN training loss 0.012758
              >> Epoch 59 finished    ANN training loss 0.012102
              >> Epoch 60 finished    ANN training loss 0.013135
              >> Epoch 61 finished    ANN training loss 0.011928
              >> Epoch 62 finished    ANN training loss 0.011289
              >> Epoch 63 finished    ANN training loss 0.010563
              >> Epoch 64 finished    ANN training loss 0.010779
              >> Epoch 65 finished    ANN training loss 0.010019
              >> Epoch 66 finished    ANN training loss 0.010024
              >> Epoch 67 finished    ANN training loss 0.009669
              >> Epoch 68 finished    ANN training loss 0.009116
              >> Epoch 69 finished    ANN training loss 0.008755
              >> Epoch 70 finished    ANN training loss 0.008667
              >> Epoch 71 finished    ANN training loss 0.008438
              >> Epoch 72 finished    ANN training loss 0.008046
              >> Epoch 73 finished    ANN training loss 0.007994
              >> Epoch 74 finished    ANN training loss 0.008057
              >> Epoch 75 finished    ANN training loss 0.007416
              >> Epoch 76 finished    ANN training loss 0.007250
              >> Epoch 77 finished    ANN training loss 0.007219
              >> Epoch 78 finished    ANN training loss 0.007242
              >> Epoch 79 finished    ANN training loss 0.007041
              >> Epoch 80 finished    ANN training loss 0.006762
              >> Epoch 81 finished    ANN training loss 0.006415
              >> Epoch 82 finished    ANN training loss 0.006224
              >> Epoch 83 finished    ANN training loss 0.006599
              >> Epoch 84 finished    ANN training loss 0.005863
              >> Epoch 85 finished    ANN training loss 0.006003
              >> Epoch 86 finished    ANN training loss 0.005592
              >> Epoch 87 finished    ANN training loss 0.005977
              >> Epoch 88 finished    ANN training loss 0.005370
              >> Epoch 89 finished    ANN training loss 0.005424
              >> Epoch 90 finished    ANN training loss 0.005224
              >> Epoch 91 finished    ANN training loss 0.004995
              >> Epoch 92 finished    ANN training loss 0.004827
              >> Epoch 93 finished    ANN training loss 0.004883
              >> Epoch 94 finished    ANN training loss 0.004543
              >> Epoch 95 finished    ANN training loss 0.004558
              >> Epoch 96 finished    ANN training loss 0.004311
              >> Epoch 97 finished    ANN training loss 0.004562
              >> Epoch 98 finished    ANN training loss 0.004251
              >> Epoch 99 finished    ANN training loss 0.004214
              [END] Fine tuning step
              Done.
              Accuracy: 0.925000
```

```
In [24]:    print('ACCURACY: ' + str(onelayer_acc[3]))
```

```
ACCURACY: 0.925
```

Setting 5

hidden_layers_structure=[500]

```
In [25]:    onelayer_acc[4] = deep_belief_net(hidden_layers_structure=[500])
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 56.192665
>> Epoch 2 finished      RBM Reconstruction error 49.764816
>> Epoch 3 finished      RBM Reconstruction error 39.970650
>> Epoch 4 finished      RBM Reconstruction error 47.955738
>> Epoch 5 finished      RBM Reconstruction error 38.048859
>> Epoch 6 finished      RBM Reconstruction error 36.557178
>> Epoch 7 finished      RBM Reconstruction error 22.669106
>> Epoch 8 finished      RBM Reconstruction error 48.748360
>> Epoch 9 finished      RBM Reconstruction error 57.597557
>> Epoch 10 finished     RBM Reconstruction error 32.826927
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.807150
>> Epoch 1 finished      ANN training loss 0.564415
>> Epoch 2 finished      ANN training loss 0.470352
>> Epoch 3 finished      ANN training loss 0.396800
>> Epoch 4 finished      ANN training loss 0.366528
>> Epoch 5 finished      ANN training loss 0.313878
>> Epoch 6 finished      ANN training loss 0.300360
>> Epoch 7 finished      ANN training loss 0.273658
>> Epoch 8 finished      ANN training loss 0.244247
>> Epoch 9 finished      ANN training loss 0.226939
>> Epoch 10 finished     ANN training loss 0.216623
>> Epoch 11 finished     ANN training loss 0.193205
>> Epoch 12 finished     ANN training loss 0.183846
>> Epoch 13 finished     ANN training loss 0.165159
>> Epoch 14 finished     ANN training loss 0.158479
>> Epoch 15 finished     ANN training loss 0.142269
>> Epoch 16 finished     ANN training loss 0.130295
>> Epoch 17 finished     ANN training loss 0.121850
>> Epoch 18 finished     ANN training loss 0.110316
>> Epoch 19 finished     ANN training loss 0.103539
>> Epoch 20 finished     ANN training loss 0.102060
>> Epoch 21 finished     ANN training loss 0.086728
>> Epoch 22 finished     ANN training loss 0.084157
>> Epoch 23 finished     ANN training loss 0.079235
>> Epoch 24 finished     ANN training loss 0.069335
>> Epoch 25 finished     ANN training loss 0.065721
>> Epoch 26 finished     ANN training loss 0.062261
>> Epoch 27 finished     ANN training loss 0.057246
>> Epoch 28 finished     ANN training loss 0.054196
>> Epoch 29 finished     ANN training loss 0.050689
>> Epoch 30 finished     ANN training loss 0.048315
>> Epoch 31 finished     ANN training loss 0.044980
>> Epoch 32 finished     ANN training loss 0.041336
>> Epoch 33 finished     ANN training loss 0.039494
>> Epoch 34 finished     ANN training loss 0.037713
>> Epoch 35 finished     ANN training loss 0.035863
>> Epoch 36 finished     ANN training loss 0.034670
>> Epoch 37 finished     ANN training loss 0.031809
>> Epoch 38 finished     ANN training loss 0.030921
```

```
>> Epoch 39 finished    ANN training loss 0.030657
>> Epoch 40 finished    ANN training loss 0.027944
>> Epoch 41 finished    ANN training loss 0.025821
>> Epoch 42 finished    ANN training loss 0.025341
>> Epoch 43 finished    ANN training loss 0.024332
>> Epoch 44 finished    ANN training loss 0.022425
>> Epoch 45 finished    ANN training loss 0.021186
>> Epoch 46 finished    ANN training loss 0.020227
>> Epoch 47 finished    ANN training loss 0.019697
>> Epoch 48 finished    ANN training loss 0.020635
>> Epoch 49 finished    ANN training loss 0.018131
>> Epoch 50 finished    ANN training loss 0.017273
>> Epoch 51 finished    ANN training loss 0.016298
>> Epoch 52 finished    ANN training loss 0.017280
>> Epoch 53 finished    ANN training loss 0.015914
>> Epoch 54 finished    ANN training loss 0.016130
>> Epoch 55 finished    ANN training loss 0.014796
>> Epoch 56 finished    ANN training loss 0.014006
>> Epoch 57 finished    ANN training loss 0.013298
>> Epoch 58 finished    ANN training loss 0.013001
>> Epoch 59 finished    ANN training loss 0.012679
>> Epoch 60 finished    ANN training loss 0.011761
>> Epoch 61 finished    ANN training loss 0.012224
>> Epoch 62 finished    ANN training loss 0.011151
>> Epoch 63 finished    ANN training loss 0.010751
>> Epoch 64 finished    ANN training loss 0.011168
>> Epoch 65 finished    ANN training loss 0.010703
>> Epoch 66 finished    ANN training loss 0.010149
>> Epoch 67 finished    ANN training loss 0.009659
>> Epoch 68 finished    ANN training loss 0.009157
>> Epoch 69 finished    ANN training loss 0.008897
>> Epoch 70 finished    ANN training loss 0.008683
>> Epoch 71 finished    ANN training loss 0.008385
>> Epoch 72 finished    ANN training loss 0.008611
>> Epoch 73 finished    ANN training loss 0.008355
>> Epoch 74 finished    ANN training loss 0.007766
>> Epoch 75 finished    ANN training loss 0.007492
>> Epoch 76 finished    ANN training loss 0.007223
>> Epoch 77 finished    ANN training loss 0.007085
>> Epoch 78 finished    ANN training loss 0.006592
>> Epoch 79 finished    ANN training loss 0.006890
>> Epoch 80 finished    ANN training loss 0.006434
>> Epoch 81 finished    ANN training loss 0.006338
>> Epoch 82 finished    ANN training loss 0.006357
>> Epoch 83 finished    ANN training loss 0.005957
>> Epoch 84 finished    ANN training loss 0.005783
>> Epoch 85 finished    ANN training loss 0.005643
>> Epoch 86 finished    ANN training loss 0.005788
>> Epoch 87 finished    ANN training loss 0.005514
>> Epoch 88 finished    ANN training loss 0.005403
>> Epoch 89 finished    ANN training loss 0.005462
>> Epoch 90 finished    ANN training loss 0.005035
>> Epoch 91 finished    ANN training loss 0.005009
>> Epoch 92 finished    ANN training loss 0.004970
>> Epoch 93 finished    ANN training loss 0.004813
>> Epoch 94 finished    ANN training loss 0.004701
>> Epoch 95 finished    ANN training loss 0.004578
>> Epoch 96 finished    ANN training loss 0.004513
>> Epoch 97 finished    ANN training loss 0.004193
>> Epoch 98 finished    ANN training loss 0.004197
>> Epoch 99 finished    ANN training loss 0.004290
[END] Fine tuning step
Done.
Accuracy: 0.920000
```

In [26]:
```python
print('ACCURACY: ' + str(onelayer_acc[4]))
```

```
ACCURACY: 0.92
```

In [27]:
```python
# Collated results
print(onelayer_acc)
print('Most accurate 1-layer setting is Setting ' + str(onelayer_acc.index(max
```
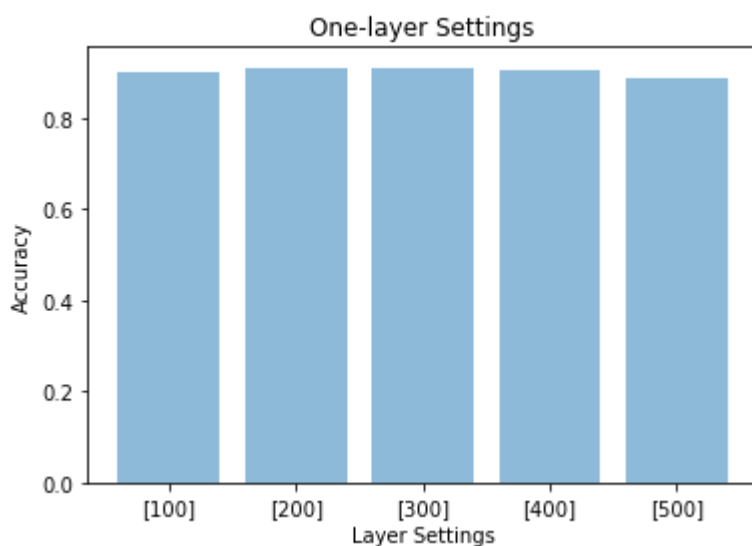
```
[0.91, 0.915, 0.91, 0.925, 0.92]
Most accurate 1-layer setting is Setting 4
```

In [28]:
```python
# Create bar graph
plt.clf()
objects = ('[100]', '[200]', '[300]', '[400]', '[500]')
y_pos = np.arange(len(objects))
performance = [0.9,0.91,0.91,0.905,0.885]

plt.bar(y_pos, performance, align='center', alpha=0.5)
plt.xticks(y_pos, objects)
plt.xlabel('Layer Settings')
plt.ylabel('Accuracy')
plt.title('One-layer Settings')

plt.show()
plt.clf()
```



```
<Figure size 432x288 with 0 Axes>
```

Different 2-layer structures

In [29]:
```python
# Store accuracies
twolayer_acc = [0, 0, 0, 0, 0, 0, 0, 0]
```

Testing layer_1=100 performance:

Setting 1 – (100) on 200

hidden_layers_structure=[100, 200]

In [30]:
```python
twolayer_acc[0] = deep_belief_net(hidden_layers_structure=[100, 200])
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 79.374649
>> Epoch 2 finished      RBM Reconstruction error 67.140266
>> Epoch 3 finished      RBM Reconstruction error 62.985001
>> Epoch 4 finished      RBM Reconstruction error 75.959839
>> Epoch 5 finished      RBM Reconstruction error 86.681122
>> Epoch 6 finished      RBM Reconstruction error 55.794071
>> Epoch 7 finished      RBM Reconstruction error 61.128662
>> Epoch 8 finished      RBM Reconstruction error 59.591640
>> Epoch 9 finished      RBM Reconstruction error 77.757370
>> Epoch 10 finished     RBM Reconstruction error 70.530952
>> Epoch 1 finished      RBM Reconstruction error 267.905792
>> Epoch 2 finished      RBM Reconstruction error 341.416626
>> Epoch 3 finished      RBM Reconstruction error 348.704132
>> Epoch 4 finished      RBM Reconstruction error 510.415222
>> Epoch 5 finished      RBM Reconstruction error 408.542725
>> Epoch 6 finished      RBM Reconstruction error 493.022064
>> Epoch 7 finished      RBM Reconstruction error 440.875000
>> Epoch 8 finished      RBM Reconstruction error 531.033386
>> Epoch 9 finished      RBM Reconstruction error 607.113220
>> Epoch 10 finished     RBM Reconstruction error 495.345459
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.678231
>> Epoch 1 finished      ANN training loss 0.534832
>> Epoch 2 finished      ANN training loss 0.413190
>> Epoch 3 finished      ANN training loss 0.367403
>> Epoch 4 finished      ANN training loss 0.308878
>> Epoch 5 finished      ANN training loss 0.268009
>> Epoch 6 finished      ANN training loss 0.262234
>> Epoch 7 finished      ANN training loss 0.237101
>> Epoch 8 finished      ANN training loss 0.212039
>> Epoch 9 finished      ANN training loss 0.182842
>> Epoch 10 finished     ANN training loss 0.165388
>> Epoch 11 finished     ANN training loss 0.150437
>> Epoch 12 finished     ANN training loss 0.136103
>> Epoch 13 finished     ANN training loss 0.133416
>> Epoch 14 finished     ANN training loss 0.115399
>> Epoch 15 finished     ANN training loss 0.116453
>> Epoch 16 finished     ANN training loss 0.096186
>> Epoch 17 finished     ANN training loss 0.090626
>> Epoch 18 finished     ANN training loss 0.080112
>> Epoch 19 finished     ANN training loss 0.070163
>> Epoch 20 finished     ANN training loss 0.065557
>> Epoch 21 finished     ANN training loss 0.064237
>> Epoch 22 finished     ANN training loss 0.058382
>> Epoch 23 finished     ANN training loss 0.052497
>> Epoch 24 finished     ANN training loss 0.046720
>> Epoch 25 finished     ANN training loss 0.044644
>> Epoch 26 finished     ANN training loss 0.046889
>> Epoch 27 finished     ANN training loss 0.035678
>> Epoch 28 finished     ANN training loss 0.036833
>> Epoch 29 finished     ANN training loss 0.037246
>> Epoch 30 finished     ANN training loss 0.030282
>> Epoch 31 finished     ANN training loss 0.027454
>> Epoch 32 finished     ANN training loss 0.023638
>> Epoch 33 finished     ANN training loss 0.027469
>> Epoch 34 finished     ANN training loss 0.022819
>> Epoch 35 finished     ANN training loss 0.024739
>> Epoch 36 finished     ANN training loss 0.025703
>> Epoch 37 finished     ANN training loss 0.018306
>> Epoch 38 finished     ANN training loss 0.018302
```

```
>> Epoch 39 finished     ANN training loss 0.017651
>> Epoch 40 finished     ANN training loss 0.015268
>> Epoch 41 finished     ANN training loss 0.013655
>> Epoch 42 finished     ANN training loss 0.013784
>> Epoch 43 finished     ANN training loss 0.012985
>> Epoch 44 finished     ANN training loss 0.013676
>> Epoch 45 finished     ANN training loss 0.010109
>> Epoch 46 finished     ANN training loss 0.011957
>> Epoch 47 finished     ANN training loss 0.010025
>> Epoch 48 finished     ANN training loss 0.010394
>> Epoch 49 finished     ANN training loss 0.010651
>> Epoch 50 finished     ANN training loss 0.009239
>> Epoch 51 finished     ANN training loss 0.009096
>> Epoch 52 finished     ANN training loss 0.008305
>> Epoch 53 finished     ANN training loss 0.007778
>> Epoch 54 finished     ANN training loss 0.007623
>> Epoch 55 finished     ANN training loss 0.008029
>> Epoch 56 finished     ANN training loss 0.006515
>> Epoch 57 finished     ANN training loss 0.007940
>> Epoch 58 finished     ANN training loss 0.007083
>> Epoch 59 finished     ANN training loss 0.006657
>> Epoch 60 finished     ANN training loss 0.005659
>> Epoch 61 finished     ANN training loss 0.005713
>> Epoch 62 finished     ANN training loss 0.005602
>> Epoch 63 finished     ANN training loss 0.004602
>> Epoch 64 finished     ANN training loss 0.004061
>> Epoch 65 finished     ANN training loss 0.004606
>> Epoch 66 finished     ANN training loss 0.003558
>> Epoch 67 finished     ANN training loss 0.004126
>> Epoch 68 finished     ANN training loss 0.004720
>> Epoch 69 finished     ANN training loss 0.003774
>> Epoch 70 finished     ANN training loss 0.003213
>> Epoch 71 finished     ANN training loss 0.004063
>> Epoch 72 finished     ANN training loss 0.004298
>> Epoch 73 finished     ANN training loss 0.003465
>> Epoch 74 finished     ANN training loss 0.003252
>> Epoch 75 finished     ANN training loss 0.004233
>> Epoch 76 finished     ANN training loss 0.003266
>> Epoch 77 finished     ANN training loss 0.002727
>> Epoch 78 finished     ANN training loss 0.002284
>> Epoch 79 finished     ANN training loss 0.002393
>> Epoch 80 finished     ANN training loss 0.003297
>> Epoch 81 finished     ANN training loss 0.002788
>> Epoch 82 finished     ANN training loss 0.002249
>> Epoch 83 finished     ANN training loss 0.002132
>> Epoch 84 finished     ANN training loss 0.002154
>> Epoch 85 finished     ANN training loss 0.002170
>> Epoch 86 finished     ANN training loss 0.001731
>> Epoch 87 finished     ANN training loss 0.001930
>> Epoch 88 finished     ANN training loss 0.001708
>> Epoch 89 finished     ANN training loss 0.001665
>> Epoch 90 finished     ANN training loss 0.001693
>> Epoch 91 finished     ANN training loss 0.001914
>> Epoch 92 finished     ANN training loss 0.002027
>> Epoch 93 finished     ANN training loss 0.001719
>> Epoch 94 finished     ANN training loss 0.001769
>> Epoch 95 finished     ANN training loss 0.001749
>> Epoch 96 finished     ANN training loss 0.001628
>> Epoch 97 finished     ANN training loss 0.001885
>> Epoch 98 finished     ANN training loss 0.001687
>> Epoch 99 finished     ANN training loss 0.001623
[END] Fine tuning step
Done.
```

In [31]:
```python
print('ACCURACY: ' + str(twolayer_acc[0]))
```

ACCURACY: 0.915

Setting 2 – (100) on 500

hidden_layers_structure=[100, 500]

In [32]:
```python
twolayer_acc[1] = deep_belief_net(hidden_layers_structure=[100, 500])
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 46.900723
>> Epoch 2 finished      RBM Reconstruction error 58.844337
>> Epoch 3 finished      RBM Reconstruction error 43.177505
>> Epoch 4 finished      RBM Reconstruction error 51.222061
>> Epoch 5 finished      RBM Reconstruction error 61.009644
>> Epoch 6 finished      RBM Reconstruction error 48.352509
>> Epoch 7 finished      RBM Reconstruction error 56.135422
>> Epoch 8 finished      RBM Reconstruction error 62.211838
>> Epoch 9 finished      RBM Reconstruction error 54.295658
>> Epoch 10 finished     RBM Reconstruction error 60.772980
>> Epoch 1 finished      RBM Reconstruction error 267.859772
>> Epoch 2 finished      RBM Reconstruction error 225.061951
>> Epoch 3 finished      RBM Reconstruction error 188.880936
>> Epoch 4 finished      RBM Reconstruction error 295.289886
>> Epoch 5 finished      RBM Reconstruction error 238.730621
>> Epoch 6 finished      RBM Reconstruction error 196.554642
>> Epoch 7 finished      RBM Reconstruction error 390.598724
>> Epoch 8 finished      RBM Reconstruction error 300.621643
>> Epoch 9 finished      RBM Reconstruction error 192.369415
>> Epoch 10 finished     RBM Reconstruction error 241.131882
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.655090
>> Epoch 1 finished      ANN training loss 0.519671
>> Epoch 2 finished      ANN training loss 0.424776
>> Epoch 3 finished      ANN training loss 0.344556
>> Epoch 4 finished      ANN training loss 0.294002
>> Epoch 5 finished      ANN training loss 0.259555
>> Epoch 6 finished      ANN training loss 0.227636
>> Epoch 7 finished      ANN training loss 0.226134
>> Epoch 8 finished      ANN training loss 0.192655
>> Epoch 9 finished      ANN training loss 0.170256
>> Epoch 10 finished     ANN training loss 0.151603
>> Epoch 11 finished     ANN training loss 0.148299
>> Epoch 12 finished     ANN training loss 0.130624
>> Epoch 13 finished     ANN training loss 0.122690
>> Epoch 14 finished     ANN training loss 0.105357
>> Epoch 15 finished     ANN training loss 0.094765
>> Epoch 16 finished     ANN training loss 0.091541
>> Epoch 17 finished     ANN training loss 0.078635
>> Epoch 18 finished     ANN training loss 0.075306
>> Epoch 19 finished     ANN training loss 0.069898
>> Epoch 20 finished     ANN training loss 0.060313
>> Epoch 21 finished     ANN training loss 0.058699
>> Epoch 22 finished     ANN training loss 0.059849
>> Epoch 23 finished     ANN training loss 0.047306
>> Epoch 24 finished     ANN training loss 0.040965
>> Epoch 25 finished     ANN training loss 0.044648
>> Epoch 26 finished     ANN training loss 0.039472
>> Epoch 27 finished     ANN training loss 0.035901
>> Epoch 28 finished     ANN training loss 0.035944
```

```
>> Epoch 29 finished      ANN training loss 0.027704
>> Epoch 30 finished      ANN training loss 0.028995
>> Epoch 31 finished      ANN training loss 0.029808
>> Epoch 32 finished      ANN training loss 0.027962
>> Epoch 33 finished      ANN training loss 0.024353
>> Epoch 34 finished      ANN training loss 0.023927
>> Epoch 35 finished      ANN training loss 0.022628
>> Epoch 36 finished      ANN training loss 0.021696
>> Epoch 37 finished      ANN training loss 0.018049
>> Epoch 38 finished      ANN training loss 0.016429
>> Epoch 39 finished      ANN training loss 0.015042
>> Epoch 40 finished      ANN training loss 0.015295
>> Epoch 41 finished      ANN training loss 0.013337
>> Epoch 42 finished      ANN training loss 0.012755
>> Epoch 43 finished      ANN training loss 0.012167
>> Epoch 44 finished      ANN training loss 0.011956
>> Epoch 45 finished      ANN training loss 0.010398
>> Epoch 46 finished      ANN training loss 0.010038
>> Epoch 47 finished      ANN training loss 0.010485
>> Epoch 48 finished      ANN training loss 0.010167
>> Epoch 49 finished      ANN training loss 0.009580
>> Epoch 50 finished      ANN training loss 0.008789
>> Epoch 51 finished      ANN training loss 0.008090
>> Epoch 52 finished      ANN training loss 0.007969
>> Epoch 53 finished      ANN training loss 0.007156
>> Epoch 54 finished      ANN training loss 0.006996
>> Epoch 55 finished      ANN training loss 0.006067
>> Epoch 56 finished      ANN training loss 0.005709
>> Epoch 57 finished      ANN training loss 0.006361
>> Epoch 58 finished      ANN training loss 0.005719
>> Epoch 59 finished      ANN training loss 0.005650
>> Epoch 60 finished      ANN training loss 0.005276
>> Epoch 61 finished      ANN training loss 0.006485
>> Epoch 62 finished      ANN training loss 0.006583
>> Epoch 63 finished      ANN training loss 0.004637
>> Epoch 64 finished      ANN training loss 0.004141
>> Epoch 65 finished      ANN training loss 0.004181
>> Epoch 66 finished      ANN training loss 0.004513
>> Epoch 67 finished      ANN training loss 0.003850
>> Epoch 68 finished      ANN training loss 0.004143
>> Epoch 69 finished      ANN training loss 0.004499
>> Epoch 70 finished      ANN training loss 0.003854
>> Epoch 71 finished      ANN training loss 0.004295
>> Epoch 72 finished      ANN training loss 0.003509
>> Epoch 73 finished      ANN training loss 0.003128
>> Epoch 74 finished      ANN training loss 0.003751
>> Epoch 75 finished      ANN training loss 0.003114
>> Epoch 76 finished      ANN training loss 0.003320
>> Epoch 77 finished      ANN training loss 0.004103
>> Epoch 78 finished      ANN training loss 0.003369
>> Epoch 79 finished      ANN training loss 0.003081
>> Epoch 80 finished      ANN training loss 0.003164
>> Epoch 81 finished      ANN training loss 0.002609
>> Epoch 82 finished      ANN training loss 0.003658
>> Epoch 83 finished      ANN training loss 0.002517
>> Epoch 84 finished      ANN training loss 0.002544
>> Epoch 85 finished      ANN training loss 0.002970
>> Epoch 86 finished      ANN training loss 0.002467
>> Epoch 87 finished      ANN training loss 0.002379
>> Epoch 88 finished      ANN training loss 0.002195
>> Epoch 89 finished      ANN training loss 0.002379
>> Epoch 90 finished      ANN training loss 0.002187
>> Epoch 91 finished      ANN training loss 0.002067
>> Epoch 92 finished      ANN training loss 0.001939
>> Epoch 93 finished      ANN training loss 0.001989
```

```
>> Epoch 94 finished      ANN training loss 0.002001
>> Epoch 95 finished      ANN training loss 0.001831
>> Epoch 96 finished      ANN training loss 0.001825
>> Epoch 97 finished      ANN training loss 0.001718
>> Epoch 98 finished      ANN training loss 0.001775
>> Epoch 99 finished      ANN training loss 0.001570
[END] Fine tuning step
Done
```

In [34]:
```python
print('ACCURACY: ' + str(twolayer_acc[1]))
```

```
ACCURACY: 0.915
```

Testing layer_1=500 performance:

Setting 3 – (500) on 200

hidden_layers_structure=[500, 200]

In [35]:
```python
twolayer_acc[2] = deep_belief_net(hidden_layers_structure=[500, 200])
```

```
[START] Pre-training step:
>> Epoch 1 finished       RBM Reconstruction error 66.616905
>> Epoch 2 finished       RBM Reconstruction error 41.794498
>> Epoch 3 finished       RBM Reconstruction error 40.064198
>> Epoch 4 finished       RBM Reconstruction error 49.759266
>> Epoch 5 finished       RBM Reconstruction error 45.772545
>> Epoch 6 finished       RBM Reconstruction error 51.655350
>> Epoch 7 finished       RBM Reconstruction error 34.008072
>> Epoch 8 finished       RBM Reconstruction error 40.369316
>> Epoch 9 finished       RBM Reconstruction error 47.192348
>> Epoch 10 finished      RBM Reconstruction error 32.536373
>> Epoch 1 finished       RBM Reconstruction error 139.700043
>> Epoch 2 finished       RBM Reconstruction error 139.479324
>> Epoch 3 finished       RBM Reconstruction error 154.507370
>> Epoch 4 finished       RBM Reconstruction error 149.979294
>> Epoch 5 finished       RBM Reconstruction error 177.211273
>> Epoch 6 finished       RBM Reconstruction error 171.639984
>> Epoch 7 finished       RBM Reconstruction error 284.741333
>> Epoch 8 finished       RBM Reconstruction error 255.479370
>> Epoch 9 finished       RBM Reconstruction error 256.613159
>> Epoch 10 finished      RBM Reconstruction error 259.745453
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished       ANN training loss 0.657874
>> Epoch 1 finished       ANN training loss 0.490750
>> Epoch 2 finished       ANN training loss 0.418871
>> Epoch 3 finished       ANN training loss 0.371595
>> Epoch 4 finished       ANN training loss 0.303596
>> Epoch 5 finished       ANN training loss 0.254828
>> Epoch 6 finished       ANN training loss 0.228769
>> Epoch 7 finished       ANN training loss 0.190201
>> Epoch 8 finished       ANN training loss 0.183969
>> Epoch 9 finished       ANN training loss 0.174994
>> Epoch 10 finished      ANN training loss 0.137839
>> Epoch 11 finished      ANN training loss 0.135722
>> Epoch 12 finished      ANN training loss 0.112763
>> Epoch 13 finished      ANN training loss 0.107191
>> Epoch 14 finished      ANN training loss 0.100026
>> Epoch 15 finished      ANN training loss 0.081416
>> Epoch 16 finished      ANN training loss 0.081809
>> Epoch 17 finished      ANN training loss 0.070781
>> Epoch 18 finished      ANN training loss 0.064466
```

```
>> Epoch 19 finished    ANN training loss 0.060430
>> Epoch 20 finished    ANN training loss 0.056110
>> Epoch 21 finished    ANN training loss 0.049476
>> Epoch 22 finished    ANN training loss 0.048510
>> Epoch 23 finished    ANN training loss 0.040786
>> Epoch 24 finished    ANN training loss 0.038424
>> Epoch 25 finished    ANN training loss 0.036943
>> Epoch 26 finished    ANN training loss 0.033430
>> Epoch 27 finished    ANN training loss 0.027127
>> Epoch 28 finished    ANN training loss 0.029400
>> Epoch 29 finished    ANN training loss 0.026401
>> Epoch 30 finished    ANN training loss 0.023717
>> Epoch 31 finished    ANN training loss 0.022168
>> Epoch 32 finished    ANN training loss 0.022820
>> Epoch 33 finished    ANN training loss 0.021149
>> Epoch 34 finished    ANN training loss 0.020552
>> Epoch 35 finished    ANN training loss 0.015224
>> Epoch 36 finished    ANN training loss 0.019159
>> Epoch 37 finished    ANN training loss 0.014946
>> Epoch 38 finished    ANN training loss 0.015595
>> Epoch 39 finished    ANN training loss 0.012482
>> Epoch 40 finished    ANN training loss 0.012273
>> Epoch 41 finished    ANN training loss 0.011136
>> Epoch 42 finished    ANN training loss 0.011097
>> Epoch 43 finished    ANN training loss 0.010602
>> Epoch 44 finished    ANN training loss 0.008973
>> Epoch 45 finished    ANN training loss 0.008432
>> Epoch 46 finished    ANN training loss 0.008714
>> Epoch 47 finished    ANN training loss 0.008342
>> Epoch 48 finished    ANN training loss 0.008721
>> Epoch 49 finished    ANN training loss 0.007404
>> Epoch 50 finished    ANN training loss 0.008252
>> Epoch 51 finished    ANN training loss 0.006198
>> Epoch 52 finished    ANN training loss 0.006139
>> Epoch 53 finished    ANN training loss 0.006267
>> Epoch 54 finished    ANN training loss 0.005249
>> Epoch 55 finished    ANN training loss 0.005675
>> Epoch 56 finished    ANN training loss 0.007387
>> Epoch 57 finished    ANN training loss 0.005238
>> Epoch 58 finished    ANN training loss 0.005009
>> Epoch 59 finished    ANN training loss 0.004082
>> Epoch 60 finished    ANN training loss 0.004925
>> Epoch 61 finished    ANN training loss 0.004018
>> Epoch 62 finished    ANN training loss 0.003953
>> Epoch 63 finished    ANN training loss 0.004372
>> Epoch 64 finished    ANN training loss 0.003574
>> Epoch 65 finished    ANN training loss 0.003137
>> Epoch 66 finished    ANN training loss 0.003196
>> Epoch 67 finished    ANN training loss 0.003031
>> Epoch 68 finished    ANN training loss 0.002775
>> Epoch 69 finished    ANN training loss 0.003340
>> Epoch 70 finished    ANN training loss 0.002560
>> Epoch 71 finished    ANN training loss 0.002965
>> Epoch 72 finished    ANN training loss 0.002645
>> Epoch 73 finished    ANN training loss 0.003353
>> Epoch 74 finished    ANN training loss 0.002821
>> Epoch 75 finished    ANN training loss 0.002891
>> Epoch 76 finished    ANN training loss 0.002221
>> Epoch 77 finished    ANN training loss 0.001979
>> Epoch 78 finished    ANN training loss 0.002301
>> Epoch 79 finished    ANN training loss 0.001860
>> Epoch 80 finished    ANN training loss 0.001911
>> Epoch 81 finished    ANN training loss 0.001802
>> Epoch 82 finished    ANN training loss 0.001864
>> Epoch 83 finished    ANN training loss 0.001685
```

```
>> Epoch 84 finished     ANN training loss 0.001816
>> Epoch 85 finished     ANN training loss 0.001712
>> Epoch 86 finished     ANN training loss 0.001780
>> Epoch 87 finished     ANN training loss 0.001511
>> Epoch 88 finished     ANN training loss 0.001829
>> Epoch 89 finished     ANN training loss 0.001786
>> Epoch 90 finished     ANN training loss 0.001788
>> Epoch 91 finished     ANN training loss 0.001396
>> Epoch 92 finished     ANN training loss 0.001532
>> Epoch 93 finished     ANN training loss 0.001492
>> Epoch 94 finished     ANN training loss 0.001431
>> Epoch 95 finished     ANN training loss 0.001299
>> Epoch 96 finished     ANN training loss 0.001569
>> Epoch 97 finished     ANN training loss 0.001452
>> Epoch 98 finished     ANN training loss 0.001459
>> Epoch 99 finished     ANN training loss 0.001264
[END] Fine tuning step
Done.
```

In [36]:
```python
print('ACCURACY: ' + str(twolayer_acc[2]))
```

```
ACCURACY: 0.92
```

Setting 4 – (500) on 500

hidden_layers_structure=[500, 500]

In [37]:
```python
twolayer_acc[3] = deep_belief_net(hidden_layers_structure=[500, 500])
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 71.661751
>> Epoch 2 finished     RBM Reconstruction error 57.248215
>> Epoch 3 finished     RBM Reconstruction error 51.039303
>> Epoch 4 finished     RBM Reconstruction error 36.137207
>> Epoch 5 finished     RBM Reconstruction error 37.001850
>> Epoch 6 finished     RBM Reconstruction error 32.274765
>> Epoch 7 finished     RBM Reconstruction error 41.225483
>> Epoch 8 finished     RBM Reconstruction error 27.219765
>> Epoch 9 finished     RBM Reconstruction error 45.696922
>> Epoch 10 finished    RBM Reconstruction error 38.599415
>> Epoch 1 finished     RBM Reconstruction error 124.731964
>> Epoch 2 finished     RBM Reconstruction error 75.605820
>> Epoch 3 finished     RBM Reconstruction error 180.343048
>> Epoch 4 finished     RBM Reconstruction error 186.135315
>> Epoch 5 finished     RBM Reconstruction error 172.192368
>> Epoch 6 finished     RBM Reconstruction error 125.186134
>> Epoch 7 finished     RBM Reconstruction error 184.999771
>> Epoch 8 finished     RBM Reconstruction error 188.884750
>> Epoch 9 finished     RBM Reconstruction error 131.298843
>> Epoch 10 finished    RBM Reconstruction error 148.734741
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.660491
>> Epoch 1 finished     ANN training loss 0.489562
>> Epoch 2 finished     ANN training loss 0.392955
>> Epoch 3 finished     ANN training loss 0.367938
>> Epoch 4 finished     ANN training loss 0.293265
>> Epoch 5 finished     ANN training loss 0.250625
>> Epoch 6 finished     ANN training loss 0.210597
>> Epoch 7 finished     ANN training loss 0.181460
>> Epoch 8 finished     ANN training loss 0.167114
>> Epoch 9 finished     ANN training loss 0.160760
>> Epoch 10 finished    ANN training loss 0.132280
```

```
>> Epoch 11 finished     ANN training loss 0.110675
>> Epoch 12 finished     ANN training loss 0.104748
>> Epoch 13 finished     ANN training loss 0.096836
>> Epoch 14 finished     ANN training loss 0.084379
>> Epoch 15 finished     ANN training loss 0.092434
>> Epoch 16 finished     ANN training loss 0.072570
>> Epoch 17 finished     ANN training loss 0.061137
>> Epoch 18 finished     ANN training loss 0.071292
>> Epoch 19 finished     ANN training loss 0.052609
>> Epoch 20 finished     ANN training loss 0.052656
>> Epoch 21 finished     ANN training loss 0.040762
>> Epoch 22 finished     ANN training loss 0.047511
>> Epoch 23 finished     ANN training loss 0.034841
>> Epoch 24 finished     ANN training loss 0.029626
>> Epoch 25 finished     ANN training loss 0.029027
>> Epoch 26 finished     ANN training loss 0.027281
>> Epoch 27 finished     ANN training loss 0.031472
>> Epoch 28 finished     ANN training loss 0.022944
>> Epoch 29 finished     ANN training loss 0.022094
>> Epoch 30 finished     ANN training loss 0.021607
>> Epoch 31 finished     ANN training loss 0.018819
>> Epoch 32 finished     ANN training loss 0.018088
>> Epoch 33 finished     ANN training loss 0.015578
>> Epoch 34 finished     ANN training loss 0.014821
>> Epoch 35 finished     ANN training loss 0.014754
>> Epoch 36 finished     ANN training loss 0.013215
>> Epoch 37 finished     ANN training loss 0.013180
>> Epoch 38 finished     ANN training loss 0.012334
>> Epoch 39 finished     ANN training loss 0.011340
>> Epoch 40 finished     ANN training loss 0.010903
>> Epoch 41 finished     ANN training loss 0.009551
>> Epoch 42 finished     ANN training loss 0.009597
>> Epoch 43 finished     ANN training loss 0.008119
>> Epoch 44 finished     ANN training loss 0.007534
>> Epoch 45 finished     ANN training loss 0.007236
>> Epoch 46 finished     ANN training loss 0.008007
>> Epoch 47 finished     ANN training loss 0.007704
>> Epoch 48 finished     ANN training loss 0.007291
>> Epoch 49 finished     ANN training loss 0.006352
>> Epoch 50 finished     ANN training loss 0.006105
>> Epoch 51 finished     ANN training loss 0.006388
>> Epoch 52 finished     ANN training loss 0.005272
>> Epoch 53 finished     ANN training loss 0.005689
>> Epoch 54 finished     ANN training loss 0.005405
>> Epoch 55 finished     ANN training loss 0.004688
>> Epoch 56 finished     ANN training loss 0.004148
>> Epoch 57 finished     ANN training loss 0.004590
>> Epoch 58 finished     ANN training loss 0.004238
>> Epoch 59 finished     ANN training loss 0.004169
>> Epoch 60 finished     ANN training loss 0.003835
>> Epoch 61 finished     ANN training loss 0.003647
>> Epoch 62 finished     ANN training loss 0.003732
>> Epoch 63 finished     ANN training loss 0.003312
>> Epoch 64 finished     ANN training loss 0.003365
>> Epoch 65 finished     ANN training loss 0.003090
>> Epoch 66 finished     ANN training loss 0.003446
>> Epoch 67 finished     ANN training loss 0.002781
>> Epoch 68 finished     ANN training loss 0.003004
>> Epoch 69 finished     ANN training loss 0.003034
>> Epoch 70 finished     ANN training loss 0.002909
>> Epoch 71 finished     ANN training loss 0.002802
>> Epoch 72 finished     ANN training loss 0.002567
>> Epoch 73 finished     ANN training loss 0.002420
>> Epoch 74 finished     ANN training loss 0.002339
>> Epoch 75 finished     ANN training loss 0.002678
```

```
>> Epoch 76 finished    ANN training loss 0.002441
>> Epoch 77 finished    ANN training loss 0.002296
>> Epoch 78 finished    ANN training loss 0.002319
>> Epoch 79 finished    ANN training loss 0.002183
>> Epoch 80 finished    ANN training loss 0.002513
>> Epoch 81 finished    ANN training loss 0.001895
>> Epoch 82 finished    ANN training loss 0.002353
>> Epoch 83 finished    ANN training loss 0.001722
>> Epoch 84 finished    ANN training loss 0.001619
>> Epoch 85 finished    ANN training loss 0.001785
>> Epoch 86 finished    ANN training loss 0.001882
>> Epoch 87 finished    ANN training loss 0.001897
>> Epoch 88 finished    ANN training loss 0.001458
>> Epoch 89 finished    ANN training loss 0.001540
>> Epoch 90 finished    ANN training loss 0.001412
>> Epoch 91 finished    ANN training loss 0.001483
>> Epoch 92 finished    ANN training loss 0.001313
>> Epoch 93 finished    ANN training loss 0.001155
>> Epoch 94 finished    ANN training loss 0.001166
>> Epoch 95 finished    ANN training loss 0.001079
>> Epoch 96 finished    ANN training loss 0.001114
>> Epoch 97 finished    ANN training loss 0.000990
>> Epoch 98 finished    ANN training loss 0.001224
>> Epoch 99 finished    ANN training loss 0.001181
[END] Fine tuning step
Done.
```

In [38]:
```python
print('ACCURACY: ' + str(twolayer_acc[3]))
```

```
ACCURACY: 0.93
```

In [39]:
```python
# Collated results
print(twolayer_acc)
print('Most accurate 2-layer setting is Setting ' + str(twolayer_acc.index(ma:
```

```
[0.915, 0.915, 0.92, 0.93, 0, 0, 0, 0]
Most accurate 2-layer setting is Setting 4
```

In [40]:
```python
# Create bar graph
plt.clf()
objects = ('[100, 200]', '[100, 500]', '[500, 200]', '[500, 500]')
y_pos = np.arange(len(objects))
performance = [0.905,0.92,0.89,0.89]

plt.bar(y_pos, performance, align='center', alpha=0.5)
plt.xticks(y_pos, objects)
plt.xlabel('Layer Settings')
plt.ylabel('Accuracy')
plt.title('Two-layer Settings')

plt.show()
plt.clf()
```

Two-layer Settings

```
<Figure size 432x288 with 0 Axes>
```
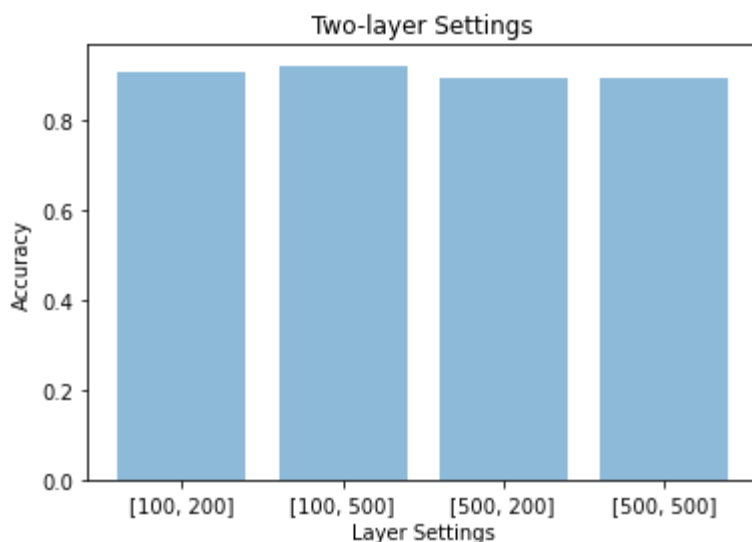
Different 3-layer structures

In [41]:
```
# Store accuracies
threelayer_acc = [0, 0, 0, 0, 0, 0, 0]
```

Setting 1 – Baseline

hidden_layers_structure=[100, 200, 300]

In [44]:
```
threelayer_acc[0] = deep_belief_net(hidden_layers_structure=[100, 200, 300])
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 69.211891
>> Epoch 2 finished      RBM Reconstruction error 54.715435
>> Epoch 3 finished      RBM Reconstruction error 65.167702
>> Epoch 4 finished      RBM Reconstruction error 84.242981
>> Epoch 5 finished      RBM Reconstruction error 57.315968
>> Epoch 6 finished      RBM Reconstruction error 100.032951
>> Epoch 7 finished      RBM Reconstruction error 93.880310
>> Epoch 8 finished      RBM Reconstruction error 126.621506
>> Epoch 9 finished      RBM Reconstruction error 103.421570
>> Epoch 10 finished     RBM Reconstruction error 102.365608
>> Epoch 1 finished      RBM Reconstruction error 346.209290
>> Epoch 2 finished      RBM Reconstruction error 374.893646
>> Epoch 3 finished      RBM Reconstruction error 491.747742
>> Epoch 4 finished      RBM Reconstruction error 729.175598
>> Epoch 5 finished      RBM Reconstruction error 617.200256
>> Epoch 6 finished      RBM Reconstruction error 800.803772
>> Epoch 7 finished      RBM Reconstruction error 777.229614
>> Epoch 8 finished      RBM Reconstruction error 772.667480
>> Epoch 9 finished      RBM Reconstruction error 727.426392
>> Epoch 10 finished     RBM Reconstruction error 745.967529
>> Epoch 1 finished      RBM Reconstruction error 11459.107422
>> Epoch 2 finished      RBM Reconstruction error 18461.373047
>> Epoch 3 finished      RBM Reconstruction error 36919.609375
>> Epoch 4 finished      RBM Reconstruction error 50508.015625
>> Epoch 5 finished      RBM Reconstruction error 50366.011719
>> Epoch 6 finished      RBM Reconstruction error 55213.621094
>> Epoch 7 finished      RBM Reconstruction error 70355.671875
```

```
>> Epoch 8 finished      RBM Reconstruction error 71196.914062
>> Epoch 9 finished      RBM Reconstruction error 75190.921875
>> Epoch 10 finished     RBM Reconstruction error 81700.390625
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 1.580584
>> Epoch 1 finished      ANN training loss 1.194760
>> Epoch 2 finished      ANN training loss 0.925701
>> Epoch 3 finished      ANN training loss 0.783431
>> Epoch 4 finished      ANN training loss 0.678023
>> Epoch 5 finished      ANN training loss 0.565544
>> Epoch 6 finished      ANN training loss 0.499443
>> Epoch 7 finished      ANN training loss 0.440925
>> Epoch 8 finished      ANN training loss 0.374729
>> Epoch 9 finished      ANN training loss 0.324563
>> Epoch 10 finished     ANN training loss 0.286204
>> Epoch 11 finished     ANN training loss 0.260415
>> Epoch 12 finished     ANN training loss 0.257141
>> Epoch 13 finished     ANN training loss 0.244947
>> Epoch 14 finished     ANN training loss 0.219555
>> Epoch 15 finished     ANN training loss 0.179129
>> Epoch 16 finished     ANN training loss 0.210747
>> Epoch 17 finished     ANN training loss 0.179460
>> Epoch 18 finished     ANN training loss 0.154251
>> Epoch 19 finished     ANN training loss 0.167423
>> Epoch 20 finished     ANN training loss 0.122682
>> Epoch 21 finished     ANN training loss 0.119368
>> Epoch 22 finished     ANN training loss 0.122256
>> Epoch 23 finished     ANN training loss 0.090236
>> Epoch 24 finished     ANN training loss 0.090379
>> Epoch 25 finished     ANN training loss 0.093834
>> Epoch 26 finished     ANN training loss 0.066902
>> Epoch 27 finished     ANN training loss 0.067678
>> Epoch 28 finished     ANN training loss 0.058022
>> Epoch 29 finished     ANN training loss 0.053510
>> Epoch 30 finished     ANN training loss 0.059847
>> Epoch 31 finished     ANN training loss 0.050838
>> Epoch 32 finished     ANN training loss 0.053311
>> Epoch 33 finished     ANN training loss 0.046493
>> Epoch 34 finished     ANN training loss 0.054898
>> Epoch 35 finished     ANN training loss 0.034509
>> Epoch 36 finished     ANN training loss 0.045126
>> Epoch 37 finished     ANN training loss 0.038577
>> Epoch 38 finished     ANN training loss 0.037325
>> Epoch 39 finished     ANN training loss 0.048366
>> Epoch 40 finished     ANN training loss 0.025499
>> Epoch 41 finished     ANN training loss 0.030443
>> Epoch 42 finished     ANN training loss 0.029826
>> Epoch 43 finished     ANN training loss 0.026014
>> Epoch 44 finished     ANN training loss 0.025371
>> Epoch 45 finished     ANN training loss 0.022160
>> Epoch 46 finished     ANN training loss 0.020218
>> Epoch 47 finished     ANN training loss 0.031927
>> Epoch 48 finished     ANN training loss 0.021658
>> Epoch 49 finished     ANN training loss 0.020687
>> Epoch 50 finished     ANN training loss 0.028883
>> Epoch 51 finished     ANN training loss 0.025723
>> Epoch 52 finished     ANN training loss 0.023819
>> Epoch 53 finished     ANN training loss 0.019441
>> Epoch 54 finished     ANN training loss 0.020782
>> Epoch 55 finished     ANN training loss 0.023676
>> Epoch 56 finished     ANN training loss 0.024203
>> Epoch 57 finished     ANN training loss 0.017896
>> Epoch 58 finished     ANN training loss 0.017443
>> Epoch 59 finished     ANN training loss 0.011332
```

```
>> Epoch 60 finished     ANN training loss 0.011712
>> Epoch 61 finished     ANN training loss 0.013364
>> Epoch 62 finished     ANN training loss 0.012547
>> Epoch 63 finished     ANN training loss 0.012622
>> Epoch 64 finished     ANN training loss 0.013190
>> Epoch 65 finished     ANN training loss 0.012341
>> Epoch 66 finished     ANN training loss 0.016282
>> Epoch 67 finished     ANN training loss 0.010343
>> Epoch 68 finished     ANN training loss 0.009073
>> Epoch 69 finished     ANN training loss 0.009885
>> Epoch 70 finished     ANN training loss 0.009054
>> Epoch 71 finished     ANN training loss 0.008841
>> Epoch 72 finished     ANN training loss 0.009537
>> Epoch 73 finished     ANN training loss 0.012629
>> Epoch 74 finished     ANN training loss 0.012985
>> Epoch 75 finished     ANN training loss 0.011929
>> Epoch 76 finished     ANN training loss 0.010100
>> Epoch 77 finished     ANN training loss 0.005749
>> Epoch 78 finished     ANN training loss 0.010081
>> Epoch 79 finished     ANN training loss 0.005840
>> Epoch 80 finished     ANN training loss 0.007349
>> Epoch 81 finished     ANN training loss 0.005691
>> Epoch 82 finished     ANN training loss 0.004833
>> Epoch 83 finished     ANN training loss 0.005270
>> Epoch 84 finished     ANN training loss 0.005854
>> Epoch 85 finished     ANN training loss 0.008042
>> Epoch 86 finished     ANN training loss 0.004677
>> Epoch 87 finished     ANN training loss 0.006828
>> Epoch 88 finished     ANN training loss 0.006649
>> Epoch 89 finished     ANN training loss 0.005791
>> Epoch 90 finished     ANN training loss 0.007586
>> Epoch 91 finished     ANN training loss 0.007884
>> Epoch 92 finished     ANN training loss 0.009073
>> Epoch 93 finished     ANN training loss 0.007698
>> Epoch 94 finished     ANN training loss 0.005238
>> Epoch 95 finished     ANN training loss 0.005730
>> Epoch 96 finished     ANN training loss 0.006825
>> Epoch 97 finished     ANN training loss 0.004438
>> Epoch 98 finished     ANN training loss 0.004480
>> Epoch 99 finished     ANN training loss 0.005031
[END] Fine tuning step
Done.
```

In [45]:
```python
print('ACCURACY: ' + str(threelayer_acc[0]))
```

```
ACCURACY: 0.905
```

Setting 2 – 1st Layer = 500

hidden_layers_structure=[500, 200, 300]

In [46]:
```python
threelayer_acc[1] = deep_belief_net(hidden_layers_structure=[500, 200, 300])
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 64.890564
>> Epoch 2 finished     RBM Reconstruction error 64.352226
>> Epoch 3 finished     RBM Reconstruction error 66.013908
>> Epoch 4 finished     RBM Reconstruction error 43.504204
>> Epoch 5 finished     RBM Reconstruction error 37.202518
>> Epoch 6 finished     RBM Reconstruction error 34.903088
>> Epoch 7 finished     RBM Reconstruction error 32.947681
>> Epoch 8 finished     RBM Reconstruction error 32.995579
>> Epoch 9 finished     RBM Reconstruction error 38.589195
```

```
                 >> Epoch 10 finished     RBM Reconstruction error 53.157158
                 >> Epoch 1 finished      RBM Reconstruction error 265.494537
                 >> Epoch 2 finished      RBM Reconstruction error 293.698242
                 >> Epoch 3 finished      RBM Reconstruction error 319.521240
                 >> Epoch 4 finished      RBM Reconstruction error 491.695862
                 >> Epoch 5 finished      RBM Reconstruction error 325.683319
                 >> Epoch 6 finished      RBM Reconstruction error 387.864807
                 >> Epoch 7 finished      RBM Reconstruction error 347.527710
                 >> Epoch 8 finished      RBM Reconstruction error 288.222107
                 >> Epoch 9 finished      RBM Reconstruction error 441.854614
                 >> Epoch 10 finished     RBM Reconstruction error 365.168640
                 >> Epoch 1 finished      RBM Reconstruction error 7704.830078
                 >> Epoch 2 finished      RBM Reconstruction error 8756.724609
                 >> Epoch 3 finished      RBM Reconstruction error 14747.218750
                 >> Epoch 4 finished      RBM Reconstruction error 13782.094727
                 >> Epoch 5 finished      RBM Reconstruction error 20590.453125
                 >> Epoch 6 finished      RBM Reconstruction error 17249.955078
                 >> Epoch 7 finished      RBM Reconstruction error 23698.279297
                 >> Epoch 8 finished      RBM Reconstruction error 22634.957031
                 >> Epoch 9 finished      RBM Reconstruction error 35549.710938
                 >> Epoch 10 finished     RBM Reconstruction error 33558.386719
                 [END] Pre-training step
                 [START] Fine tuning step:
                 >> Epoch 0 finished      ANN training loss 1.148739
                 >> Epoch 1 finished      ANN training loss 0.770206
                 >> Epoch 2 finished      ANN training loss 0.570758
                 >> Epoch 3 finished      ANN training loss 0.423928
                 >> Epoch 4 finished      ANN training loss 0.373262
                 >> Epoch 5 finished      ANN training loss 0.294912
                 >> Epoch 6 finished      ANN training loss 0.236317
                 >> Epoch 7 finished      ANN training loss 0.256555
                 >> Epoch 8 finished      ANN training loss 0.181814
                 >> Epoch 9 finished      ANN training loss 0.156014
                 >> Epoch 10 finished     ANN training loss 0.157873
                 >> Epoch 11 finished     ANN training loss 0.112084
                 >> Epoch 12 finished     ANN training loss 0.102756
                 >> Epoch 13 finished     ANN training loss 0.106336
                 >> Epoch 14 finished     ANN training loss 0.084706
                 >> Epoch 15 finished     ANN training loss 0.081579
                 >> Epoch 16 finished     ANN training loss 0.069330
                 >> Epoch 17 finished     ANN training loss 0.066856
                 >> Epoch 18 finished     ANN training loss 0.056585
                 >> Epoch 19 finished     ANN training loss 0.072584
                 >> Epoch 20 finished     ANN training loss 0.058569
                 >> Epoch 21 finished     ANN training loss 0.054657
                 >> Epoch 22 finished     ANN training loss 0.050575
                 >> Epoch 23 finished     ANN training loss 0.040919
                 >> Epoch 24 finished     ANN training loss 0.036358
                 >> Epoch 25 finished     ANN training loss 0.033245
                 >> Epoch 26 finished     ANN training loss 0.032542
                 >> Epoch 27 finished     ANN training loss 0.033480
                 >> Epoch 28 finished     ANN training loss 0.029375
                 >> Epoch 29 finished     ANN training loss 0.019737
                 >> Epoch 30 finished     ANN training loss 0.021683
                 >> Epoch 31 finished     ANN training loss 0.019821
                 >> Epoch 32 finished     ANN training loss 0.017043
                 >> Epoch 33 finished     ANN training loss 0.015202
                 >> Epoch 34 finished     ANN training loss 0.016184
                 >> Epoch 35 finished     ANN training loss 0.014409
                 >> Epoch 36 finished     ANN training loss 0.015413
                 >> Epoch 37 finished     ANN training loss 0.010383
                 >> Epoch 38 finished     ANN training loss 0.012022
                 >> Epoch 39 finished     ANN training loss 0.011709
                 >> Epoch 40 finished     ANN training loss 0.011447
                 >> Epoch 41 finished     ANN training loss 0.007633
```

```
>> Epoch 42 finished     ANN training loss 0.007799
>> Epoch 43 finished     ANN training loss 0.006248
>> Epoch 44 finished     ANN training loss 0.006012
>> Epoch 45 finished     ANN training loss 0.004822
>> Epoch 46 finished     ANN training loss 0.006340
>> Epoch 47 finished     ANN training loss 0.004101
>> Epoch 48 finished     ANN training loss 0.003524
>> Epoch 49 finished     ANN training loss 0.004045
>> Epoch 50 finished     ANN training loss 0.004038
>> Epoch 51 finished     ANN training loss 0.002426
>> Epoch 52 finished     ANN training loss 0.001912
>> Epoch 53 finished     ANN training loss 0.002844
>> Epoch 54 finished     ANN training loss 0.005721
>> Epoch 55 finished     ANN training loss 0.002943
>> Epoch 56 finished     ANN training loss 0.002222
>> Epoch 57 finished     ANN training loss 0.002616
>> Epoch 58 finished     ANN training loss 0.002046
>> Epoch 59 finished     ANN training loss 0.001357
>> Epoch 60 finished     ANN training loss 0.001450
>> Epoch 61 finished     ANN training loss 0.001482
>> Epoch 62 finished     ANN training loss 0.001142
>> Epoch 63 finished     ANN training loss 0.001222
>> Epoch 64 finished     ANN training loss 0.001581
>> Epoch 65 finished     ANN training loss 0.002686
>> Epoch 66 finished     ANN training loss 0.001035
>> Epoch 67 finished     ANN training loss 0.001389
>> Epoch 68 finished     ANN training loss 0.001359
>> Epoch 69 finished     ANN training loss 0.000933
>> Epoch 70 finished     ANN training loss 0.001213
>> Epoch 71 finished     ANN training loss 0.001068
>> Epoch 72 finished     ANN training loss 0.000659
>> Epoch 73 finished     ANN training loss 0.000580
>> Epoch 74 finished     ANN training loss 0.000587
>> Epoch 75 finished     ANN training loss 0.000927
>> Epoch 76 finished     ANN training loss 0.021917
>> Epoch 77 finished     ANN training loss 0.002161
>> Epoch 78 finished     ANN training loss 0.001041
>> Epoch 79 finished     ANN training loss 0.001683
>> Epoch 80 finished     ANN training loss 0.001074
>> Epoch 81 finished     ANN training loss 0.000763
>> Epoch 82 finished     ANN training loss 0.000818
>> Epoch 83 finished     ANN training loss 0.000978
>> Epoch 84 finished     ANN training loss 0.001042
>> Epoch 85 finished     ANN training loss 0.000871
>> Epoch 86 finished     ANN training loss 0.001035
>> Epoch 87 finished     ANN training loss 0.001564
>> Epoch 88 finished     ANN training loss 0.000981
>> Epoch 89 finished     ANN training loss 0.000645
>> Epoch 90 finished     ANN training loss 0.000562
>> Epoch 91 finished     ANN training loss 0.000525
>> Epoch 92 finished     ANN training loss 0.000495
>> Epoch 93 finished     ANN training loss 0.000774
>> Epoch 94 finished     ANN training loss 0.000486
>> Epoch 95 finished     ANN training loss 0.000467
>> Epoch 96 finished     ANN training loss 0.000382
>> Epoch 97 finished     ANN training loss 0.000421
>> Epoch 98 finished     ANN training loss 0.011721
>> Epoch 99 finished     ANN training loss 0.000538
[END] Fine tuning step
Done.
```

In [47]:
```python
print('ACCURACY: ' + str(threelayer_acc[1]))
```

```
ACCURACY: 0.915
```

Setting 3 – 2nd Layer = 500

hidden_layers_structure=[100, 500, 300]

In [48]:
```python
threelayer_acc[2] = deep_belief_net(hidden_layers_structure=[100, 500, 300])
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 46.037357
>> Epoch 2 finished     RBM Reconstruction error 90.269768
>> Epoch 3 finished     RBM Reconstruction error 54.883526
>> Epoch 4 finished     RBM Reconstruction error 90.055466
>> Epoch 5 finished     RBM Reconstruction error 48.924706
>> Epoch 6 finished     RBM Reconstruction error 59.731728
>> Epoch 7 finished     RBM Reconstruction error 68.522606
>> Epoch 8 finished     RBM Reconstruction error 76.011360
>> Epoch 9 finished     RBM Reconstruction error 67.557816
>> Epoch 10 finished    RBM Reconstruction error 77.150909
>> Epoch 1 finished     RBM Reconstruction error 693.408936
>> Epoch 2 finished     RBM Reconstruction error 475.906860
>> Epoch 3 finished     RBM Reconstruction error 517.780701
>> Epoch 4 finished     RBM Reconstruction error 512.426208
>> Epoch 5 finished     RBM Reconstruction error 403.576843
>> Epoch 6 finished     RBM Reconstruction error 414.917175
>> Epoch 7 finished     RBM Reconstruction error 432.829529
>> Epoch 8 finished     RBM Reconstruction error 677.364441
>> Epoch 9 finished     RBM Reconstruction error 506.351013
>> Epoch 10 finished    RBM Reconstruction error 512.856201
>> Epoch 1 finished     RBM Reconstruction error 20082.324219
>> Epoch 2 finished     RBM Reconstruction error 19763.488281
>> Epoch 3 finished     RBM Reconstruction error 26652.082031
>> Epoch 4 finished     RBM Reconstruction error 35193.226562
>> Epoch 5 finished     RBM Reconstruction error 43998.519531
>> Epoch 6 finished     RBM Reconstruction error 54127.585938
>> Epoch 7 finished     RBM Reconstruction error 55989.539062
>> Epoch 8 finished     RBM Reconstruction error 77291.226562
>> Epoch 9 finished     RBM Reconstruction error 93704.960938
>> Epoch 10 finished    RBM Reconstruction error 90798.687500
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 1.368032
>> Epoch 1 finished     ANN training loss 0.965836
>> Epoch 2 finished     ANN training loss 0.824202
>> Epoch 3 finished     ANN training loss 0.637604
>> Epoch 4 finished     ANN training loss 0.625319
>> Epoch 5 finished     ANN training loss 0.492506
>> Epoch 6 finished     ANN training loss 0.464184
>> Epoch 7 finished     ANN training loss 0.369553
>> Epoch 8 finished     ANN training loss 0.331659
>> Epoch 9 finished     ANN training loss 0.307416
>> Epoch 10 finished    ANN training loss 0.248093
>> Epoch 11 finished    ANN training loss 0.245124
>> Epoch 12 finished    ANN training loss 0.221395
>> Epoch 13 finished    ANN training loss 0.204238
>> Epoch 14 finished    ANN training loss 0.201492
>> Epoch 15 finished    ANN training loss 0.163309
>> Epoch 16 finished    ANN training loss 0.155370
>> Epoch 17 finished    ANN training loss 0.141065
>> Epoch 18 finished    ANN training loss 0.117621
>> Epoch 19 finished    ANN training loss 0.110302
>> Epoch 20 finished    ANN training loss 0.138922
>> Epoch 21 finished    ANN training loss 0.147155
>> Epoch 22 finished    ANN training loss 0.107724
```

```
>> Epoch 23 finished    ANN training loss 0.086279
>> Epoch 24 finished    ANN training loss 0.083002
>> Epoch 25 finished    ANN training loss 0.072218
>> Epoch 26 finished    ANN training loss 0.066615
>> Epoch 27 finished    ANN training loss 0.066570
>> Epoch 28 finished    ANN training loss 0.064705
>> Epoch 29 finished    ANN training loss 0.051858
>> Epoch 30 finished    ANN training loss 0.047943
>> Epoch 31 finished    ANN training loss 0.058598
>> Epoch 32 finished    ANN training loss 0.048704
>> Epoch 33 finished    ANN training loss 0.053961
>> Epoch 34 finished    ANN training loss 0.042221
>> Epoch 35 finished    ANN training loss 0.037252
>> Epoch 36 finished    ANN training loss 0.039174
>> Epoch 37 finished    ANN training loss 0.031617
>> Epoch 38 finished    ANN training loss 0.031995
>> Epoch 39 finished    ANN training loss 0.028332
>> Epoch 40 finished    ANN training loss 0.025115
>> Epoch 41 finished    ANN training loss 0.023724
>> Epoch 42 finished    ANN training loss 0.022677
>> Epoch 43 finished    ANN training loss 0.023166
>> Epoch 44 finished    ANN training loss 0.025624
>> Epoch 45 finished    ANN training loss 0.020415
>> Epoch 46 finished    ANN training loss 0.024133
>> Epoch 47 finished    ANN training loss 0.016326
>> Epoch 48 finished    ANN training loss 0.016199
>> Epoch 49 finished    ANN training loss 0.016581
>> Epoch 50 finished    ANN training loss 0.015776
>> Epoch 51 finished    ANN training loss 0.012655
>> Epoch 52 finished    ANN training loss 0.013531
>> Epoch 53 finished    ANN training loss 0.014778
>> Epoch 54 finished    ANN training loss 0.014632
>> Epoch 55 finished    ANN training loss 0.012877
>> Epoch 56 finished    ANN training loss 0.012540
>> Epoch 57 finished    ANN training loss 0.009692
>> Epoch 58 finished    ANN training loss 0.011601
>> Epoch 59 finished    ANN training loss 0.012456
>> Epoch 60 finished    ANN training loss 0.008918
>> Epoch 61 finished    ANN training loss 0.009407
>> Epoch 62 finished    ANN training loss 0.011221
>> Epoch 63 finished    ANN training loss 0.010915
>> Epoch 64 finished    ANN training loss 0.012434
>> Epoch 65 finished    ANN training loss 0.009233
>> Epoch 66 finished    ANN training loss 0.011796
>> Epoch 67 finished    ANN training loss 0.008571
>> Epoch 68 finished    ANN training loss 0.010558
>> Epoch 69 finished    ANN training loss 0.013745
>> Epoch 70 finished    ANN training loss 0.007248
>> Epoch 71 finished    ANN training loss 0.007332
>> Epoch 72 finished    ANN training loss 0.006959
>> Epoch 73 finished    ANN training loss 0.008246
>> Epoch 74 finished    ANN training loss 0.005313
>> Epoch 75 finished    ANN training loss 0.005633
>> Epoch 76 finished    ANN training loss 0.011271
>> Epoch 77 finished    ANN training loss 0.005037
>> Epoch 78 finished    ANN training loss 0.004283
>> Epoch 79 finished    ANN training loss 0.003606
>> Epoch 80 finished    ANN training loss 0.003277
>> Epoch 81 finished    ANN training loss 0.005034
>> Epoch 82 finished    ANN training loss 0.005416
>> Epoch 83 finished    ANN training loss 0.004572
>> Epoch 84 finished    ANN training loss 0.003049
>> Epoch 85 finished    ANN training loss 0.003888
>> Epoch 86 finished    ANN training loss 0.004188
>> Epoch 87 finished    ANN training loss 0.004338
```

```
>> Epoch 88 finished    ANN training loss 0.002636
>> Epoch 89 finished    ANN training loss 0.004734
>> Epoch 90 finished    ANN training loss 0.004708
>> Epoch 91 finished    ANN training loss 0.003443
>> Epoch 92 finished    ANN training loss 0.003586
>> Epoch 93 finished    ANN training loss 0.002316
>> Epoch 94 finished    ANN training loss 0.002712
>> Epoch 95 finished    ANN training loss 0.003219
>> Epoch 96 finished    ANN training loss 0.002898
>> Epoch 97 finished    ANN training loss 0.001889
>> Epoch 98 finished    ANN training loss 0.005270
>> Epoch 99 finished    ANN training loss 0.004183
[END] Fine tuning step
Done.
```

In [49]:
```python
print('ACCURACY: ' + str(threelayer_acc[2]))
```

```
ACCURACY: 0.905
```

Setting 4 – 3rd Layer = 500

hidden_layers_structure=[100, 200, 500]

In [50]:
```python
threelayer_acc[3] = deep_belief_net(hidden_layers_structure=[100, 200, 500])
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 58.408165
>> Epoch 2 finished     RBM Reconstruction error 69.195312
>> Epoch 3 finished     RBM Reconstruction error 71.488205
>> Epoch 4 finished     RBM Reconstruction error 42.269623
>> Epoch 5 finished     RBM Reconstruction error 61.457363
>> Epoch 6 finished     RBM Reconstruction error 79.939407
>> Epoch 7 finished     RBM Reconstruction error 101.641739
>> Epoch 8 finished     RBM Reconstruction error 84.693886
>> Epoch 9 finished     RBM Reconstruction error 96.495857
>> Epoch 10 finished    RBM Reconstruction error 97.584984
>> Epoch 1 finished     RBM Reconstruction error 374.778687
>> Epoch 2 finished     RBM Reconstruction error 617.015137
>> Epoch 3 finished     RBM Reconstruction error 481.513519
>> Epoch 4 finished     RBM Reconstruction error 1032.019043
>> Epoch 5 finished     RBM Reconstruction error 872.648376
>> Epoch 6 finished     RBM Reconstruction error 882.761902
>> Epoch 7 finished     RBM Reconstruction error 1119.452759
>> Epoch 8 finished     RBM Reconstruction error 1263.858398
>> Epoch 9 finished     RBM Reconstruction error 1300.469727
>> Epoch 10 finished    RBM Reconstruction error 1353.029663
>> Epoch 1 finished     RBM Reconstruction error 13897.667969
>> Epoch 2 finished     RBM Reconstruction error 26535.505859
>> Epoch 3 finished     RBM Reconstruction error 50756.683594
>> Epoch 4 finished     RBM Reconstruction error 53545.750000
>> Epoch 5 finished     RBM Reconstruction error 38055.984375
>> Epoch 6 finished     RBM Reconstruction error 82117.398438
>> Epoch 7 finished     RBM Reconstruction error 76303.906250
>> Epoch 8 finished     RBM Reconstruction error 58658.738281
>> Epoch 9 finished     RBM Reconstruction error 71391.468750
>> Epoch 10 finished    RBM Reconstruction error 89981.617188
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 1.119905
>> Epoch 1 finished     ANN training loss 0.909399
>> Epoch 2 finished     ANN training loss 0.682351
>> Epoch 3 finished     ANN training loss 0.569214
>> Epoch 4 finished     ANN training loss 0.482639
```

```
>> Epoch 5 finished    ANN training loss 0.371544
>> Epoch 6 finished    ANN training loss 0.334282
>> Epoch 7 finished    ANN training loss 0.308384
>> Epoch 8 finished    ANN training loss 0.230581
>> Epoch 9 finished    ANN training loss 0.207830
>> Epoch 10 finished   ANN training loss 0.205981
>> Epoch 11 finished   ANN training loss 0.145182
>> Epoch 12 finished   ANN training loss 0.126699
>> Epoch 13 finished   ANN training loss 0.111036
>> Epoch 14 finished   ANN training loss 0.122788
>> Epoch 15 finished   ANN training loss 0.108345
>> Epoch 16 finished   ANN training loss 0.094774
>> Epoch 17 finished   ANN training loss 0.075767
>> Epoch 18 finished   ANN training loss 0.064752
>> Epoch 19 finished   ANN training loss 0.072787
>> Epoch 20 finished   ANN training loss 0.053335
>> Epoch 21 finished   ANN training loss 0.065728
>> Epoch 22 finished   ANN training loss 0.066765
>> Epoch 23 finished   ANN training loss 0.059071
>> Epoch 24 finished   ANN training loss 0.042531
>> Epoch 25 finished   ANN training loss 0.037095
>> Epoch 26 finished   ANN training loss 0.044392
>> Epoch 27 finished   ANN training loss 0.029427
>> Epoch 28 finished   ANN training loss 0.026206
>> Epoch 29 finished   ANN training loss 0.034820
>> Epoch 30 finished   ANN training loss 0.031917
>> Epoch 31 finished   ANN training loss 0.019695
>> Epoch 32 finished   ANN training loss 0.026772
>> Epoch 33 finished   ANN training loss 0.021182
>> Epoch 34 finished   ANN training loss 0.019129
>> Epoch 35 finished   ANN training loss 0.019079
>> Epoch 36 finished   ANN training loss 0.017632
>> Epoch 37 finished   ANN training loss 0.012927
>> Epoch 38 finished   ANN training loss 0.019722
>> Epoch 39 finished   ANN training loss 0.015793
>> Epoch 40 finished   ANN training loss 0.016437
>> Epoch 41 finished   ANN training loss 0.014072
>> Epoch 42 finished   ANN training loss 0.019872
>> Epoch 43 finished   ANN training loss 0.011392
>> Epoch 44 finished   ANN training loss 0.013529
>> Epoch 45 finished   ANN training loss 0.007584
>> Epoch 46 finished   ANN training loss 0.009698
>> Epoch 47 finished   ANN training loss 0.009805
>> Epoch 48 finished   ANN training loss 0.008928
>> Epoch 49 finished   ANN training loss 0.005349
>> Epoch 50 finished   ANN training loss 0.005724
>> Epoch 51 finished   ANN training loss 0.007827
>> Epoch 52 finished   ANN training loss 0.005161
>> Epoch 53 finished   ANN training loss 0.006110
>> Epoch 54 finished   ANN training loss 0.008521
>> Epoch 55 finished   ANN training loss 0.008896
>> Epoch 56 finished   ANN training loss 0.009951
>> Epoch 57 finished   ANN training loss 0.005751
>> Epoch 58 finished   ANN training loss 0.004731
>> Epoch 59 finished   ANN training loss 0.004270
>> Epoch 60 finished   ANN training loss 0.008654
>> Epoch 61 finished   ANN training loss 0.005985
>> Epoch 62 finished   ANN training loss 0.007761
>> Epoch 63 finished   ANN training loss 0.008057
>> Epoch 64 finished   ANN training loss 0.004299
>> Epoch 65 finished   ANN training loss 0.004801
>> Epoch 66 finished   ANN training loss 0.003753
>> Epoch 67 finished   ANN training loss 0.004286
>> Epoch 68 finished   ANN training loss 0.004568
>> Epoch 69 finished   ANN training loss 0.004588
```

```
>> Epoch 70 finished     ANN training loss 0.003805
>> Epoch 71 finished     ANN training loss 0.005524
>> Epoch 72 finished     ANN training loss 0.002980
>> Epoch 73 finished     ANN training loss 0.003374
>> Epoch 74 finished     ANN training loss 0.003371
>> Epoch 75 finished     ANN training loss 0.003845
>> Epoch 76 finished     ANN training loss 0.004075
>> Epoch 77 finished     ANN training loss 0.005952
>> Epoch 78 finished     ANN training loss 0.004317
>> Epoch 79 finished     ANN training loss 0.004397
>> Epoch 80 finished     ANN training loss 0.003549
>> Epoch 81 finished     ANN training loss 0.005461
>> Epoch 82 finished     ANN training loss 0.003525
>> Epoch 83 finished     ANN training loss 0.003562
>> Epoch 84 finished     ANN training loss 0.004389
>> Epoch 85 finished     ANN training loss 0.002285
>> Epoch 86 finished     ANN training loss 0.003203
>> Epoch 87 finished     ANN training loss 0.002455
>> Epoch 88 finished     ANN training loss 0.002817
>> Epoch 89 finished     ANN training loss 0.005536
>> Epoch 90 finished     ANN training loss 0.002001
>> Epoch 91 finished     ANN training loss 0.002743
>> Epoch 92 finished     ANN training loss 0.001895
>> Epoch 93 finished     ANN training loss 0.001581
>> Epoch 94 finished     ANN training loss 0.001748
>> Epoch 95 finished     ANN training loss 0.001589
>> Epoch 96 finished     ANN training loss 0.001303
>> Epoch 97 finished     ANN training loss 0.001715
>> Epoch 98 finished     ANN training loss 0.002865
>> Epoch 99 finished     ANN training loss 0.002316
[END] Fine tuning step
Done
```

In [51]:
```python
print('ACCURACY: ' + str(threelayer_acc[3]))
```

```
ACCURACY: 0.91
```

Setting 5 – 1st Layer = 500, 2nd Layer = 500

hidden_layers_structure=[500, 500, 300]

In [52]:
```python
threelayer_acc[4] = deep_belief_net(hidden_layers_structure=[500, 500, 300])
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 53.484531
>> Epoch 2 finished      RBM Reconstruction error 49.617989
>> Epoch 3 finished      RBM Reconstruction error 28.611094
>> Epoch 4 finished      RBM Reconstruction error 46.947323
>> Epoch 5 finished      RBM Reconstruction error 26.846586
>> Epoch 6 finished      RBM Reconstruction error 36.614113
>> Epoch 7 finished      RBM Reconstruction error 23.046961
>> Epoch 8 finished      RBM Reconstruction error 43.888760
>> Epoch 9 finished      RBM Reconstruction error 37.438507
>> Epoch 10 finished     RBM Reconstruction error 20.884056
>> Epoch 1 finished      RBM Reconstruction error 44.684120
>> Epoch 2 finished      RBM Reconstruction error 40.053890
>> Epoch 3 finished      RBM Reconstruction error 34.717075
>> Epoch 4 finished      RBM Reconstruction error 58.272724
>> Epoch 5 finished      RBM Reconstruction error 19.762663
>> Epoch 6 finished      RBM Reconstruction error 48.689640
>> Epoch 7 finished      RBM Reconstruction error 41.754356
>> Epoch 8 finished      RBM Reconstruction error 35.288944
>> Epoch 9 finished      RBM Reconstruction error 33.576466
```

```
              >> Epoch 10 finished    RBM Reconstruction error 58.882156
              >> Epoch 1 finished     RBM Reconstruction error 302.683289
              >> Epoch 2 finished     RBM Reconstruction error 494.964233
              >> Epoch 3 finished     RBM Reconstruction error 459.660461
              >> Epoch 4 finished     RBM Reconstruction error 486.647186
              >> Epoch 5 finished     RBM Reconstruction error 530.887207
              >> Epoch 6 finished     RBM Reconstruction error 494.535339
              >> Epoch 7 finished     RBM Reconstruction error 635.821899
              >> Epoch 8 finished     RBM Reconstruction error 487.871063
              >> Epoch 9 finished     RBM Reconstruction error 576.013428
              >> Epoch 10 finished    RBM Reconstruction error 580.948303
              [END] Pre-training step
              [START] Fine tuning step:
              >> Epoch 0 finished     ANN training loss 0.618450
              >> Epoch 1 finished     ANN training loss 0.420340
              >> Epoch 2 finished     ANN training loss 0.371379
              >> Epoch 3 finished     ANN training loss 0.272224
              >> Epoch 4 finished     ANN training loss 0.231351
              >> Epoch 5 finished     ANN training loss 0.187486
              >> Epoch 6 finished     ANN training loss 0.186028
              >> Epoch 7 finished     ANN training loss 0.156209
              >> Epoch 8 finished     ANN training loss 0.127174
              >> Epoch 9 finished     ANN training loss 0.124143
              >> Epoch 10 finished    ANN training loss 0.101501
              >> Epoch 11 finished    ANN training loss 0.099455
              >> Epoch 12 finished    ANN training loss 0.067864
              >> Epoch 13 finished    ANN training loss 0.066500
              >> Epoch 14 finished    ANN training loss 0.057930
              >> Epoch 15 finished    ANN training loss 0.052993
              >> Epoch 16 finished    ANN training loss 0.051266
              >> Epoch 17 finished    ANN training loss 0.042247
              >> Epoch 18 finished    ANN training loss 0.049701
              >> Epoch 19 finished    ANN training loss 0.037037
              >> Epoch 20 finished    ANN training loss 0.035621
              >> Epoch 21 finished    ANN training loss 0.028847
              >> Epoch 22 finished    ANN training loss 0.026278
              >> Epoch 23 finished    ANN training loss 0.024064
              >> Epoch 24 finished    ANN training loss 0.023868
              >> Epoch 25 finished    ANN training loss 0.021595
              >> Epoch 26 finished    ANN training loss 0.022288
              >> Epoch 27 finished    ANN training loss 0.017450
              >> Epoch 28 finished    ANN training loss 0.021444
              >> Epoch 29 finished    ANN training loss 0.014531
              >> Epoch 30 finished    ANN training loss 0.014011
              >> Epoch 31 finished    ANN training loss 0.015504
              >> Epoch 32 finished    ANN training loss 0.011549
              >> Epoch 33 finished    ANN training loss 0.011439
              >> Epoch 34 finished    ANN training loss 0.011122
              >> Epoch 35 finished    ANN training loss 0.008329
              >> Epoch 36 finished    ANN training loss 0.008541
              >> Epoch 37 finished    ANN training loss 0.007277
              >> Epoch 38 finished    ANN training loss 0.008585
              >> Epoch 39 finished    ANN training loss 0.005722
              >> Epoch 40 finished    ANN training loss 0.007295
              >> Epoch 41 finished    ANN training loss 0.005362
              >> Epoch 42 finished    ANN training loss 0.005623
              >> Epoch 43 finished    ANN training loss 0.004942
              >> Epoch 44 finished    ANN training loss 0.003925
              >> Epoch 45 finished    ANN training loss 0.004307
              >> Epoch 46 finished    ANN training loss 0.003705
              >> Epoch 47 finished    ANN training loss 0.003339
              >> Epoch 48 finished    ANN training loss 0.002857
              >> Epoch 49 finished    ANN training loss 0.004071
              >> Epoch 50 finished    ANN training loss 0.003528
              >> Epoch 51 finished    ANN training loss 0.002837
```

```
>> Epoch 52 finished    ANN training loss 0.002737
>> Epoch 53 finished    ANN training loss 0.002371
>> Epoch 54 finished    ANN training loss 0.001788
>> Epoch 55 finished    ANN training loss 0.001632
>> Epoch 56 finished    ANN training loss 0.002442
>> Epoch 57 finished    ANN training loss 0.002046
>> Epoch 58 finished    ANN training loss 0.001969
>> Epoch 59 finished    ANN training loss 0.001716
>> Epoch 60 finished    ANN training loss 0.001657
>> Epoch 61 finished    ANN training loss 0.001847
>> Epoch 62 finished    ANN training loss 0.001518
>> Epoch 63 finished    ANN training loss 0.001185
>> Epoch 64 finished    ANN training loss 0.001212
>> Epoch 65 finished    ANN training loss 0.003035
>> Epoch 66 finished    ANN training loss 0.001409
>> Epoch 67 finished    ANN training loss 0.001151
>> Epoch 68 finished    ANN training loss 0.001186
>> Epoch 69 finished    ANN training loss 0.000978
>> Epoch 70 finished    ANN training loss 0.000953
>> Epoch 71 finished    ANN training loss 0.000965
>> Epoch 72 finished    ANN training loss 0.000900
>> Epoch 73 finished    ANN training loss 0.000799
>> Epoch 74 finished    ANN training loss 0.000662
>> Epoch 75 finished    ANN training loss 0.000717
>> Epoch 76 finished    ANN training loss 0.000637
>> Epoch 77 finished    ANN training loss 0.000770
>> Epoch 78 finished    ANN training loss 0.000790
>> Epoch 79 finished    ANN training loss 0.000887
>> Epoch 80 finished    ANN training loss 0.000701
>> Epoch 81 finished    ANN training loss 0.000633
>> Epoch 82 finished    ANN training loss 0.000643
>> Epoch 83 finished    ANN training loss 0.000557
>> Epoch 84 finished    ANN training loss 0.000585
>> Epoch 85 finished    ANN training loss 0.000480
>> Epoch 86 finished    ANN training loss 0.000438
>> Epoch 87 finished    ANN training loss 0.000466
>> Epoch 88 finished    ANN training loss 0.000410
>> Epoch 89 finished    ANN training loss 0.000461
>> Epoch 90 finished    ANN training loss 0.000627
>> Epoch 91 finished    ANN training loss 0.000476
>> Epoch 92 finished    ANN training loss 0.000444
>> Epoch 93 finished    ANN training loss 0.000492
>> Epoch 94 finished    ANN training loss 0.001626
>> Epoch 95 finished    ANN training loss 0.000596
>> Epoch 96 finished    ANN training loss 0.000460
>> Epoch 97 finished    ANN training loss 0.000393
>> Epoch 98 finished    ANN training loss 0.000369
>> Epoch 99 finished    ANN training loss 0.000291
[END] Fine tuning step
Done
```

In [53]:
```python
print('ACCURACY: ' + str(threelayer_acc[4]))
```

```
ACCURACY: 0.925
```

Setting 6 – 1st Layer = 500, 3rd Layer = 500

hidden_layers_structure=[500, 200, 500]

In [54]:
```python
threelayer_acc[5] = deep_belief_net(hidden_layers_structure=[500, 200, 500])
```

```
[START] Pre-training step:
>> Epoch 1 finished    RBM Reconstruction error 47.435226
```

```
            >> Epoch 2 finished      RBM Reconstruction error 65.411766
            >> Epoch 3 finished      RBM Reconstruction error 40.892231
            >> Epoch 4 finished      RBM Reconstruction error 29.415909
            >> Epoch 5 finished      RBM Reconstruction error 52.996983
            >> Epoch 6 finished      RBM Reconstruction error 21.949629
            >> Epoch 7 finished      RBM Reconstruction error 24.500845
            >> Epoch 8 finished      RBM Reconstruction error 27.317327
            >> Epoch 9 finished      RBM Reconstruction error 49.982723
            >> Epoch 10 finished     RBM Reconstruction error 47.436172
            >> Epoch 1 finished      RBM Reconstruction error 271.394684
            >> Epoch 2 finished      RBM Reconstruction error 90.636230
            >> Epoch 3 finished      RBM Reconstruction error 165.255737
            >> Epoch 4 finished      RBM Reconstruction error 186.123322
            >> Epoch 5 finished      RBM Reconstruction error 264.922668
            >> Epoch 6 finished      RBM Reconstruction error 203.708313
            >> Epoch 7 finished      RBM Reconstruction error 174.804886
            >> Epoch 8 finished      RBM Reconstruction error 199.951172
            >> Epoch 9 finished      RBM Reconstruction error 273.661652
            >> Epoch 10 finished     RBM Reconstruction error 195.511536
            >> Epoch 1 finished      RBM Reconstruction error 2191.128418
            >> Epoch 2 finished      RBM Reconstruction error 2868.894287
            >> Epoch 3 finished      RBM Reconstruction error 4583.454590
            >> Epoch 4 finished      RBM Reconstruction error 4213.567871
            >> Epoch 5 finished      RBM Reconstruction error 4605.455566
            >> Epoch 6 finished      RBM Reconstruction error 4974.555664
            >> Epoch 7 finished      RBM Reconstruction error 5970.238770
            >> Epoch 8 finished      RBM Reconstruction error 5938.312012
            >> Epoch 9 finished      RBM Reconstruction error 6314.316895
            >> Epoch 10 finished     RBM Reconstruction error 6525.642578
            [END] Pre-training step
            [START] Fine tuning step:
            >> Epoch 0 finished      ANN training loss 0.705950
            >> Epoch 1 finished      ANN training loss 0.501846
            >> Epoch 2 finished      ANN training loss 0.384075
            >> Epoch 3 finished      ANN training loss 0.317613
            >> Epoch 4 finished      ANN training loss 0.285993
            >> Epoch 5 finished      ANN training loss 0.218323
            >> Epoch 6 finished      ANN training loss 0.220026
            >> Epoch 7 finished      ANN training loss 0.171106
            >> Epoch 8 finished      ANN training loss 0.170636
            >> Epoch 9 finished      ANN training loss 0.119489
            >> Epoch 10 finished     ANN training loss 0.116837
            >> Epoch 11 finished     ANN training loss 0.112188
            >> Epoch 12 finished     ANN training loss 0.077588
            >> Epoch 13 finished     ANN training loss 0.093665
            >> Epoch 14 finished     ANN training loss 0.059614
            >> Epoch 15 finished     ANN training loss 0.052859
            >> Epoch 16 finished     ANN training loss 0.045846
            >> Epoch 17 finished     ANN training loss 0.046793
            >> Epoch 18 finished     ANN training loss 0.038132
            >> Epoch 19 finished     ANN training loss 0.030542
            >> Epoch 20 finished     ANN training loss 0.029776
            >> Epoch 21 finished     ANN training loss 0.027568
            >> Epoch 22 finished     ANN training loss 0.026064
            >> Epoch 23 finished     ANN training loss 0.021152
            >> Epoch 24 finished     ANN training loss 0.018378
            >> Epoch 25 finished     ANN training loss 0.019202
            >> Epoch 26 finished     ANN training loss 0.018589
            >> Epoch 27 finished     ANN training loss 0.019108
            >> Epoch 28 finished     ANN training loss 0.012930
            >> Epoch 29 finished     ANN training loss 0.012161
            >> Epoch 30 finished     ANN training loss 0.010855
            >> Epoch 31 finished     ANN training loss 0.017628
            >> Epoch 32 finished     ANN training loss 0.009240
            >> Epoch 33 finished     ANN training loss 0.007286
```

```
>> Epoch 34 finished    ANN training loss 0.006707
>> Epoch 35 finished    ANN training loss 0.005772
>> Epoch 36 finished    ANN training loss 0.005389
>> Epoch 37 finished    ANN training loss 0.005200
>> Epoch 38 finished    ANN training loss 0.004847
>> Epoch 39 finished    ANN training loss 0.005911
>> Epoch 40 finished    ANN training loss 0.004184
>> Epoch 41 finished    ANN training loss 0.003993
>> Epoch 42 finished    ANN training loss 0.003854
>> Epoch 43 finished    ANN training loss 0.004542
>> Epoch 44 finished    ANN training loss 0.003205
>> Epoch 45 finished    ANN training loss 0.003073
>> Epoch 46 finished    ANN training loss 0.004969
>> Epoch 47 finished    ANN training loss 0.003377
>> Epoch 48 finished    ANN training loss 0.002288
>> Epoch 49 finished    ANN training loss 0.001990
>> Epoch 50 finished    ANN training loss 0.002185
>> Epoch 51 finished    ANN training loss 0.002228
>> Epoch 52 finished    ANN training loss 0.001598
>> Epoch 53 finished    ANN training loss 0.002845
>> Epoch 54 finished    ANN training loss 0.001946
>> Epoch 55 finished    ANN training loss 0.001628
>> Epoch 56 finished    ANN training loss 0.002171
>> Epoch 57 finished    ANN training loss 0.001924
>> Epoch 58 finished    ANN training loss 0.001438
>> Epoch 59 finished    ANN training loss 0.001108
>> Epoch 60 finished    ANN training loss 0.001005
>> Epoch 61 finished    ANN training loss 0.001268
>> Epoch 62 finished    ANN training loss 0.001319
>> Epoch 63 finished    ANN training loss 0.000848
>> Epoch 64 finished    ANN training loss 0.001764
>> Epoch 65 finished    ANN training loss 0.000830
>> Epoch 66 finished    ANN training loss 0.000916
>> Epoch 67 finished    ANN training loss 0.001221
>> Epoch 68 finished    ANN training loss 0.000744
>> Epoch 69 finished    ANN training loss 0.001084
>> Epoch 70 finished    ANN training loss 0.000744
>> Epoch 71 finished    ANN training loss 0.000532
>> Epoch 72 finished    ANN training loss 0.000845
>> Epoch 73 finished    ANN training loss 0.001255
>> Epoch 74 finished    ANN training loss 0.001226
>> Epoch 75 finished    ANN training loss 0.000830
>> Epoch 76 finished    ANN training loss 0.000964
>> Epoch 77 finished    ANN training loss 0.000761
>> Epoch 78 finished    ANN training loss 0.000797
>> Epoch 79 finished    ANN training loss 0.000592
>> Epoch 80 finished    ANN training loss 0.000542
>> Epoch 81 finished    ANN training loss 0.000728
>> Epoch 82 finished    ANN training loss 0.000507
>> Epoch 83 finished    ANN training loss 0.000683
>> Epoch 84 finished    ANN training loss 0.000737
>> Epoch 85 finished    ANN training loss 0.000369
>> Epoch 86 finished    ANN training loss 0.000815
>> Epoch 87 finished    ANN training loss 0.001076
>> Epoch 88 finished    ANN training loss 0.000593
>> Epoch 89 finished    ANN training loss 0.000633
>> Epoch 90 finished    ANN training loss 0.000600
>> Epoch 91 finished    ANN training loss 0.000652
>> Epoch 92 finished    ANN training loss 0.000585
>> Epoch 93 finished    ANN training loss 0.000347
>> Epoch 94 finished    ANN training loss 0.000321
>> Epoch 95 finished    ANN training loss 0.000256
>> Epoch 96 finished    ANN training loss 0.000236
>> Epoch 97 finished    ANN training loss 0.000312
>> Epoch 98 finished    ANN training loss 0.001116
```

```
>> Epoch 99 finished    ANN training loss 0.000288
[END] Fine tuning step
```

In [55]: `print('ACCURACY: ' + str(threelayer_acc[5]))`

```
ACCURACY: 0.92
```

Setting 7 – 2nd Layer = 500, 3rd Layer = 500

hidden_layers_structure=[100, 500, 500]

In [56]: `threelayer_acc[6] = deep_belief_net(hidden_layers_structure=[100, 500, 500])`

```
[START] Pre-training step:
>> Epoch 1 finished    RBM Reconstruction error 74.895760
>> Epoch 2 finished    RBM Reconstruction error 85.589020
>> Epoch 3 finished    RBM Reconstruction error 75.232468
>> Epoch 4 finished    RBM Reconstruction error 70.381668
>> Epoch 5 finished    RBM Reconstruction error 78.885025
>> Epoch 6 finished    RBM Reconstruction error 81.908279
>> Epoch 7 finished    RBM Reconstruction error 71.334549
>> Epoch 8 finished    RBM Reconstruction error 73.247963
>> Epoch 9 finished    RBM Reconstruction error 85.922073
>> Epoch 10 finished   RBM Reconstruction error 90.483337
>> Epoch 1 finished    RBM Reconstruction error 287.300110
>> Epoch 2 finished    RBM Reconstruction error 563.882263
>> Epoch 3 finished    RBM Reconstruction error 699.517517
>> Epoch 4 finished    RBM Reconstruction error 413.560638
>> Epoch 5 finished    RBM Reconstruction error 516.107971
>> Epoch 6 finished    RBM Reconstruction error 698.975769
>> Epoch 7 finished    RBM Reconstruction error 453.494598
>> Epoch 8 finished    RBM Reconstruction error 722.497742
>> Epoch 9 finished    RBM Reconstruction error 656.940063
>> Epoch 10 finished   RBM Reconstruction error 627.395447
>> Epoch 1 finished    RBM Reconstruction error 22307.554688
>> Epoch 2 finished    RBM Reconstruction error 26080.412109
>> Epoch 3 finished    RBM Reconstruction error 29038.660156
>> Epoch 4 finished    RBM Reconstruction error 31783.369141
>> Epoch 5 finished    RBM Reconstruction error 40547.296875
>> Epoch 6 finished    RBM Reconstruction error 45807.648438
>> Epoch 7 finished    RBM Reconstruction error 49722.925781
>> Epoch 8 finished    RBM Reconstruction error 50296.851562
>> Epoch 9 finished    RBM Reconstruction error 44169.890625
>> Epoch 10 finished   RBM Reconstruction error 58293.144531
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished    ANN training loss 1.142354
>> Epoch 1 finished    ANN training loss 0.741675
>> Epoch 2 finished    ANN training loss 0.618078
>> Epoch 3 finished    ANN training loss 0.503561
>> Epoch 4 finished    ANN training loss 0.400187
>> Epoch 5 finished    ANN training loss 0.368017
>> Epoch 6 finished    ANN training loss 0.335961
>> Epoch 7 finished    ANN training loss 0.253038
>> Epoch 8 finished    ANN training loss 0.244035
>> Epoch 9 finished    ANN training loss 0.227803
>> Epoch 10 finished   ANN training loss 0.206103
>> Epoch 11 finished   ANN training loss 0.198385
>> Epoch 12 finished   ANN training loss 0.184478
>> Epoch 13 finished   ANN training loss 0.134006
>> Epoch 14 finished   ANN training loss 0.123082
>> Epoch 15 finished   ANN training loss 0.120894
>> Epoch 16 finished   ANN training loss 0.114036
```

```
>> Epoch 17 finished     ANN training loss 0.108684
>> Epoch 18 finished     ANN training loss 0.088408
>> Epoch 19 finished     ANN training loss 0.084145
>> Epoch 20 finished     ANN training loss 0.079510
>> Epoch 21 finished     ANN training loss 0.068226
>> Epoch 22 finished     ANN training loss 0.069401
>> Epoch 23 finished     ANN training loss 0.066966
>> Epoch 24 finished     ANN training loss 0.059350
>> Epoch 25 finished     ANN training loss 0.058920
>> Epoch 26 finished     ANN training loss 0.061407
>> Epoch 27 finished     ANN training loss 0.049875
>> Epoch 28 finished     ANN training loss 0.062418
>> Epoch 29 finished     ANN training loss 0.049559
>> Epoch 30 finished     ANN training loss 0.051677
>> Epoch 31 finished     ANN training loss 0.043280
>> Epoch 32 finished     ANN training loss 0.037446
>> Epoch 33 finished     ANN training loss 0.039280
>> Epoch 34 finished     ANN training loss 0.037099
>> Epoch 35 finished     ANN training loss 0.038508
>> Epoch 36 finished     ANN training loss 0.030147
>> Epoch 37 finished     ANN training loss 0.035359
>> Epoch 38 finished     ANN training loss 0.030200
>> Epoch 39 finished     ANN training loss 0.028446
>> Epoch 40 finished     ANN training loss 0.035360
>> Epoch 41 finished     ANN training loss 0.026857
>> Epoch 42 finished     ANN training loss 0.022487
>> Epoch 43 finished     ANN training loss 0.023180
>> Epoch 44 finished     ANN training loss 0.019519
>> Epoch 45 finished     ANN training loss 0.019643
>> Epoch 46 finished     ANN training loss 0.020917
>> Epoch 47 finished     ANN training loss 0.019906
>> Epoch 48 finished     ANN training loss 0.021182
>> Epoch 49 finished     ANN training loss 0.019993
>> Epoch 50 finished     ANN training loss 0.019495
>> Epoch 51 finished     ANN training loss 0.012777
>> Epoch 52 finished     ANN training loss 0.017926
>> Epoch 53 finished     ANN training loss 0.013932
>> Epoch 54 finished     ANN training loss 0.011079
>> Epoch 55 finished     ANN training loss 0.013040
>> Epoch 56 finished     ANN training loss 0.010757
>> Epoch 57 finished     ANN training loss 0.011092
>> Epoch 58 finished     ANN training loss 0.011699
>> Epoch 59 finished     ANN training loss 0.018164
>> Epoch 60 finished     ANN training loss 0.015491
>> Epoch 61 finished     ANN training loss 0.011143
>> Epoch 62 finished     ANN training loss 0.011673
>> Epoch 63 finished     ANN training loss 0.006940
>> Epoch 64 finished     ANN training loss 0.006353
>> Epoch 65 finished     ANN training loss 0.010197
>> Epoch 66 finished     ANN training loss 0.008399
>> Epoch 67 finished     ANN training loss 0.007237
>> Epoch 68 finished     ANN training loss 0.005689
>> Epoch 69 finished     ANN training loss 0.006715
>> Epoch 70 finished     ANN training loss 0.005677
>> Epoch 71 finished     ANN training loss 0.004988
>> Epoch 72 finished     ANN training loss 0.004328
>> Epoch 73 finished     ANN training loss 0.005476
>> Epoch 74 finished     ANN training loss 0.005665
>> Epoch 75 finished     ANN training loss 0.007465
>> Epoch 76 finished     ANN training loss 0.006398
>> Epoch 77 finished     ANN training loss 0.005059
>> Epoch 78 finished     ANN training loss 0.003641
>> Epoch 79 finished     ANN training loss 0.003520
>> Epoch 80 finished     ANN training loss 0.004537
>> Epoch 81 finished     ANN training loss 0.004653
```

```
>> Epoch 82 finished     ANN training loss 0.003046
>> Epoch 83 finished     ANN training loss 0.004958
>> Epoch 84 finished     ANN training loss 0.003206
>> Epoch 85 finished     ANN training loss 0.003467
>> Epoch 86 finished     ANN training loss 0.003210
>> Epoch 87 finished     ANN training loss 0.003064
>> Epoch 88 finished     ANN training loss 0.003068
>> Epoch 89 finished     ANN training loss 0.003391
>> Epoch 90 finished     ANN training loss 0.002906
>> Epoch 91 finished     ANN training loss 0.002788
>> Epoch 92 finished     ANN training loss 0.003122
>> Epoch 93 finished     ANN training loss 0.002835
>> Epoch 94 finished     ANN training loss 0.002755
>> Epoch 95 finished     ANN training loss 0.002521
>> Epoch 96 finished     ANN training loss 0.002588
>> Epoch 97 finished     ANN training loss 0.002841
>> Epoch 98 finished     ANN training loss 0.002459
>> Epoch 99 finished     ANN training loss 0.001963
[END] Fine tuning step
Done.
```

In [57]:
```python
print('ACCURACY: ' + str(threelayer_acc[6]))
```

```
ACCURACY: 0.91
```

In [58]:
```python
#Collated results
print(threelayer_acc)
print('Most accurate 3-layer setting is Setting ' + str(threelayer_acc.index(
```

```
[0.905, 0.915, 0.905, 0.91, 0.925, 0.92, 0.91]
Most accurate 3-layer setting is Setting 5
```

In [59]:
```python
# Create bar graph
plt.clf()
objects = ('[100, 200, 300]', '[500, 200, 300]', '[100, 500, 300]', '[100, 200
y_pos = np.arange(len(objects))
performance = [0.9,0.925,0.895,0.87, 0.91, 0.875, 0.87]

plt.bar(y_pos, performance, align='center', alpha=0.5, width=0.5)
plt.xticks(y_pos, objects, rotation=30)
plt.xlabel('Layer Settings')
plt.ylabel('Accuracy')
plt.title('Three-layer Settings')


plt.show()
plt.clf()
```

Three-layer Settings

```
<Figure size 432x288 with 0 Axes>
```
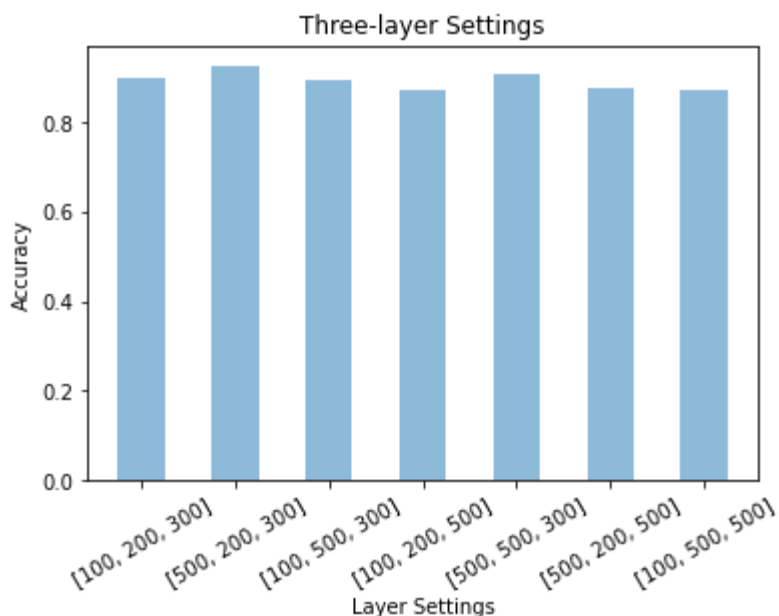
Different Pre-training (RBM) Learning Rates:

In [60]:
```python
# Store accuracies
rbm_acc = [0, 0, 0, 0, 0]
```

Setting 1

learning_rate_rbm=0.01

In [61]:
```python
rbm_acc[0] = deep_belief_net(learning_rate_rbm=0.01)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 48.676327
>> Epoch 2 finished     RBM Reconstruction error 44.983673
>> Epoch 3 finished     RBM Reconstruction error 37.189789
>> Epoch 4 finished     RBM Reconstruction error 32.108334
>> Epoch 5 finished     RBM Reconstruction error 29.079042
>> Epoch 6 finished     RBM Reconstruction error 26.841358
>> Epoch 7 finished     RBM Reconstruction error 25.027222
>> Epoch 8 finished     RBM Reconstruction error 23.722651
>> Epoch 9 finished     RBM Reconstruction error 22.607672
>> Epoch 10 finished    RBM Reconstruction error 21.722998
>> Epoch 1 finished     RBM Reconstruction error 25.245600
>> Epoch 2 finished     RBM Reconstruction error 18.901453
>> Epoch 3 finished     RBM Reconstruction error 10.708242
>> Epoch 4 finished     RBM Reconstruction error 7.466425
>> Epoch 5 finished     RBM Reconstruction error 5.650034
>> Epoch 6 finished     RBM Reconstruction error 4.540646
>> Epoch 7 finished     RBM Reconstruction error 3.837914
>> Epoch 8 finished     RBM Reconstruction error 3.387722
>> Epoch 9 finished     RBM Reconstruction error 2.928828
>> Epoch 10 finished    RBM Reconstruction error 2.709045
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 1.031388
>> Epoch 1 finished     ANN training loss 0.698853
>> Epoch 2 finished     ANN training loss 0.578371
```

```
>> Epoch 3 finished      ANN training loss 0.471742
>> Epoch 4 finished      ANN training loss 0.438442
>> Epoch 5 finished      ANN training loss 0.378788
>> Epoch 6 finished      ANN training loss 0.329750
>> Epoch 7 finished      ANN training loss 0.296313
>> Epoch 8 finished      ANN training loss 0.287987
>> Epoch 9 finished      ANN training loss 0.236950
>> Epoch 10 finished     ANN training loss 0.274150
>> Epoch 11 finished     ANN training loss 0.195219
>> Epoch 12 finished     ANN training loss 0.198504
>> Epoch 13 finished     ANN training loss 0.161178
>> Epoch 14 finished     ANN training loss 0.153865
>> Epoch 15 finished     ANN training loss 0.149770
>> Epoch 16 finished     ANN training loss 0.125424
>> Epoch 17 finished     ANN training loss 0.110138
>> Epoch 18 finished     ANN training loss 0.120597
>> Epoch 19 finished     ANN training loss 0.087653
>> Epoch 20 finished     ANN training loss 0.083731
>> Epoch 21 finished     ANN training loss 0.071885
>> Epoch 22 finished     ANN training loss 0.070991
>> Epoch 23 finished     ANN training loss 0.062647
>> Epoch 24 finished     ANN training loss 0.063783
>> Epoch 25 finished     ANN training loss 0.050657
>> Epoch 26 finished     ANN training loss 0.046961
>> Epoch 27 finished     ANN training loss 0.041112
>> Epoch 28 finished     ANN training loss 0.039394
>> Epoch 29 finished     ANN training loss 0.030572
>> Epoch 30 finished     ANN training loss 0.032830
>> Epoch 31 finished     ANN training loss 0.027804
>> Epoch 32 finished     ANN training loss 0.022658
>> Epoch 33 finished     ANN training loss 0.023533
>> Epoch 34 finished     ANN training loss 0.040336
>> Epoch 35 finished     ANN training loss 0.021596
>> Epoch 36 finished     ANN training loss 0.017419
>> Epoch 37 finished     ANN training loss 0.018029
>> Epoch 38 finished     ANN training loss 0.021564
>> Epoch 39 finished     ANN training loss 0.015428
>> Epoch 40 finished     ANN training loss 0.016025
>> Epoch 41 finished     ANN training loss 0.013834
>> Epoch 42 finished     ANN training loss 0.012360
>> Epoch 43 finished     ANN training loss 0.012491
>> Epoch 44 finished     ANN training loss 0.009236
>> Epoch 45 finished     ANN training loss 0.009869
>> Epoch 46 finished     ANN training loss 0.013663
>> Epoch 47 finished     ANN training loss 0.008555
>> Epoch 48 finished     ANN training loss 0.009036
>> Epoch 49 finished     ANN training loss 0.007324
>> Epoch 50 finished     ANN training loss 0.007412
>> Epoch 51 finished     ANN training loss 0.005840
>> Epoch 52 finished     ANN training loss 0.006838
>> Epoch 53 finished     ANN training loss 0.006508
>> Epoch 54 finished     ANN training loss 0.005439
>> Epoch 55 finished     ANN training loss 0.006234
>> Epoch 56 finished     ANN training loss 0.005158
>> Epoch 57 finished     ANN training loss 0.007660
>> Epoch 58 finished     ANN training loss 0.004611
>> Epoch 59 finished     ANN training loss 0.004291
>> Epoch 60 finished     ANN training loss 0.004049
>> Epoch 61 finished     ANN training loss 0.003814
>> Epoch 62 finished     ANN training loss 0.003774
>> Epoch 63 finished     ANN training loss 0.003721
>> Epoch 64 finished     ANN training loss 0.003675
>> Epoch 65 finished     ANN training loss 0.003255
>> Epoch 66 finished     ANN training loss 0.003487
>> Epoch 67 finished     ANN training loss 0.003269
```

```
>> Epoch 68 finished     ANN training loss 0.003429
>> Epoch 69 finished     ANN training loss 0.002832
>> Epoch 70 finished     ANN training loss 0.003182
>> Epoch 71 finished     ANN training loss 0.002601
>> Epoch 72 finished     ANN training loss 0.002468
>> Epoch 73 finished     ANN training loss 0.002914
>> Epoch 74 finished     ANN training loss 0.003348
>> Epoch 75 finished     ANN training loss 0.002607
>> Epoch 76 finished     ANN training loss 0.003349
>> Epoch 77 finished     ANN training loss 0.002008
>> Epoch 78 finished     ANN training loss 0.002095
>> Epoch 79 finished     ANN training loss 0.001980
>> Epoch 80 finished     ANN training loss 0.001866
>> Epoch 81 finished     ANN training loss 0.002689
>> Epoch 82 finished     ANN training loss 0.002575
>> Epoch 83 finished     ANN training loss 0.001595
>> Epoch 84 finished     ANN training loss 0.001677
>> Epoch 85 finished     ANN training loss 0.001653
>> Epoch 86 finished     ANN training loss 0.001344
>> Epoch 87 finished     ANN training loss 0.001573
>> Epoch 88 finished     ANN training loss 0.001442
>> Epoch 89 finished     ANN training loss 0.001547
>> Epoch 90 finished     ANN training loss 0.001407
>> Epoch 91 finished     ANN training loss 0.001592
>> Epoch 92 finished     ANN training loss 0.001101
>> Epoch 93 finished     ANN training loss 0.001561
>> Epoch 94 finished     ANN training loss 0.001251
>> Epoch 95 finished     ANN training loss 0.001467
>> Epoch 96 finished     ANN training loss 0.001001
>> Epoch 97 finished     ANN training loss 0.001051
>> Epoch 98 finished     ANN training loss 0.001021
>> Epoch 99 finished     ANN training loss 0.001340
[END] Fine tuning step
Done.
```

In [62]:
```python
print('ACCURACY: ' + str(rbm_acc[0]))
```

```
ACCURACY: 0.895
```

Setting 2

learning_rate_rbm=0.05

In [63]:
```python
rbm_acc[1] = deep_belief_net(learning_rate_rbm=0.05)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 94.117859
>> Epoch 2 finished      RBM Reconstruction error 52.268402
>> Epoch 3 finished      RBM Reconstruction error 64.728737
>> Epoch 4 finished      RBM Reconstruction error 81.388184
>> Epoch 5 finished      RBM Reconstruction error 48.622433
>> Epoch 6 finished      RBM Reconstruction error 34.124168
>> Epoch 7 finished      RBM Reconstruction error 47.252640
>> Epoch 8 finished      RBM Reconstruction error 66.236252
>> Epoch 9 finished      RBM Reconstruction error 42.664062
>> Epoch 10 finished     RBM Reconstruction error 28.159138
>> Epoch 1 finished      RBM Reconstruction error 70.359612
>> Epoch 2 finished      RBM Reconstruction error 78.932182
>> Epoch 3 finished      RBM Reconstruction error 69.850471
>> Epoch 4 finished      RBM Reconstruction error 102.608810
>> Epoch 5 finished      RBM Reconstruction error 102.450813
>> Epoch 6 finished      RBM Reconstruction error 117.915955
>> Epoch 7 finished      RBM Reconstruction error 100.429787
```

```
                    >> Epoch 8 finished      RBM Reconstruction error 128.298401
                    >> Epoch 9 finished      RBM Reconstruction error 98.683792
                    >> Epoch 10 finished     RBM Reconstruction error 138.419083
                    [END] Pre-training step
                    [START] Fine tuning step:
                    >> Epoch 0 finished      ANN training loss 0.697164
                    >> Epoch 1 finished      ANN training loss 0.511610
                    >> Epoch 2 finished      ANN training loss 0.402958
                    >> Epoch 3 finished      ANN training loss 0.354107
                    >> Epoch 4 finished      ANN training loss 0.306825
                    >> Epoch 5 finished      ANN training loss 0.306450
                    >> Epoch 6 finished      ANN training loss 0.240411
                    >> Epoch 7 finished      ANN training loss 0.218182
                    >> Epoch 8 finished      ANN training loss 0.218609
                    >> Epoch 9 finished      ANN training loss 0.171138
                    >> Epoch 10 finished     ANN training loss 0.156822
                    >> Epoch 11 finished     ANN training loss 0.142558
                    >> Epoch 12 finished     ANN training loss 0.118076
                    >> Epoch 13 finished     ANN training loss 0.109248
                    >> Epoch 14 finished     ANN training loss 0.099005
                    >> Epoch 15 finished     ANN training loss 0.102111
                    >> Epoch 16 finished     ANN training loss 0.084690
                    >> Epoch 17 finished     ANN training loss 0.076107
                    >> Epoch 18 finished     ANN training loss 0.069730
                    >> Epoch 19 finished     ANN training loss 0.060799
                    >> Epoch 20 finished     ANN training loss 0.056368
                    >> Epoch 21 finished     ANN training loss 0.051745
                    >> Epoch 22 finished     ANN training loss 0.048154
                    >> Epoch 23 finished     ANN training loss 0.046710
                    >> Epoch 24 finished     ANN training loss 0.045579
                    >> Epoch 25 finished     ANN training loss 0.034644
                    >> Epoch 26 finished     ANN training loss 0.036664
                    >> Epoch 27 finished     ANN training loss 0.031476
                    >> Epoch 28 finished     ANN training loss 0.029145
                    >> Epoch 29 finished     ANN training loss 0.026279
                    >> Epoch 30 finished     ANN training loss 0.024618
                    >> Epoch 31 finished     ANN training loss 0.022609
                    >> Epoch 32 finished     ANN training loss 0.021729
                    >> Epoch 33 finished     ANN training loss 0.018747
                    >> Epoch 34 finished     ANN training loss 0.017236
                    >> Epoch 35 finished     ANN training loss 0.016656
                    >> Epoch 36 finished     ANN training loss 0.016192
                    >> Epoch 37 finished     ANN training loss 0.015062
                    >> Epoch 38 finished     ANN training loss 0.013273
                    >> Epoch 39 finished     ANN training loss 0.011154
                    >> Epoch 40 finished     ANN training loss 0.012872
                    >> Epoch 41 finished     ANN training loss 0.011676
                    >> Epoch 42 finished     ANN training loss 0.010933
                    >> Epoch 43 finished     ANN training loss 0.010014
                    >> Epoch 44 finished     ANN training loss 0.010499
                    >> Epoch 45 finished     ANN training loss 0.011103
                    >> Epoch 46 finished     ANN training loss 0.009723
                    >> Epoch 47 finished     ANN training loss 0.008240
                    >> Epoch 48 finished     ANN training loss 0.008232
                    >> Epoch 49 finished     ANN training loss 0.006863
                    >> Epoch 50 finished     ANN training loss 0.007137
                    >> Epoch 51 finished     ANN training loss 0.006950
                    >> Epoch 52 finished     ANN training loss 0.007001
                    >> Epoch 53 finished     ANN training loss 0.005637
                    >> Epoch 54 finished     ANN training loss 0.005751
                    >> Epoch 55 finished     ANN training loss 0.005118
                    >> Epoch 56 finished     ANN training loss 0.005571
                    >> Epoch 57 finished     ANN training loss 0.004007
                    >> Epoch 58 finished     ANN training loss 0.004096
                    >> Epoch 59 finished     ANN training loss 0.004607
```

```
>> Epoch 60 finished     ANN training loss 0.005163
>> Epoch 61 finished     ANN training loss 0.004935
>> Epoch 62 finished     ANN training loss 0.004361
>> Epoch 63 finished     ANN training loss 0.003653
>> Epoch 64 finished     ANN training loss 0.003530
>> Epoch 65 finished     ANN training loss 0.003372
>> Epoch 66 finished     ANN training loss 0.003626
>> Epoch 67 finished     ANN training loss 0.002988
>> Epoch 68 finished     ANN training loss 0.002660
>> Epoch 69 finished     ANN training loss 0.002819
>> Epoch 70 finished     ANN training loss 0.002478
>> Epoch 71 finished     ANN training loss 0.002772
>> Epoch 72 finished     ANN training loss 0.002560
>> Epoch 73 finished     ANN training loss 0.002443
>> Epoch 74 finished     ANN training loss 0.002414
>> Epoch 75 finished     ANN training loss 0.002151
>> Epoch 76 finished     ANN training loss 0.002132
>> Epoch 77 finished     ANN training loss 0.002391
>> Epoch 78 finished     ANN training loss 0.002215
>> Epoch 79 finished     ANN training loss 0.002274
>> Epoch 80 finished     ANN training loss 0.001956
>> Epoch 81 finished     ANN training loss 0.001756
>> Epoch 82 finished     ANN training loss 0.001879
>> Epoch 83 finished     ANN training loss 0.001628
>> Epoch 84 finished     ANN training loss 0.001651
>> Epoch 85 finished     ANN training loss 0.001509
>> Epoch 86 finished     ANN training loss 0.001369
>> Epoch 87 finished     ANN training loss 0.001396
>> Epoch 88 finished     ANN training loss 0.001494
>> Epoch 89 finished     ANN training loss 0.001334
>> Epoch 90 finished     ANN training loss 0.001288
>> Epoch 91 finished     ANN training loss 0.001407
>> Epoch 92 finished     ANN training loss 0.001189
>> Epoch 93 finished     ANN training loss 0.001230
>> Epoch 94 finished     ANN training loss 0.001383
>> Epoch 95 finished     ANN training loss 0.001098
>> Epoch 96 finished     ANN training loss 0.001277
>> Epoch 97 finished     ANN training loss 0.001462
>> Epoch 98 finished     ANN training loss 0.001170
>> Epoch 99 finished     ANN training loss 0.001121
[END] Fine tuning step
Done.
```

In [64]:
```python
print('ACCURACY: ' + str(rbm_acc[1]))
```

```
ACCURACY: 0.925
```

Setting 3

learning_rate_rbm=0.1

In [66]:
```python
rbm_acc[2] = deep_belief_net(learning_rate_rbm=0.1)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 160.164536
>> Epoch 2 finished     RBM Reconstruction error 210.062515
>> Epoch 3 finished     RBM Reconstruction error 200.079437
>> Epoch 4 finished     RBM Reconstruction error 248.465836
>> Epoch 5 finished     RBM Reconstruction error 249.755737
>> Epoch 6 finished     RBM Reconstruction error 249.164856
>> Epoch 7 finished     RBM Reconstruction error 224.799500
>> Epoch 8 finished     RBM Reconstruction error 185.062149
>> Epoch 9 finished     RBM Reconstruction error 232.932480
```

```
                 >> Epoch 10 finished     RBM Reconstruction error 266.111877
                 >> Epoch 1 finished      RBM Reconstruction error 5655.453125
                 >> Epoch 2 finished      RBM Reconstruction error 2792.553711
                 >> Epoch 3 finished      RBM Reconstruction error 5171.014160
                 >> Epoch 4 finished      RBM Reconstruction error 7408.390137
                 >> Epoch 5 finished      RBM Reconstruction error 7781.333984
                 >> Epoch 6 finished      RBM Reconstruction error 12144.424805
                 >> Epoch 7 finished      RBM Reconstruction error 16212.991211
                 >> Epoch 8 finished      RBM Reconstruction error 20276.886719
                 >> Epoch 9 finished      RBM Reconstruction error 12120.339844
                 >> Epoch 10 finished     RBM Reconstruction error 18856.796875
                 [END] Pre-training step
                 [START] Fine tuning step:
                 >> Epoch 0 finished      ANN training loss 1.055440
                 >> Epoch 1 finished      ANN training loss 0.808861
                 >> Epoch 2 finished      ANN training loss 0.639016
                 >> Epoch 3 finished      ANN training loss 0.563351
                 >> Epoch 4 finished      ANN training loss 0.483953
                 >> Epoch 5 finished      ANN training loss 0.408092
                 >> Epoch 6 finished      ANN training loss 0.375929
                 >> Epoch 7 finished      ANN training loss 0.328771
                 >> Epoch 8 finished      ANN training loss 0.322075
                 >> Epoch 9 finished      ANN training loss 0.271771
                 >> Epoch 10 finished     ANN training loss 0.244280
                 >> Epoch 11 finished     ANN training loss 0.241296
                 >> Epoch 12 finished     ANN training loss 0.245327
                 >> Epoch 13 finished     ANN training loss 0.194926
                 >> Epoch 14 finished     ANN training loss 0.183459
                 >> Epoch 15 finished     ANN training loss 0.180053
                 >> Epoch 16 finished     ANN training loss 0.149320
                 >> Epoch 17 finished     ANN training loss 0.148266
                 >> Epoch 18 finished     ANN training loss 0.135523
                 >> Epoch 19 finished     ANN training loss 0.131037
                 >> Epoch 20 finished     ANN training loss 0.120590
                 >> Epoch 21 finished     ANN training loss 0.109792
                 >> Epoch 22 finished     ANN training loss 0.105820
                 >> Epoch 23 finished     ANN training loss 0.094101
                 >> Epoch 24 finished     ANN training loss 0.084638
                 >> Epoch 25 finished     ANN training loss 0.080262
                 >> Epoch 26 finished     ANN training loss 0.081477
                 >> Epoch 27 finished     ANN training loss 0.069037
                 >> Epoch 28 finished     ANN training loss 0.072296
                 >> Epoch 29 finished     ANN training loss 0.060090
                 >> Epoch 30 finished     ANN training loss 0.056916
                 >> Epoch 31 finished     ANN training loss 0.054997
                 >> Epoch 32 finished     ANN training loss 0.053393
                 >> Epoch 33 finished     ANN training loss 0.049004
                 >> Epoch 34 finished     ANN training loss 0.041385
                 >> Epoch 35 finished     ANN training loss 0.041481
                 >> Epoch 36 finished     ANN training loss 0.046173
                 >> Epoch 37 finished     ANN training loss 0.035106
                 >> Epoch 38 finished     ANN training loss 0.035385
                 >> Epoch 39 finished     ANN training loss 0.032396
                 >> Epoch 40 finished     ANN training loss 0.031652
                 >> Epoch 41 finished     ANN training loss 0.032979
                 >> Epoch 42 finished     ANN training loss 0.027082
                 >> Epoch 43 finished     ANN training loss 0.028412
                 >> Epoch 44 finished     ANN training loss 0.029043
                 >> Epoch 45 finished     ANN training loss 0.024924
                 >> Epoch 46 finished     ANN training loss 0.022635
                 >> Epoch 47 finished     ANN training loss 0.021207
                 >> Epoch 48 finished     ANN training loss 0.023568
                 >> Epoch 49 finished     ANN training loss 0.021258
                 >> Epoch 50 finished     ANN training loss 0.018640
                 >> Epoch 51 finished     ANN training loss 0.017819
```

```
>> Epoch 52 finished    ANN training loss 0.016779
>> Epoch 53 finished    ANN training loss 0.015532
>> Epoch 54 finished    ANN training loss 0.015907
>> Epoch 55 finished    ANN training loss 0.015925
>> Epoch 56 finished    ANN training loss 0.013016
>> Epoch 57 finished    ANN training loss 0.012353
>> Epoch 58 finished    ANN training loss 0.012906
>> Epoch 59 finished    ANN training loss 0.010998
>> Epoch 60 finished    ANN training loss 0.011406
>> Epoch 61 finished    ANN training loss 0.010510
>> Epoch 62 finished    ANN training loss 0.011793
>> Epoch 63 finished    ANN training loss 0.011529
>> Epoch 64 finished    ANN training loss 0.011751
>> Epoch 65 finished    ANN training loss 0.010251
>> Epoch 66 finished    ANN training loss 0.008513
>> Epoch 67 finished    ANN training loss 0.008053
>> Epoch 68 finished    ANN training loss 0.009782
>> Epoch 69 finished    ANN training loss 0.007693
>> Epoch 70 finished    ANN training loss 0.007948
>> Epoch 71 finished    ANN training loss 0.007992
>> Epoch 72 finished    ANN training loss 0.008252
>> Epoch 73 finished    ANN training loss 0.007088
>> Epoch 74 finished    ANN training loss 0.006534
>> Epoch 75 finished    ANN training loss 0.006166
>> Epoch 76 finished    ANN training loss 0.005775
>> Epoch 77 finished    ANN training loss 0.005136
>> Epoch 78 finished    ANN training loss 0.004990
>> Epoch 79 finished    ANN training loss 0.003969
>> Epoch 80 finished    ANN training loss 0.004551
>> Epoch 81 finished    ANN training loss 0.003993
>> Epoch 82 finished    ANN training loss 0.004105
>> Epoch 83 finished    ANN training loss 0.004157
>> Epoch 84 finished    ANN training loss 0.004661
>> Epoch 85 finished    ANN training loss 0.004663
>> Epoch 86 finished    ANN training loss 0.003927
>> Epoch 87 finished    ANN training loss 0.003849
>> Epoch 88 finished    ANN training loss 0.003416
>> Epoch 89 finished    ANN training loss 0.003235
>> Epoch 90 finished    ANN training loss 0.003278
>> Epoch 91 finished    ANN training loss 0.003998
>> Epoch 92 finished    ANN training loss 0.004016
>> Epoch 93 finished    ANN training loss 0.003774
>> Epoch 94 finished    ANN training loss 0.004134
>> Epoch 95 finished    ANN training loss 0.004541
>> Epoch 96 finished    ANN training loss 0.004077
>> Epoch 97 finished    ANN training loss 0.003132
>> Epoch 98 finished    ANN training loss 0.002965
>> Epoch 99 finished    ANN training loss 0.003258
[END] Fine tuning step
Done.
```

In [67]:
```python
print('ACCURACY: ' + str(rbm_acc[2]))
```

```
ACCURACY: 0.925
```

Setting 4

learning_rate_rbm=0.5

In [68]:
```python
rbm_acc[3] = deep_belief_net(learning_rate_rbm=0.5)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 659944.875000
```

```
                >> Epoch 2 finished        RBM Reconstruction error 787932.250000
                >> Epoch 3 finished        RBM Reconstruction error 966067.687500
                >> Epoch 4 finished        RBM Reconstruction error 851286.875000
                >> Epoch 5 finished        RBM Reconstruction error 768199.187500
                >> Epoch 6 finished        RBM Reconstruction error 872080.062500
                >> Epoch 7 finished        RBM Reconstruction error 1002583.375000
                >> Epoch 8 finished        RBM Reconstruction error 942753.437500
                >> Epoch 9 finished        RBM Reconstruction error 845925.625000
                >> Epoch 10 finished       RBM Reconstruction error 747044.625000
                >> Epoch 1 finished        RBM Reconstruction error 17573135515648.000000
                >> Epoch 2 finished        RBM Reconstruction error 35479558815744.000000
                >> Epoch 3 finished        RBM Reconstruction error 20757310603264.000000
                >> Epoch 4 finished        RBM Reconstruction error 33263219376128.000000
                >> Epoch 5 finished        RBM Reconstruction error 20254757486592.000000
                >> Epoch 6 finished        RBM Reconstruction error 33756924608512.000000
                >> Epoch 7 finished        RBM Reconstruction error 16201875980288.000000
                >> Epoch 8 finished        RBM Reconstruction error 32528901603328.000000
                >> Epoch 9 finished        RBM Reconstruction error 20109468893184.000000
                >> Epoch 10 finished       RBM Reconstruction error 24747140186112.000000
                [END] Pre-training step
                [START] Fine tuning step:
                >> Epoch 0 finished        ANN training loss 2.302652
                >> Epoch 1 finished        ANN training loss 2.302344
                >> Epoch 2 finished        ANN training loss 2.302136
                >> Epoch 3 finished        ANN training loss 2.301996
                >> Epoch 4 finished        ANN training loss 2.301924
                >> Epoch 5 finished        ANN training loss 2.301873
                >> Epoch 6 finished        ANN training loss 2.301846
                >> Epoch 7 finished        ANN training loss 2.301834
                >> Epoch 8 finished        ANN training loss 2.301826
                >> Epoch 9 finished        ANN training loss 2.301821
                >> Epoch 10 finished       ANN training loss 2.301816
                >> Epoch 11 finished       ANN training loss 2.301815
                >> Epoch 12 finished       ANN training loss 2.301812
                >> Epoch 13 finished       ANN training loss 2.301810
                >> Epoch 14 finished       ANN training loss 2.301809
                >> Epoch 15 finished       ANN training loss 2.301808
                >> Epoch 16 finished       ANN training loss 2.301805
                >> Epoch 17 finished       ANN training loss 2.301807
                >> Epoch 18 finished       ANN training loss 2.301808
                >> Epoch 19 finished       ANN training loss 2.301808
                >> Epoch 20 finished       ANN training loss 2.301806
                >> Epoch 21 finished       ANN training loss 2.301806
                >> Epoch 22 finished       ANN training loss 2.301807
                >> Epoch 23 finished       ANN training loss 2.301808
                >> Epoch 24 finished       ANN training loss 2.301808
                >> Epoch 25 finished       ANN training loss 2.301807
                >> Epoch 26 finished       ANN training loss 2.301807
                >> Epoch 27 finished       ANN training loss 2.301806
                >> Epoch 28 finished       ANN training loss 2.301807
                >> Epoch 29 finished       ANN training loss 2.301807
                >> Epoch 30 finished       ANN training loss 2.301808
                >> Epoch 31 finished       ANN training loss 2.301806
                >> Epoch 32 finished       ANN training loss 2.301806
                >> Epoch 33 finished       ANN training loss 2.301806
                >> Epoch 34 finished       ANN training loss 2.301807
                >> Epoch 35 finished       ANN training loss 2.301805
                >> Epoch 36 finished       ANN training loss 2.301806
                >> Epoch 37 finished       ANN training loss 2.301806
                >> Epoch 38 finished       ANN training loss 2.301808
                >> Epoch 39 finished       ANN training loss 2.301807
                >> Epoch 40 finished       ANN training loss 2.301809
                >> Epoch 41 finished       ANN training loss 2.301808
                >> Epoch 42 finished       ANN training loss 2.301808
                >> Epoch 43 finished       ANN training loss 2.301809
```

```
>> Epoch 44 finished    ANN training loss 2.301807
>> Epoch 45 finished    ANN training loss 2.301810
>> Epoch 46 finished    ANN training loss 2.301808
>> Epoch 47 finished    ANN training loss 2.301808
>> Epoch 48 finished    ANN training loss 2.301811
>> Epoch 49 finished    ANN training loss 2.301811
>> Epoch 50 finished    ANN training loss 2.301810
>> Epoch 51 finished    ANN training loss 2.301807
>> Epoch 52 finished    ANN training loss 2.301809
>> Epoch 53 finished    ANN training loss 2.301808
>> Epoch 54 finished    ANN training loss 2.301808
>> Epoch 55 finished    ANN training loss 2.301809
>> Epoch 56 finished    ANN training loss 2.301810
>> Epoch 57 finished    ANN training loss 2.301809
>> Epoch 58 finished    ANN training loss 2.301807
>> Epoch 59 finished    ANN training loss 2.301806
>> Epoch 60 finished    ANN training loss 2.301808
>> Epoch 61 finished    ANN training loss 2.301808
>> Epoch 62 finished    ANN training loss 2.301808
>> Epoch 63 finished    ANN training loss 2.301809
>> Epoch 64 finished    ANN training loss 2.301808
>> Epoch 65 finished    ANN training loss 2.301807
>> Epoch 66 finished    ANN training loss 2.301806
>> Epoch 67 finished    ANN training loss 2.301806
>> Epoch 68 finished    ANN training loss 2.301806
>> Epoch 69 finished    ANN training loss 2.301807
>> Epoch 70 finished    ANN training loss 2.301806
>> Epoch 71 finished    ANN training loss 2.301807
>> Epoch 72 finished    ANN training loss 2.301809
>> Epoch 73 finished    ANN training loss 2.301808
>> Epoch 74 finished    ANN training loss 2.301806
>> Epoch 75 finished    ANN training loss 2.301807
>> Epoch 76 finished    ANN training loss 2.301807
>> Epoch 77 finished    ANN training loss 2.301805
>> Epoch 78 finished    ANN training loss 2.301806
>> Epoch 79 finished    ANN training loss 2.301805
>> Epoch 80 finished    ANN training loss 2.301805
>> Epoch 81 finished    ANN training loss 2.301805
>> Epoch 82 finished    ANN training loss 2.301808
>> Epoch 83 finished    ANN training loss 2.301808
>> Epoch 84 finished    ANN training loss 2.301810
>> Epoch 85 finished    ANN training loss 2.301808
>> Epoch 86 finished    ANN training loss 2.301808
>> Epoch 87 finished    ANN training loss 2.301808
>> Epoch 88 finished    ANN training loss 2.301806
>> Epoch 89 finished    ANN training loss 2.301808
>> Epoch 90 finished    ANN training loss 2.301809
>> Epoch 91 finished    ANN training loss 2.301808
>> Epoch 92 finished    ANN training loss 2.301808
>> Epoch 93 finished    ANN training loss 2.301809
>> Epoch 94 finished    ANN training loss 2.301811
>> Epoch 95 finished    ANN training loss 2.301808
>> Epoch 96 finished    ANN training loss 2.301809
>> Epoch 97 finished    ANN training loss 2.301805
>> Epoch 98 finished    ANN training loss 2.301808
>> Epoch 99 finished    ANN training loss 2.301808
[END] Fine tuning step
Done.
```

In [69]:
```python
print('ACCURACY: ' + str(rbm_acc[3]))
```

```
ACCURACY: 0.07
```

Setting 5

learning_rate_rbm=1.0

In [70]:
```
rbm_acc[4] = deep_belief_net(learning_rate_rbm=1.0)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 64719360.000000
>> Epoch 2 finished     RBM Reconstruction error 52101428.000000
>> Epoch 3 finished     RBM Reconstruction error 73726448.000000
>> Epoch 4 finished     RBM Reconstruction error 78145640.000000
>> Epoch 5 finished     RBM Reconstruction error 78830472.000000
>> Epoch 6 finished     RBM Reconstruction error 61287808.000000
>> Epoch 7 finished     RBM Reconstruction error 56961512.000000
>> Epoch 8 finished     RBM Reconstruction error 57858744.000000
>> Epoch 9 finished     RBM Reconstruction error 58905796.000000
>> Epoch 10 finished    RBM Reconstruction error 60400040.000000
>> Epoch 1 finished     RBM Reconstruction error 158461615795077120000.000000
>> Epoch 2 finished     RBM Reconstruction error 117894105145398001664.000000
>> Epoch 3 finished     RBM Reconstruction error 129137271246384267264.000000
>> Epoch 4 finished     RBM Reconstruction error 137155209103289614336.000000
>> Epoch 5 finished     RBM Reconstruction error 106870621467641380864.000000
>> Epoch 6 finished     RBM Reconstruction error 121985801328724541440.000000
>> Epoch 7 finished     RBM Reconstruction error 133737522343882784768.000000
>> Epoch 8 finished     RBM Reconstruction error 136982005235589316608.000000
>> Epoch 9 finished     RBM Reconstruction error 132234516336992059392.000000
>> Epoch 10 finished    RBM Reconstruction error 118541972580855709696.000000
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 2.303047
>> Epoch 1 finished     ANN training loss 2.302773
>> Epoch 2 finished     ANN training loss 2.302444
>> Epoch 3 finished     ANN training loss 2.302197
>> Epoch 4 finished     ANN training loss 2.302058
>> Epoch 5 finished     ANN training loss 2.301948
>> Epoch 6 finished     ANN training loss 2.301892
>> Epoch 7 finished     ANN training loss 2.301873
>> Epoch 8 finished     ANN training loss 2.301846
>> Epoch 9 finished     ANN training loss 2.301833
>> Epoch 10 finished    ANN training loss 2.301822
>> Epoch 11 finished    ANN training loss 2.301822
>> Epoch 12 finished    ANN training loss 2.301822
>> Epoch 13 finished    ANN training loss 2.301818
>> Epoch 14 finished    ANN training loss 2.301816
>> Epoch 15 finished    ANN training loss 2.301815
>> Epoch 16 finished    ANN training loss 2.301813
>> Epoch 17 finished    ANN training loss 2.301807
>> Epoch 18 finished    ANN training loss 2.301844
>> Epoch 19 finished    ANN training loss 2.301825
>> Epoch 20 finished    ANN training loss 2.301814
>> Epoch 21 finished    ANN training loss 2.301814
>> Epoch 22 finished    ANN training loss 2.301811
>> Epoch 23 finished    ANN training loss 2.301810
>> Epoch 24 finished    ANN training loss 2.301813
>> Epoch 25 finished    ANN training loss 2.301808
>> Epoch 26 finished    ANN training loss 2.301809
>> Epoch 27 finished    ANN training loss 2.301810
>> Epoch 28 finished    ANN training loss 2.301809
>> Epoch 29 finished    ANN training loss 2.301807
>> Epoch 30 finished    ANN training loss 2.301805
>> Epoch 31 finished    ANN training loss 2.300120
>> Epoch 32 finished    ANN training loss 2.301818
>> Epoch 33 finished    ANN training loss 2.301810
>> Epoch 34 finished    ANN training loss 2.301826
>> Epoch 35 finished    ANN training loss 2.301830
```

```
>> Epoch 36 finished    ANN training loss 2.301830
>> Epoch 37 finished    ANN training loss 2.301830
>> Epoch 38 finished    ANN training loss 2.301839
>> Epoch 39 finished    ANN training loss 2.301849
>> Epoch 40 finished    ANN training loss 2.301862
>> Epoch 41 finished    ANN training loss 2.301884
>> Epoch 42 finished    ANN training loss 2.301927
>> Epoch 43 finished    ANN training loss 2.301968
>> Epoch 44 finished    ANN training loss 2.302024
>> Epoch 45 finished    ANN training loss 2.302189
>> Epoch 46 finished    ANN training loss 2.302360
>> Epoch 47 finished    ANN training loss 2.302679
>> Epoch 48 finished    ANN training loss 2.293964
>> Epoch 49 finished    ANN training loss 2.303125
>> Epoch 50 finished    ANN training loss 2.303401
>> Epoch 51 finished    ANN training loss 2.303262
>> Epoch 52 finished    ANN training loss 2.303241
>> Epoch 53 finished    ANN training loss 2.303434
>> Epoch 54 finished    ANN training loss 2.303587
>> Epoch 55 finished    ANN training loss 2.303831
>> Epoch 56 finished    ANN training loss 2.303696
>> Epoch 57 finished    ANN training loss 2.303664
>> Epoch 58 finished    ANN training loss 2.303646
>> Epoch 59 finished    ANN training loss 2.303725
>> Epoch 60 finished    ANN training loss 2.303984
>> Epoch 61 finished    ANN training loss 2.303880
>> Epoch 62 finished    ANN training loss 2.304004
>> Epoch 63 finished    ANN training loss 2.304679
>> Epoch 64 finished    ANN training loss 2.304989
>> Epoch 65 finished    ANN training loss 2.304720
>> Epoch 66 finished    ANN training loss 2.304526
>> Epoch 67 finished    ANN training loss 2.304274
>> Epoch 68 finished    ANN training loss 2.304306
>> Epoch 69 finished    ANN training loss 2.304354
>> Epoch 70 finished    ANN training loss 2.304672
>> Epoch 71 finished    ANN training loss 2.304369
>> Epoch 72 finished    ANN training loss 2.304423
>> Epoch 73 finished    ANN training loss 2.304207
>> Epoch 74 finished    ANN training loss 2.304089
>> Epoch 75 finished    ANN training loss 2.304088
>> Epoch 76 finished    ANN training loss 2.304371
>> Epoch 77 finished    ANN training loss 2.304699
>> Epoch 78 finished    ANN training loss 2.304737
>> Epoch 79 finished    ANN training loss 2.304569
>> Epoch 80 finished    ANN training loss 2.304573
>> Epoch 81 finished    ANN training loss 2.304322
>> Epoch 82 finished    ANN training loss 2.304173
>> Epoch 83 finished    ANN training loss 2.304614
>> Epoch 84 finished    ANN training loss 2.304327
>> Epoch 85 finished    ANN training loss 2.304223
>> Epoch 86 finished    ANN training loss 2.304059
>> Epoch 87 finished    ANN training loss 2.303887
>> Epoch 88 finished    ANN training loss 2.304258
>> Epoch 89 finished    ANN training loss 2.304428
>> Epoch 90 finished    ANN training loss 2.304466
>> Epoch 91 finished    ANN training loss 2.304476
>> Epoch 92 finished    ANN training loss 2.304698
>> Epoch 93 finished    ANN training loss 2.304370
>> Epoch 94 finished    ANN training loss 2.304367
>> Epoch 95 finished    ANN training loss 2.304404
>> Epoch 96 finished    ANN training loss 2.304243
>> Epoch 97 finished    ANN training loss 2.304262
>> Epoch 98 finished    ANN training loss 2.304664
>> Epoch 99 finished    ANN training loss 2.304306
[END] Fine tuning step
```

```
        Done.
```

```
In [71]:  print('ACCURACY: ' + str(rbm_acc[4]))
```

```
        ACCURACY: 0.085
```

```
In [72]:  # Collated results
          print(rbm_acc)
          print('Most accurate rbm learning_rate setting is Setting ' + str(rbm_acc.inde
```

```
        [0.895, 0.925, 0.925, 0.07, 0.085]
        Most accurate rbm learning_rate setting is Setting 2
```

```
In [73]:  # Create bar graph
          plt.clf()
          objects = ('0.01', '0.05', '0.10', '0.50', '1.0')
          y_pos = np.arange(len(objects))
          performance = [0.895,0.91,0.885,0.595, 0.215]

          plt.bar(y_pos, performance, align='center', alpha=0.8)
          plt.xticks(y_pos, objects, rotation=30)
          plt.xlabel('Settings')
          plt.ylabel('Accuracy')
          plt.title('learning_rate_rbm Settings')

          plt.show()
          plt.clf()
```



```
        <Figure size 432x288 with 0 Axes>
```
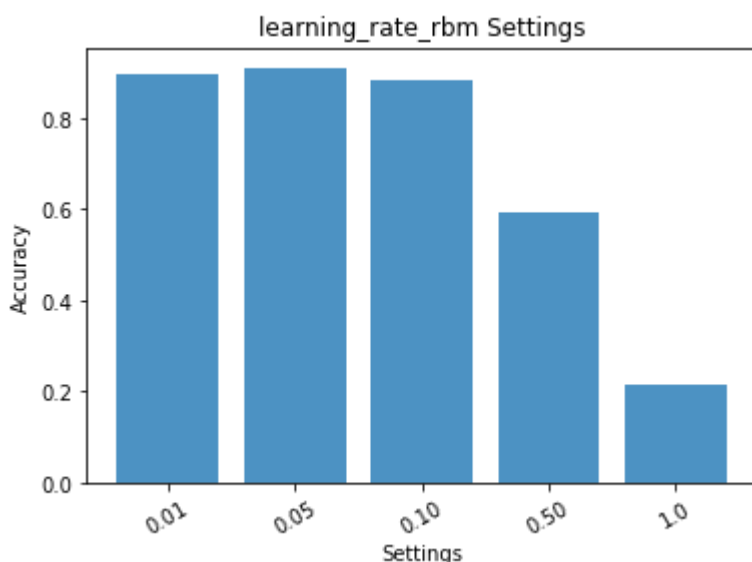
Different Learning Rates:

```
In [74]:  # Store accuracies
          learning_rate_acc = [0, 0, 0, 0, 0]
```

Setting 1

learning_rate=0.01

```
In [75]:   learning_rate_acc[0] = deep_belief_net(learning_rate=0.01)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 69.933800
>> Epoch 2 finished      RBM Reconstruction error 86.468925
>> Epoch 3 finished      RBM Reconstruction error 60.413849
>> Epoch 4 finished      RBM Reconstruction error 37.420773
>> Epoch 5 finished      RBM Reconstruction error 57.553745
>> Epoch 6 finished      RBM Reconstruction error 48.849998
>> Epoch 7 finished      RBM Reconstruction error 46.914040
>> Epoch 8 finished      RBM Reconstruction error 32.126434
>> Epoch 9 finished      RBM Reconstruction error 43.242886
>> Epoch 10 finished     RBM Reconstruction error 46.625622
>> Epoch 1 finished      RBM Reconstruction error 208.352875
>> Epoch 2 finished      RBM Reconstruction error 196.485397
>> Epoch 3 finished      RBM Reconstruction error 153.115433
>> Epoch 4 finished      RBM Reconstruction error 172.141602
>> Epoch 5 finished      RBM Reconstruction error 146.398560
>> Epoch 6 finished      RBM Reconstruction error 135.346878
>> Epoch 7 finished      RBM Reconstruction error 246.178574
>> Epoch 8 finished      RBM Reconstruction error 313.933014
>> Epoch 9 finished      RBM Reconstruction error 209.161133
>> Epoch 10 finished     RBM Reconstruction error 190.459106
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 1.629365
>> Epoch 1 finished      ANN training loss 1.279105
>> Epoch 2 finished      ANN training loss 1.059501
>> Epoch 3 finished      ANN training loss 0.914509
>> Epoch 4 finished      ANN training loss 0.816454
>> Epoch 5 finished      ANN training loss 0.744698
>> Epoch 6 finished      ANN training loss 0.686117
>> Epoch 7 finished      ANN training loss 0.645617
>> Epoch 8 finished      ANN training loss 0.608573
>> Epoch 9 finished      ANN training loss 0.577660
>> Epoch 10 finished     ANN training loss 0.550672
>> Epoch 11 finished     ANN training loss 0.532825
>> Epoch 12 finished     ANN training loss 0.508937
>> Epoch 13 finished     ANN training loss 0.495999
>> Epoch 14 finished     ANN training loss 0.477021
>> Epoch 15 finished     ANN training loss 0.465330
>> Epoch 16 finished     ANN training loss 0.452623
>> Epoch 17 finished     ANN training loss 0.440344
>> Epoch 18 finished     ANN training loss 0.432176
>> Epoch 19 finished     ANN training loss 0.419401
>> Epoch 20 finished     ANN training loss 0.409559
>> Epoch 21 finished     ANN training loss 0.403169
>> Epoch 22 finished     ANN training loss 0.395906
>> Epoch 23 finished     ANN training loss 0.388536
>> Epoch 24 finished     ANN training loss 0.381234
>> Epoch 25 finished     ANN training loss 0.372231
>> Epoch 26 finished     ANN training loss 0.365119
>> Epoch 27 finished     ANN training loss 0.361248
>> Epoch 28 finished     ANN training loss 0.359318
>> Epoch 29 finished     ANN training loss 0.348451
>> Epoch 30 finished     ANN training loss 0.343703
>> Epoch 31 finished     ANN training loss 0.338539
>> Epoch 32 finished     ANN training loss 0.332721
>> Epoch 33 finished     ANN training loss 0.326364
>> Epoch 34 finished     ANN training loss 0.322866
>> Epoch 35 finished     ANN training loss 0.315578
>> Epoch 36 finished     ANN training loss 0.311409
>> Epoch 37 finished     ANN training loss 0.307143
>> Epoch 38 finished     ANN training loss 0.301555
```

```
>> Epoch 39 finished    ANN training loss 0.298471
>> Epoch 40 finished    ANN training loss 0.294797
>> Epoch 41 finished    ANN training loss 0.291421
>> Epoch 42 finished    ANN training loss 0.286068
>> Epoch 43 finished    ANN training loss 0.280822
>> Epoch 44 finished    ANN training loss 0.281135
>> Epoch 45 finished    ANN training loss 0.272934
>> Epoch 46 finished    ANN training loss 0.270998
>> Epoch 47 finished    ANN training loss 0.265909
>> Epoch 48 finished    ANN training loss 0.262369
>> Epoch 49 finished    ANN training loss 0.260038
>> Epoch 50 finished    ANN training loss 0.255623
>> Epoch 51 finished    ANN training loss 0.254204
>> Epoch 52 finished    ANN training loss 0.250070
>> Epoch 53 finished    ANN training loss 0.250241
>> Epoch 54 finished    ANN training loss 0.244649
>> Epoch 55 finished    ANN training loss 0.240994
>> Epoch 56 finished    ANN training loss 0.238792
>> Epoch 57 finished    ANN training loss 0.235977
>> Epoch 58 finished    ANN training loss 0.234095
>> Epoch 59 finished    ANN training loss 0.230959
>> Epoch 60 finished    ANN training loss 0.226960
>> Epoch 61 finished    ANN training loss 0.224025
>> Epoch 62 finished    ANN training loss 0.221200
>> Epoch 63 finished    ANN training loss 0.218461
>> Epoch 64 finished    ANN training loss 0.217176
>> Epoch 65 finished    ANN training loss 0.212729
>> Epoch 66 finished    ANN training loss 0.210462
>> Epoch 67 finished    ANN training loss 0.207862
>> Epoch 68 finished    ANN training loss 0.206948
>> Epoch 69 finished    ANN training loss 0.204125
>> Epoch 70 finished    ANN training loss 0.201825
>> Epoch 71 finished    ANN training loss 0.200427
>> Epoch 72 finished    ANN training loss 0.196757
>> Epoch 73 finished    ANN training loss 0.196490
>> Epoch 74 finished    ANN training loss 0.192354
>> Epoch 75 finished    ANN training loss 0.189790
>> Epoch 76 finished    ANN training loss 0.189221
>> Epoch 77 finished    ANN training loss 0.187079
>> Epoch 78 finished    ANN training loss 0.183960
>> Epoch 79 finished    ANN training loss 0.181910
>> Epoch 80 finished    ANN training loss 0.178902
>> Epoch 81 finished    ANN training loss 0.177419
>> Epoch 82 finished    ANN training loss 0.175729
>> Epoch 83 finished    ANN training loss 0.173142
>> Epoch 84 finished    ANN training loss 0.171444
>> Epoch 85 finished    ANN training loss 0.170271
>> Epoch 86 finished    ANN training loss 0.169083
>> Epoch 87 finished    ANN training loss 0.168768
>> Epoch 88 finished    ANN training loss 0.164169
>> Epoch 89 finished    ANN training loss 0.162057
>> Epoch 90 finished    ANN training loss 0.160132
>> Epoch 91 finished    ANN training loss 0.158354
>> Epoch 92 finished    ANN training loss 0.157897
>> Epoch 93 finished    ANN training loss 0.157818
>> Epoch 94 finished    ANN training loss 0.154748
>> Epoch 95 finished    ANN training loss 0.152439
>> Epoch 96 finished    ANN training loss 0.151026
>> Epoch 97 finished    ANN training loss 0.150095
>> Epoch 98 finished    ANN training loss 0.147264
>> Epoch 99 finished    ANN training loss 0.146539
[END] Fine tuning step
Done.
```

```
In [76]:  print('ACCURACY: ' + str(learning_rate_acc[0]))
```

```
ACCURACY: 0.89
```

Setting 2

learning_rate=0.05

```
In [77]:  learning_rate_acc[1] = deep_belief_net(learning_rate=0.05)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 103.053932
>> Epoch 2 finished     RBM Reconstruction error 83.255623
>> Epoch 3 finished     RBM Reconstruction error 67.956223
>> Epoch 4 finished     RBM Reconstruction error 58.407803
>> Epoch 5 finished     RBM Reconstruction error 44.890244
>> Epoch 6 finished     RBM Reconstruction error 61.732590
>> Epoch 7 finished     RBM Reconstruction error 28.954615
>> Epoch 8 finished     RBM Reconstruction error 58.617508
>> Epoch 9 finished     RBM Reconstruction error 46.534317
>> Epoch 10 finished    RBM Reconstruction error 56.053905
>> Epoch 1 finished     RBM Reconstruction error 238.889465
>> Epoch 2 finished     RBM Reconstruction error 256.781281
>> Epoch 3 finished     RBM Reconstruction error 257.730835
>> Epoch 4 finished     RBM Reconstruction error 223.796326
>> Epoch 5 finished     RBM Reconstruction error 225.551773
>> Epoch 6 finished     RBM Reconstruction error 273.075012
>> Epoch 7 finished     RBM Reconstruction error 274.740936
>> Epoch 8 finished     RBM Reconstruction error 248.027222
>> Epoch 9 finished     RBM Reconstruction error 306.634583
>> Epoch 10 finished    RBM Reconstruction error 440.243591
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.782082
>> Epoch 1 finished     ANN training loss 0.593705
>> Epoch 2 finished     ANN training loss 0.505861
>> Epoch 3 finished     ANN training loss 0.477037
>> Epoch 4 finished     ANN training loss 0.439587
>> Epoch 5 finished     ANN training loss 0.389118
>> Epoch 6 finished     ANN training loss 0.359429
>> Epoch 7 finished     ANN training loss 0.334283
>> Epoch 8 finished     ANN training loss 0.324409
>> Epoch 9 finished     ANN training loss 0.290854
>> Epoch 10 finished    ANN training loss 0.281184
>> Epoch 11 finished    ANN training loss 0.256170
>> Epoch 12 finished    ANN training loss 0.253099
>> Epoch 13 finished    ANN training loss 0.231107
>> Epoch 14 finished    ANN training loss 0.216666
>> Epoch 15 finished    ANN training loss 0.204839
>> Epoch 16 finished    ANN training loss 0.206297
>> Epoch 17 finished    ANN training loss 0.180103
>> Epoch 18 finished    ANN training loss 0.165963
>> Epoch 19 finished    ANN training loss 0.165647
>> Epoch 20 finished    ANN training loss 0.156310
>> Epoch 21 finished    ANN training loss 0.146792
>> Epoch 22 finished    ANN training loss 0.133899
>> Epoch 23 finished    ANN training loss 0.130649
>> Epoch 24 finished    ANN training loss 0.122780
>> Epoch 25 finished    ANN training loss 0.115134
>> Epoch 26 finished    ANN training loss 0.116041
>> Epoch 27 finished    ANN training loss 0.104789
>> Epoch 28 finished    ANN training loss 0.104240
```

```
>> Epoch 29 finished    ANN training loss 0.098319
>> Epoch 30 finished    ANN training loss 0.098756
>> Epoch 31 finished    ANN training loss 0.089121
>> Epoch 32 finished    ANN training loss 0.085279
>> Epoch 33 finished    ANN training loss 0.082884
>> Epoch 34 finished    ANN training loss 0.078826
>> Epoch 35 finished    ANN training loss 0.069467
>> Epoch 36 finished    ANN training loss 0.067952
>> Epoch 37 finished    ANN training loss 0.064318
>> Epoch 38 finished    ANN training loss 0.061697
>> Epoch 39 finished    ANN training loss 0.063148
>> Epoch 40 finished    ANN training loss 0.055854
>> Epoch 41 finished    ANN training loss 0.051667
>> Epoch 42 finished    ANN training loss 0.052734
>> Epoch 43 finished    ANN training loss 0.051653
>> Epoch 44 finished    ANN training loss 0.048571
>> Epoch 45 finished    ANN training loss 0.045261
>> Epoch 46 finished    ANN training loss 0.042220
>> Epoch 47 finished    ANN training loss 0.043575
>> Epoch 48 finished    ANN training loss 0.039726
>> Epoch 49 finished    ANN training loss 0.038059
>> Epoch 50 finished    ANN training loss 0.041982
>> Epoch 51 finished    ANN training loss 0.036944
>> Epoch 52 finished    ANN training loss 0.033312
>> Epoch 53 finished    ANN training loss 0.031878
>> Epoch 54 finished    ANN training loss 0.034168
>> Epoch 55 finished    ANN training loss 0.030390
>> Epoch 56 finished    ANN training loss 0.029356
>> Epoch 57 finished    ANN training loss 0.027582
>> Epoch 58 finished    ANN training loss 0.026400
>> Epoch 59 finished    ANN training loss 0.026022
>> Epoch 60 finished    ANN training loss 0.026777
>> Epoch 61 finished    ANN training loss 0.024125
>> Epoch 62 finished    ANN training loss 0.023355
>> Epoch 63 finished    ANN training loss 0.021910
>> Epoch 64 finished    ANN training loss 0.021456
>> Epoch 65 finished    ANN training loss 0.021160
>> Epoch 66 finished    ANN training loss 0.020390
>> Epoch 67 finished    ANN training loss 0.018512
>> Epoch 68 finished    ANN training loss 0.019700
>> Epoch 69 finished    ANN training loss 0.017312
>> Epoch 70 finished    ANN training loss 0.016398
>> Epoch 71 finished    ANN training loss 0.015336
>> Epoch 72 finished    ANN training loss 0.015841
>> Epoch 73 finished    ANN training loss 0.015287
>> Epoch 74 finished    ANN training loss 0.015168
>> Epoch 75 finished    ANN training loss 0.014664
>> Epoch 76 finished    ANN training loss 0.014059
>> Epoch 77 finished    ANN training loss 0.014142
>> Epoch 78 finished    ANN training loss 0.013599
>> Epoch 79 finished    ANN training loss 0.013549
>> Epoch 80 finished    ANN training loss 0.013242
>> Epoch 81 finished    ANN training loss 0.012400
>> Epoch 82 finished    ANN training loss 0.013169
>> Epoch 83 finished    ANN training loss 0.011579
>> Epoch 84 finished    ANN training loss 0.011487
>> Epoch 85 finished    ANN training loss 0.012151
>> Epoch 86 finished    ANN training loss 0.010846
>> Epoch 87 finished    ANN training loss 0.010092
>> Epoch 88 finished    ANN training loss 0.010239
>> Epoch 89 finished    ANN training loss 0.009644
>> Epoch 90 finished    ANN training loss 0.009252
>> Epoch 91 finished    ANN training loss 0.008728
>> Epoch 92 finished    ANN training loss 0.010050
>> Epoch 93 finished    ANN training loss 0.009089
```

```
>> Epoch 94 finished     ANN training loss 0.008579
>> Epoch 95 finished     ANN training loss 0.008284
>> Epoch 96 finished     ANN training loss 0.008328
>> Epoch 97 finished     ANN training loss 0.008808
>> Epoch 98 finished     ANN training loss 0.008253
>> Epoch 99 finished     ANN training loss 0.008129
[END] Fine tuning step
Done
```

In [78]:
```python
print('ACCURACY: ' + str(learning_rate_acc[1]))
```

```
ACCURACY: 0.92
```

Setting 3

learning_rate=0.1

In [79]:
```python
learning_rate_acc[2] = deep_belief_net(learning_rate=0.1)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 47.652290
>> Epoch 2 finished     RBM Reconstruction error 55.271156
>> Epoch 3 finished     RBM Reconstruction error 48.212074
>> Epoch 4 finished     RBM Reconstruction error 33.137135
>> Epoch 5 finished     RBM Reconstruction error 39.583824
>> Epoch 6 finished     RBM Reconstruction error 43.962959
>> Epoch 7 finished     RBM Reconstruction error 35.656364
>> Epoch 8 finished     RBM Reconstruction error 36.410442
>> Epoch 9 finished     RBM Reconstruction error 34.619732
>> Epoch 10 finished    RBM Reconstruction error 32.343910
>> Epoch 1 finished     RBM Reconstruction error 55.459496
>> Epoch 2 finished     RBM Reconstruction error 95.580605
>> Epoch 3 finished     RBM Reconstruction error 105.353058
>> Epoch 4 finished     RBM Reconstruction error 130.964539
>> Epoch 5 finished     RBM Reconstruction error 138.146347
>> Epoch 6 finished     RBM Reconstruction error 87.875450
>> Epoch 7 finished     RBM Reconstruction error 118.518761
>> Epoch 8 finished     RBM Reconstruction error 89.706543
>> Epoch 9 finished     RBM Reconstruction error 109.253838
>> Epoch 10 finished    RBM Reconstruction error 135.404419
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.657151
>> Epoch 1 finished     ANN training loss 0.493530
>> Epoch 2 finished     ANN training loss 0.377674
>> Epoch 3 finished     ANN training loss 0.373210
>> Epoch 4 finished     ANN training loss 0.274853
>> Epoch 5 finished     ANN training loss 0.261747
>> Epoch 6 finished     ANN training loss 0.222844
>> Epoch 7 finished     ANN training loss 0.206062
>> Epoch 8 finished     ANN training loss 0.171021
>> Epoch 9 finished     ANN training loss 0.149654
>> Epoch 10 finished    ANN training loss 0.137944
>> Epoch 11 finished    ANN training loss 0.168323
>> Epoch 12 finished    ANN training loss 0.123973
>> Epoch 13 finished    ANN training loss 0.095754
>> Epoch 14 finished    ANN training loss 0.109095
>> Epoch 15 finished    ANN training loss 0.083682
>> Epoch 16 finished    ANN training loss 0.072084
>> Epoch 17 finished    ANN training loss 0.066666
>> Epoch 18 finished    ANN training loss 0.071365
>> Epoch 19 finished    ANN training loss 0.055275
>> Epoch 20 finished    ANN training loss 0.051152
```

```
>> Epoch 21 finished     ANN training loss 0.045655
>> Epoch 22 finished     ANN training loss 0.042054
>> Epoch 23 finished     ANN training loss 0.034709
>> Epoch 24 finished     ANN training loss 0.033314
>> Epoch 25 finished     ANN training loss 0.032465
>> Epoch 26 finished     ANN training loss 0.026967
>> Epoch 27 finished     ANN training loss 0.024518
>> Epoch 28 finished     ANN training loss 0.025480
>> Epoch 29 finished     ANN training loss 0.023100
>> Epoch 30 finished     ANN training loss 0.020183
>> Epoch 31 finished     ANN training loss 0.019314
>> Epoch 32 finished     ANN training loss 0.017291
>> Epoch 33 finished     ANN training loss 0.018470
>> Epoch 34 finished     ANN training loss 0.016602
>> Epoch 35 finished     ANN training loss 0.014977
>> Epoch 36 finished     ANN training loss 0.014587
>> Epoch 37 finished     ANN training loss 0.013785
>> Epoch 38 finished     ANN training loss 0.012783
>> Epoch 39 finished     ANN training loss 0.011944
>> Epoch 40 finished     ANN training loss 0.011293
>> Epoch 41 finished     ANN training loss 0.010660
>> Epoch 42 finished     ANN training loss 0.010000
>> Epoch 43 finished     ANN training loss 0.009628
>> Epoch 44 finished     ANN training loss 0.008598
>> Epoch 45 finished     ANN training loss 0.008143
>> Epoch 46 finished     ANN training loss 0.007193
>> Epoch 47 finished     ANN training loss 0.007968
>> Epoch 48 finished     ANN training loss 0.007827
>> Epoch 49 finished     ANN training loss 0.007814
>> Epoch 50 finished     ANN training loss 0.006888
>> Epoch 51 finished     ANN training loss 0.006506
>> Epoch 52 finished     ANN training loss 0.005970
>> Epoch 53 finished     ANN training loss 0.006577
>> Epoch 54 finished     ANN training loss 0.006193
>> Epoch 55 finished     ANN training loss 0.004916
>> Epoch 56 finished     ANN training loss 0.004508
>> Epoch 57 finished     ANN training loss 0.004520
>> Epoch 58 finished     ANN training loss 0.004065
>> Epoch 59 finished     ANN training loss 0.003666
>> Epoch 60 finished     ANN training loss 0.003412
>> Epoch 61 finished     ANN training loss 0.004051
>> Epoch 62 finished     ANN training loss 0.003390
>> Epoch 63 finished     ANN training loss 0.003180
>> Epoch 64 finished     ANN training loss 0.003303
>> Epoch 65 finished     ANN training loss 0.003750
>> Epoch 66 finished     ANN training loss 0.003348
>> Epoch 67 finished     ANN training loss 0.003086
>> Epoch 68 finished     ANN training loss 0.003153
>> Epoch 69 finished     ANN training loss 0.003046
>> Epoch 70 finished     ANN training loss 0.003026
>> Epoch 71 finished     ANN training loss 0.002603
>> Epoch 72 finished     ANN training loss 0.002791
>> Epoch 73 finished     ANN training loss 0.002581
>> Epoch 74 finished     ANN training loss 0.002312
>> Epoch 75 finished     ANN training loss 0.002532
>> Epoch 76 finished     ANN training loss 0.002242
>> Epoch 77 finished     ANN training loss 0.002637
>> Epoch 78 finished     ANN training loss 0.002213
>> Epoch 79 finished     ANN training loss 0.001911
>> Epoch 80 finished     ANN training loss 0.001898
>> Epoch 81 finished     ANN training loss 0.001758
>> Epoch 82 finished     ANN training loss 0.001751
>> Epoch 83 finished     ANN training loss 0.001590
>> Epoch 84 finished     ANN training loss 0.002314
>> Epoch 85 finished     ANN training loss 0.001564
```

```
>> Epoch 86 finished     ANN training loss 0.001448
>> Epoch 87 finished     ANN training loss 0.001613
>> Epoch 88 finished     ANN training loss 0.003464
>> Epoch 89 finished     ANN training loss 0.001611
>> Epoch 90 finished     ANN training loss 0.001433
>> Epoch 91 finished     ANN training loss 0.001442
>> Epoch 92 finished     ANN training loss 0.001296
>> Epoch 93 finished     ANN training loss 0.001741
>> Epoch 94 finished     ANN training loss 0.001336
>> Epoch 95 finished     ANN training loss 0.001406
>> Epoch 96 finished     ANN training loss 0.001200
>> Epoch 97 finished     ANN training loss 0.001083
>> Epoch 98 finished     ANN training loss 0.001213
>> Epoch 99 finished     ANN training loss 0.001116
[END] Fine tuning step
Done
```

In [80]:
```python
print('ACCURACY: ' + str(learning_rate_acc[2]))
```

```
ACCURACY: 0.925
```

Setting 4

learning_rate=0.5

In [81]:
```python
learning_rate_acc[3] = deep_belief_net(learning_rate=0.5)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 66.080261
>> Epoch 2 finished     RBM Reconstruction error 91.634460
>> Epoch 3 finished     RBM Reconstruction error 87.947868
>> Epoch 4 finished     RBM Reconstruction error 60.693130
>> Epoch 5 finished     RBM Reconstruction error 40.038055
>> Epoch 6 finished     RBM Reconstruction error 66.025490
>> Epoch 7 finished     RBM Reconstruction error 32.787392
>> Epoch 8 finished     RBM Reconstruction error 55.634209
>> Epoch 9 finished     RBM Reconstruction error 39.156128
>> Epoch 10 finished    RBM Reconstruction error 40.610870
>> Epoch 1 finished     RBM Reconstruction error 72.047874
>> Epoch 2 finished     RBM Reconstruction error 73.710304
>> Epoch 3 finished     RBM Reconstruction error 126.095909
>> Epoch 4 finished     RBM Reconstruction error 131.791779
>> Epoch 5 finished     RBM Reconstruction error 196.352539
>> Epoch 6 finished     RBM Reconstruction error 100.173981
>> Epoch 7 finished     RBM Reconstruction error 192.914551
>> Epoch 8 finished     RBM Reconstruction error 182.272186
>> Epoch 9 finished     RBM Reconstruction error 205.986252
>> Epoch 10 finished    RBM Reconstruction error 171.381775
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.625497
>> Epoch 1 finished     ANN training loss 0.443053
>> Epoch 2 finished     ANN training loss 0.266654
>> Epoch 3 finished     ANN training loss 0.312450
>> Epoch 4 finished     ANN training loss 0.113105
>> Epoch 5 finished     ANN training loss 0.087273
>> Epoch 6 finished     ANN training loss 0.134224
>> Epoch 7 finished     ANN training loss 0.062731
>> Epoch 8 finished     ANN training loss 0.049890
>> Epoch 9 finished     ANN training loss 0.083968
>> Epoch 10 finished    ANN training loss 0.031370
>> Epoch 11 finished    ANN training loss 0.027858
>> Epoch 12 finished    ANN training loss 0.036975
```

```
>> Epoch 13 finished    ANN training loss 0.018078
>> Epoch 14 finished    ANN training loss 0.025839
>> Epoch 15 finished    ANN training loss 0.042755
>> Epoch 16 finished    ANN training loss 0.015244
>> Epoch 17 finished    ANN training loss 0.010195
>> Epoch 18 finished    ANN training loss 0.016056
>> Epoch 19 finished    ANN training loss 0.010570
>> Epoch 20 finished    ANN training loss 0.005912
>> Epoch 21 finished    ANN training loss 0.037383
>> Epoch 22 finished    ANN training loss 0.019192
>> Epoch 23 finished    ANN training loss 0.005719
>> Epoch 24 finished    ANN training loss 0.002678
>> Epoch 25 finished    ANN training loss 0.003906
>> Epoch 26 finished    ANN training loss 0.003647
>> Epoch 27 finished    ANN training loss 0.002898
>> Epoch 28 finished    ANN training loss 0.004228
>> Epoch 29 finished    ANN training loss 0.002741
>> Epoch 30 finished    ANN training loss 0.008772
>> Epoch 31 finished    ANN training loss 0.008482
>> Epoch 32 finished    ANN training loss 0.004358
>> Epoch 33 finished    ANN training loss 0.041635
>> Epoch 34 finished    ANN training loss 0.001244
>> Epoch 35 finished    ANN training loss 0.001848
>> Epoch 36 finished    ANN training loss 0.002650
>> Epoch 37 finished    ANN training loss 0.004173
>> Epoch 38 finished    ANN training loss 0.011905
>> Epoch 39 finished    ANN training loss 0.001364
>> Epoch 40 finished    ANN training loss 0.007689
>> Epoch 41 finished    ANN training loss 0.001544
>> Epoch 42 finished    ANN training loss 0.000782
>> Epoch 43 finished    ANN training loss 0.002078
>> Epoch 44 finished    ANN training loss 0.000957
>> Epoch 45 finished    ANN training loss 0.000402
>> Epoch 46 finished    ANN training loss 0.000553
>> Epoch 47 finished    ANN training loss 0.004701
>> Epoch 48 finished    ANN training loss 0.002965
>> Epoch 49 finished    ANN training loss 0.001008
>> Epoch 50 finished    ANN training loss 0.000825
>> Epoch 51 finished    ANN training loss 0.000679
>> Epoch 52 finished    ANN training loss 0.004910
>> Epoch 53 finished    ANN training loss 0.002777
>> Epoch 54 finished    ANN training loss 0.002326
>> Epoch 55 finished    ANN training loss 0.001592
>> Epoch 56 finished    ANN training loss 0.001784
>> Epoch 57 finished    ANN training loss 0.100423
>> Epoch 58 finished    ANN training loss 0.000539
>> Epoch 59 finished    ANN training loss 0.000370
>> Epoch 60 finished    ANN training loss 0.005256
>> Epoch 61 finished    ANN training loss 0.001440
>> Epoch 62 finished    ANN training loss 0.000945
>> Epoch 63 finished    ANN training loss 0.000955
>> Epoch 64 finished    ANN training loss 0.000496
>> Epoch 65 finished    ANN training loss 0.000135
>> Epoch 66 finished    ANN training loss 0.000102
>> Epoch 67 finished    ANN training loss 0.000683
>> Epoch 68 finished    ANN training loss 0.003279
>> Epoch 69 finished    ANN training loss 0.000170
>> Epoch 70 finished    ANN training loss 0.000104
>> Epoch 71 finished    ANN training loss 0.000065
>> Epoch 72 finished    ANN training loss 0.000058
>> Epoch 73 finished    ANN training loss 0.001415
>> Epoch 74 finished    ANN training loss 0.000088
>> Epoch 75 finished    ANN training loss 0.000364
>> Epoch 76 finished    ANN training loss 0.000103
>> Epoch 77 finished    ANN training loss 0.000454
```

```
        >> Epoch 78 finished    ANN training loss 0.000215
        >> Epoch 79 finished    ANN training loss 0.000653
        >> Epoch 80 finished    ANN training loss 0.000137
        >> Epoch 81 finished    ANN training loss 0.018381
        >> Epoch 82 finished    ANN training loss 0.000126
        >> Epoch 83 finished    ANN training loss 0.000193
        >> Epoch 84 finished    ANN training loss 0.007115
        >> Epoch 85 finished    ANN training loss 0.000196
        >> Epoch 86 finished    ANN training loss 0.001507
        >> Epoch 87 finished    ANN training loss 0.000209
        >> Epoch 88 finished    ANN training loss 0.000152
        >> Epoch 89 finished    ANN training loss 0.001545
        >> Epoch 90 finished    ANN training loss 0.002522
        >> Epoch 91 finished    ANN training loss 0.001260
        >> Epoch 92 finished    ANN training loss 0.000640
        >> Epoch 93 finished    ANN training loss 0.000399
        >> Epoch 94 finished    ANN training loss 0.000192
        >> Epoch 95 finished    ANN training loss 0.000459
        >> Epoch 96 finished    ANN training loss 0.001434
        >> Epoch 97 finished    ANN training loss 0.000236
        >> Epoch 98 finished    ANN training loss 0.000135
        >> Epoch 99 finished    ANN training loss 0.002107
        [END] Fine tuning step
        Done
```

In [82]:
```python
print('ACCURACY: ' + str(learning_rate_acc[3]))
```

```
ACCURACY: 0.915
```

Setting 5

learning_rate=1.0

In [83]:
```python
learning_rate_acc[4] = deep_belief_net(learning_rate=1.0)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 72.270477
>> Epoch 2 finished     RBM Reconstruction error 81.801888
>> Epoch 3 finished     RBM Reconstruction error 46.275944
>> Epoch 4 finished     RBM Reconstruction error 50.945541
>> Epoch 5 finished     RBM Reconstruction error 45.906464
>> Epoch 6 finished     RBM Reconstruction error 52.310688
>> Epoch 7 finished     RBM Reconstruction error 28.218534
>> Epoch 8 finished     RBM Reconstruction error 38.909161
>> Epoch 9 finished     RBM Reconstruction error 37.254112
>> Epoch 10 finished    RBM Reconstruction error 32.678345
>> Epoch 1 finished     RBM Reconstruction error 83.250877
>> Epoch 2 finished     RBM Reconstruction error 104.853477
>> Epoch 3 finished     RBM Reconstruction error 136.333603
>> Epoch 4 finished     RBM Reconstruction error 100.361305
>> Epoch 5 finished     RBM Reconstruction error 133.560608
>> Epoch 6 finished     RBM Reconstruction error 118.718063
>> Epoch 7 finished     RBM Reconstruction error 140.663452
>> Epoch 8 finished     RBM Reconstruction error 126.779884
>> Epoch 9 finished     RBM Reconstruction error 129.488190
>> Epoch 10 finished    RBM Reconstruction error 82.820702
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 1.784486
>> Epoch 1 finished     ANN training loss 1.236545
>> Epoch 2 finished     ANN training loss 1.051392
>> Epoch 3 finished     ANN training loss 1.002878
>> Epoch 4 finished     ANN training loss 0.682209
>> Epoch 5 finished     ANN training loss 0.785251
```

```
>> Epoch 6 finished      ANN training loss 0.514953
>> Epoch 7 finished      ANN training loss 0.589532
>> Epoch 8 finished      ANN training loss 0.414532
>> Epoch 9 finished      ANN training loss 0.413148
>> Epoch 10 finished     ANN training loss 0.467909
>> Epoch 11 finished     ANN training loss 0.428593
>> Epoch 12 finished     ANN training loss 0.469807
>> Epoch 13 finished     ANN training loss 0.910338
>> Epoch 14 finished     ANN training loss 0.312067
>> Epoch 15 finished     ANN training loss 0.220670
>> Epoch 16 finished     ANN training loss 0.734210
>> Epoch 17 finished     ANN training loss 0.181733
>> Epoch 18 finished     ANN training loss 0.142107
>> Epoch 19 finished     ANN training loss 0.193240
>> Epoch 20 finished     ANN training loss 0.209811
>> Epoch 21 finished     ANN training loss 0.108896
>> Epoch 22 finished     ANN training loss 0.084323
>> Epoch 23 finished     ANN training loss 0.106669
>> Epoch 24 finished     ANN training loss 0.110347
>> Epoch 25 finished     ANN training loss 0.170654
>> Epoch 26 finished     ANN training loss 0.091176
>> Epoch 27 finished     ANN training loss 0.159304
>> Epoch 28 finished     ANN training loss 0.117409
>> Epoch 29 finished     ANN training loss 0.049898
>> Epoch 30 finished     ANN training loss 0.044145
>> Epoch 31 finished     ANN training loss 0.067317
>> Epoch 32 finished     ANN training loss 0.075125
>> Epoch 33 finished     ANN training loss 0.044914
>> Epoch 34 finished     ANN training loss 0.025610
>> Epoch 35 finished     ANN training loss 0.066149
>> Epoch 36 finished     ANN training loss 0.052959
>> Epoch 37 finished     ANN training loss 0.042279
>> Epoch 38 finished     ANN training loss 0.098137
>> Epoch 39 finished     ANN training loss 0.051835
>> Epoch 40 finished     ANN training loss 0.055665
>> Epoch 41 finished     ANN training loss 0.022152
>> Epoch 42 finished     ANN training loss 0.041295
>> Epoch 43 finished     ANN training loss 0.062445
>> Epoch 44 finished     ANN training loss 0.047148
>> Epoch 45 finished     ANN training loss 0.038272
>> Epoch 46 finished     ANN training loss 0.020030
>> Epoch 47 finished     ANN training loss 0.029258
>> Epoch 48 finished     ANN training loss 0.026438
>> Epoch 49 finished     ANN training loss 0.095146
>> Epoch 50 finished     ANN training loss 0.021292
>> Epoch 51 finished     ANN training loss 0.036980
>> Epoch 52 finished     ANN training loss 0.069420
>> Epoch 53 finished     ANN training loss 0.029707
>> Epoch 54 finished     ANN training loss 0.011608
>> Epoch 55 finished     ANN training loss 0.012328
>> Epoch 56 finished     ANN training loss 0.008602
>> Epoch 57 finished     ANN training loss 0.010130
>> Epoch 58 finished     ANN training loss 0.004296
>> Epoch 59 finished     ANN training loss 0.025018
>> Epoch 60 finished     ANN training loss 0.033085
>> Epoch 61 finished     ANN training loss 0.003564
>> Epoch 62 finished     ANN training loss 0.029988
>> Epoch 63 finished     ANN training loss 0.006880
>> Epoch 64 finished     ANN training loss 0.093447
>> Epoch 65 finished     ANN training loss 0.032250
>> Epoch 66 finished     ANN training loss 0.032537
>> Epoch 67 finished     ANN training loss 0.030323
>> Epoch 68 finished     ANN training loss 0.042899
>> Epoch 69 finished     ANN training loss 0.024002
>> Epoch 70 finished     ANN training loss 0.012982
```

```
>> Epoch 71 finished    ANN training loss 0.021231
>> Epoch 72 finished    ANN training loss 0.028176
>> Epoch 73 finished    ANN training loss 0.032740
>> Epoch 74 finished    ANN training loss 0.018218
>> Epoch 75 finished    ANN training loss 0.016554
>> Epoch 76 finished    ANN training loss 0.014098
>> Epoch 77 finished    ANN training loss 0.014523
>> Epoch 78 finished    ANN training loss 0.023437
>> Epoch 79 finished    ANN training loss 0.008770
>> Epoch 80 finished    ANN training loss 0.014129
>> Epoch 81 finished    ANN training loss 0.004421
>> Epoch 82 finished    ANN training loss 0.056209
>> Epoch 83 finished    ANN training loss 0.020073
>> Epoch 84 finished    ANN training loss 0.029482
>> Epoch 85 finished    ANN training loss 0.012197
>> Epoch 86 finished    ANN training loss 0.012146
>> Epoch 87 finished    ANN training loss 0.007191
>> Epoch 88 finished    ANN training loss 0.013365
>> Epoch 89 finished    ANN training loss 0.012833
>> Epoch 90 finished    ANN training loss 0.027089
>> Epoch 91 finished    ANN training loss 0.022890
>> Epoch 92 finished    ANN training loss 0.008142
>> Epoch 93 finished    ANN training loss 0.009520
>> Epoch 94 finished    ANN training loss 0.010478
>> Epoch 95 finished    ANN training loss 0.014582
>> Epoch 96 finished    ANN training loss 0.009667
>> Epoch 97 finished    ANN training loss 0.010653
>> Epoch 98 finished    ANN training loss 0.009629
>> Epoch 99 finished    ANN training loss 0.011932
[END] Fine tuning step
Done.
Accuracy: 0.930000
```

In [84]:
```python
print('ACCURACY: ' + str(learning_rate_acc[4]))
```

```
ACCURACY: 0.93
```

In [85]:
```python
# Collated results
print(learning_rate_acc)
print('Most accurate learning_rate setting is Setting ' + str(learning_rate_ac
```

```
[0.89, 0.92, 0.925, 0.915, 0.93]
Most accurate learning_rate setting is Setting 5
```

In [86]:
```python
# Create bar graph
plt.clf()
objects = ('0.01', '0.05', '0.10', '0.50', '1.0')
y_pos = np.arange(len(objects))
performance = [0.885,0.895,0.915,0.895, 0.875]

plt.bar(y_pos, performance, align='center', alpha=1.)
plt.xticks(y_pos, objects, rotation=30)
plt.xlabel('Settings')
plt.ylabel('Accuracy')
plt.title('learning_rate Settings')

plt.show()
plt.clf()
```

```
<Figure size 432x288 with 0 Axes>
```
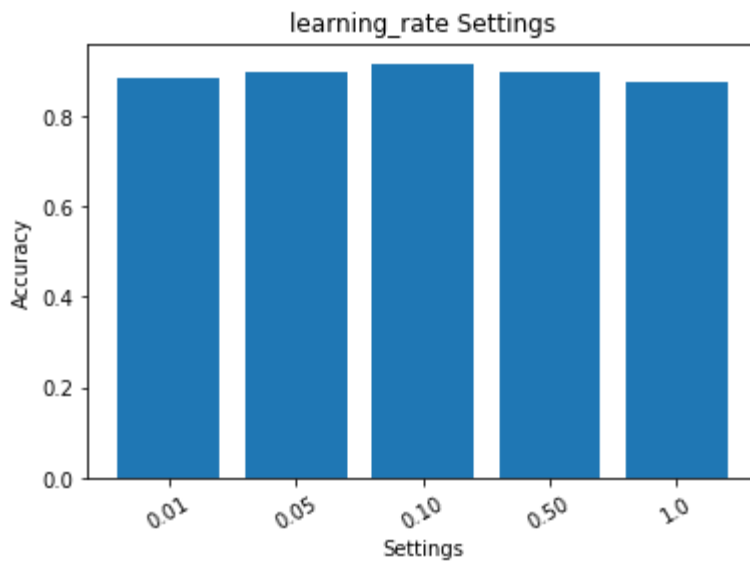
Different Pre-training Lengths:

```
In [87]:   # Store accuracies
           epoch_rbm_acc = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
```

Setting 1

n_epochs_rbm=1

```
In [89]:   epoch_rbm_acc[0] = deep_belief_net(n_epochs_rbm=1)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 54.133324
>> Epoch 1 finished      RBM Reconstruction error 186.200073
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 2.176536
>> Epoch 1 finished      ANN training loss 1.886552
>> Epoch 2 finished      ANN training loss 1.566326
>> Epoch 3 finished      ANN training loss 1.279872
>> Epoch 4 finished      ANN training loss 1.101892
>> Epoch 5 finished      ANN training loss 0.955066
>> Epoch 6 finished      ANN training loss 0.858420
>> Epoch 7 finished      ANN training loss 0.743757
>> Epoch 8 finished      ANN training loss 0.679228
>> Epoch 9 finished      ANN training loss 0.560115
>> Epoch 10 finished     ANN training loss 0.475118
>> Epoch 11 finished     ANN training loss 0.445670
>> Epoch 12 finished     ANN training loss 0.390593
>> Epoch 13 finished     ANN training loss 0.372699
>> Epoch 14 finished     ANN training loss 0.330413
>> Epoch 15 finished     ANN training loss 0.298382
>> Epoch 16 finished     ANN training loss 0.279288
>> Epoch 17 finished     ANN training loss 0.267730
>> Epoch 18 finished     ANN training loss 0.257929
>> Epoch 19 finished     ANN training loss 0.207795
>> Epoch 20 finished     ANN training loss 0.212080
>> Epoch 21 finished     ANN training loss 0.188913
>> Epoch 22 finished     ANN training loss 0.151036
```

```
>> Epoch 23 finished      ANN training loss 0.162748
>> Epoch 24 finished      ANN training loss 0.148730
>> Epoch 25 finished      ANN training loss 0.139550
>> Epoch 26 finished      ANN training loss 0.118637
>> Epoch 27 finished      ANN training loss 0.107832
>> Epoch 28 finished      ANN training loss 0.100572
>> Epoch 29 finished      ANN training loss 0.090064
>> Epoch 30 finished      ANN training loss 0.093168
>> Epoch 31 finished      ANN training loss 0.122952
>> Epoch 32 finished      ANN training loss 0.068589
>> Epoch 33 finished      ANN training loss 0.073530
>> Epoch 34 finished      ANN training loss 0.064477
>> Epoch 35 finished      ANN training loss 0.052682
>> Epoch 36 finished      ANN training loss 0.053517
>> Epoch 37 finished      ANN training loss 0.043368
>> Epoch 38 finished      ANN training loss 0.046191
>> Epoch 39 finished      ANN training loss 0.040723
>> Epoch 40 finished      ANN training loss 0.038071
>> Epoch 41 finished      ANN training loss 0.035844
>> Epoch 42 finished      ANN training loss 0.032580
>> Epoch 43 finished      ANN training loss 0.031440
>> Epoch 44 finished      ANN training loss 0.030940
>> Epoch 45 finished      ANN training loss 0.025004
>> Epoch 46 finished      ANN training loss 0.025485
>> Epoch 47 finished      ANN training loss 0.034077
>> Epoch 48 finished      ANN training loss 0.018855
>> Epoch 49 finished      ANN training loss 0.026004
>> Epoch 50 finished      ANN training loss 0.018260
>> Epoch 51 finished      ANN training loss 0.015772
>> Epoch 52 finished      ANN training loss 0.014571
>> Epoch 53 finished      ANN training loss 0.017756
>> Epoch 54 finished      ANN training loss 0.014397
>> Epoch 55 finished      ANN training loss 0.014987
>> Epoch 56 finished      ANN training loss 0.017929
>> Epoch 57 finished      ANN training loss 0.013392
>> Epoch 58 finished      ANN training loss 0.013023
>> Epoch 59 finished      ANN training loss 0.013521
>> Epoch 60 finished      ANN training loss 0.012485
>> Epoch 61 finished      ANN training loss 0.008115
>> Epoch 62 finished      ANN training loss 0.008428
>> Epoch 63 finished      ANN training loss 0.009117
>> Epoch 64 finished      ANN training loss 0.009082
>> Epoch 65 finished      ANN training loss 0.007596
>> Epoch 66 finished      ANN training loss 0.008884
>> Epoch 67 finished      ANN training loss 0.007591
>> Epoch 68 finished      ANN training loss 0.006304
>> Epoch 69 finished      ANN training loss 0.005949
>> Epoch 70 finished      ANN training loss 0.006765
>> Epoch 71 finished      ANN training loss 0.005489
>> Epoch 72 finished      ANN training loss 0.006013
>> Epoch 73 finished      ANN training loss 0.005303
>> Epoch 74 finished      ANN training loss 0.004564
>> Epoch 75 finished      ANN training loss 0.005381
>> Epoch 76 finished      ANN training loss 0.004588
>> Epoch 77 finished      ANN training loss 0.005255
>> Epoch 78 finished      ANN training loss 0.004246
>> Epoch 79 finished      ANN training loss 0.003941
>> Epoch 80 finished      ANN training loss 0.003553
>> Epoch 81 finished      ANN training loss 0.003588
>> Epoch 82 finished      ANN training loss 0.003404
>> Epoch 83 finished      ANN training loss 0.002582
>> Epoch 84 finished      ANN training loss 0.002499
>> Epoch 85 finished      ANN training loss 0.005473
>> Epoch 86 finished      ANN training loss 0.003155
>> Epoch 87 finished      ANN training loss 0.003976
```

```
>> Epoch 88 finished     ANN training loss 0.003612
>> Epoch 89 finished     ANN training loss 0.002397
>> Epoch 90 finished     ANN training loss 0.002645
>> Epoch 91 finished     ANN training loss 0.002445
>> Epoch 92 finished     ANN training loss 0.002145
>> Epoch 93 finished     ANN training loss 0.002753
>> Epoch 94 finished     ANN training loss 0.002109
>> Epoch 95 finished     ANN training loss 0.001884
>> Epoch 96 finished     ANN training loss 0.001634
>> Epoch 97 finished     ANN training loss 0.002355
>> Epoch 98 finished     ANN training loss 0.001735
>> Epoch 99 finished     ANN training loss 0.002307
[END] Fine tuning step
Done.
Accuracy: 0.880000
```

In [90]:
```python
print('ACCURACY: ' + str(epoch_rbm_acc[0]))
```

```
ACCURACY: 0.88
```

Setting 2

n_epochs_rbm=2

In [91]:
```python
epoch_rbm_acc[1] = deep_belief_net(n_epochs_rbm=2)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 75.499611
>> Epoch 2 finished     RBM Reconstruction error 51.906788
>> Epoch 1 finished     RBM Reconstruction error 311.572845
>> Epoch 2 finished     RBM Reconstruction error 163.014496
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 1.406206
>> Epoch 1 finished     ANN training loss 1.033983
>> Epoch 2 finished     ANN training loss 0.859397
>> Epoch 3 finished     ANN training loss 0.742048
>> Epoch 4 finished     ANN training loss 0.672420
>> Epoch 5 finished     ANN training loss 0.604227
>> Epoch 6 finished     ANN training loss 0.509879
>> Epoch 7 finished     ANN training loss 0.451311
>> Epoch 8 finished     ANN training loss 0.393184
>> Epoch 9 finished     ANN training loss 0.342961
>> Epoch 10 finished     ANN training loss 0.300598
>> Epoch 11 finished     ANN training loss 0.278065
>> Epoch 12 finished     ANN training loss 0.252543
>> Epoch 13 finished     ANN training loss 0.237767
>> Epoch 14 finished     ANN training loss 0.215873
>> Epoch 15 finished     ANN training loss 0.191894
>> Epoch 16 finished     ANN training loss 0.183744
>> Epoch 17 finished     ANN training loss 0.163935
>> Epoch 18 finished     ANN training loss 0.145984
>> Epoch 19 finished     ANN training loss 0.127589
>> Epoch 20 finished     ANN training loss 0.138214
>> Epoch 21 finished     ANN training loss 0.113581
>> Epoch 22 finished     ANN training loss 0.099124
>> Epoch 23 finished     ANN training loss 0.087590
>> Epoch 24 finished     ANN training loss 0.089463
>> Epoch 25 finished     ANN training loss 0.081815
>> Epoch 26 finished     ANN training loss 0.079989
>> Epoch 27 finished     ANN training loss 0.070151
>> Epoch 28 finished     ANN training loss 0.056714
>> Epoch 29 finished     ANN training loss 0.055306
>> Epoch 30 finished     ANN training loss 0.051711
```

```
>> Epoch 31 finished    ANN training loss 0.046722
>> Epoch 32 finished    ANN training loss 0.046583
>> Epoch 33 finished    ANN training loss 0.042314
>> Epoch 34 finished    ANN training loss 0.052939
>> Epoch 35 finished    ANN training loss 0.030549
>> Epoch 36 finished    ANN training loss 0.027775
>> Epoch 37 finished    ANN training loss 0.024974
>> Epoch 38 finished    ANN training loss 0.025100
>> Epoch 39 finished    ANN training loss 0.022156
>> Epoch 40 finished    ANN training loss 0.017354
>> Epoch 41 finished    ANN training loss 0.020108
>> Epoch 42 finished    ANN training loss 0.017079
>> Epoch 43 finished    ANN training loss 0.016311
>> Epoch 44 finished    ANN training loss 0.015735
>> Epoch 45 finished    ANN training loss 0.017427
>> Epoch 46 finished    ANN training loss 0.014546
>> Epoch 47 finished    ANN training loss 0.015083
>> Epoch 48 finished    ANN training loss 0.010674
>> Epoch 49 finished    ANN training loss 0.010786
>> Epoch 50 finished    ANN training loss 0.010343
>> Epoch 51 finished    ANN training loss 0.009560
>> Epoch 52 finished    ANN training loss 0.008939
>> Epoch 53 finished    ANN training loss 0.013078
>> Epoch 54 finished    ANN training loss 0.009162
>> Epoch 55 finished    ANN training loss 0.009893
>> Epoch 56 finished    ANN training loss 0.007682
>> Epoch 57 finished    ANN training loss 0.006834
>> Epoch 58 finished    ANN training loss 0.006762
>> Epoch 59 finished    ANN training loss 0.007925
>> Epoch 60 finished    ANN training loss 0.008234
>> Epoch 61 finished    ANN training loss 0.007150
>> Epoch 62 finished    ANN training loss 0.007815
>> Epoch 63 finished    ANN training loss 0.005335
>> Epoch 64 finished    ANN training loss 0.006160
>> Epoch 65 finished    ANN training loss 0.004428
>> Epoch 66 finished    ANN training loss 0.004696
>> Epoch 67 finished    ANN training loss 0.006126
>> Epoch 68 finished    ANN training loss 0.006380
>> Epoch 69 finished    ANN training loss 0.005669
>> Epoch 70 finished    ANN training loss 0.004266
>> Epoch 71 finished    ANN training loss 0.005353
>> Epoch 72 finished    ANN training loss 0.004110
>> Epoch 73 finished    ANN training loss 0.004347
>> Epoch 74 finished    ANN training loss 0.003618
>> Epoch 75 finished    ANN training loss 0.004209
>> Epoch 76 finished    ANN training loss 0.003468
>> Epoch 77 finished    ANN training loss 0.004476
>> Epoch 78 finished    ANN training loss 0.003011
>> Epoch 79 finished    ANN training loss 0.002798
>> Epoch 80 finished    ANN training loss 0.002408
>> Epoch 81 finished    ANN training loss 0.002430
>> Epoch 82 finished    ANN training loss 0.002424
>> Epoch 83 finished    ANN training loss 0.003720
>> Epoch 84 finished    ANN training loss 0.002028
>> Epoch 85 finished    ANN training loss 0.001976
>> Epoch 86 finished    ANN training loss 0.002047
>> Epoch 87 finished    ANN training loss 0.001772
>> Epoch 88 finished    ANN training loss 0.002159
>> Epoch 89 finished    ANN training loss 0.001816
>> Epoch 90 finished    ANN training loss 0.002121
>> Epoch 91 finished    ANN training loss 0.001646
>> Epoch 92 finished    ANN training loss 0.001465
>> Epoch 93 finished    ANN training loss 0.001892
>> Epoch 94 finished    ANN training loss 0.001550
>> Epoch 95 finished    ANN training loss 0.001412
```

```
>> Epoch 96 finished    ANN training loss 0.001299
>> Epoch 97 finished    ANN training loss 0.001636
>> Epoch 98 finished    ANN training loss 0.001239
>> Epoch 99 finished    ANN training loss 0.001126
[END] Fine tuning step
Done.
Accuracy: 0.915000
```

In [92]:
```python
print('ACCURACY: ' + str(epoch_rbm_acc[1]))
```

```
ACCURACY: 0.915
```

Setting 3

n_epochs_rbm=5

In [93]:
```python
epoch_rbm_acc[2] = deep_belief_net(n_epochs_rbm=5)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 60.762997
>> Epoch 2 finished     RBM Reconstruction error 45.667091
>> Epoch 3 finished     RBM Reconstruction error 52.430508
>> Epoch 4 finished     RBM Reconstruction error 50.332523
>> Epoch 5 finished     RBM Reconstruction error 50.899242
>> Epoch 1 finished     RBM Reconstruction error 308.078918
>> Epoch 2 finished     RBM Reconstruction error 218.658325
>> Epoch 3 finished     RBM Reconstruction error 354.645477
>> Epoch 4 finished     RBM Reconstruction error 232.560944
>> Epoch 5 finished     RBM Reconstruction error 259.198486
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.847052
>> Epoch 1 finished     ANN training loss 0.596296
>> Epoch 2 finished     ANN training loss 0.506592
>> Epoch 3 finished     ANN training loss 0.430068
>> Epoch 4 finished     ANN training loss 0.378345
>> Epoch 5 finished     ANN training loss 0.326063
>> Epoch 6 finished     ANN training loss 0.295778
>> Epoch 7 finished     ANN training loss 0.257471
>> Epoch 8 finished     ANN training loss 0.238699
>> Epoch 9 finished     ANN training loss 0.200042
>> Epoch 10 finished    ANN training loss 0.187703
>> Epoch 11 finished    ANN training loss 0.169778
>> Epoch 12 finished    ANN training loss 0.154833
>> Epoch 13 finished    ANN training loss 0.145112
>> Epoch 14 finished    ANN training loss 0.126320
>> Epoch 15 finished    ANN training loss 0.123864
>> Epoch 16 finished    ANN training loss 0.112698
>> Epoch 17 finished    ANN training loss 0.103344
>> Epoch 18 finished    ANN training loss 0.093607
>> Epoch 19 finished    ANN training loss 0.085473
>> Epoch 20 finished    ANN training loss 0.096053
>> Epoch 21 finished    ANN training loss 0.079637
>> Epoch 22 finished    ANN training loss 0.064363
>> Epoch 23 finished    ANN training loss 0.058853
>> Epoch 24 finished    ANN training loss 0.055402
>> Epoch 25 finished    ANN training loss 0.048572
>> Epoch 26 finished    ANN training loss 0.045404
>> Epoch 27 finished    ANN training loss 0.045625
>> Epoch 28 finished    ANN training loss 0.042693
>> Epoch 29 finished    ANN training loss 0.039445
>> Epoch 30 finished    ANN training loss 0.032827
>> Epoch 31 finished    ANN training loss 0.030562
>> Epoch 32 finished    ANN training loss 0.025914
```

```
>> Epoch 33 finished     ANN training loss 0.028416
>> Epoch 34 finished     ANN training loss 0.024119
>> Epoch 35 finished     ANN training loss 0.022955
>> Epoch 36 finished     ANN training loss 0.021726
>> Epoch 37 finished     ANN training loss 0.019045
>> Epoch 38 finished     ANN training loss 0.019607
>> Epoch 39 finished     ANN training loss 0.016411
>> Epoch 40 finished     ANN training loss 0.016079
>> Epoch 41 finished     ANN training loss 0.015336
>> Epoch 42 finished     ANN training loss 0.014267
>> Epoch 43 finished     ANN training loss 0.013012
>> Epoch 44 finished     ANN training loss 0.011176
>> Epoch 45 finished     ANN training loss 0.010063
>> Epoch 46 finished     ANN training loss 0.011684
>> Epoch 47 finished     ANN training loss 0.010094
>> Epoch 48 finished     ANN training loss 0.009332
>> Epoch 49 finished     ANN training loss 0.007660
>> Epoch 50 finished     ANN training loss 0.007969
>> Epoch 51 finished     ANN training loss 0.007431
>> Epoch 52 finished     ANN training loss 0.007255
>> Epoch 53 finished     ANN training loss 0.007042
>> Epoch 54 finished     ANN training loss 0.007086
>> Epoch 55 finished     ANN training loss 0.007494
>> Epoch 56 finished     ANN training loss 0.006802
>> Epoch 57 finished     ANN training loss 0.006202
>> Epoch 58 finished     ANN training loss 0.005640
>> Epoch 59 finished     ANN training loss 0.005120
>> Epoch 60 finished     ANN training loss 0.005213
>> Epoch 61 finished     ANN training loss 0.004282
>> Epoch 62 finished     ANN training loss 0.003938
>> Epoch 63 finished     ANN training loss 0.004205
>> Epoch 64 finished     ANN training loss 0.004427
>> Epoch 65 finished     ANN training loss 0.003942
>> Epoch 66 finished     ANN training loss 0.003986
>> Epoch 67 finished     ANN training loss 0.003600
>> Epoch 68 finished     ANN training loss 0.003570
>> Epoch 69 finished     ANN training loss 0.003526
>> Epoch 70 finished     ANN training loss 0.002974
>> Epoch 71 finished     ANN training loss 0.003263
>> Epoch 72 finished     ANN training loss 0.003239
>> Epoch 73 finished     ANN training loss 0.003031
>> Epoch 74 finished     ANN training loss 0.002755
>> Epoch 75 finished     ANN training loss 0.002357
>> Epoch 76 finished     ANN training loss 0.002584
>> Epoch 77 finished     ANN training loss 0.002637
>> Epoch 78 finished     ANN training loss 0.002883
>> Epoch 79 finished     ANN training loss 0.002007
>> Epoch 80 finished     ANN training loss 0.002045
>> Epoch 81 finished     ANN training loss 0.002628
>> Epoch 82 finished     ANN training loss 0.002253
>> Epoch 83 finished     ANN training loss 0.001678
>> Epoch 84 finished     ANN training loss 0.001688
>> Epoch 85 finished     ANN training loss 0.001698
>> Epoch 86 finished     ANN training loss 0.002060
>> Epoch 87 finished     ANN training loss 0.001639
>> Epoch 88 finished     ANN training loss 0.001852
>> Epoch 89 finished     ANN training loss 0.001653
>> Epoch 90 finished     ANN training loss 0.001628
>> Epoch 91 finished     ANN training loss 0.002187
>> Epoch 92 finished     ANN training loss 0.002082
>> Epoch 93 finished     ANN training loss 0.001655
>> Epoch 94 finished     ANN training loss 0.001499
>> Epoch 95 finished     ANN training loss 0.001431
>> Epoch 96 finished     ANN training loss 0.001411
>> Epoch 97 finished     ANN training loss 0.001858
```

```
>> Epoch 98 finished     ANN training loss 0.001385
>> Epoch 99 finished     ANN training loss 0.001599
[END] Fine tuning step
Done.
Accuracy: 0.930000
```

In [94]:
```python
print('ACCURACY: ' + str(epoch_rbm_acc[2]))
```

ACCURACY: 0.93

Setting 4 (Default)

n_epochs_rbm=10

In [96]:
```python
epoch_rbm_acc[3] = default_acc
print('ACCURACY: ' + str(default_acc))
```

ACCURACY: 0.92

Setting 5

n_epochs_rbm=20

In [97]:
```python
epoch_rbm_acc[4] = deep_belief_net(n_epochs_rbm=20)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 54.319412
>> Epoch 2 finished     RBM Reconstruction error 63.459541
>> Epoch 3 finished     RBM Reconstruction error 39.351551
>> Epoch 4 finished     RBM Reconstruction error 54.099335
>> Epoch 5 finished     RBM Reconstruction error 64.219872
>> Epoch 6 finished     RBM Reconstruction error 31.824020
>> Epoch 7 finished     RBM Reconstruction error 71.651001
>> Epoch 8 finished     RBM Reconstruction error 37.982578
>> Epoch 9 finished     RBM Reconstruction error 31.841446
>> Epoch 10 finished    RBM Reconstruction error 51.448280
>> Epoch 11 finished    RBM Reconstruction error 42.309395
>> Epoch 12 finished    RBM Reconstruction error 29.266645
>> Epoch 13 finished    RBM Reconstruction error 24.917553
>> Epoch 14 finished    RBM Reconstruction error 23.888802
>> Epoch 15 finished    RBM Reconstruction error 41.501144
>> Epoch 16 finished    RBM Reconstruction error 39.057430
>> Epoch 17 finished    RBM Reconstruction error 46.352142
>> Epoch 18 finished    RBM Reconstruction error 30.200499
>> Epoch 19 finished    RBM Reconstruction error 33.579601
>> Epoch 20 finished    RBM Reconstruction error 41.781570
>> Epoch 1 finished     RBM Reconstruction error 78.465813
>> Epoch 2 finished     RBM Reconstruction error 147.174637
>> Epoch 3 finished     RBM Reconstruction error 148.045120
>> Epoch 4 finished     RBM Reconstruction error 95.456169
>> Epoch 5 finished     RBM Reconstruction error 95.083298
>> Epoch 6 finished     RBM Reconstruction error 85.185837
>> Epoch 7 finished     RBM Reconstruction error 128.573334
>> Epoch 8 finished     RBM Reconstruction error 165.656723
>> Epoch 9 finished     RBM Reconstruction error 127.142197
>> Epoch 10 finished    RBM Reconstruction error 157.904526
>> Epoch 11 finished    RBM Reconstruction error 166.077332
>> Epoch 12 finished    RBM Reconstruction error 133.084335
>> Epoch 13 finished    RBM Reconstruction error 163.618927
>> Epoch 14 finished    RBM Reconstruction error 129.413208
>> Epoch 15 finished    RBM Reconstruction error 122.651169
>> Epoch 16 finished    RBM Reconstruction error 166.202515
```

```
                      >> Epoch 17 finished     RBM Reconstruction error 119.266937
                      >> Epoch 18 finished     RBM Reconstruction error 144.564194
                      >> Epoch 19 finished     RBM Reconstruction error 183.519806
                      >> Epoch 20 finished     RBM Reconstruction error 177.120789
                      [END] Pre-training step
                      [START] Fine tuning step:
                      >> Epoch 0 finished     ANN training loss 0.639783
                      >> Epoch 1 finished     ANN training loss 0.392679
                      >> Epoch 2 finished     ANN training loss 0.336364
                      >> Epoch 3 finished     ANN training loss 0.282583
                      >> Epoch 4 finished     ANN training loss 0.235083
                      >> Epoch 5 finished     ANN training loss 0.248435
                      >> Epoch 6 finished     ANN training loss 0.197437
                      >> Epoch 7 finished     ANN training loss 0.172333
                      >> Epoch 8 finished     ANN training loss 0.143293
                      >> Epoch 9 finished     ANN training loss 0.130299
                      >> Epoch 10 finished    ANN training loss 0.117909
                      >> Epoch 11 finished    ANN training loss 0.099051
                      >> Epoch 12 finished    ANN training loss 0.099966
                      >> Epoch 13 finished    ANN training loss 0.087086
                      >> Epoch 14 finished    ANN training loss 0.077297
                      >> Epoch 15 finished    ANN training loss 0.069222
                      >> Epoch 16 finished    ANN training loss 0.060532
                      >> Epoch 17 finished    ANN training loss 0.058772
                      >> Epoch 18 finished    ANN training loss 0.057153
                      >> Epoch 19 finished    ANN training loss 0.047141
                      >> Epoch 20 finished    ANN training loss 0.041294
                      >> Epoch 21 finished    ANN training loss 0.037280
                      >> Epoch 22 finished    ANN training loss 0.032907
                      >> Epoch 23 finished    ANN training loss 0.034287
                      >> Epoch 24 finished    ANN training loss 0.030070
                      >> Epoch 25 finished    ANN training loss 0.026440
                      >> Epoch 26 finished    ANN training loss 0.025297
                      >> Epoch 27 finished    ANN training loss 0.023434
                      >> Epoch 28 finished    ANN training loss 0.022735
                      >> Epoch 29 finished    ANN training loss 0.022677
                      >> Epoch 30 finished    ANN training loss 0.022540
                      >> Epoch 31 finished    ANN training loss 0.017956
                      >> Epoch 32 finished    ANN training loss 0.015973
                      >> Epoch 33 finished    ANN training loss 0.014733
                      >> Epoch 34 finished    ANN training loss 0.013212
                      >> Epoch 35 finished    ANN training loss 0.013613
                      >> Epoch 36 finished    ANN training loss 0.013192
                      >> Epoch 37 finished    ANN training loss 0.011684
                      >> Epoch 38 finished    ANN training loss 0.010789
                      >> Epoch 39 finished    ANN training loss 0.011014
                      >> Epoch 40 finished    ANN training loss 0.010853
                      >> Epoch 41 finished    ANN training loss 0.009158
                      >> Epoch 42 finished    ANN training loss 0.009084
                      >> Epoch 43 finished    ANN training loss 0.008462
                      >> Epoch 44 finished    ANN training loss 0.008418
                      >> Epoch 45 finished    ANN training loss 0.007343
                      >> Epoch 46 finished    ANN training loss 0.008198
                      >> Epoch 47 finished    ANN training loss 0.007078
                      >> Epoch 48 finished    ANN training loss 0.007133
                      >> Epoch 49 finished    ANN training loss 0.005850
                      >> Epoch 50 finished    ANN training loss 0.005475
                      >> Epoch 51 finished    ANN training loss 0.005193
                      >> Epoch 52 finished    ANN training loss 0.004970
                      >> Epoch 53 finished    ANN training loss 0.005013
                      >> Epoch 54 finished    ANN training loss 0.004270
                      >> Epoch 55 finished    ANN training loss 0.004066
                      >> Epoch 56 finished    ANN training loss 0.003833
                      >> Epoch 57 finished    ANN training loss 0.003882
                      >> Epoch 58 finished    ANN training loss 0.003740
```

```
>> Epoch 59 finished      ANN training loss 0.003658
>> Epoch 60 finished      ANN training loss 0.003532
>> Epoch 61 finished      ANN training loss 0.003219
>> Epoch 62 finished      ANN training loss 0.003095
>> Epoch 63 finished      ANN training loss 0.002721
>> Epoch 64 finished      ANN training loss 0.002891
>> Epoch 65 finished      ANN training loss 0.002764
>> Epoch 66 finished      ANN training loss 0.002750
>> Epoch 67 finished      ANN training loss 0.002492
>> Epoch 68 finished      ANN training loss 0.002599
>> Epoch 69 finished      ANN training loss 0.002281
>> Epoch 70 finished      ANN training loss 0.002060
>> Epoch 71 finished      ANN training loss 0.002117
>> Epoch 72 finished      ANN training loss 0.003146
>> Epoch 73 finished      ANN training loss 0.002006
>> Epoch 74 finished      ANN training loss 0.001905
>> Epoch 75 finished      ANN training loss 0.001953
>> Epoch 76 finished      ANN training loss 0.001742
>> Epoch 77 finished      ANN training loss 0.001677
>> Epoch 78 finished      ANN training loss 0.001592
>> Epoch 79 finished      ANN training loss 0.001942
>> Epoch 80 finished      ANN training loss 0.001762
>> Epoch 81 finished      ANN training loss 0.001838
>> Epoch 82 finished      ANN training loss 0.001541
>> Epoch 83 finished      ANN training loss 0.001714
>> Epoch 84 finished      ANN training loss 0.001500
>> Epoch 85 finished      ANN training loss 0.001609
>> Epoch 86 finished      ANN training loss 0.001485
>> Epoch 87 finished      ANN training loss 0.001705
>> Epoch 88 finished      ANN training loss 0.001504
>> Epoch 89 finished      ANN training loss 0.001417
>> Epoch 90 finished      ANN training loss 0.001541
>> Epoch 91 finished      ANN training loss 0.001368
>> Epoch 92 finished      ANN training loss 0.001294
>> Epoch 93 finished      ANN training loss 0.001257
>> Epoch 94 finished      ANN training loss 0.001133
>> Epoch 95 finished      ANN training loss 0.001057
>> Epoch 96 finished      ANN training loss 0.001009
>> Epoch 97 finished      ANN training loss 0.000925
>> Epoch 98 finished      ANN training loss 0.000993
>> Epoch 99 finished      ANN training loss 0.000974
[END] Fine tuning step
Done.
```

In [98]:
```python
print('ACCURACY: ' + str(epoch_rbm_acc[4]))
```

```
ACCURACY: 0.925
```

Setting 6

n_epochs_rbm=30

In [99]:
```python
epoch_rbm_acc[5] = deep_belief_net(n_epochs_rbm=30)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 119.058693
>> Epoch 2 finished      RBM Reconstruction error 65.557838
>> Epoch 3 finished      RBM Reconstruction error 67.544075
>> Epoch 4 finished      RBM Reconstruction error 39.892689
>> Epoch 5 finished      RBM Reconstruction error 43.711231
>> Epoch 6 finished      RBM Reconstruction error 57.967655
>> Epoch 7 finished      RBM Reconstruction error 50.951454
>> Epoch 8 finished      RBM Reconstruction error 55.691795
```

```
                    >> Epoch 9 finished      RBM Reconstruction error 40.283005
                    >> Epoch 10 finished     RBM Reconstruction error 45.715225
                    >> Epoch 11 finished     RBM Reconstruction error 37.194252
                    >> Epoch 12 finished     RBM Reconstruction error 31.848616
                    >> Epoch 13 finished     RBM Reconstruction error 43.089619
                    >> Epoch 14 finished     RBM Reconstruction error 59.848587
                    >> Epoch 15 finished     RBM Reconstruction error 42.244930
                    >> Epoch 16 finished     RBM Reconstruction error 53.655136
                    >> Epoch 17 finished     RBM Reconstruction error 47.361298
                    >> Epoch 18 finished     RBM Reconstruction error 45.188522
                    >> Epoch 19 finished     RBM Reconstruction error 44.613564
                    >> Epoch 20 finished     RBM Reconstruction error 48.804211
                    >> Epoch 21 finished     RBM Reconstruction error 44.465992
                    >> Epoch 22 finished     RBM Reconstruction error 50.147743
                    >> Epoch 23 finished     RBM Reconstruction error 51.446888
                    >> Epoch 24 finished     RBM Reconstruction error 44.338604
                    >> Epoch 25 finished     RBM Reconstruction error 46.279552
                    >> Epoch 26 finished     RBM Reconstruction error 57.635422
                    >> Epoch 27 finished     RBM Reconstruction error 51.885620
                    >> Epoch 28 finished     RBM Reconstruction error 59.122746
                    >> Epoch 29 finished     RBM Reconstruction error 52.097000
                    >> Epoch 30 finished     RBM Reconstruction error 59.785477
                    >> Epoch 1 finished      RBM Reconstruction error 127.247795
                    >> Epoch 2 finished      RBM Reconstruction error 160.988297
                    >> Epoch 3 finished      RBM Reconstruction error 78.756531
                    >> Epoch 4 finished      RBM Reconstruction error 214.832825
                    >> Epoch 5 finished      RBM Reconstruction error 210.697708
                    >> Epoch 6 finished      RBM Reconstruction error 145.715408
                    >> Epoch 7 finished      RBM Reconstruction error 138.853806
                    >> Epoch 8 finished      RBM Reconstruction error 169.987045
                    >> Epoch 9 finished      RBM Reconstruction error 178.030624
                    >> Epoch 10 finished     RBM Reconstruction error 189.227676
                    >> Epoch 11 finished     RBM Reconstruction error 153.257660
                    >> Epoch 12 finished     RBM Reconstruction error 199.059616
                    >> Epoch 13 finished     RBM Reconstruction error 164.430237
                    >> Epoch 14 finished     RBM Reconstruction error 147.864761
                    >> Epoch 15 finished     RBM Reconstruction error 242.900269
                    >> Epoch 16 finished     RBM Reconstruction error 242.457672
                    >> Epoch 17 finished     RBM Reconstruction error 185.456253
                    >> Epoch 18 finished     RBM Reconstruction error 223.098328
                    >> Epoch 19 finished     RBM Reconstruction error 224.546860
                    >> Epoch 20 finished     RBM Reconstruction error 167.609573
                    >> Epoch 21 finished     RBM Reconstruction error 192.305405
                    >> Epoch 22 finished     RBM Reconstruction error 150.278717
                    >> Epoch 23 finished     RBM Reconstruction error 173.953766
                    >> Epoch 24 finished     RBM Reconstruction error 118.062347
                    >> Epoch 25 finished     RBM Reconstruction error 203.252182
                    >> Epoch 26 finished     RBM Reconstruction error 158.866028
                    >> Epoch 27 finished     RBM Reconstruction error 177.342300
                    >> Epoch 28 finished     RBM Reconstruction error 214.501648
                    >> Epoch 29 finished     RBM Reconstruction error 203.130386
                    >> Epoch 30 finished     RBM Reconstruction error 191.975174
                    [END] Pre-training step
                    [START] Fine tuning step:
                    >> Epoch 0 finished      ANN training loss 0.580009
                    >> Epoch 1 finished      ANN training loss 0.418021
                    >> Epoch 2 finished      ANN training loss 0.371747
                    >> Epoch 3 finished      ANN training loss 0.306114
                    >> Epoch 4 finished      ANN training loss 0.261978
                    >> Epoch 5 finished      ANN training loss 0.222210
                    >> Epoch 6 finished      ANN training loss 0.204540
                    >> Epoch 7 finished      ANN training loss 0.178271
                    >> Epoch 8 finished      ANN training loss 0.147977
                    >> Epoch 9 finished      ANN training loss 0.160757
                    >> Epoch 10 finished     ANN training loss 0.120485
```

```
>> Epoch 11 finished     ANN training loss 0.105766
>> Epoch 12 finished     ANN training loss 0.099921
>> Epoch 13 finished     ANN training loss 0.092332
>> Epoch 14 finished     ANN training loss 0.077099
>> Epoch 15 finished     ANN training loss 0.070151
>> Epoch 16 finished     ANN training loss 0.065056
>> Epoch 17 finished     ANN training loss 0.067782
>> Epoch 18 finished     ANN training loss 0.053442
>> Epoch 19 finished     ANN training loss 0.046238
>> Epoch 20 finished     ANN training loss 0.044684
>> Epoch 21 finished     ANN training loss 0.038788
>> Epoch 22 finished     ANN training loss 0.040962
>> Epoch 23 finished     ANN training loss 0.034788
>> Epoch 24 finished     ANN training loss 0.032209
>> Epoch 25 finished     ANN training loss 0.034088
>> Epoch 26 finished     ANN training loss 0.028738
>> Epoch 27 finished     ANN training loss 0.023392
>> Epoch 28 finished     ANN training loss 0.024621
>> Epoch 29 finished     ANN training loss 0.019795
>> Epoch 30 finished     ANN training loss 0.020886
>> Epoch 31 finished     ANN training loss 0.018728
>> Epoch 32 finished     ANN training loss 0.017961
>> Epoch 33 finished     ANN training loss 0.016736
>> Epoch 34 finished     ANN training loss 0.016476
>> Epoch 35 finished     ANN training loss 0.014979
>> Epoch 36 finished     ANN training loss 0.013809
>> Epoch 37 finished     ANN training loss 0.014531
>> Epoch 38 finished     ANN training loss 0.011500
>> Epoch 39 finished     ANN training loss 0.010957
>> Epoch 40 finished     ANN training loss 0.010617
>> Epoch 41 finished     ANN training loss 0.010137
>> Epoch 42 finished     ANN training loss 0.008667
>> Epoch 43 finished     ANN training loss 0.010664
>> Epoch 44 finished     ANN training loss 0.008521
>> Epoch 45 finished     ANN training loss 0.009039
>> Epoch 46 finished     ANN training loss 0.009006
>> Epoch 47 finished     ANN training loss 0.007954
>> Epoch 48 finished     ANN training loss 0.007146
>> Epoch 49 finished     ANN training loss 0.006985
>> Epoch 50 finished     ANN training loss 0.006996
>> Epoch 51 finished     ANN training loss 0.005860
>> Epoch 52 finished     ANN training loss 0.006715
>> Epoch 53 finished     ANN training loss 0.007014
>> Epoch 54 finished     ANN training loss 0.005921
>> Epoch 55 finished     ANN training loss 0.005558
>> Epoch 56 finished     ANN training loss 0.004830
>> Epoch 57 finished     ANN training loss 0.004388
>> Epoch 58 finished     ANN training loss 0.004356
>> Epoch 59 finished     ANN training loss 0.003932
>> Epoch 60 finished     ANN training loss 0.003928
>> Epoch 61 finished     ANN training loss 0.003668
>> Epoch 62 finished     ANN training loss 0.003612
>> Epoch 63 finished     ANN training loss 0.004259
>> Epoch 64 finished     ANN training loss 0.004055
>> Epoch 65 finished     ANN training loss 0.003285
>> Epoch 66 finished     ANN training loss 0.003120
>> Epoch 67 finished     ANN training loss 0.003168
>> Epoch 68 finished     ANN training loss 0.002879
>> Epoch 69 finished     ANN training loss 0.003044
>> Epoch 70 finished     ANN training loss 0.002532
>> Epoch 71 finished     ANN training loss 0.002785
>> Epoch 72 finished     ANN training loss 0.002547
>> Epoch 73 finished     ANN training loss 0.002392
>> Epoch 74 finished     ANN training loss 0.002516
>> Epoch 75 finished     ANN training loss 0.002373
```

```
>> Epoch 76 finished     ANN training loss 0.002245
>> Epoch 77 finished     ANN training loss 0.002073
>> Epoch 78 finished     ANN training loss 0.002004
>> Epoch 79 finished     ANN training loss 0.001920
>> Epoch 80 finished     ANN training loss 0.002021
>> Epoch 81 finished     ANN training loss 0.002042
>> Epoch 82 finished     ANN training loss 0.002018
>> Epoch 83 finished     ANN training loss 0.001783
>> Epoch 84 finished     ANN training loss 0.002063
>> Epoch 85 finished     ANN training loss 0.001850
>> Epoch 86 finished     ANN training loss 0.001736
>> Epoch 87 finished     ANN training loss 0.001565
>> Epoch 88 finished     ANN training loss 0.001532
>> Epoch 89 finished     ANN training loss 0.001432
>> Epoch 90 finished     ANN training loss 0.001241
>> Epoch 91 finished     ANN training loss 0.001839
>> Epoch 92 finished     ANN training loss 0.001353
>> Epoch 93 finished     ANN training loss 0.001246
>> Epoch 94 finished     ANN training loss 0.001366
>> Epoch 95 finished     ANN training loss 0.001405
>> Epoch 96 finished     ANN training loss 0.001113
>> Epoch 97 finished     ANN training loss 0.001057
>> Epoch 98 finished     ANN training loss 0.001125
>> Epoch 99 finished     ANN training loss 0.001351
[END] Fine tuning step
Done.
```

In [100…
```python
print('ACCURACY: ' + str(epoch_rbm_acc[5]))
```

```
ACCURACY: 0.925
```

Setting 7

n_epochs_rbm=40

In [101…
```python
epoch_rbm_acc[6] = deep_belief_net(n_epochs_rbm=40)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 98.491325
>> Epoch 2 finished     RBM Reconstruction error 62.166748
>> Epoch 3 finished     RBM Reconstruction error 43.109913
>> Epoch 4 finished     RBM Reconstruction error 34.269939
>> Epoch 5 finished     RBM Reconstruction error 51.258476
>> Epoch 6 finished     RBM Reconstruction error 44.414074
>> Epoch 7 finished     RBM Reconstruction error 44.369331
>> Epoch 8 finished     RBM Reconstruction error 39.630882
>> Epoch 9 finished     RBM Reconstruction error 38.195812
>> Epoch 10 finished     RBM Reconstruction error 46.515759
>> Epoch 11 finished     RBM Reconstruction error 58.347984
>> Epoch 12 finished     RBM Reconstruction error 49.590366
>> Epoch 13 finished     RBM Reconstruction error 32.750656
>> Epoch 14 finished     RBM Reconstruction error 56.219135
>> Epoch 15 finished     RBM Reconstruction error 38.937584
>> Epoch 16 finished     RBM Reconstruction error 44.719715
>> Epoch 17 finished     RBM Reconstruction error 40.375450
>> Epoch 18 finished     RBM Reconstruction error 48.133820
>> Epoch 19 finished     RBM Reconstruction error 46.230270
>> Epoch 20 finished     RBM Reconstruction error 37.790718
>> Epoch 21 finished     RBM Reconstruction error 37.964008
>> Epoch 22 finished     RBM Reconstruction error 28.959040
>> Epoch 23 finished     RBM Reconstruction error 45.854630
>> Epoch 24 finished     RBM Reconstruction error 41.324127
>> Epoch 25 finished     RBM Reconstruction error 46.382412
```

```
                    >> Epoch 26 finished    RBM Reconstruction error 43.990635
                    >> Epoch 27 finished    RBM Reconstruction error 38.740189
                    >> Epoch 28 finished    RBM Reconstruction error 46.253212
                    >> Epoch 29 finished    RBM Reconstruction error 46.192284
                    >> Epoch 30 finished    RBM Reconstruction error 44.224640
                    >> Epoch 31 finished    RBM Reconstruction error 49.471237
                    >> Epoch 32 finished    RBM Reconstruction error 53.220654
                    >> Epoch 33 finished    RBM Reconstruction error 62.776901
                    >> Epoch 34 finished    RBM Reconstruction error 41.693722
                    >> Epoch 35 finished    RBM Reconstruction error 51.083996
                    >> Epoch 36 finished    RBM Reconstruction error 59.423817
                    >> Epoch 37 finished    RBM Reconstruction error 47.981895
                    >> Epoch 38 finished    RBM Reconstruction error 48.889694
                    >> Epoch 39 finished    RBM Reconstruction error 56.875370
                    >> Epoch 40 finished    RBM Reconstruction error 44.700844
                    >> Epoch 1 finished     RBM Reconstruction error 110.313927
                    >> Epoch 2 finished     RBM Reconstruction error 134.939697
                    >> Epoch 3 finished     RBM Reconstruction error 132.079590
                    >> Epoch 4 finished     RBM Reconstruction error 208.770004
                    >> Epoch 5 finished     RBM Reconstruction error 167.162537
                    >> Epoch 6 finished     RBM Reconstruction error 127.829567
                    >> Epoch 7 finished     RBM Reconstruction error 161.938049
                    >> Epoch 8 finished     RBM Reconstruction error 89.116798
                    >> Epoch 9 finished     RBM Reconstruction error 94.803734
                    >> Epoch 10 finished    RBM Reconstruction error 55.572735
                    >> Epoch 11 finished    RBM Reconstruction error 103.354340
                    >> Epoch 12 finished    RBM Reconstruction error 105.283310
                    >> Epoch 13 finished    RBM Reconstruction error 112.827698
                    >> Epoch 14 finished    RBM Reconstruction error 106.298225
                    >> Epoch 15 finished    RBM Reconstruction error 112.952438
                    >> Epoch 16 finished    RBM Reconstruction error 64.986298
                    >> Epoch 17 finished    RBM Reconstruction error 154.728577
                    >> Epoch 18 finished    RBM Reconstruction error 112.032379
                    >> Epoch 19 finished    RBM Reconstruction error 68.847481
                    >> Epoch 20 finished    RBM Reconstruction error 110.694313
                    >> Epoch 21 finished    RBM Reconstruction error 139.197403
                    >> Epoch 22 finished    RBM Reconstruction error 110.178009
                    >> Epoch 23 finished    RBM Reconstruction error 92.777145
                    >> Epoch 24 finished    RBM Reconstruction error 100.466171
                    >> Epoch 25 finished    RBM Reconstruction error 109.964066
                    >> Epoch 26 finished    RBM Reconstruction error 94.963379
                    >> Epoch 27 finished    RBM Reconstruction error 82.277405
                    >> Epoch 28 finished    RBM Reconstruction error 120.845139
                    >> Epoch 29 finished    RBM Reconstruction error 86.145096
                    >> Epoch 30 finished    RBM Reconstruction error 107.836601
                    >> Epoch 31 finished    RBM Reconstruction error 83.286819
                    >> Epoch 32 finished    RBM Reconstruction error 87.500702
                    >> Epoch 33 finished    RBM Reconstruction error 102.135857
                    >> Epoch 34 finished    RBM Reconstruction error 110.949600
                    >> Epoch 35 finished    RBM Reconstruction error 106.777245
                    >> Epoch 36 finished    RBM Reconstruction error 90.700058
                    >> Epoch 37 finished    RBM Reconstruction error 126.906837
                    >> Epoch 38 finished    RBM Reconstruction error 105.766190
                    >> Epoch 39 finished    RBM Reconstruction error 120.708176
                    >> Epoch 40 finished    RBM Reconstruction error 87.147110
                    [END] Pre-training step
                    [START] Fine tuning step:
                    >> Epoch 0 finished     ANN training loss 0.585433
                    >> Epoch 1 finished     ANN training loss 0.430126
                    >> Epoch 2 finished     ANN training loss 0.365303
                    >> Epoch 3 finished     ANN training loss 0.278007
                    >> Epoch 4 finished     ANN training loss 0.227414
                    >> Epoch 5 finished     ANN training loss 0.199426
                    >> Epoch 6 finished     ANN training loss 0.184337
                    >> Epoch 7 finished     ANN training loss 0.145943
```

```
>> Epoch 8 finished     ANN training loss 0.135998
>> Epoch 9 finished     ANN training loss 0.127751
>> Epoch 10 finished    ANN training loss 0.105964
>> Epoch 11 finished    ANN training loss 0.108622
>> Epoch 12 finished    ANN training loss 0.093477
>> Epoch 13 finished    ANN training loss 0.074975
>> Epoch 14 finished    ANN training loss 0.075563
>> Epoch 15 finished    ANN training loss 0.078443
>> Epoch 16 finished    ANN training loss 0.059268
>> Epoch 17 finished    ANN training loss 0.050735
>> Epoch 18 finished    ANN training loss 0.049961
>> Epoch 19 finished    ANN training loss 0.041482
>> Epoch 20 finished    ANN training loss 0.040375
>> Epoch 21 finished    ANN training loss 0.038014
>> Epoch 22 finished    ANN training loss 0.039363
>> Epoch 23 finished    ANN training loss 0.029863
>> Epoch 24 finished    ANN training loss 0.031237
>> Epoch 25 finished    ANN training loss 0.028480
>> Epoch 26 finished    ANN training loss 0.023438
>> Epoch 27 finished    ANN training loss 0.021009
>> Epoch 28 finished    ANN training loss 0.019586
>> Epoch 29 finished    ANN training loss 0.018735
>> Epoch 30 finished    ANN training loss 0.025469
>> Epoch 31 finished    ANN training loss 0.017652
>> Epoch 32 finished    ANN training loss 0.017556
>> Epoch 33 finished    ANN training loss 0.016264
>> Epoch 34 finished    ANN training loss 0.013507
>> Epoch 35 finished    ANN training loss 0.012228
>> Epoch 36 finished    ANN training loss 0.011597
>> Epoch 37 finished    ANN training loss 0.011180
>> Epoch 38 finished    ANN training loss 0.010400
>> Epoch 39 finished    ANN training loss 0.009539
>> Epoch 40 finished    ANN training loss 0.010413
>> Epoch 41 finished    ANN training loss 0.007948
>> Epoch 42 finished    ANN training loss 0.007762
>> Epoch 43 finished    ANN training loss 0.007450
>> Epoch 44 finished    ANN training loss 0.007315
>> Epoch 45 finished    ANN training loss 0.006207
>> Epoch 46 finished    ANN training loss 0.006075
>> Epoch 47 finished    ANN training loss 0.005612
>> Epoch 48 finished    ANN training loss 0.006060
>> Epoch 49 finished    ANN training loss 0.005869
>> Epoch 50 finished    ANN training loss 0.005192
>> Epoch 51 finished    ANN training loss 0.004819
>> Epoch 52 finished    ANN training loss 0.004715
>> Epoch 53 finished    ANN training loss 0.004737
>> Epoch 54 finished    ANN training loss 0.004159
>> Epoch 55 finished    ANN training loss 0.003859
>> Epoch 56 finished    ANN training loss 0.004112
>> Epoch 57 finished    ANN training loss 0.004127
>> Epoch 58 finished    ANN training loss 0.004178
>> Epoch 59 finished    ANN training loss 0.003380
>> Epoch 60 finished    ANN training loss 0.003477
>> Epoch 61 finished    ANN training loss 0.003638
>> Epoch 62 finished    ANN training loss 0.003087
>> Epoch 63 finished    ANN training loss 0.002828
>> Epoch 64 finished    ANN training loss 0.002718
>> Epoch 65 finished    ANN training loss 0.002884
>> Epoch 66 finished    ANN training loss 0.003152
>> Epoch 67 finished    ANN training loss 0.002765
>> Epoch 68 finished    ANN training loss 0.002771
>> Epoch 69 finished    ANN training loss 0.002501
>> Epoch 70 finished    ANN training loss 0.002561
>> Epoch 71 finished    ANN training loss 0.002290
>> Epoch 72 finished    ANN training loss 0.002116
```

```
>> Epoch 73 finished      ANN training loss 0.001919
>> Epoch 74 finished      ANN training loss 0.001898
>> Epoch 75 finished      ANN training loss 0.001949
>> Epoch 76 finished      ANN training loss 0.002098
>> Epoch 77 finished      ANN training loss 0.002842
>> Epoch 78 finished      ANN training loss 0.001775
>> Epoch 79 finished      ANN training loss 0.001782
>> Epoch 80 finished      ANN training loss 0.001818
>> Epoch 81 finished      ANN training loss 0.001550
>> Epoch 82 finished      ANN training loss 0.001628
>> Epoch 83 finished      ANN training loss 0.001463
>> Epoch 84 finished      ANN training loss 0.001509
>> Epoch 85 finished      ANN training loss 0.001545
>> Epoch 86 finished      ANN training loss 0.001594
>> Epoch 87 finished      ANN training loss 0.001632
>> Epoch 88 finished      ANN training loss 0.001967
>> Epoch 89 finished      ANN training loss 0.001663
>> Epoch 90 finished      ANN training loss 0.001477
>> Epoch 91 finished      ANN training loss 0.001539
>> Epoch 92 finished      ANN training loss 0.001367
>> Epoch 93 finished      ANN training loss 0.001280
>> Epoch 94 finished      ANN training loss 0.001401
>> Epoch 95 finished      ANN training loss 0.001499
>> Epoch 96 finished      ANN training loss 0.001467
>> Epoch 97 finished      ANN training loss 0.001265
>> Epoch 98 finished      ANN training loss 0.001613
>> Epoch 99 finished      ANN training loss 0.001143
[END] Fine tuning step
```

In [102…
```python
print('ACCURACY: ' + str(epoch_rbm_acc[6]))
```

```
ACCURACY: 0.93
```

Setting 8

n_epochs_rbm=50

In [103…
```python
epoch_rbm_acc[7] = deep_belief_net(n_epochs_rbm=50)
```

```
[START] Pre-training step:
>> Epoch 1 finished       RBM Reconstruction error 69.991081
>> Epoch 2 finished       RBM Reconstruction error 53.935459
>> Epoch 3 finished       RBM Reconstruction error 41.196545
>> Epoch 4 finished       RBM Reconstruction error 54.571129
>> Epoch 5 finished       RBM Reconstruction error 43.848213
>> Epoch 6 finished       RBM Reconstruction error 59.311092
>> Epoch 7 finished       RBM Reconstruction error 40.106819
>> Epoch 8 finished       RBM Reconstruction error 47.300243
>> Epoch 9 finished       RBM Reconstruction error 36.876217
>> Epoch 10 finished      RBM Reconstruction error 27.118109
>> Epoch 11 finished      RBM Reconstruction error 60.691174
>> Epoch 12 finished      RBM Reconstruction error 53.345062
>> Epoch 13 finished      RBM Reconstruction error 35.359818
>> Epoch 14 finished      RBM Reconstruction error 35.779781
>> Epoch 15 finished      RBM Reconstruction error 35.554428
>> Epoch 16 finished      RBM Reconstruction error 40.402821
>> Epoch 17 finished      RBM Reconstruction error 44.550732
>> Epoch 18 finished      RBM Reconstruction error 51.913441
>> Epoch 19 finished      RBM Reconstruction error 42.347816
>> Epoch 20 finished      RBM Reconstruction error 45.685772
>> Epoch 21 finished      RBM Reconstruction error 41.956974
>> Epoch 22 finished      RBM Reconstruction error 55.436699
>> Epoch 23 finished      RBM Reconstruction error 47.472412
```

```
>> Epoch 24 finished    RBM Reconstruction error 50.265915
>> Epoch 25 finished    RBM Reconstruction error 57.223549
>> Epoch 26 finished    RBM Reconstruction error 43.798874
>> Epoch 27 finished    RBM Reconstruction error 53.447498
>> Epoch 28 finished    RBM Reconstruction error 48.546768
>> Epoch 29 finished    RBM Reconstruction error 49.385399
>> Epoch 30 finished    RBM Reconstruction error 48.369366
>> Epoch 31 finished    RBM Reconstruction error 57.247372
>> Epoch 32 finished    RBM Reconstruction error 45.389969
>> Epoch 33 finished    RBM Reconstruction error 56.202621
>> Epoch 34 finished    RBM Reconstruction error 58.838085
>> Epoch 35 finished    RBM Reconstruction error 47.516792
>> Epoch 36 finished    RBM Reconstruction error 47.032001
>> Epoch 37 finished    RBM Reconstruction error 44.362881
>> Epoch 38 finished    RBM Reconstruction error 42.631405
>> Epoch 39 finished    RBM Reconstruction error 37.179169
>> Epoch 40 finished    RBM Reconstruction error 55.456768
>> Epoch 41 finished    RBM Reconstruction error 54.769619
>> Epoch 42 finished    RBM Reconstruction error 55.015293
>> Epoch 43 finished    RBM Reconstruction error 49.508907
>> Epoch 44 finished    RBM Reconstruction error 51.706089
>> Epoch 45 finished    RBM Reconstruction error 44.344501
>> Epoch 46 finished    RBM Reconstruction error 49.774357
>> Epoch 47 finished    RBM Reconstruction error 49.533279
>> Epoch 48 finished    RBM Reconstruction error 52.947086
>> Epoch 49 finished    RBM Reconstruction error 39.453072
>> Epoch 50 finished    RBM Reconstruction error 57.382793
>> Epoch 1 finished     RBM Reconstruction error 213.133987
>> Epoch 2 finished     RBM Reconstruction error 338.352448
>> Epoch 3 finished     RBM Reconstruction error 299.145416
>> Epoch 4 finished     RBM Reconstruction error 251.689087
>> Epoch 5 finished     RBM Reconstruction error 307.814728
>> Epoch 6 finished     RBM Reconstruction error 266.905151
>> Epoch 7 finished     RBM Reconstruction error 311.959290
>> Epoch 8 finished     RBM Reconstruction error 353.286804
>> Epoch 9 finished     RBM Reconstruction error 322.057983
>> Epoch 10 finished    RBM Reconstruction error 310.856354
>> Epoch 11 finished    RBM Reconstruction error 327.176239
>> Epoch 12 finished    RBM Reconstruction error 308.853210
>> Epoch 13 finished    RBM Reconstruction error 352.459076
>> Epoch 14 finished    RBM Reconstruction error 319.874878
>> Epoch 15 finished    RBM Reconstruction error 341.069214
>> Epoch 16 finished    RBM Reconstruction error 267.378235
>> Epoch 17 finished    RBM Reconstruction error 407.438507
>> Epoch 18 finished    RBM Reconstruction error 321.490204
>> Epoch 19 finished    RBM Reconstruction error 374.025848
>> Epoch 20 finished    RBM Reconstruction error 329.614380
>> Epoch 21 finished    RBM Reconstruction error 334.114990
>> Epoch 22 finished    RBM Reconstruction error 378.316162
>> Epoch 23 finished    RBM Reconstruction error 349.021454
>> Epoch 24 finished    RBM Reconstruction error 344.572174
>> Epoch 25 finished    RBM Reconstruction error 335.653870
>> Epoch 26 finished    RBM Reconstruction error 292.200043
>> Epoch 27 finished    RBM Reconstruction error 340.525238
>> Epoch 28 finished    RBM Reconstruction error 317.476654
>> Epoch 29 finished    RBM Reconstruction error 365.472687
>> Epoch 30 finished    RBM Reconstruction error 335.029144
>> Epoch 31 finished    RBM Reconstruction error 337.888428
>> Epoch 32 finished    RBM Reconstruction error 416.404205
>> Epoch 33 finished    RBM Reconstruction error 364.206940
>> Epoch 34 finished    RBM Reconstruction error 351.500824
>> Epoch 35 finished    RBM Reconstruction error 438.052277
>> Epoch 36 finished    RBM Reconstruction error 362.763306
>> Epoch 37 finished    RBM Reconstruction error 353.291962
>> Epoch 38 finished    RBM Reconstruction error 397.952576
```

```
                >> Epoch 39 finished     RBM Reconstruction error 368.366638
                >> Epoch 40 finished     RBM Reconstruction error 434.857941
                >> Epoch 41 finished     RBM Reconstruction error 320.781525
                >> Epoch 42 finished     RBM Reconstruction error 376.645233
                >> Epoch 43 finished     RBM Reconstruction error 335.900665
                >> Epoch 44 finished     RBM Reconstruction error 398.253357
                >> Epoch 45 finished     RBM Reconstruction error 404.312744
                >> Epoch 46 finished     RBM Reconstruction error 334.645874
                >> Epoch 47 finished     RBM Reconstruction error 375.031952
                >> Epoch 48 finished     RBM Reconstruction error 350.045624
                >> Epoch 49 finished     RBM Reconstruction error 344.914459
                >> Epoch 50 finished     RBM Reconstruction error 344.322266
                [END] Pre-training step
                [START] Fine tuning step:
                >> Epoch 0 finished     ANN training loss 0.584264
                >> Epoch 1 finished     ANN training loss 0.601146
                >> Epoch 2 finished     ANN training loss 0.339275
                >> Epoch 3 finished     ANN training loss 0.276337
                >> Epoch 4 finished     ANN training loss 0.229558
                >> Epoch 5 finished     ANN training loss 0.211784
                >> Epoch 6 finished     ANN training loss 0.171505
                >> Epoch 7 finished     ANN training loss 0.159481
                >> Epoch 8 finished     ANN training loss 0.136390
                >> Epoch 9 finished     ANN training loss 0.122148
                >> Epoch 10 finished     ANN training loss 0.119484
                >> Epoch 11 finished     ANN training loss 0.126666
                >> Epoch 12 finished     ANN training loss 0.089896
                >> Epoch 13 finished     ANN training loss 0.083611
                >> Epoch 14 finished     ANN training loss 0.074343
                >> Epoch 15 finished     ANN training loss 0.067437
                >> Epoch 16 finished     ANN training loss 0.061726
                >> Epoch 17 finished     ANN training loss 0.056064
                >> Epoch 18 finished     ANN training loss 0.049404
                >> Epoch 19 finished     ANN training loss 0.039220
                >> Epoch 20 finished     ANN training loss 0.042682
                >> Epoch 21 finished     ANN training loss 0.040789
                >> Epoch 22 finished     ANN training loss 0.034783
                >> Epoch 23 finished     ANN training loss 0.028799
                >> Epoch 24 finished     ANN training loss 0.025559
                >> Epoch 25 finished     ANN training loss 0.026683
                >> Epoch 26 finished     ANN training loss 0.026904
                >> Epoch 27 finished     ANN training loss 0.022445
                >> Epoch 28 finished     ANN training loss 0.018863
                >> Epoch 29 finished     ANN training loss 0.017471
                >> Epoch 30 finished     ANN training loss 0.014674
                >> Epoch 31 finished     ANN training loss 0.014660
                >> Epoch 32 finished     ANN training loss 0.012769
                >> Epoch 33 finished     ANN training loss 0.013057
                >> Epoch 34 finished     ANN training loss 0.012746
                >> Epoch 35 finished     ANN training loss 0.012224
                >> Epoch 36 finished     ANN training loss 0.009964
                >> Epoch 37 finished     ANN training loss 0.010785
                >> Epoch 38 finished     ANN training loss 0.008956
                >> Epoch 39 finished     ANN training loss 0.009095
                >> Epoch 40 finished     ANN training loss 0.007297
                >> Epoch 41 finished     ANN training loss 0.008115
                >> Epoch 42 finished     ANN training loss 0.006544
                >> Epoch 43 finished     ANN training loss 0.006402
                >> Epoch 44 finished     ANN training loss 0.007203
                >> Epoch 45 finished     ANN training loss 0.005386
                >> Epoch 46 finished     ANN training loss 0.005045
                >> Epoch 47 finished     ANN training loss 0.004793
                >> Epoch 48 finished     ANN training loss 0.004895
                >> Epoch 49 finished     ANN training loss 0.003995
                >> Epoch 50 finished     ANN training loss 0.004342
```

```
>> Epoch 51 finished    ANN training loss 0.003956
>> Epoch 52 finished    ANN training loss 0.004419
>> Epoch 53 finished    ANN training loss 0.003506
>> Epoch 54 finished    ANN training loss 0.003394
>> Epoch 55 finished    ANN training loss 0.003094
>> Epoch 56 finished    ANN training loss 0.003003
>> Epoch 57 finished    ANN training loss 0.002911
>> Epoch 58 finished    ANN training loss 0.003127
>> Epoch 59 finished    ANN training loss 0.002690
>> Epoch 60 finished    ANN training loss 0.002647
>> Epoch 61 finished    ANN training loss 0.002495
>> Epoch 62 finished    ANN training loss 0.002301
>> Epoch 63 finished    ANN training loss 0.002322
>> Epoch 64 finished    ANN training loss 0.002254
>> Epoch 65 finished    ANN training loss 0.002566
>> Epoch 66 finished    ANN training loss 0.002215
>> Epoch 67 finished    ANN training loss 0.001974
>> Epoch 68 finished    ANN training loss 0.002304
>> Epoch 69 finished    ANN training loss 0.001946
>> Epoch 70 finished    ANN training loss 0.001960
>> Epoch 71 finished    ANN training loss 0.002041
>> Epoch 72 finished    ANN training loss 0.002321
>> Epoch 73 finished    ANN training loss 0.001933
>> Epoch 74 finished    ANN training loss 0.001724
>> Epoch 75 finished    ANN training loss 0.001629
>> Epoch 76 finished    ANN training loss 0.001743
>> Epoch 77 finished    ANN training loss 0.003076
>> Epoch 78 finished    ANN training loss 0.001888
>> Epoch 79 finished    ANN training loss 0.001550
>> Epoch 80 finished    ANN training loss 0.001675
>> Epoch 81 finished    ANN training loss 0.001476
>> Epoch 82 finished    ANN training loss 0.001949
>> Epoch 83 finished    ANN training loss 0.001521
>> Epoch 84 finished    ANN training loss 0.001630
>> Epoch 85 finished    ANN training loss 0.001235
>> Epoch 86 finished    ANN training loss 0.001156
>> Epoch 87 finished    ANN training loss 0.001300
>> Epoch 88 finished    ANN training loss 0.001013
>> Epoch 89 finished    ANN training loss 0.001001
>> Epoch 90 finished    ANN training loss 0.000935
>> Epoch 91 finished    ANN training loss 0.001067
>> Epoch 92 finished    ANN training loss 0.000849
>> Epoch 93 finished    ANN training loss 0.000783
>> Epoch 94 finished    ANN training loss 0.000877
>> Epoch 95 finished    ANN training loss 0.000764
>> Epoch 96 finished    ANN training loss 0.000745
>> Epoch 97 finished    ANN training loss 0.000785
>> Epoch 98 finished    ANN training loss 0.000750
>> Epoch 99 finished    ANN training loss 0.000882
[END] Fine tuning step
Done.
```

In [104…
```python
print('ACCURACY: ' + str(epoch_rbm_acc[7]))
```

```
ACCURACY: 0.935
```

Setting 9

n_epochs_rbm=100

In [105…
```python
epoch_rbm_acc[8] = deep_belief_net(n_epochs_rbm=100)
```

```
[START] Pre-training step:
```

```
>> Epoch 1 finished        RBM Reconstruction error 84.992477
>> Epoch 2 finished        RBM Reconstruction error 52.556793
>> Epoch 3 finished        RBM Reconstruction error 73.466675
>> Epoch 4 finished        RBM Reconstruction error 80.173210
>> Epoch 5 finished        RBM Reconstruction error 74.324738
>> Epoch 6 finished        RBM Reconstruction error 48.524315
>> Epoch 7 finished        RBM Reconstruction error 52.935352
>> Epoch 8 finished        RBM Reconstruction error 42.551929
>> Epoch 9 finished        RBM Reconstruction error 57.618774
>> Epoch 10 finished       RBM Reconstruction error 52.438831
>> Epoch 11 finished       RBM Reconstruction error 67.684494
>> Epoch 12 finished       RBM Reconstruction error 50.824688
>> Epoch 13 finished       RBM Reconstruction error 54.989883
>> Epoch 14 finished       RBM Reconstruction error 41.339443
>> Epoch 15 finished       RBM Reconstruction error 51.853363
>> Epoch 16 finished       RBM Reconstruction error 62.527103
>> Epoch 17 finished       RBM Reconstruction error 44.851845
>> Epoch 18 finished       RBM Reconstruction error 57.342430
>> Epoch 19 finished       RBM Reconstruction error 68.836800
>> Epoch 20 finished       RBM Reconstruction error 64.142677
>> Epoch 21 finished       RBM Reconstruction error 50.309280
>> Epoch 22 finished       RBM Reconstruction error 66.416504
>> Epoch 23 finished       RBM Reconstruction error 65.265877
>> Epoch 24 finished       RBM Reconstruction error 68.634033
>> Epoch 25 finished       RBM Reconstruction error 72.447258
>> Epoch 26 finished       RBM Reconstruction error 62.991241
>> Epoch 27 finished       RBM Reconstruction error 53.245419
>> Epoch 28 finished       RBM Reconstruction error 51.869347
>> Epoch 29 finished       RBM Reconstruction error 60.460190
>> Epoch 30 finished       RBM Reconstruction error 63.755905
>> Epoch 31 finished       RBM Reconstruction error 57.239609
>> Epoch 32 finished       RBM Reconstruction error 72.437836
>> Epoch 33 finished       RBM Reconstruction error 58.030655
>> Epoch 34 finished       RBM Reconstruction error 76.129059
>> Epoch 35 finished       RBM Reconstruction error 59.967358
>> Epoch 36 finished       RBM Reconstruction error 58.605927
>> Epoch 37 finished       RBM Reconstruction error 46.845284
>> Epoch 38 finished       RBM Reconstruction error 63.994873
>> Epoch 39 finished       RBM Reconstruction error 81.558426
>> Epoch 40 finished       RBM Reconstruction error 69.042480
>> Epoch 41 finished       RBM Reconstruction error 70.586403
>> Epoch 42 finished       RBM Reconstruction error 69.694931
>> Epoch 43 finished       RBM Reconstruction error 58.761074
>> Epoch 44 finished       RBM Reconstruction error 59.303436
>> Epoch 45 finished       RBM Reconstruction error 70.437767
>> Epoch 46 finished       RBM Reconstruction error 72.135811
>> Epoch 47 finished       RBM Reconstruction error 72.889763
>> Epoch 48 finished       RBM Reconstruction error 66.220627
>> Epoch 49 finished       RBM Reconstruction error 60.591026
>> Epoch 50 finished       RBM Reconstruction error 59.660934
>> Epoch 51 finished       RBM Reconstruction error 52.676762
>> Epoch 52 finished       RBM Reconstruction error 58.841507
>> Epoch 53 finished       RBM Reconstruction error 59.250389
>> Epoch 54 finished       RBM Reconstruction error 61.562881
>> Epoch 55 finished       RBM Reconstruction error 64.020500
>> Epoch 56 finished       RBM Reconstruction error 75.542999
>> Epoch 57 finished       RBM Reconstruction error 86.135468
>> Epoch 58 finished       RBM Reconstruction error 72.930153
>> Epoch 59 finished       RBM Reconstruction error 68.531693
>> Epoch 60 finished       RBM Reconstruction error 66.590271
>> Epoch 61 finished       RBM Reconstruction error 65.800110
>> Epoch 62 finished       RBM Reconstruction error 70.119133
>> Epoch 63 finished       RBM Reconstruction error 51.320995
>> Epoch 64 finished       RBM Reconstruction error 74.674095
>> Epoch 65 finished       RBM Reconstruction error 60.624901
```

```
>> Epoch 66 finished      RBM Reconstruction error 65.577812
>> Epoch 67 finished      RBM Reconstruction error 59.038124
>> Epoch 68 finished      RBM Reconstruction error 71.874603
>> Epoch 69 finished      RBM Reconstruction error 61.118320
>> Epoch 70 finished      RBM Reconstruction error 61.531944
>> Epoch 71 finished      RBM Reconstruction error 74.493698
>> Epoch 72 finished      RBM Reconstruction error 61.616100
>> Epoch 73 finished      RBM Reconstruction error 68.625793
>> Epoch 74 finished      RBM Reconstruction error 68.173172
>> Epoch 75 finished      RBM Reconstruction error 73.596764
>> Epoch 76 finished      RBM Reconstruction error 71.690948
>> Epoch 77 finished      RBM Reconstruction error 65.570526
>> Epoch 78 finished      RBM Reconstruction error 67.789726
>> Epoch 79 finished      RBM Reconstruction error 70.412102
>> Epoch 80 finished      RBM Reconstruction error 65.344635
>> Epoch 81 finished      RBM Reconstruction error 74.531395
>> Epoch 82 finished      RBM Reconstruction error 64.325745
>> Epoch 83 finished      RBM Reconstruction error 74.523148
>> Epoch 84 finished      RBM Reconstruction error 76.646523
>> Epoch 85 finished      RBM Reconstruction error 78.887550
>> Epoch 86 finished      RBM Reconstruction error 66.124756
>> Epoch 87 finished      RBM Reconstruction error 78.859802
>> Epoch 88 finished      RBM Reconstruction error 71.580421
>> Epoch 89 finished      RBM Reconstruction error 65.830467
>> Epoch 90 finished      RBM Reconstruction error 61.026554
>> Epoch 91 finished      RBM Reconstruction error 67.471886
>> Epoch 92 finished      RBM Reconstruction error 72.046974
>> Epoch 93 finished      RBM Reconstruction error 86.530197
>> Epoch 94 finished      RBM Reconstruction error 74.723808
>> Epoch 95 finished      RBM Reconstruction error 80.348633
>> Epoch 96 finished      RBM Reconstruction error 83.790108
>> Epoch 97 finished      RBM Reconstruction error 60.073048
>> Epoch 98 finished      RBM Reconstruction error 74.876457
>> Epoch 99 finished      RBM Reconstruction error 68.328323
>> Epoch 100 finished     RBM Reconstruction error 72.572624
>> Epoch 1 finished       RBM Reconstruction error 166.821716
>> Epoch 2 finished       RBM Reconstruction error 178.397888
>> Epoch 3 finished       RBM Reconstruction error 231.433197
>> Epoch 4 finished       RBM Reconstruction error 263.356140
>> Epoch 5 finished       RBM Reconstruction error 329.514954
>> Epoch 6 finished       RBM Reconstruction error 266.165741
>> Epoch 7 finished       RBM Reconstruction error 244.663712
>> Epoch 8 finished       RBM Reconstruction error 284.585052
>> Epoch 9 finished       RBM Reconstruction error 280.442444
>> Epoch 10 finished      RBM Reconstruction error 259.345001
>> Epoch 11 finished      RBM Reconstruction error 329.892212
>> Epoch 12 finished      RBM Reconstruction error 385.542969
>> Epoch 13 finished      RBM Reconstruction error 341.492035
>> Epoch 14 finished      RBM Reconstruction error 357.654053
>> Epoch 15 finished      RBM Reconstruction error 340.163788
>> Epoch 16 finished      RBM Reconstruction error 318.769623
>> Epoch 17 finished      RBM Reconstruction error 346.287109
>> Epoch 18 finished      RBM Reconstruction error 409.188629
>> Epoch 19 finished      RBM Reconstruction error 409.677124
>> Epoch 20 finished      RBM Reconstruction error 393.112030
>> Epoch 21 finished      RBM Reconstruction error 338.218933
>> Epoch 22 finished      RBM Reconstruction error 400.326416
>> Epoch 23 finished      RBM Reconstruction error 350.357056
>> Epoch 24 finished      RBM Reconstruction error 333.267303
>> Epoch 25 finished      RBM Reconstruction error 299.476959
>> Epoch 26 finished      RBM Reconstruction error 379.188293
>> Epoch 27 finished      RBM Reconstruction error 375.037384
>> Epoch 28 finished      RBM Reconstruction error 325.156494
>> Epoch 29 finished      RBM Reconstruction error 398.434723
>> Epoch 30 finished      RBM Reconstruction error 395.710327
```

```
>> Epoch 31 finished      RBM Reconstruction error 434.418793
>> Epoch 32 finished      RBM Reconstruction error 368.240540
>> Epoch 33 finished      RBM Reconstruction error 410.497253
>> Epoch 34 finished      RBM Reconstruction error 500.624298
>> Epoch 35 finished      RBM Reconstruction error 397.939148
>> Epoch 36 finished      RBM Reconstruction error 469.171326
>> Epoch 37 finished      RBM Reconstruction error 428.012787
>> Epoch 38 finished      RBM Reconstruction error 437.173706
>> Epoch 39 finished      RBM Reconstruction error 416.097565
>> Epoch 40 finished      RBM Reconstruction error 390.610107
>> Epoch 41 finished      RBM Reconstruction error 506.024597
>> Epoch 42 finished      RBM Reconstruction error 448.386108
>> Epoch 43 finished      RBM Reconstruction error 408.992004
>> Epoch 44 finished      RBM Reconstruction error 390.676178
>> Epoch 45 finished      RBM Reconstruction error 462.731171
>> Epoch 46 finished      RBM Reconstruction error 442.611176
>> Epoch 47 finished      RBM Reconstruction error 411.340790
>> Epoch 48 finished      RBM Reconstruction error 442.644623
>> Epoch 49 finished      RBM Reconstruction error 374.582275
>> Epoch 50 finished      RBM Reconstruction error 349.972748
>> Epoch 51 finished      RBM Reconstruction error 449.284760
>> Epoch 52 finished      RBM Reconstruction error 421.688660
>> Epoch 53 finished      RBM Reconstruction error 431.388123
>> Epoch 54 finished      RBM Reconstruction error 455.646088
>> Epoch 55 finished      RBM Reconstruction error 441.548523
>> Epoch 56 finished      RBM Reconstruction error 390.123505
>> Epoch 57 finished      RBM Reconstruction error 404.121216
>> Epoch 58 finished      RBM Reconstruction error 499.455383
>> Epoch 59 finished      RBM Reconstruction error 491.206238
>> Epoch 60 finished      RBM Reconstruction error 469.942810
>> Epoch 61 finished      RBM Reconstruction error 378.776733
>> Epoch 62 finished      RBM Reconstruction error 401.625458
>> Epoch 63 finished      RBM Reconstruction error 432.655701
>> Epoch 64 finished      RBM Reconstruction error 378.751770
>> Epoch 65 finished      RBM Reconstruction error 427.068665
>> Epoch 66 finished      RBM Reconstruction error 431.678741
>> Epoch 67 finished      RBM Reconstruction error 425.514221
>> Epoch 68 finished      RBM Reconstruction error 420.490387
>> Epoch 69 finished      RBM Reconstruction error 445.810669
>> Epoch 70 finished      RBM Reconstruction error 421.802734
>> Epoch 71 finished      RBM Reconstruction error 486.526611
>> Epoch 72 finished      RBM Reconstruction error 383.343872
>> Epoch 73 finished      RBM Reconstruction error 398.779724
>> Epoch 74 finished      RBM Reconstruction error 454.570618
>> Epoch 75 finished      RBM Reconstruction error 458.796570
>> Epoch 76 finished      RBM Reconstruction error 435.384857
>> Epoch 77 finished      RBM Reconstruction error 434.145935
>> Epoch 78 finished      RBM Reconstruction error 405.343567
>> Epoch 79 finished      RBM Reconstruction error 408.926056
>> Epoch 80 finished      RBM Reconstruction error 404.321808
>> Epoch 81 finished      RBM Reconstruction error 416.005615
>> Epoch 82 finished      RBM Reconstruction error 454.045044
>> Epoch 83 finished      RBM Reconstruction error 452.026184
>> Epoch 84 finished      RBM Reconstruction error 394.969299
>> Epoch 85 finished      RBM Reconstruction error 393.848816
>> Epoch 86 finished      RBM Reconstruction error 446.170807
>> Epoch 87 finished      RBM Reconstruction error 447.480743
>> Epoch 88 finished      RBM Reconstruction error 416.879852
>> Epoch 89 finished      RBM Reconstruction error 485.849854
>> Epoch 90 finished      RBM Reconstruction error 417.005280
>> Epoch 91 finished      RBM Reconstruction error 412.727112
>> Epoch 92 finished      RBM Reconstruction error 432.149536
>> Epoch 93 finished      RBM Reconstruction error 443.331329
>> Epoch 94 finished      RBM Reconstruction error 395.693939
>> Epoch 95 finished      RBM Reconstruction error 414.196472
```

```
                >> Epoch 96 finished     RBM Reconstruction error 441.622894
                >> Epoch 97 finished     RBM Reconstruction error 408.144989
                >> Epoch 98 finished     RBM Reconstruction error 404.593597
                >> Epoch 99 finished     RBM Reconstruction error 403.426514
                >> Epoch 100 finished    RBM Reconstruction error 396.056885
                [END] Pre-training step
                [START] Fine tuning step:
                >> Epoch 0 finished      ANN training loss 0.576869
                >> Epoch 1 finished      ANN training loss 0.407056
                >> Epoch 2 finished      ANN training loss 0.345779
                >> Epoch 3 finished      ANN training loss 0.261881
                >> Epoch 4 finished      ANN training loss 0.240444
                >> Epoch 5 finished      ANN training loss 0.198612
                >> Epoch 6 finished      ANN training loss 0.194819
                >> Epoch 7 finished      ANN training loss 0.165919
                >> Epoch 8 finished      ANN training loss 0.132419
                >> Epoch 9 finished      ANN training loss 0.128545
                >> Epoch 10 finished     ANN training loss 0.107657
                >> Epoch 11 finished     ANN training loss 0.100526
                >> Epoch 12 finished     ANN training loss 0.082155
                >> Epoch 13 finished     ANN training loss 0.074399
                >> Epoch 14 finished     ANN training loss 0.071147
                >> Epoch 15 finished     ANN training loss 0.067799
                >> Epoch 16 finished     ANN training loss 0.055883
                >> Epoch 17 finished     ANN training loss 0.049922
                >> Epoch 18 finished     ANN training loss 0.048260
                >> Epoch 19 finished     ANN training loss 0.040317
                >> Epoch 20 finished     ANN training loss 0.036422
                >> Epoch 21 finished     ANN training loss 0.032949
                >> Epoch 22 finished     ANN training loss 0.034304
                >> Epoch 23 finished     ANN training loss 0.031671
                >> Epoch 24 finished     ANN training loss 0.026090
                >> Epoch 25 finished     ANN training loss 0.023633
                >> Epoch 26 finished     ANN training loss 0.027602
                >> Epoch 27 finished     ANN training loss 0.021058
                >> Epoch 28 finished     ANN training loss 0.017867
                >> Epoch 29 finished     ANN training loss 0.018436
                >> Epoch 30 finished     ANN training loss 0.015290
                >> Epoch 31 finished     ANN training loss 0.015817
                >> Epoch 32 finished     ANN training loss 0.014544
                >> Epoch 33 finished     ANN training loss 0.014058
                >> Epoch 34 finished     ANN training loss 0.013738
                >> Epoch 35 finished     ANN training loss 0.014632
                >> Epoch 36 finished     ANN training loss 0.011158
                >> Epoch 37 finished     ANN training loss 0.010219
                >> Epoch 38 finished     ANN training loss 0.009698
                >> Epoch 39 finished     ANN training loss 0.009048
                >> Epoch 40 finished     ANN training loss 0.008777
                >> Epoch 41 finished     ANN training loss 0.007614
                >> Epoch 42 finished     ANN training loss 0.007825
                >> Epoch 43 finished     ANN training loss 0.007512
                >> Epoch 44 finished     ANN training loss 0.008187
                >> Epoch 45 finished     ANN training loss 0.006796
                >> Epoch 46 finished     ANN training loss 0.007157
                >> Epoch 47 finished     ANN training loss 0.006648
                >> Epoch 48 finished     ANN training loss 0.006239
                >> Epoch 49 finished     ANN training loss 0.005633
                >> Epoch 50 finished     ANN training loss 0.005273
                >> Epoch 51 finished     ANN training loss 0.005476
                >> Epoch 52 finished     ANN training loss 0.004579
                >> Epoch 53 finished     ANN training loss 0.004341
                >> Epoch 54 finished     ANN training loss 0.004947
                >> Epoch 55 finished     ANN training loss 0.004789
                >> Epoch 56 finished     ANN training loss 0.003734
                >> Epoch 57 finished     ANN training loss 0.003994
```

```
>> Epoch 58 finished      ANN training loss 0.003475
>> Epoch 59 finished      ANN training loss 0.003076
>> Epoch 60 finished      ANN training loss 0.002800
>> Epoch 61 finished      ANN training loss 0.003819
>> Epoch 62 finished      ANN training loss 0.003440
>> Epoch 63 finished      ANN training loss 0.003221
>> Epoch 64 finished      ANN training loss 0.002572
>> Epoch 65 finished      ANN training loss 0.003055
>> Epoch 66 finished      ANN training loss 0.002751
>> Epoch 67 finished      ANN training loss 0.002545
>> Epoch 68 finished      ANN training loss 0.002377
>> Epoch 69 finished      ANN training loss 0.002148
>> Epoch 70 finished      ANN training loss 0.001939
>> Epoch 71 finished      ANN training loss 0.001876
>> Epoch 72 finished      ANN training loss 0.002231
>> Epoch 73 finished      ANN training loss 0.001977
>> Epoch 74 finished      ANN training loss 0.001693
>> Epoch 75 finished      ANN training loss 0.001671
>> Epoch 76 finished      ANN training loss 0.001542
>> Epoch 77 finished      ANN training loss 0.001481
>> Epoch 78 finished      ANN training loss 0.001561
>> Epoch 79 finished      ANN training loss 0.001599
>> Epoch 80 finished      ANN training loss 0.001304
>> Epoch 81 finished      ANN training loss 0.001401
>> Epoch 82 finished      ANN training loss 0.001284
>> Epoch 83 finished      ANN training loss 0.001515
>> Epoch 84 finished      ANN training loss 0.001475
>> Epoch 85 finished      ANN training loss 0.001241
>> Epoch 86 finished      ANN training loss 0.001370
>> Epoch 87 finished      ANN training loss 0.001128
>> Epoch 88 finished      ANN training loss 0.001349
>> Epoch 89 finished      ANN training loss 0.001245
>> Epoch 90 finished      ANN training loss 0.001305
>> Epoch 91 finished      ANN training loss 0.001100
>> Epoch 92 finished      ANN training loss 0.001052
>> Epoch 93 finished      ANN training loss 0.001122
>> Epoch 94 finished      ANN training loss 0.001050
>> Epoch 95 finished      ANN training loss 0.001096
>> Epoch 96 finished      ANN training loss 0.001131
>> Epoch 97 finished      ANN training loss 0.001043
>> Epoch 98 finished      ANN training loss 0.001037
>> Epoch 99 finished      ANN training loss 0.001104
[END] Fine tuning step
```

In [106…
```python
print('ACCURACY: ' + str(epoch_rbm_acc[8]))
```

```
ACCURACY: 0.935
```

Setting 10

n_epochs_rbm=200

In [107…
```python
epoch_rbm_acc[9] = deep_belief_net(n_epochs_rbm=200)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 86.169647
>> Epoch 2 finished      RBM Reconstruction error 81.358040
>> Epoch 3 finished      RBM Reconstruction error 60.489590
>> Epoch 4 finished      RBM Reconstruction error 40.834915
>> Epoch 5 finished      RBM Reconstruction error 65.904037
>> Epoch 6 finished      RBM Reconstruction error 63.146137
>> Epoch 7 finished      RBM Reconstruction error 44.753300
>> Epoch 8 finished      RBM Reconstruction error 48.984268
>> Epoch 9 finished      RBM Reconstruction error 38.161121
```

```
>> Epoch 10 finished     RBM Reconstruction error 49.548874
>> Epoch 11 finished     RBM Reconstruction error 39.734428
>> Epoch 12 finished     RBM Reconstruction error 49.296494
>> Epoch 13 finished     RBM Reconstruction error 45.057617
>> Epoch 14 finished     RBM Reconstruction error 55.243423
>> Epoch 15 finished     RBM Reconstruction error 70.538704
>> Epoch 16 finished     RBM Reconstruction error 51.605606
>> Epoch 17 finished     RBM Reconstruction error 50.278858
>> Epoch 18 finished     RBM Reconstruction error 51.347343
>> Epoch 19 finished     RBM Reconstruction error 48.179760
>> Epoch 20 finished     RBM Reconstruction error 54.281837
>> Epoch 21 finished     RBM Reconstruction error 55.873173
>> Epoch 22 finished     RBM Reconstruction error 44.195770
>> Epoch 23 finished     RBM Reconstruction error 51.919102
>> Epoch 24 finished     RBM Reconstruction error 44.696171
>> Epoch 25 finished     RBM Reconstruction error 63.384068
>> Epoch 26 finished     RBM Reconstruction error 51.782612
>> Epoch 27 finished     RBM Reconstruction error 44.389736
>> Epoch 28 finished     RBM Reconstruction error 69.149544
>> Epoch 29 finished     RBM Reconstruction error 58.376766
>> Epoch 30 finished     RBM Reconstruction error 61.423660
>> Epoch 31 finished     RBM Reconstruction error 50.851192
>> Epoch 32 finished     RBM Reconstruction error 54.898991
>> Epoch 33 finished     RBM Reconstruction error 54.685997
>> Epoch 34 finished     RBM Reconstruction error 59.066662
>> Epoch 35 finished     RBM Reconstruction error 58.568642
>> Epoch 36 finished     RBM Reconstruction error 41.347946
>> Epoch 37 finished     RBM Reconstruction error 66.320129
>> Epoch 38 finished     RBM Reconstruction error 42.053623
>> Epoch 39 finished     RBM Reconstruction error 66.066628
>> Epoch 40 finished     RBM Reconstruction error 51.240334
>> Epoch 41 finished     RBM Reconstruction error 56.586914
>> Epoch 42 finished     RBM Reconstruction error 61.814941
>> Epoch 43 finished     RBM Reconstruction error 73.004051
>> Epoch 44 finished     RBM Reconstruction error 61.175583
>> Epoch 45 finished     RBM Reconstruction error 57.854366
>> Epoch 46 finished     RBM Reconstruction error 60.186592
>> Epoch 47 finished     RBM Reconstruction error 55.606598
>> Epoch 48 finished     RBM Reconstruction error 62.470951
>> Epoch 49 finished     RBM Reconstruction error 61.750484
>> Epoch 50 finished     RBM Reconstruction error 61.097965
>> Epoch 51 finished     RBM Reconstruction error 56.686623
>> Epoch 52 finished     RBM Reconstruction error 53.605816
>> Epoch 53 finished     RBM Reconstruction error 69.164619
>> Epoch 54 finished     RBM Reconstruction error 59.010941
>> Epoch 55 finished     RBM Reconstruction error 60.593632
>> Epoch 56 finished     RBM Reconstruction error 65.537514
>> Epoch 57 finished     RBM Reconstruction error 63.109623
>> Epoch 58 finished     RBM Reconstruction error 56.241947
>> Epoch 59 finished     RBM Reconstruction error 74.845139
>> Epoch 60 finished     RBM Reconstruction error 64.817276
>> Epoch 61 finished     RBM Reconstruction error 55.165424
>> Epoch 62 finished     RBM Reconstruction error 66.517609
>> Epoch 63 finished     RBM Reconstruction error 69.718819
>> Epoch 64 finished     RBM Reconstruction error 61.343643
>> Epoch 65 finished     RBM Reconstruction error 73.802361
>> Epoch 66 finished     RBM Reconstruction error 68.328934
>> Epoch 67 finished     RBM Reconstruction error 57.592617
>> Epoch 68 finished     RBM Reconstruction error 73.209778
>> Epoch 69 finished     RBM Reconstruction error 65.677193
>> Epoch 70 finished     RBM Reconstruction error 75.776428
>> Epoch 71 finished     RBM Reconstruction error 83.466217
>> Epoch 72 finished     RBM Reconstruction error 78.278069
>> Epoch 73 finished     RBM Reconstruction error 67.068916
>> Epoch 74 finished     RBM Reconstruction error 94.925179
```

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>> Epoch 75 finished     RBM Reconstruction error 67.252594
>> Epoch 76 finished     RBM Reconstruction error 73.531258
>> Epoch 77 finished     RBM Reconstruction error 73.991745
>> Epoch 78 finished     RBM Reconstruction error 65.813904
>> Epoch 79 finished     RBM Reconstruction error 67.631790
>> Epoch 80 finished     RBM Reconstruction error 68.221146
>> Epoch 81 finished     RBM Reconstruction error 70.927673
>> Epoch 82 finished     RBM Reconstruction error 92.732536
>> Epoch 83 finished     RBM Reconstruction error 84.057869
>> Epoch 84 finished     RBM Reconstruction error 70.770325
>> Epoch 85 finished     RBM Reconstruction error 76.784637
>> Epoch 86 finished     RBM Reconstruction error 69.351105
>> Epoch 87 finished     RBM Reconstruction error 73.990410
>> Epoch 88 finished     RBM Reconstruction error 63.194855
>> Epoch 89 finished     RBM Reconstruction error 80.614197
>> Epoch 90 finished     RBM Reconstruction error 70.397087
>> Epoch 91 finished     RBM Reconstruction error 83.896873
>> Epoch 92 finished     RBM Reconstruction error 76.449364
>> Epoch 93 finished     RBM Reconstruction error 67.390244
>> Epoch 94 finished     RBM Reconstruction error 69.847427
>> Epoch 95 finished     RBM Reconstruction error 80.721565
>> Epoch 96 finished     RBM Reconstruction error 101.535843
>> Epoch 97 finished     RBM Reconstruction error 69.988991
>> Epoch 98 finished     RBM Reconstruction error 76.583069
>> Epoch 99 finished     RBM Reconstruction error 64.983322
>> Epoch 100 finished    RBM Reconstruction error 80.810028
>> Epoch 101 finished    RBM Reconstruction error 73.804680
>> Epoch 102 finished    RBM Reconstruction error 76.415520
>> Epoch 103 finished    RBM Reconstruction error 74.318832
>> Epoch 104 finished    RBM Reconstruction error 77.692200
>> Epoch 105 finished    RBM Reconstruction error 83.253944
>> Epoch 106 finished    RBM Reconstruction error 78.030594
>> Epoch 107 finished    RBM Reconstruction error 77.043137
>> Epoch 108 finished    RBM Reconstruction error 78.982445
>> Epoch 109 finished    RBM Reconstruction error 86.739471
>> Epoch 110 finished    RBM Reconstruction error 85.330849
>> Epoch 111 finished    RBM Reconstruction error 74.359673
>> Epoch 112 finished    RBM Reconstruction error 87.982132
>> Epoch 113 finished    RBM Reconstruction error 77.173943
>> Epoch 114 finished    RBM Reconstruction error 77.547699
>> Epoch 115 finished    RBM Reconstruction error 76.070030
>> Epoch 116 finished    RBM Reconstruction error 78.245758
>> Epoch 117 finished    RBM Reconstruction error 77.661072
>> Epoch 118 finished    RBM Reconstruction error 77.824265
>> Epoch 119 finished    RBM Reconstruction error 83.252792
>> Epoch 120 finished    RBM Reconstruction error 73.695251
>> Epoch 121 finished    RBM Reconstruction error 74.751289
>> Epoch 122 finished    RBM Reconstruction error 66.545647
>> Epoch 123 finished    RBM Reconstruction error 71.500481
>> Epoch 124 finished    RBM Reconstruction error 77.872147
>> Epoch 125 finished    RBM Reconstruction error 76.337883
>> Epoch 126 finished    RBM Reconstruction error 79.714294
>> Epoch 127 finished    RBM Reconstruction error 71.653366
>> Epoch 128 finished    RBM Reconstruction error 79.781425
>> Epoch 129 finished    RBM Reconstruction error 68.465622
>> Epoch 130 finished    RBM Reconstruction error 73.658562
>> Epoch 131 finished    RBM Reconstruction error 87.482605
>> Epoch 132 finished    RBM Reconstruction error 88.910751
>> Epoch 133 finished    RBM Reconstruction error 71.230736
>> Epoch 134 finished    RBM Reconstruction error 83.502472
>> Epoch 135 finished    RBM Reconstruction error 79.419579
>> Epoch 136 finished    RBM Reconstruction error 71.616287
>> Epoch 137 finished    RBM Reconstruction error 82.100830
>> Epoch 138 finished    RBM Reconstruction error 73.456741
>> Epoch 139 finished    RBM Reconstruction error 73.453003
```

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>> Epoch 140 finished    RBM Reconstruction error 82.125877
>> Epoch 141 finished    RBM Reconstruction error 82.988487
>> Epoch 142 finished    RBM Reconstruction error 76.397919
>> Epoch 143 finished    RBM Reconstruction error 82.337692
>> Epoch 144 finished    RBM Reconstruction error 81.587013
>> Epoch 145 finished    RBM Reconstruction error 75.689514
>> Epoch 146 finished    RBM Reconstruction error 79.387154
>> Epoch 147 finished    RBM Reconstruction error 76.072952
>> Epoch 148 finished    RBM Reconstruction error 95.129082
>> Epoch 149 finished    RBM Reconstruction error 74.569229
>> Epoch 150 finished    RBM Reconstruction error 73.790115
>> Epoch 151 finished    RBM Reconstruction error 83.404228
>> Epoch 152 finished    RBM Reconstruction error 90.879547
>> Epoch 153 finished    RBM Reconstruction error 100.215530
>> Epoch 154 finished    RBM Reconstruction error 86.833084
>> Epoch 155 finished    RBM Reconstruction error 81.367180
>> Epoch 156 finished    RBM Reconstruction error 70.140007
>> Epoch 157 finished    RBM Reconstruction error 75.073547
>> Epoch 158 finished    RBM Reconstruction error 84.982422
>> Epoch 159 finished    RBM Reconstruction error 83.696251
>> Epoch 160 finished    RBM Reconstruction error 97.877678
>> Epoch 161 finished    RBM Reconstruction error 92.834785
>> Epoch 162 finished    RBM Reconstruction error 75.993179
>> Epoch 163 finished    RBM Reconstruction error 72.128563
>> Epoch 164 finished    RBM Reconstruction error 84.952599
>> Epoch 165 finished    RBM Reconstruction error 90.093224
>> Epoch 166 finished    RBM Reconstruction error 74.558708
>> Epoch 167 finished    RBM Reconstruction error 77.679665
>> Epoch 168 finished    RBM Reconstruction error 74.439850
>> Epoch 169 finished    RBM Reconstruction error 77.217209
>> Epoch 170 finished    RBM Reconstruction error 83.473640
>> Epoch 171 finished    RBM Reconstruction error 85.622849
>> Epoch 172 finished    RBM Reconstruction error 75.487206
>> Epoch 173 finished    RBM Reconstruction error 75.090172
>> Epoch 174 finished    RBM Reconstruction error 81.217461
>> Epoch 175 finished    RBM Reconstruction error 84.559418
>> Epoch 176 finished    RBM Reconstruction error 79.244530
>> Epoch 177 finished    RBM Reconstruction error 79.027519
>> Epoch 178 finished    RBM Reconstruction error 83.754539
>> Epoch 179 finished    RBM Reconstruction error 85.253136
>> Epoch 180 finished    RBM Reconstruction error 89.411407
>> Epoch 181 finished    RBM Reconstruction error 83.771263
>> Epoch 182 finished    RBM Reconstruction error 85.432816
>> Epoch 183 finished    RBM Reconstruction error 94.084122
>> Epoch 184 finished    RBM Reconstruction error 81.510033
>> Epoch 185 finished    RBM Reconstruction error 85.016922
>> Epoch 186 finished    RBM Reconstruction error 84.395645
>> Epoch 187 finished    RBM Reconstruction error 90.970016
>> Epoch 188 finished    RBM Reconstruction error 84.848083
>> Epoch 189 finished    RBM Reconstruction error 92.935577
>> Epoch 190 finished    RBM Reconstruction error 88.207207
>> Epoch 191 finished    RBM Reconstruction error 83.159416
>> Epoch 192 finished    RBM Reconstruction error 89.521912
>> Epoch 193 finished    RBM Reconstruction error 98.056778
>> Epoch 194 finished    RBM Reconstruction error 83.408142
>> Epoch 195 finished    RBM Reconstruction error 79.687767
>> Epoch 196 finished    RBM Reconstruction error 85.398499
>> Epoch 197 finished    RBM Reconstruction error 81.319656
>> Epoch 198 finished    RBM Reconstruction error 80.226807
>> Epoch 199 finished    RBM Reconstruction error 91.611427
>> Epoch 200 finished    RBM Reconstruction error 84.971115
>> Epoch 1 finished       RBM Reconstruction error 287.830597
>> Epoch 2 finished       RBM Reconstruction error 323.149261
>> Epoch 3 finished       RBM Reconstruction error 252.951263
>> Epoch 4 finished       RBM Reconstruction error 258.009155
```

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>> Epoch 5 finished     RBM Reconstruction error 333.345123
>> Epoch 6 finished     RBM Reconstruction error 487.712341
>> Epoch 7 finished     RBM Reconstruction error 347.790588
>> Epoch 8 finished     RBM Reconstruction error 264.041199
>> Epoch 9 finished     RBM Reconstruction error 329.729218
>> Epoch 10 finished    RBM Reconstruction error 321.138489
>> Epoch 11 finished    RBM Reconstruction error 305.326599
>> Epoch 12 finished    RBM Reconstruction error 341.571014
>> Epoch 13 finished    RBM Reconstruction error 425.777191
>> Epoch 14 finished    RBM Reconstruction error 492.711029
>> Epoch 15 finished    RBM Reconstruction error 487.143524
>> Epoch 16 finished    RBM Reconstruction error 394.336334
>> Epoch 17 finished    RBM Reconstruction error 380.845123
>> Epoch 18 finished    RBM Reconstruction error 477.089294
>> Epoch 19 finished    RBM Reconstruction error 525.601929
>> Epoch 20 finished    RBM Reconstruction error 374.534302
>> Epoch 21 finished    RBM Reconstruction error 436.522369
>> Epoch 22 finished    RBM Reconstruction error 530.643372
>> Epoch 23 finished    RBM Reconstruction error 433.983215
>> Epoch 24 finished    RBM Reconstruction error 540.533875
>> Epoch 25 finished    RBM Reconstruction error 449.924438
>> Epoch 26 finished    RBM Reconstruction error 440.710388
>> Epoch 27 finished    RBM Reconstruction error 466.263519
>> Epoch 28 finished    RBM Reconstruction error 442.993958
>> Epoch 29 finished    RBM Reconstruction error 459.286316
>> Epoch 30 finished    RBM Reconstruction error 451.170319
>> Epoch 31 finished    RBM Reconstruction error 533.898010
>> Epoch 32 finished    RBM Reconstruction error 579.201477
>> Epoch 33 finished    RBM Reconstruction error 509.056335
>> Epoch 34 finished    RBM Reconstruction error 494.003784
>> Epoch 35 finished    RBM Reconstruction error 468.574615
>> Epoch 36 finished    RBM Reconstruction error 453.717377
>> Epoch 37 finished    RBM Reconstruction error 472.755005
>> Epoch 38 finished    RBM Reconstruction error 548.911621
>> Epoch 39 finished    RBM Reconstruction error 507.398895
>> Epoch 40 finished    RBM Reconstruction error 425.570221
>> Epoch 41 finished    RBM Reconstruction error 545.266479
>> Epoch 42 finished    RBM Reconstruction error 508.583038
>> Epoch 43 finished    RBM Reconstruction error 466.329987
>> Epoch 44 finished    RBM Reconstruction error 504.993073
>> Epoch 45 finished    RBM Reconstruction error 518.451599
>> Epoch 46 finished    RBM Reconstruction error 543.099976
>> Epoch 47 finished    RBM Reconstruction error 514.068848
>> Epoch 48 finished    RBM Reconstruction error 524.385010
>> Epoch 49 finished    RBM Reconstruction error 544.380554
>> Epoch 50 finished    RBM Reconstruction error 489.181732
>> Epoch 51 finished    RBM Reconstruction error 431.480011
>> Epoch 52 finished    RBM Reconstruction error 533.855774
>> Epoch 53 finished    RBM Reconstruction error 489.243286
>> Epoch 54 finished    RBM Reconstruction error 496.322113
>> Epoch 55 finished    RBM Reconstruction error 483.236847
>> Epoch 56 finished    RBM Reconstruction error 521.697937
>> Epoch 57 finished    RBM Reconstruction error 468.555695
>> Epoch 58 finished    RBM Reconstruction error 510.729858
>> Epoch 59 finished    RBM Reconstruction error 473.394409
>> Epoch 60 finished    RBM Reconstruction error 472.054871
>> Epoch 61 finished    RBM Reconstruction error 461.579285
>> Epoch 62 finished    RBM Reconstruction error 449.784027
>> Epoch 63 finished    RBM Reconstruction error 498.795380
>> Epoch 64 finished    RBM Reconstruction error 487.803528
>> Epoch 65 finished    RBM Reconstruction error 475.901886
>> Epoch 66 finished    RBM Reconstruction error 559.555603
>> Epoch 67 finished    RBM Reconstruction error 529.383972
>> Epoch 68 finished    RBM Reconstruction error 507.898529
>> Epoch 69 finished    RBM Reconstruction error 504.421753
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>> Epoch 70 finished    RBM Reconstruction error 463.379517
>> Epoch 71 finished    RBM Reconstruction error 537.247742
>> Epoch 72 finished    RBM Reconstruction error 470.558197
>> Epoch 73 finished    RBM Reconstruction error 501.816711
>> Epoch 74 finished    RBM Reconstruction error 545.857483
>> Epoch 75 finished    RBM Reconstruction error 573.621460
>> Epoch 76 finished    RBM Reconstruction error 537.900024
>> Epoch 77 finished    RBM Reconstruction error 511.548218
>> Epoch 78 finished    RBM Reconstruction error 541.434631
>> Epoch 79 finished    RBM Reconstruction error 525.470337
>> Epoch 80 finished    RBM Reconstruction error 547.909302
>> Epoch 81 finished    RBM Reconstruction error 476.379852
>> Epoch 82 finished    RBM Reconstruction error 496.112976
>> Epoch 83 finished    RBM Reconstruction error 493.870483
>> Epoch 84 finished    RBM Reconstruction error 508.424133
>> Epoch 85 finished    RBM Reconstruction error 491.556946
>> Epoch 86 finished    RBM Reconstruction error 547.499268
>> Epoch 87 finished    RBM Reconstruction error 541.558228
>> Epoch 88 finished    RBM Reconstruction error 509.784424
>> Epoch 89 finished    RBM Reconstruction error 531.049011
>> Epoch 90 finished    RBM Reconstruction error 473.747772
>> Epoch 91 finished    RBM Reconstruction error 538.157654
>> Epoch 92 finished    RBM Reconstruction error 507.703735
>> Epoch 93 finished    RBM Reconstruction error 526.731812
>> Epoch 94 finished    RBM Reconstruction error 467.144379
>> Epoch 95 finished    RBM Reconstruction error 477.169128
>> Epoch 96 finished    RBM Reconstruction error 461.572815
>> Epoch 97 finished    RBM Reconstruction error 547.458740
>> Epoch 98 finished    RBM Reconstruction error 516.406616
>> Epoch 99 finished    RBM Reconstruction error 531.138611
>> Epoch 100 finished   RBM Reconstruction error 565.549011
>> Epoch 101 finished   RBM Reconstruction error 506.119995
>> Epoch 102 finished   RBM Reconstruction error 529.180786
>> Epoch 103 finished   RBM Reconstruction error 507.806732
>> Epoch 104 finished   RBM Reconstruction error 535.891724
>> Epoch 105 finished   RBM Reconstruction error 546.504639
>> Epoch 106 finished   RBM Reconstruction error 519.683899
>> Epoch 107 finished   RBM Reconstruction error 497.724762
>> Epoch 108 finished   RBM Reconstruction error 542.475952
>> Epoch 109 finished   RBM Reconstruction error 524.110779
>> Epoch 110 finished   RBM Reconstruction error 564.368958
>> Epoch 111 finished   RBM Reconstruction error 563.614319
>> Epoch 112 finished   RBM Reconstruction error 530.627991
>> Epoch 113 finished   RBM Reconstruction error 527.164246
>> Epoch 114 finished   RBM Reconstruction error 506.067383
>> Epoch 115 finished   RBM Reconstruction error 554.619568
>> Epoch 116 finished   RBM Reconstruction error 519.718445
>> Epoch 117 finished   RBM Reconstruction error 527.304138
>> Epoch 118 finished   RBM Reconstruction error 496.443604
>> Epoch 119 finished   RBM Reconstruction error 450.829529
>> Epoch 120 finished   RBM Reconstruction error 510.649536
>> Epoch 121 finished   RBM Reconstruction error 519.881897
>> Epoch 122 finished   RBM Reconstruction error 557.935730
>> Epoch 123 finished   RBM Reconstruction error 515.735229
>> Epoch 124 finished   RBM Reconstruction error 523.202332
>> Epoch 125 finished   RBM Reconstruction error 476.216431
>> Epoch 126 finished   RBM Reconstruction error 547.662842
>> Epoch 127 finished   RBM Reconstruction error 552.725403
>> Epoch 128 finished   RBM Reconstruction error 551.952759
>> Epoch 129 finished   RBM Reconstruction error 528.844238
>> Epoch 130 finished   RBM Reconstruction error 586.989441
>> Epoch 131 finished   RBM Reconstruction error 510.629852
>> Epoch 132 finished   RBM Reconstruction error 528.456238
>> Epoch 133 finished   RBM Reconstruction error 490.756409
>> Epoch 134 finished   RBM Reconstruction error 567.987183
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>> Epoch 135 finished    RBM Reconstruction error 498.159485
>> Epoch 136 finished    RBM Reconstruction error 513.407654
>> Epoch 137 finished    RBM Reconstruction error 518.971130
>> Epoch 138 finished    RBM Reconstruction error 524.058350
>> Epoch 139 finished    RBM Reconstruction error 545.792908
>> Epoch 140 finished    RBM Reconstruction error 538.389465
>> Epoch 141 finished    RBM Reconstruction error 552.671021
>> Epoch 142 finished    RBM Reconstruction error 544.624817
>> Epoch 143 finished    RBM Reconstruction error 509.464600
>> Epoch 144 finished    RBM Reconstruction error 507.593658
>> Epoch 145 finished    RBM Reconstruction error 497.818726
>> Epoch 146 finished    RBM Reconstruction error 501.663208
>> Epoch 147 finished    RBM Reconstruction error 586.163696
>> Epoch 148 finished    RBM Reconstruction error 543.924316
>> Epoch 149 finished    RBM Reconstruction error 553.488342
>> Epoch 150 finished    RBM Reconstruction error 504.382294
>> Epoch 151 finished    RBM Reconstruction error 546.111511
>> Epoch 152 finished    RBM Reconstruction error 567.015747
>> Epoch 153 finished    RBM Reconstruction error 542.365906
>> Epoch 154 finished    RBM Reconstruction error 508.317352
>> Epoch 155 finished    RBM Reconstruction error 511.143188
>> Epoch 156 finished    RBM Reconstruction error 523.533569
>> Epoch 157 finished    RBM Reconstruction error 491.992706
>> Epoch 158 finished    RBM Reconstruction error 537.225586
>> Epoch 159 finished    RBM Reconstruction error 504.751099
>> Epoch 160 finished    RBM Reconstruction error 557.211670
>> Epoch 161 finished    RBM Reconstruction error 506.961212
>> Epoch 162 finished    RBM Reconstruction error 526.593994
>> Epoch 163 finished    RBM Reconstruction error 502.207642
>> Epoch 164 finished    RBM Reconstruction error 557.939697
>> Epoch 165 finished    RBM Reconstruction error 528.606934
>> Epoch 166 finished    RBM Reconstruction error 563.265442
>> Epoch 167 finished    RBM Reconstruction error 514.486084
>> Epoch 168 finished    RBM Reconstruction error 513.973389
>> Epoch 169 finished    RBM Reconstruction error 535.867432
>> Epoch 170 finished    RBM Reconstruction error 561.356384
>> Epoch 171 finished    RBM Reconstruction error 524.609131
>> Epoch 172 finished    RBM Reconstruction error 518.933838
>> Epoch 173 finished    RBM Reconstruction error 497.827515
>> Epoch 174 finished    RBM Reconstruction error 520.868530
>> Epoch 175 finished    RBM Reconstruction error 496.534607
>> Epoch 176 finished    RBM Reconstruction error 582.810486
>> Epoch 177 finished    RBM Reconstruction error 518.333435
>> Epoch 178 finished    RBM Reconstruction error 589.350952
>> Epoch 179 finished    RBM Reconstruction error 552.725891
>> Epoch 180 finished    RBM Reconstruction error 545.217407
>> Epoch 181 finished    RBM Reconstruction error 562.634277
>> Epoch 182 finished    RBM Reconstruction error 527.428833
>> Epoch 183 finished    RBM Reconstruction error 540.541870
>> Epoch 184 finished    RBM Reconstruction error 537.282837
>> Epoch 185 finished    RBM Reconstruction error 535.384827
>> Epoch 186 finished    RBM Reconstruction error 535.844543
>> Epoch 187 finished    RBM Reconstruction error 518.362183
>> Epoch 188 finished    RBM Reconstruction error 553.779236
>> Epoch 189 finished    RBM Reconstruction error 537.115417
>> Epoch 190 finished    RBM Reconstruction error 498.032074
>> Epoch 191 finished    RBM Reconstruction error 519.525574
>> Epoch 192 finished    RBM Reconstruction error 558.555908
>> Epoch 193 finished    RBM Reconstruction error 542.932129
>> Epoch 194 finished    RBM Reconstruction error 506.329071
>> Epoch 195 finished    RBM Reconstruction error 498.104340
>> Epoch 196 finished    RBM Reconstruction error 522.869629
>> Epoch 197 finished    RBM Reconstruction error 534.738159
>> Epoch 198 finished    RBM Reconstruction error 554.097839
>> Epoch 199 finished    RBM Reconstruction error 594.726013
```

```
         >> Epoch 200 finished    RBM Reconstruction error 542.792053
         [END] Pre-training step
         [START] Fine tuning step:
         >> Epoch 0 finished     ANN training loss 0.560108
         >> Epoch 1 finished     ANN training loss 0.478133
         >> Epoch 2 finished     ANN training loss 0.326959
         >> Epoch 3 finished     ANN training loss 0.273707
         >> Epoch 4 finished     ANN training loss 0.233515
         >> Epoch 5 finished     ANN training loss 0.184579
         >> Epoch 6 finished     ANN training loss 0.173294
         >> Epoch 7 finished     ANN training loss 0.152690
         >> Epoch 8 finished     ANN training loss 0.131315
         >> Epoch 9 finished     ANN training loss 0.101903
         >> Epoch 10 finished    ANN training loss 0.100464
         >> Epoch 11 finished    ANN training loss 0.077701
         >> Epoch 12 finished    ANN training loss 0.074068
         >> Epoch 13 finished    ANN training loss 0.070626
         >> Epoch 14 finished    ANN training loss 0.062504
         >> Epoch 15 finished    ANN training loss 0.052151
         >> Epoch 16 finished    ANN training loss 0.050839
         >> Epoch 17 finished    ANN training loss 0.041720
         >> Epoch 18 finished    ANN training loss 0.045319
         >> Epoch 19 finished    ANN training loss 0.036140
         >> Epoch 20 finished    ANN training loss 0.030284
         >> Epoch 21 finished    ANN training loss 0.031474
         >> Epoch 22 finished    ANN training loss 0.024104
         >> Epoch 23 finished    ANN training loss 0.025288
         >> Epoch 24 finished    ANN training loss 0.020760
         >> Epoch 25 finished    ANN training loss 0.019948
         >> Epoch 26 finished    ANN training loss 0.019727
         >> Epoch 27 finished    ANN training loss 0.017002
         >> Epoch 28 finished    ANN training loss 0.017408
         >> Epoch 29 finished    ANN training loss 0.014865
         >> Epoch 30 finished    ANN training loss 0.017195
         >> Epoch 31 finished    ANN training loss 0.012178
         >> Epoch 32 finished    ANN training loss 0.012078
         >> Epoch 33 finished    ANN training loss 0.011508
         >> Epoch 34 finished    ANN training loss 0.010311
         >> Epoch 35 finished    ANN training loss 0.010251
         >> Epoch 36 finished    ANN training loss 0.009114
         >> Epoch 37 finished    ANN training loss 0.008137
         >> Epoch 38 finished    ANN training loss 0.007561
         >> Epoch 39 finished    ANN training loss 0.009356
         >> Epoch 40 finished    ANN training loss 0.008041
         >> Epoch 41 finished    ANN training loss 0.006675
         >> Epoch 42 finished    ANN training loss 0.006967
         >> Epoch 43 finished    ANN training loss 0.006316
         >> Epoch 44 finished    ANN training loss 0.006178
         >> Epoch 45 finished    ANN training loss 0.005090
         >> Epoch 46 finished    ANN training loss 0.004839
         >> Epoch 47 finished    ANN training loss 0.005528
         >> Epoch 48 finished    ANN training loss 0.005558
         >> Epoch 49 finished    ANN training loss 0.004318
         >> Epoch 50 finished    ANN training loss 0.004103
         >> Epoch 51 finished    ANN training loss 0.003702
         >> Epoch 52 finished    ANN training loss 0.003993
         >> Epoch 53 finished    ANN training loss 0.003434
         >> Epoch 54 finished    ANN training loss 0.003578
         >> Epoch 55 finished    ANN training loss 0.002954
         >> Epoch 56 finished    ANN training loss 0.002660
         >> Epoch 57 finished    ANN training loss 0.003508
         >> Epoch 58 finished    ANN training loss 0.002743
         >> Epoch 59 finished    ANN training loss 0.002926
         >> Epoch 60 finished    ANN training loss 0.002511
         >> Epoch 61 finished    ANN training loss 0.002084
```

```
>> Epoch 62 finished     ANN training loss 0.002145
>> Epoch 63 finished     ANN training loss 0.002103
>> Epoch 64 finished     ANN training loss 0.001781
>> Epoch 65 finished     ANN training loss 0.001953
>> Epoch 66 finished     ANN training loss 0.002772
>> Epoch 67 finished     ANN training loss 0.001792
>> Epoch 68 finished     ANN training loss 0.001873
>> Epoch 69 finished     ANN training loss 0.001706
>> Epoch 70 finished     ANN training loss 0.001847
>> Epoch 71 finished     ANN training loss 0.002355
>> Epoch 72 finished     ANN training loss 0.002011
>> Epoch 73 finished     ANN training loss 0.001785
>> Epoch 74 finished     ANN training loss 0.001674
>> Epoch 75 finished     ANN training loss 0.001480
>> Epoch 76 finished     ANN training loss 0.001611
>> Epoch 77 finished     ANN training loss 0.001493
>> Epoch 78 finished     ANN training loss 0.001313
>> Epoch 79 finished     ANN training loss 0.001934
>> Epoch 80 finished     ANN training loss 0.001204
>> Epoch 81 finished     ANN training loss 0.001126
>> Epoch 82 finished     ANN training loss 0.001206
>> Epoch 83 finished     ANN training loss 0.001159
>> Epoch 84 finished     ANN training loss 0.001021
>> Epoch 85 finished     ANN training loss 0.000978
>> Epoch 86 finished     ANN training loss 0.001200
>> Epoch 87 finished     ANN training loss 0.001134
>> Epoch 88 finished     ANN training loss 0.001004
>> Epoch 89 finished     ANN training loss 0.001177
>> Epoch 90 finished     ANN training loss 0.001069
>> Epoch 91 finished     ANN training loss 0.000993
>> Epoch 92 finished     ANN training loss 0.000942
>> Epoch 93 finished     ANN training loss 0.000937
>> Epoch 94 finished     ANN training loss 0.000810
>> Epoch 95 finished     ANN training loss 0.000777
>> Epoch 96 finished     ANN training loss 0.000862
>> Epoch 97 finished     ANN training loss 0.000792
>> Epoch 98 finished     ANN training loss 0.000853
>> Epoch 99 finished     ANN training loss 0.000891
```

In [108...
```python
print('ACCURACY: ' + str(epoch_rbm_acc[9]))
```

```
ACCURACY: 0.925
```

In [109...
```python
# Collated results
print(epoch_rbm_acc)
print('Most accurate n_epochs_rbm setting is Setting ' + str(epoch_rbm_acc.ind
```

```
[0.88, 0.915, 0.93, 0.92, 0.925, 0.925, 0.93, 0.935, 0.935, 0.925]
Most accurate n_epochs_rbm setting is Setting 8
```

```
In [110…
# Create bar graph
plt.clf()
objects = ('1', '2', '5', '10', '20', '30', '40', '50', '100', '200')
y_pos = np.arange(len(objects))
performance = [0.88, 0.88, 0.91000000000000003, 0.91000000000000003, 0.905000(

plt.bar(y_pos, performance, align='center', alpha=0.8)
plt.xticks(y_pos, objects, rotation=30)
plt.xlabel('Settings')
plt.ylabel('Accuracy')
plt.title('n_epochs_rbm Settings')

plt.show()
plt.clf()
```



```
<Figure size 432x288 with 0 Axes>
```
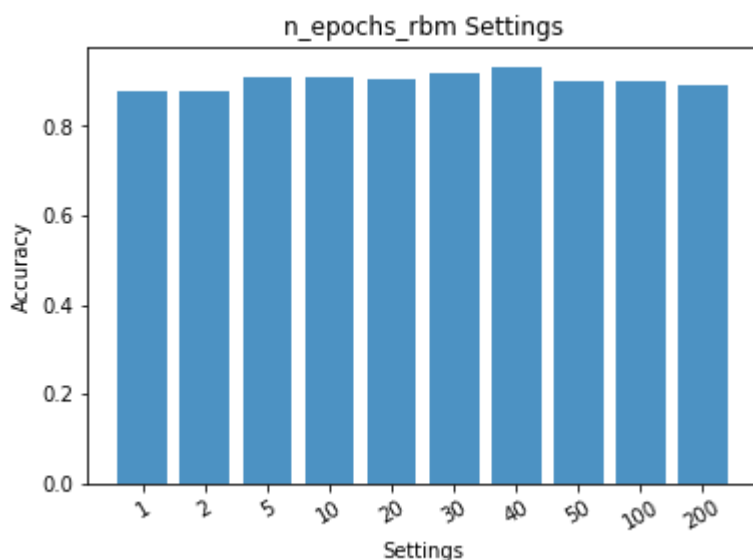
Different Fine-tuning / Backprop Lengths:

```
In [111…
# Store accuracies
backprop_acc = [0, 0, 0, 0, 0, 0, 0]
```

Setting 1

n_iter_backprop=1

```
In [112…
backprop_acc[0] = deep_belief_net(n_iter_backprop=1)
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 46.417393
>> Epoch 2 finished     RBM Reconstruction error 47.657658
>> Epoch 3 finished     RBM Reconstruction error 54.955650
>> Epoch 4 finished     RBM Reconstruction error 50.019699
>> Epoch 5 finished     RBM Reconstruction error 35.628067
>> Epoch 6 finished     RBM Reconstruction error 27.058317
>> Epoch 7 finished     RBM Reconstruction error 22.336702
>> Epoch 8 finished     RBM Reconstruction error 29.815464
>> Epoch 9 finished     RBM Reconstruction error 37.099140
>> Epoch 10 finished    RBM Reconstruction error 33.422985
```

```
>> Epoch 1 finished       RBM Reconstruction error 109.720528
>> Epoch 2 finished       RBM Reconstruction error 73.426537
>> Epoch 3 finished       RBM Reconstruction error 165.549896
>> Epoch 4 finished       RBM Reconstruction error 118.949020
>> Epoch 5 finished       RBM Reconstruction error 56.879375
>> Epoch 6 finished       RBM Reconstruction error 83.812889
>> Epoch 7 finished       RBM Reconstruction error 78.645920
>> Epoch 8 finished       RBM Reconstruction error 108.058670
>> Epoch 9 finished       RBM Reconstruction error 113.879547
>> Epoch 10 finished      RBM Reconstruction error 198.149704
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished       ANN training loss 0.689387
[END] Fine tuning step
Done.
Accuracy: 0.785000
```

In [113...
```python
print('ACCURACY: ' + str(backprop_acc[0]))
```

```
ACCURACY: 0.785
```

Setting 2

n_iter_backprop=5

In [114...
```python
backprop_acc[1] = deep_belief_net(n_iter_backprop=5)
```

```
[START] Pre-training step:
>> Epoch 1 finished       RBM Reconstruction error 53.670822
>> Epoch 2 finished       RBM Reconstruction error 51.106125
>> Epoch 3 finished       RBM Reconstruction error 46.766945
>> Epoch 4 finished       RBM Reconstruction error 73.860001
>> Epoch 5 finished       RBM Reconstruction error 37.919289
>> Epoch 6 finished       RBM Reconstruction error 57.819492
>> Epoch 7 finished       RBM Reconstruction error 42.827061
>> Epoch 8 finished       RBM Reconstruction error 66.841301
>> Epoch 9 finished       RBM Reconstruction error 44.626221
>> Epoch 10 finished      RBM Reconstruction error 49.498726
>> Epoch 1 finished       RBM Reconstruction error 266.658173
>> Epoch 2 finished       RBM Reconstruction error 286.935852
>> Epoch 3 finished       RBM Reconstruction error 368.736053
>> Epoch 4 finished       RBM Reconstruction error 222.824295
>> Epoch 5 finished       RBM Reconstruction error 194.785858
>> Epoch 6 finished       RBM Reconstruction error 210.890808
>> Epoch 7 finished       RBM Reconstruction error 237.214142
>> Epoch 8 finished       RBM Reconstruction error 190.448593
>> Epoch 9 finished       RBM Reconstruction error 182.679337
>> Epoch 10 finished      RBM Reconstruction error 181.904037
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished       ANN training loss 0.709323
>> Epoch 1 finished       ANN training loss 0.475414
>> Epoch 2 finished       ANN training loss 0.398361
>> Epoch 3 finished       ANN training loss 0.320243
>> Epoch 4 finished       ANN training loss 0.291597
[END] Fine tuning step
Done.
Accuracy: 0.845000
```

In [115...
```python
print('ACCURACY: ' + str(backprop_acc[1]))
```

```
ACCURACY: 0.845
```

Setting 3

n_iter_backprop=10

```
In [116…   backprop_acc[2] = deep_belief_net(n_iter_backprop=10)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 43.616425
>> Epoch 2 finished      RBM Reconstruction error 55.513237
>> Epoch 3 finished      RBM Reconstruction error 46.779030
>> Epoch 4 finished      RBM Reconstruction error 35.020477
>> Epoch 5 finished      RBM Reconstruction error 30.569477
>> Epoch 6 finished      RBM Reconstruction error 44.275070
>> Epoch 7 finished      RBM Reconstruction error 35.792793
>> Epoch 8 finished      RBM Reconstruction error 54.732651
>> Epoch 9 finished      RBM Reconstruction error 34.298092
>> Epoch 10 finished     RBM Reconstruction error 44.391815
>> Epoch 1 finished      RBM Reconstruction error 350.911316
>> Epoch 2 finished      RBM Reconstruction error 219.627441
>> Epoch 3 finished      RBM Reconstruction error 169.178024
>> Epoch 4 finished      RBM Reconstruction error 270.033569
>> Epoch 5 finished      RBM Reconstruction error 145.235703
>> Epoch 6 finished      RBM Reconstruction error 95.522713
>> Epoch 7 finished      RBM Reconstruction error 137.270813
>> Epoch 8 finished      RBM Reconstruction error 148.698242
>> Epoch 9 finished      RBM Reconstruction error 260.118256
>> Epoch 10 finished     RBM Reconstruction error 147.416199
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.629362
>> Epoch 1 finished      ANN training loss 0.433091
>> Epoch 2 finished      ANN training loss 0.355336
>> Epoch 3 finished      ANN training loss 0.311123
>> Epoch 4 finished      ANN training loss 0.250547
>> Epoch 5 finished      ANN training loss 0.231075
>> Epoch 6 finished      ANN training loss 0.244113
>> Epoch 7 finished      ANN training loss 0.179006
>> Epoch 8 finished      ANN training loss 0.169945
>> Epoch 9 finished      ANN training loss 0.154585
[END] Fine tuning step
Done.
Accuracy: 0.875000
```

```
In [117…   print('ACCURACY: ' + str(backprop_acc[2]))
```

```
ACCURACY: 0.875
```

Setting 4

n_iter_backprop=20

```
In [118…   backprop_acc[3] = deep_belief_net(n_iter_backprop=20)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 64.079750
>> Epoch 2 finished      RBM Reconstruction error 61.173603
>> Epoch 3 finished      RBM Reconstruction error 69.858727
>> Epoch 4 finished      RBM Reconstruction error 55.314083
>> Epoch 5 finished      RBM Reconstruction error 42.462158
>> Epoch 6 finished      RBM Reconstruction error 54.526485
>> Epoch 7 finished      RBM Reconstruction error 49.569740
```

```
>> Epoch 8 finished      RBM Reconstruction error 42.065937
>> Epoch 9 finished      RBM Reconstruction error 32.949043
>> Epoch 10 finished     RBM Reconstruction error 41.708828
>> Epoch 1 finished      RBM Reconstruction error 179.793121
>> Epoch 2 finished      RBM Reconstruction error 165.348633
>> Epoch 3 finished      RBM Reconstruction error 203.255463
>> Epoch 4 finished      RBM Reconstruction error 102.367752
>> Epoch 5 finished      RBM Reconstruction error 188.277344
>> Epoch 6 finished      RBM Reconstruction error 184.923706
>> Epoch 7 finished      RBM Reconstruction error 214.414215
>> Epoch 8 finished      RBM Reconstruction error 191.238678
>> Epoch 9 finished      RBM Reconstruction error 122.805740
>> Epoch 10 finished     RBM Reconstruction error 200.752228
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.709038
>> Epoch 1 finished      ANN training loss 0.539233
>> Epoch 2 finished      ANN training loss 0.377923
>> Epoch 3 finished      ANN training loss 0.335729
>> Epoch 4 finished      ANN training loss 0.297464
>> Epoch 5 finished      ANN training loss 0.266764
>> Epoch 6 finished      ANN training loss 0.236264
>> Epoch 7 finished      ANN training loss 0.207258
>> Epoch 8 finished      ANN training loss 0.182920
>> Epoch 9 finished      ANN training loss 0.162755
>> Epoch 10 finished     ANN training loss 0.137288
>> Epoch 11 finished     ANN training loss 0.131667
>> Epoch 12 finished     ANN training loss 0.115789
>> Epoch 13 finished     ANN training loss 0.106285
>> Epoch 14 finished     ANN training loss 0.095241
>> Epoch 15 finished     ANN training loss 0.084004
>> Epoch 16 finished     ANN training loss 0.074981
>> Epoch 17 finished     ANN training loss 0.068201
>> Epoch 18 finished     ANN training loss 0.060686
>> Epoch 19 finished     ANN training loss 0.062969
[END] Fine tuning step
Done.
Accuracy: 0.900000
```

In [119…
```python
print('ACCURACY: ' + str(backprop_acc[3]))
```

```
ACCURACY: 0.9
```

Setting 5

n_iter_backprop=50

In [120…
```python
backprop_acc[4] = deep_belief_net(n_iter_backprop=50)
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 42.539101
>> Epoch 2 finished      RBM Reconstruction error 48.427383
>> Epoch 3 finished      RBM Reconstruction error 46.007954
>> Epoch 4 finished      RBM Reconstruction error 27.606701
>> Epoch 5 finished      RBM Reconstruction error 34.014862
>> Epoch 6 finished      RBM Reconstruction error 49.891167
>> Epoch 7 finished      RBM Reconstruction error 31.004084
>> Epoch 8 finished      RBM Reconstruction error 25.910332
>> Epoch 9 finished      RBM Reconstruction error 27.662582
>> Epoch 10 finished     RBM Reconstruction error 49.573643
>> Epoch 1 finished      RBM Reconstruction error 214.598724
>> Epoch 2 finished      RBM Reconstruction error 176.054138
>> Epoch 3 finished      RBM Reconstruction error 201.304138
```

```
                 >> Epoch 4 finished      RBM Reconstruction error 234.982071
                 >> Epoch 5 finished      RBM Reconstruction error 257.270844
                 >> Epoch 6 finished      RBM Reconstruction error 155.380753
                 >> Epoch 7 finished      RBM Reconstruction error 311.022003
                 >> Epoch 8 finished      RBM Reconstruction error 268.813019
                 >> Epoch 9 finished      RBM Reconstruction error 196.346130
                 >> Epoch 10 finished     RBM Reconstruction error 188.891953
                 [END] Pre-training step
                 [START] Fine tuning step:
                 >> Epoch 0 finished      ANN training loss 0.635767
                 >> Epoch 1 finished      ANN training loss 0.441494
                 >> Epoch 2 finished      ANN training loss 0.442132
                 >> Epoch 3 finished      ANN training loss 0.311342
                 >> Epoch 4 finished      ANN training loss 0.305937
                 >> Epoch 5 finished      ANN training loss 0.286882
                 >> Epoch 6 finished      ANN training loss 0.213888
                 >> Epoch 7 finished      ANN training loss 0.206446
                 >> Epoch 8 finished      ANN training loss 0.173293
                 >> Epoch 9 finished      ANN training loss 0.161047
                 >> Epoch 10 finished     ANN training loss 0.136715
                 >> Epoch 11 finished     ANN training loss 0.123731
                 >> Epoch 12 finished     ANN training loss 0.113966
                 >> Epoch 13 finished     ANN training loss 0.108265
                 >> Epoch 14 finished     ANN training loss 0.089739
                 >> Epoch 15 finished     ANN training loss 0.083927
                 >> Epoch 16 finished     ANN training loss 0.074046
                 >> Epoch 17 finished     ANN training loss 0.070823
                 >> Epoch 18 finished     ANN training loss 0.061464
                 >> Epoch 19 finished     ANN training loss 0.052659
                 >> Epoch 20 finished     ANN training loss 0.057696
                 >> Epoch 21 finished     ANN training loss 0.047390
                 >> Epoch 22 finished     ANN training loss 0.043418
                 >> Epoch 23 finished     ANN training loss 0.039756
                 >> Epoch 24 finished     ANN training loss 0.035646
                 >> Epoch 25 finished     ANN training loss 0.033006
                 >> Epoch 26 finished     ANN training loss 0.030432
                 >> Epoch 27 finished     ANN training loss 0.030045
                 >> Epoch 28 finished     ANN training loss 0.026954
                 >> Epoch 29 finished     ANN training loss 0.024224
                 >> Epoch 30 finished     ANN training loss 0.022229
                 >> Epoch 31 finished     ANN training loss 0.021842
                 >> Epoch 32 finished     ANN training loss 0.023601
                 >> Epoch 33 finished     ANN training loss 0.018629
                 >> Epoch 34 finished     ANN training loss 0.017043
                 >> Epoch 35 finished     ANN training loss 0.017117
                 >> Epoch 36 finished     ANN training loss 0.016426
                 >> Epoch 37 finished     ANN training loss 0.014213
                 >> Epoch 38 finished     ANN training loss 0.012463
                 >> Epoch 39 finished     ANN training loss 0.011859
                 >> Epoch 40 finished     ANN training loss 0.010856
                 >> Epoch 41 finished     ANN training loss 0.010203
                 >> Epoch 42 finished     ANN training loss 0.009449
                 >> Epoch 43 finished     ANN training loss 0.014757
                 >> Epoch 44 finished     ANN training loss 0.010546
                 >> Epoch 45 finished     ANN training loss 0.008845
                 >> Epoch 46 finished     ANN training loss 0.011153
                 >> Epoch 47 finished     ANN training loss 0.007825
                 >> Epoch 48 finished     ANN training loss 0.007644
                 >> Epoch 49 finished     ANN training loss 0.006724
                 [END] Fine tuning step
                 Done.
                 Accuracy: 0.925000
```

```
In [121…   print('ACCURACY: ' + str(backprop_acc[4]))
```
```
ACCURACY: 0.925
```

Setting 6 (Default)

n_iter_backprop=100

```
In [122…   backprop_acc[5] = default_acc
```

```
In [123…   print('ACCURACY: ' + str(backprop_acc[5]))
```
```
ACCURACY: 0.92
```

Setting 7

n_iter_backprop=200

```
In [124…   backprop_acc[6] = deep_belief_net(n_iter_backprop=200)
```
```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 78.270699
>> Epoch 2 finished     RBM Reconstruction error 53.280502
>> Epoch 3 finished     RBM Reconstruction error 71.744499
>> Epoch 4 finished     RBM Reconstruction error 41.465714
>> Epoch 5 finished     RBM Reconstruction error 43.127274
>> Epoch 6 finished     RBM Reconstruction error 52.982025
>> Epoch 7 finished     RBM Reconstruction error 42.504639
>> Epoch 8 finished     RBM Reconstruction error 36.534718
>> Epoch 9 finished     RBM Reconstruction error 47.537033
>> Epoch 10 finished    RBM Reconstruction error 55.294544
>> Epoch 1 finished     RBM Reconstruction error 342.604034
>> Epoch 2 finished     RBM Reconstruction error 301.330322
>> Epoch 3 finished     RBM Reconstruction error 243.681061
>> Epoch 4 finished     RBM Reconstruction error 235.799332
>> Epoch 5 finished     RBM Reconstruction error 191.945007
>> Epoch 6 finished     RBM Reconstruction error 160.528473
>> Epoch 7 finished     RBM Reconstruction error 320.610199
>> Epoch 8 finished     RBM Reconstruction error 369.602631
>> Epoch 9 finished     RBM Reconstruction error 226.601288
>> Epoch 10 finished    RBM Reconstruction error 203.788986
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished     ANN training loss 0.647701
>> Epoch 1 finished     ANN training loss 0.474274
>> Epoch 2 finished     ANN training loss 0.382358
>> Epoch 3 finished     ANN training loss 0.342266
>> Epoch 4 finished     ANN training loss 0.303025
>> Epoch 5 finished     ANN training loss 0.260843
>> Epoch 6 finished     ANN training loss 0.240567
>> Epoch 7 finished     ANN training loss 0.206317
>> Epoch 8 finished     ANN training loss 0.180028
>> Epoch 9 finished     ANN training loss 0.157604
>> Epoch 10 finished    ANN training loss 0.148237
>> Epoch 11 finished    ANN training loss 0.123130
>> Epoch 12 finished    ANN training loss 0.114223
>> Epoch 13 finished    ANN training loss 0.104016
>> Epoch 14 finished    ANN training loss 0.101606
>> Epoch 15 finished    ANN training loss 0.088622
>> Epoch 16 finished    ANN training loss 0.080971
```

```
                    >> Epoch 17 finished    ANN training loss 0.076944
                    >> Epoch 18 finished    ANN training loss 0.065854
                    >> Epoch 19 finished    ANN training loss 0.066379
                    >> Epoch 20 finished    ANN training loss 0.055655
                    >> Epoch 21 finished    ANN training loss 0.049862
                    >> Epoch 22 finished    ANN training loss 0.049661
                    >> Epoch 23 finished    ANN training loss 0.047930
                    >> Epoch 24 finished    ANN training loss 0.042155
                    >> Epoch 25 finished    ANN training loss 0.035827
                    >> Epoch 26 finished    ANN training loss 0.036045
                    >> Epoch 27 finished    ANN training loss 0.034883
                    >> Epoch 28 finished    ANN training loss 0.030397
                    >> Epoch 29 finished    ANN training loss 0.030755
                    >> Epoch 30 finished    ANN training loss 0.028789
                    >> Epoch 31 finished    ANN training loss 0.026859
                    >> Epoch 32 finished    ANN training loss 0.022422
                    >> Epoch 33 finished    ANN training loss 0.020953
                    >> Epoch 34 finished    ANN training loss 0.020083
                    >> Epoch 35 finished    ANN training loss 0.019830
                    >> Epoch 36 finished    ANN training loss 0.017286
                    >> Epoch 37 finished    ANN training loss 0.017568
                    >> Epoch 38 finished    ANN training loss 0.019686
                    >> Epoch 39 finished    ANN training loss 0.016919
                    >> Epoch 40 finished    ANN training loss 0.013635
                    >> Epoch 41 finished    ANN training loss 0.013763
                    >> Epoch 42 finished    ANN training loss 0.013501
                    >> Epoch 43 finished    ANN training loss 0.012666
                    >> Epoch 44 finished    ANN training loss 0.011114
                    >> Epoch 45 finished    ANN training loss 0.012617
                    >> Epoch 46 finished    ANN training loss 0.010561
                    >> Epoch 47 finished    ANN training loss 0.009131
                    >> Epoch 48 finished    ANN training loss 0.012146
                    >> Epoch 49 finished    ANN training loss 0.009666
                    >> Epoch 50 finished    ANN training loss 0.008378
                    >> Epoch 51 finished    ANN training loss 0.007912
                    >> Epoch 52 finished    ANN training loss 0.006899
                    >> Epoch 53 finished    ANN training loss 0.006320
                    >> Epoch 54 finished    ANN training loss 0.006260
                    >> Epoch 55 finished    ANN training loss 0.006451
                    >> Epoch 56 finished    ANN training loss 0.005520
                    >> Epoch 57 finished    ANN training loss 0.005164
                    >> Epoch 58 finished    ANN training loss 0.005555
                    >> Epoch 59 finished    ANN training loss 0.004828
                    >> Epoch 60 finished    ANN training loss 0.004788
                    >> Epoch 61 finished    ANN training loss 0.004589
                    >> Epoch 62 finished    ANN training loss 0.004785
                    >> Epoch 63 finished    ANN training loss 0.004704
                    >> Epoch 64 finished    ANN training loss 0.004846
                    >> Epoch 65 finished    ANN training loss 0.004720
                    >> Epoch 66 finished    ANN training loss 0.004498
                    >> Epoch 67 finished    ANN training loss 0.003754
                    >> Epoch 68 finished    ANN training loss 0.003411
                    >> Epoch 69 finished    ANN training loss 0.003275
                    >> Epoch 70 finished    ANN training loss 0.003542
                    >> Epoch 71 finished    ANN training loss 0.002864
                    >> Epoch 72 finished    ANN training loss 0.003878
                    >> Epoch 73 finished    ANN training loss 0.002614
                    >> Epoch 74 finished    ANN training loss 0.002883
                    >> Epoch 75 finished    ANN training loss 0.002585
                    >> Epoch 76 finished    ANN training loss 0.002855
                    >> Epoch 77 finished    ANN training loss 0.002507
                    >> Epoch 78 finished    ANN training loss 0.002487
                    >> Epoch 79 finished    ANN training loss 0.002455
                    >> Epoch 80 finished    ANN training loss 0.002618
                    >> Epoch 81 finished    ANN training loss 0.002405
```

```
>> Epoch 82 finished    ANN training loss 0.001965
>> Epoch 83 finished    ANN training loss 0.002077
>> Epoch 84 finished    ANN training loss 0.001984
>> Epoch 85 finished    ANN training loss 0.001927
>> Epoch 86 finished    ANN training loss 0.001774
>> Epoch 87 finished    ANN training loss 0.001888
>> Epoch 88 finished    ANN training loss 0.001813
>> Epoch 89 finished    ANN training loss 0.001794
>> Epoch 90 finished    ANN training loss 0.001933
>> Epoch 91 finished    ANN training loss 0.001811
>> Epoch 92 finished    ANN training loss 0.001493
>> Epoch 93 finished    ANN training loss 0.001527
>> Epoch 94 finished    ANN training loss 0.001481
>> Epoch 95 finished    ANN training loss 0.001377
>> Epoch 96 finished    ANN training loss 0.001674
>> Epoch 97 finished    ANN training loss 0.001384
>> Epoch 98 finished    ANN training loss 0.001308
>> Epoch 99 finished    ANN training loss 0.001703
>> Epoch 100 finished   ANN training loss 0.001355
>> Epoch 101 finished   ANN training loss 0.001244
>> Epoch 102 finished   ANN training loss 0.001421
>> Epoch 103 finished   ANN training loss 0.001432
>> Epoch 104 finished   ANN training loss 0.001174
>> Epoch 105 finished   ANN training loss 0.001632
>> Epoch 106 finished   ANN training loss 0.001347
>> Epoch 107 finished   ANN training loss 0.001332
>> Epoch 108 finished   ANN training loss 0.001206
>> Epoch 109 finished   ANN training loss 0.001091
>> Epoch 110 finished   ANN training loss 0.001240
>> Epoch 111 finished   ANN training loss 0.001130
>> Epoch 112 finished   ANN training loss 0.001099
>> Epoch 113 finished   ANN training loss 0.001117
>> Epoch 114 finished   ANN training loss 0.001093
>> Epoch 115 finished   ANN training loss 0.001331
>> Epoch 116 finished   ANN training loss 0.000856
>> Epoch 117 finished   ANN training loss 0.000903
>> Epoch 118 finished   ANN training loss 0.001301
>> Epoch 119 finished   ANN training loss 0.001150
>> Epoch 120 finished   ANN training loss 0.000908
>> Epoch 121 finished   ANN training loss 0.000961
>> Epoch 122 finished   ANN training loss 0.000850
>> Epoch 123 finished   ANN training loss 0.001034
>> Epoch 124 finished   ANN training loss 0.000814
>> Epoch 125 finished   ANN training loss 0.001139
>> Epoch 126 finished   ANN training loss 0.000824
>> Epoch 127 finished   ANN training loss 0.000810
>> Epoch 128 finished   ANN training loss 0.000818
>> Epoch 129 finished   ANN training loss 0.000765
>> Epoch 130 finished   ANN training loss 0.000646
>> Epoch 131 finished   ANN training loss 0.000748
>> Epoch 132 finished   ANN training loss 0.000637
>> Epoch 133 finished   ANN training loss 0.000638
>> Epoch 134 finished   ANN training loss 0.000699
>> Epoch 135 finished   ANN training loss 0.000729
>> Epoch 136 finished   ANN training loss 0.000554
>> Epoch 137 finished   ANN training loss 0.000635
>> Epoch 138 finished   ANN training loss 0.000588
>> Epoch 139 finished   ANN training loss 0.000609
>> Epoch 140 finished   ANN training loss 0.000598
>> Epoch 141 finished   ANN training loss 0.000492
>> Epoch 142 finished   ANN training loss 0.000573
>> Epoch 143 finished   ANN training loss 0.000519
>> Epoch 144 finished   ANN training loss 0.000606
>> Epoch 145 finished   ANN training loss 0.000662
>> Epoch 146 finished   ANN training loss 0.000643
```

```
>> Epoch 147 finished   ANN training loss 0.000554
>> Epoch 148 finished   ANN training loss 0.000508
>> Epoch 149 finished   ANN training loss 0.000574
>> Epoch 150 finished   ANN training loss 0.000665
>> Epoch 151 finished   ANN training loss 0.000589
>> Epoch 152 finished   ANN training loss 0.000508
>> Epoch 153 finished   ANN training loss 0.000484
>> Epoch 154 finished   ANN training loss 0.000443
>> Epoch 155 finished   ANN training loss 0.000494
>> Epoch 156 finished   ANN training loss 0.000444
>> Epoch 157 finished   ANN training loss 0.000457
>> Epoch 158 finished   ANN training loss 0.000502
>> Epoch 159 finished   ANN training loss 0.000456
>> Epoch 160 finished   ANN training loss 0.000422
>> Epoch 161 finished   ANN training loss 0.000393
>> Epoch 162 finished   ANN training loss 0.000417
>> Epoch 163 finished   ANN training loss 0.000373
>> Epoch 164 finished   ANN training loss 0.000381
>> Epoch 165 finished   ANN training loss 0.000441
>> Epoch 166 finished   ANN training loss 0.000435
>> Epoch 167 finished   ANN training loss 0.000422
>> Epoch 168 finished   ANN training loss 0.000352
>> Epoch 169 finished   ANN training loss 0.000416
>> Epoch 170 finished   ANN training loss 0.000395
>> Epoch 171 finished   ANN training loss 0.000364
>> Epoch 172 finished   ANN training loss 0.000348
>> Epoch 173 finished   ANN training loss 0.000379
>> Epoch 174 finished   ANN training loss 0.000343
>> Epoch 175 finished   ANN training loss 0.000325
>> Epoch 176 finished   ANN training loss 0.000304
>> Epoch 177 finished   ANN training loss 0.000292
>> Epoch 178 finished   ANN training loss 0.000342
>> Epoch 179 finished   ANN training loss 0.000349
>> Epoch 180 finished   ANN training loss 0.000306
>> Epoch 181 finished   ANN training loss 0.000284
>> Epoch 182 finished   ANN training loss 0.000346
>> Epoch 183 finished   ANN training loss 0.000287
>> Epoch 184 finished   ANN training loss 0.000263
>> Epoch 185 finished   ANN training loss 0.000269
>> Epoch 186 finished   ANN training loss 0.000255
>> Epoch 187 finished   ANN training loss 0.000292
>> Epoch 188 finished   ANN training loss 0.000291
>> Epoch 189 finished   ANN training loss 0.000326
>> Epoch 190 finished   ANN training loss 0.000299
>> Epoch 191 finished   ANN training loss 0.000274
>> Epoch 192 finished   ANN training loss 0.000255
>> Epoch 193 finished   ANN training loss 0.000291
>> Epoch 194 finished   ANN training loss 0.000251
>> Epoch 195 finished   ANN training loss 0.000223
>> Epoch 196 finished   ANN training loss 0.000218
>> Epoch 197 finished   ANN training loss 0.000225
>> Epoch 198 finished   ANN training loss 0.000302
>> Epoch 199 finished   ANN training loss 0.000306
[END] Fine tuning step
Done.
```

In [125…
```
print('ACCURACY: ' + str(backprop_acc[6]))
```

```
ACCURACY: 0.93
```

In [126…
```
# Collated results
print(backprop_acc)
print('Most accurate backprop iteration setting is Setting ' + str(backprop_ac
```

```
[0.785, 0.845, 0.875, 0.9, 0.925, 0.92, 0.93]
```

Most accurate backprop iteration setting is Setting 7

```python
In [127...   # Create bar graph
             plt.clf()
             objects = ('1', '5', '10', '20', '50', '100', '200')
             y_pos = np.arange(len(objects))
             performance = [0.78500000000000003, 0.84499999999999997, 0.87, 0.8900000000000

             plt.bar(y_pos, performance, align='center', alpha=0.3)
             plt.xticks(y_pos, objects, rotation=30)
             plt.xlabel('Settings')
             plt.ylabel('Accuracy')
             plt.title('n_iter_backprop Settings')

             plt.show()
             plt.clf()
```



```
<Figure size 432x288 with 0 Axes>
```
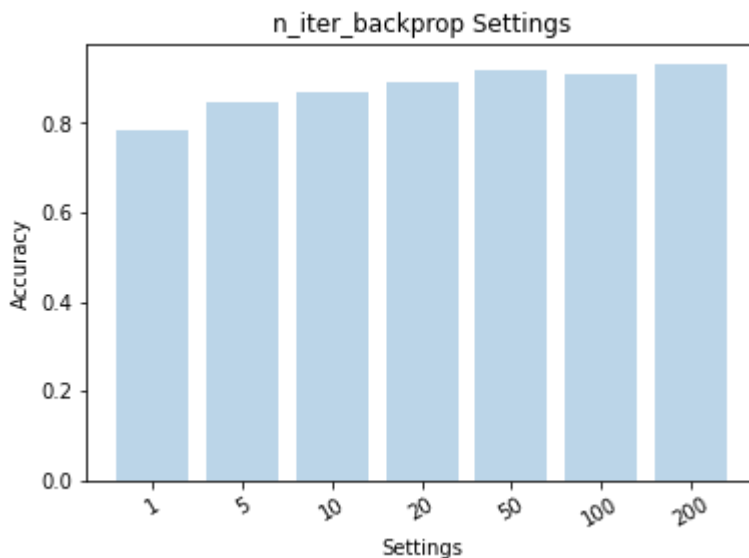
Benchmark 1:

Take the best setting for each n-layer setup and use the best performing parameters.

```python
In [129...   # 1-layer
             acc1 = deep_belief_net(hidden_layers_structure=[200],
                                    learning_rate_rbm=0.05,
                                    learning_rate=0.1,
                                    n_epochs_rbm=40,
                                    n_iter_backprop=200,
                                    batch_size=32,
                                    activation_function='relu',
                                    dropout_p=0.2)
             print('ACCURACY: ' + str(acc1))
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 62.965160
>> Epoch 2 finished     RBM Reconstruction error 56.377430
>> Epoch 3 finished     RBM Reconstruction error 41.571564
>> Epoch 4 finished     RBM Reconstruction error 49.783279
>> Epoch 5 finished     RBM Reconstruction error 69.517647
>> Epoch 6 finished     RBM Reconstruction error 45.104824
```

```
>> Epoch 7 finished      RBM Reconstruction error 43.680145
>> Epoch 8 finished      RBM Reconstruction error 37.531254
>> Epoch 9 finished      RBM Reconstruction error 54.635376
>> Epoch 10 finished     RBM Reconstruction error 53.856903
>> Epoch 11 finished     RBM Reconstruction error 26.298256
>> Epoch 12 finished     RBM Reconstruction error 60.240707
>> Epoch 13 finished     RBM Reconstruction error 42.176445
>> Epoch 14 finished     RBM Reconstruction error 45.950020
>> Epoch 15 finished     RBM Reconstruction error 52.033173
>> Epoch 16 finished     RBM Reconstruction error 42.436924
>> Epoch 17 finished     RBM Reconstruction error 47.170143
>> Epoch 18 finished     RBM Reconstruction error 51.320171
>> Epoch 19 finished     RBM Reconstruction error 48.811520
>> Epoch 20 finished     RBM Reconstruction error 29.796917
>> Epoch 21 finished     RBM Reconstruction error 43.883419
>> Epoch 22 finished     RBM Reconstruction error 37.661678
>> Epoch 23 finished     RBM Reconstruction error 39.911346
>> Epoch 24 finished     RBM Reconstruction error 55.439430
>> Epoch 25 finished     RBM Reconstruction error 57.217518
>> Epoch 26 finished     RBM Reconstruction error 35.121620
>> Epoch 27 finished     RBM Reconstruction error 50.386818
>> Epoch 28 finished     RBM Reconstruction error 58.663342
>> Epoch 29 finished     RBM Reconstruction error 50.020996
>> Epoch 30 finished     RBM Reconstruction error 50.962433
>> Epoch 31 finished     RBM Reconstruction error 50.387238
>> Epoch 32 finished     RBM Reconstruction error 33.647007
>> Epoch 33 finished     RBM Reconstruction error 44.004288
>> Epoch 34 finished     RBM Reconstruction error 63.671486
>> Epoch 35 finished     RBM Reconstruction error 45.246593
>> Epoch 36 finished     RBM Reconstruction error 54.966232
>> Epoch 37 finished     RBM Reconstruction error 41.159706
>> Epoch 38 finished     RBM Reconstruction error 46.985176
>> Epoch 39 finished     RBM Reconstruction error 65.298767
>> Epoch 40 finished     RBM Reconstruction error 55.111885
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.737916
>> Epoch 1 finished      ANN training loss 0.519546
>> Epoch 2 finished      ANN training loss 0.437401
>> Epoch 3 finished      ANN training loss 0.357565
>> Epoch 4 finished      ANN training loss 0.341053
>> Epoch 5 finished      ANN training loss 0.272484
>> Epoch 6 finished      ANN training loss 0.248520
>> Epoch 7 finished      ANN training loss 0.234667
>> Epoch 8 finished      ANN training loss 0.208356
>> Epoch 9 finished      ANN training loss 0.190628
>> Epoch 10 finished     ANN training loss 0.174290
>> Epoch 11 finished     ANN training loss 0.162094
>> Epoch 12 finished     ANN training loss 0.144602
>> Epoch 13 finished     ANN training loss 0.130844
>> Epoch 14 finished     ANN training loss 0.119703
>> Epoch 15 finished     ANN training loss 0.116365
>> Epoch 16 finished     ANN training loss 0.110318
>> Epoch 17 finished     ANN training loss 0.102484
>> Epoch 18 finished     ANN training loss 0.092412
>> Epoch 19 finished     ANN training loss 0.083125
>> Epoch 20 finished     ANN training loss 0.078500
>> Epoch 21 finished     ANN training loss 0.071512
>> Epoch 22 finished     ANN training loss 0.068592
>> Epoch 23 finished     ANN training loss 0.062787
>> Epoch 24 finished     ANN training loss 0.059403
>> Epoch 25 finished     ANN training loss 0.054001
>> Epoch 26 finished     ANN training loss 0.058337
>> Epoch 27 finished     ANN training loss 0.050384
>> Epoch 28 finished     ANN training loss 0.046054
```

```
>> Epoch 29 finished    ANN training loss 0.041735
>> Epoch 30 finished    ANN training loss 0.042602
>> Epoch 31 finished    ANN training loss 0.038610
>> Epoch 32 finished    ANN training loss 0.036508
>> Epoch 33 finished    ANN training loss 0.034588
>> Epoch 34 finished    ANN training loss 0.033740
>> Epoch 35 finished    ANN training loss 0.031696
>> Epoch 36 finished    ANN training loss 0.029101
>> Epoch 37 finished    ANN training loss 0.026640
>> Epoch 38 finished    ANN training loss 0.024914
>> Epoch 39 finished    ANN training loss 0.025707
>> Epoch 40 finished    ANN training loss 0.022630
>> Epoch 41 finished    ANN training loss 0.023126
>> Epoch 42 finished    ANN training loss 0.021629
>> Epoch 43 finished    ANN training loss 0.020262
>> Epoch 44 finished    ANN training loss 0.019355
>> Epoch 45 finished    ANN training loss 0.018792
>> Epoch 46 finished    ANN training loss 0.017383
>> Epoch 47 finished    ANN training loss 0.017221
>> Epoch 48 finished    ANN training loss 0.016227
>> Epoch 49 finished    ANN training loss 0.015892
>> Epoch 50 finished    ANN training loss 0.014825
>> Epoch 51 finished    ANN training loss 0.014546
>> Epoch 52 finished    ANN training loss 0.014850
>> Epoch 53 finished    ANN training loss 0.013662
>> Epoch 54 finished    ANN training loss 0.013524
>> Epoch 55 finished    ANN training loss 0.012895
>> Epoch 56 finished    ANN training loss 0.011968
>> Epoch 57 finished    ANN training loss 0.011810
>> Epoch 58 finished    ANN training loss 0.011306
>> Epoch 59 finished    ANN training loss 0.011003
>> Epoch 60 finished    ANN training loss 0.010592
>> Epoch 61 finished    ANN training loss 0.010766
>> Epoch 62 finished    ANN training loss 0.009290
>> Epoch 63 finished    ANN training loss 0.009143
>> Epoch 64 finished    ANN training loss 0.009304
>> Epoch 65 finished    ANN training loss 0.008643
>> Epoch 66 finished    ANN training loss 0.008357
>> Epoch 67 finished    ANN training loss 0.008837
>> Epoch 68 finished    ANN training loss 0.007608
>> Epoch 69 finished    ANN training loss 0.007456
>> Epoch 70 finished    ANN training loss 0.007268
>> Epoch 71 finished    ANN training loss 0.007091
>> Epoch 72 finished    ANN training loss 0.007159
>> Epoch 73 finished    ANN training loss 0.006757
>> Epoch 74 finished    ANN training loss 0.006431
>> Epoch 75 finished    ANN training loss 0.006475
>> Epoch 76 finished    ANN training loss 0.006236
>> Epoch 77 finished    ANN training loss 0.006127
>> Epoch 78 finished    ANN training loss 0.005718
>> Epoch 79 finished    ANN training loss 0.005478
>> Epoch 80 finished    ANN training loss 0.005542
>> Epoch 81 finished    ANN training loss 0.005624
>> Epoch 82 finished    ANN training loss 0.005346
>> Epoch 83 finished    ANN training loss 0.005258
>> Epoch 84 finished    ANN training loss 0.005086
>> Epoch 85 finished    ANN training loss 0.004860
>> Epoch 86 finished    ANN training loss 0.004812
>> Epoch 87 finished    ANN training loss 0.004779
>> Epoch 88 finished    ANN training loss 0.004760
>> Epoch 89 finished    ANN training loss 0.004473
>> Epoch 90 finished    ANN training loss 0.004319
>> Epoch 91 finished    ANN training loss 0.004439
>> Epoch 92 finished    ANN training loss 0.004202
>> Epoch 93 finished    ANN training loss 0.004094
```

```
>> Epoch 94 finished    ANN training loss 0.004137
>> Epoch 95 finished    ANN training loss 0.003769
>> Epoch 96 finished    ANN training loss 0.003795
>> Epoch 97 finished    ANN training loss 0.003814
>> Epoch 98 finished    ANN training loss 0.003826
>> Epoch 99 finished    ANN training loss 0.003565
>> Epoch 100 finished   ANN training loss 0.003546
>> Epoch 101 finished   ANN training loss 0.003441
>> Epoch 102 finished   ANN training loss 0.003406
>> Epoch 103 finished   ANN training loss 0.003359
>> Epoch 104 finished   ANN training loss 0.003242
>> Epoch 105 finished   ANN training loss 0.003265
>> Epoch 106 finished   ANN training loss 0.003538
>> Epoch 107 finished   ANN training loss 0.003255
>> Epoch 108 finished   ANN training loss 0.003223
>> Epoch 109 finished   ANN training loss 0.003036
>> Epoch 110 finished   ANN training loss 0.002898
>> Epoch 111 finished   ANN training loss 0.003045
>> Epoch 112 finished   ANN training loss 0.002911
>> Epoch 113 finished   ANN training loss 0.002831
>> Epoch 114 finished   ANN training loss 0.002840
>> Epoch 115 finished   ANN training loss 0.002838
>> Epoch 116 finished   ANN training loss 0.002851
>> Epoch 117 finished   ANN training loss 0.002694
>> Epoch 118 finished   ANN training loss 0.002705
>> Epoch 119 finished   ANN training loss 0.002732
>> Epoch 120 finished   ANN training loss 0.002688
>> Epoch 121 finished   ANN training loss 0.002687
>> Epoch 122 finished   ANN training loss 0.002592
>> Epoch 123 finished   ANN training loss 0.002535
>> Epoch 124 finished   ANN training loss 0.002575
>> Epoch 125 finished   ANN training loss 0.002574
>> Epoch 126 finished   ANN training loss 0.002543
>> Epoch 127 finished   ANN training loss 0.002506
>> Epoch 128 finished   ANN training loss 0.002366
>> Epoch 129 finished   ANN training loss 0.002322
>> Epoch 130 finished   ANN training loss 0.002239
>> Epoch 131 finished   ANN training loss 0.002181
>> Epoch 132 finished   ANN training loss 0.002062
>> Epoch 133 finished   ANN training loss 0.002070
>> Epoch 134 finished   ANN training loss 0.001994
>> Epoch 135 finished   ANN training loss 0.001988
>> Epoch 136 finished   ANN training loss 0.001986
>> Epoch 137 finished   ANN training loss 0.001932
>> Epoch 138 finished   ANN training loss 0.001977
>> Epoch 139 finished   ANN training loss 0.001995
>> Epoch 140 finished   ANN training loss 0.001877
>> Epoch 141 finished   ANN training loss 0.001825
>> Epoch 142 finished   ANN training loss 0.001758
>> Epoch 143 finished   ANN training loss 0.001719
>> Epoch 144 finished   ANN training loss 0.001699
>> Epoch 145 finished   ANN training loss 0.001816
>> Epoch 146 finished   ANN training loss 0.001809
>> Epoch 147 finished   ANN training loss 0.001751
>> Epoch 148 finished   ANN training loss 0.001694
>> Epoch 149 finished   ANN training loss 0.001765
>> Epoch 150 finished   ANN training loss 0.001773
>> Epoch 151 finished   ANN training loss 0.001638
>> Epoch 152 finished   ANN training loss 0.001578
>> Epoch 153 finished   ANN training loss 0.001464
>> Epoch 154 finished   ANN training loss 0.001500
>> Epoch 155 finished   ANN training loss 0.001479
>> Epoch 156 finished   ANN training loss 0.001545
>> Epoch 157 finished   ANN training loss 0.001538
>> Epoch 158 finished   ANN training loss 0.001472
```

```
>> Epoch 159 finished    ANN training loss 0.001415
>> Epoch 160 finished    ANN training loss 0.001439
>> Epoch 161 finished    ANN training loss 0.001398
>> Epoch 162 finished    ANN training loss 0.001352
>> Epoch 163 finished    ANN training loss 0.001374
>> Epoch 164 finished    ANN training loss 0.001348
>> Epoch 165 finished    ANN training loss 0.001315
>> Epoch 166 finished    ANN training loss 0.001245
>> Epoch 167 finished    ANN training loss 0.001349
>> Epoch 168 finished    ANN training loss 0.001273
>> Epoch 169 finished    ANN training loss 0.001269
>> Epoch 170 finished    ANN training loss 0.001264
>> Epoch 171 finished    ANN training loss 0.001236
>> Epoch 172 finished    ANN training loss 0.001213
>> Epoch 173 finished    ANN training loss 0.001180
>> Epoch 174 finished    ANN training loss 0.001178
>> Epoch 175 finished    ANN training loss 0.001168
>> Epoch 176 finished    ANN training loss 0.001131
>> Epoch 177 finished    ANN training loss 0.001278
>> Epoch 178 finished    ANN training loss 0.001182
>> Epoch 179 finished    ANN training loss 0.001241
>> Epoch 180 finished    ANN training loss 0.001137
>> Epoch 181 finished    ANN training loss 0.001138
>> Epoch 182 finished    ANN training loss 0.001084
>> Epoch 183 finished    ANN training loss 0.001062
>> Epoch 184 finished    ANN training loss 0.001165
>> Epoch 185 finished    ANN training loss 0.001086
>> Epoch 186 finished    ANN training loss 0.001056
>> Epoch 187 finished    ANN training loss 0.001265
>> Epoch 188 finished    ANN training loss 0.001136
>> Epoch 189 finished    ANN training loss 0.001021
>> Epoch 190 finished    ANN training loss 0.001006
>> Epoch 191 finished    ANN training loss 0.000993
>> Epoch 192 finished    ANN training loss 0.001082
>> Epoch 193 finished    ANN training loss 0.001087
>> Epoch 194 finished    ANN training loss 0.001013
>> Epoch 195 finished    ANN training loss 0.000969
>> Epoch 196 finished    ANN training loss 0.000955
>> Epoch 197 finished    ANN training loss 0.000914
>> Epoch 198 finished    ANN training loss 0.000934
>> Epoch 199 finished    ANN training loss 0.000903
[END] Fine tuning step
Done.
```

In [130…

```python
# 1-layer (2nd one tied)
acc2 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='relu',
                       dropout_p=0.2)
print('ACCURACY: ' + str(acc2))
```

```
[START] Pre-training step:
>> Epoch 1 finished      RBM Reconstruction error 59.534481
>> Epoch 2 finished      RBM Reconstruction error 85.250023
>> Epoch 3 finished      RBM Reconstruction error 54.699650
>> Epoch 4 finished      RBM Reconstruction error 80.817772
>> Epoch 5 finished      RBM Reconstruction error 80.662491
>> Epoch 6 finished      RBM Reconstruction error 43.503086
>> Epoch 7 finished      RBM Reconstruction error 55.378395
>> Epoch 8 finished      RBM Reconstruction error 43.733780
```

```
>> Epoch 9 finished       RBM Reconstruction error 57.075821
>> Epoch 10 finished      RBM Reconstruction error 72.376610
>> Epoch 11 finished      RBM Reconstruction error 63.547684
>> Epoch 12 finished      RBM Reconstruction error 50.875511
>> Epoch 13 finished      RBM Reconstruction error 55.329201
>> Epoch 14 finished      RBM Reconstruction error 63.671581
>> Epoch 15 finished      RBM Reconstruction error 44.878490
>> Epoch 16 finished      RBM Reconstruction error 53.757824
>> Epoch 17 finished      RBM Reconstruction error 46.167168
>> Epoch 18 finished      RBM Reconstruction error 72.337395
>> Epoch 19 finished      RBM Reconstruction error 69.765205
>> Epoch 20 finished      RBM Reconstruction error 46.501549
>> Epoch 21 finished      RBM Reconstruction error 64.065041
>> Epoch 22 finished      RBM Reconstruction error 65.597305
>> Epoch 23 finished      RBM Reconstruction error 62.805294
>> Epoch 24 finished      RBM Reconstruction error 60.807491
>> Epoch 25 finished      RBM Reconstruction error 45.779171
>> Epoch 26 finished      RBM Reconstruction error 66.202316
>> Epoch 27 finished      RBM Reconstruction error 57.785458
>> Epoch 28 finished      RBM Reconstruction error 62.540997
>> Epoch 29 finished      RBM Reconstruction error 61.863602
>> Epoch 30 finished      RBM Reconstruction error 53.859718
>> Epoch 31 finished      RBM Reconstruction error 68.695358
>> Epoch 32 finished      RBM Reconstruction error 64.742332
>> Epoch 33 finished      RBM Reconstruction error 53.195869
>> Epoch 34 finished      RBM Reconstruction error 80.075905
>> Epoch 35 finished      RBM Reconstruction error 73.219269
>> Epoch 36 finished      RBM Reconstruction error 66.706787
>> Epoch 37 finished      RBM Reconstruction error 68.994415
>> Epoch 38 finished      RBM Reconstruction error 62.665997
>> Epoch 39 finished      RBM Reconstruction error 56.164677
>> Epoch 40 finished      RBM Reconstruction error 79.310760
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished       ANN training loss 0.763332
>> Epoch 1 finished       ANN training loss 0.525281
>> Epoch 2 finished       ANN training loss 0.435748
>> Epoch 3 finished       ANN training loss 0.375584
>> Epoch 4 finished       ANN training loss 0.345087
>> Epoch 5 finished       ANN training loss 0.300132
>> Epoch 6 finished       ANN training loss 0.264026
>> Epoch 7 finished       ANN training loss 0.241888
>> Epoch 8 finished       ANN training loss 0.229965
>> Epoch 9 finished       ANN training loss 0.209940
>> Epoch 10 finished      ANN training loss 0.188133
>> Epoch 11 finished      ANN training loss 0.172643
>> Epoch 12 finished      ANN training loss 0.173558
>> Epoch 13 finished      ANN training loss 0.148977
>> Epoch 14 finished      ANN training loss 0.139720
>> Epoch 15 finished      ANN training loss 0.131389
>> Epoch 16 finished      ANN training loss 0.125240
>> Epoch 17 finished      ANN training loss 0.112581
>> Epoch 18 finished      ANN training loss 0.101163
>> Epoch 19 finished      ANN training loss 0.094257
>> Epoch 20 finished      ANN training loss 0.089537
>> Epoch 21 finished      ANN training loss 0.079658
>> Epoch 22 finished      ANN training loss 0.076691
>> Epoch 23 finished      ANN training loss 0.071429
>> Epoch 24 finished      ANN training loss 0.065621
>> Epoch 25 finished      ANN training loss 0.060549
>> Epoch 26 finished      ANN training loss 0.058332
>> Epoch 27 finished      ANN training loss 0.059031
>> Epoch 28 finished      ANN training loss 0.051245
>> Epoch 29 finished      ANN training loss 0.050937
>> Epoch 30 finished      ANN training loss 0.048095
```

```
              >> Epoch 31 finished    ANN training loss 0.041593
              >> Epoch 32 finished    ANN training loss 0.041362
              >> Epoch 33 finished    ANN training loss 0.037133
              >> Epoch 34 finished    ANN training loss 0.038192
              >> Epoch 35 finished    ANN training loss 0.035898
              >> Epoch 36 finished    ANN training loss 0.033459
              >> Epoch 37 finished    ANN training loss 0.030747
              >> Epoch 38 finished    ANN training loss 0.028680
              >> Epoch 39 finished    ANN training loss 0.028686
              >> Epoch 40 finished    ANN training loss 0.025504
              >> Epoch 41 finished    ANN training loss 0.025162
              >> Epoch 42 finished    ANN training loss 0.023140
              >> Epoch 43 finished    ANN training loss 0.023849
              >> Epoch 44 finished    ANN training loss 0.022095
              >> Epoch 45 finished    ANN training loss 0.021024
              >> Epoch 46 finished    ANN training loss 0.022923
              >> Epoch 47 finished    ANN training loss 0.018587
              >> Epoch 48 finished    ANN training loss 0.018969
              >> Epoch 49 finished    ANN training loss 0.017099
              >> Epoch 50 finished    ANN training loss 0.016660
              >> Epoch 51 finished    ANN training loss 0.016029
              >> Epoch 52 finished    ANN training loss 0.015447
              >> Epoch 53 finished    ANN training loss 0.014795
              >> Epoch 54 finished    ANN training loss 0.014225
              >> Epoch 55 finished    ANN training loss 0.013291
              >> Epoch 56 finished    ANN training loss 0.013169
              >> Epoch 57 finished    ANN training loss 0.013591
              >> Epoch 58 finished    ANN training loss 0.012515
              >> Epoch 59 finished    ANN training loss 0.012180
              >> Epoch 60 finished    ANN training loss 0.012045
              >> Epoch 61 finished    ANN training loss 0.011952
              >> Epoch 62 finished    ANN training loss 0.011128
              >> Epoch 63 finished    ANN training loss 0.011507
              >> Epoch 64 finished    ANN training loss 0.010470
              >> Epoch 65 finished    ANN training loss 0.010507
              >> Epoch 66 finished    ANN training loss 0.009612
              >> Epoch 67 finished    ANN training loss 0.009305
              >> Epoch 68 finished    ANN training loss 0.009109
              >> Epoch 69 finished    ANN training loss 0.009139
              >> Epoch 70 finished    ANN training loss 0.008798
              >> Epoch 71 finished    ANN training loss 0.008314
              >> Epoch 72 finished    ANN training loss 0.008170
              >> Epoch 73 finished    ANN training loss 0.007774
              >> Epoch 74 finished    ANN training loss 0.007651
              >> Epoch 75 finished    ANN training loss 0.007475
              >> Epoch 76 finished    ANN training loss 0.007846
              >> Epoch 77 finished    ANN training loss 0.007287
              >> Epoch 78 finished    ANN training loss 0.006672
              >> Epoch 79 finished    ANN training loss 0.006672
              >> Epoch 80 finished    ANN training loss 0.006548
              >> Epoch 81 finished    ANN training loss 0.006479
              >> Epoch 82 finished    ANN training loss 0.006301
              >> Epoch 83 finished    ANN training loss 0.006088
              >> Epoch 84 finished    ANN training loss 0.006256
              >> Epoch 85 finished    ANN training loss 0.005582
              >> Epoch 86 finished    ANN training loss 0.005451
              >> Epoch 87 finished    ANN training loss 0.005278
              >> Epoch 88 finished    ANN training loss 0.005468
              >> Epoch 89 finished    ANN training loss 0.005305
              >> Epoch 90 finished    ANN training loss 0.004851
              >> Epoch 91 finished    ANN training loss 0.004831
              >> Epoch 92 finished    ANN training loss 0.004898
              >> Epoch 93 finished    ANN training loss 0.004903
              >> Epoch 94 finished    ANN training loss 0.004671
              >> Epoch 95 finished    ANN training loss 0.004405
```

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>> Epoch 96 finished    ANN training loss 0.004505
>> Epoch 97 finished    ANN training loss 0.004372
>> Epoch 98 finished    ANN training loss 0.004399
>> Epoch 99 finished    ANN training loss 0.004075
>> Epoch 100 finished   ANN training loss 0.004117
>> Epoch 101 finished   ANN training loss 0.003964
>> Epoch 102 finished   ANN training loss 0.003997
>> Epoch 103 finished   ANN training loss 0.003944
>> Epoch 104 finished   ANN training loss 0.003803
>> Epoch 105 finished   ANN training loss 0.003541
>> Epoch 106 finished   ANN training loss 0.003883
>> Epoch 107 finished   ANN training loss 0.003565
>> Epoch 108 finished   ANN training loss 0.003408
>> Epoch 109 finished   ANN training loss 0.003632
>> Epoch 110 finished   ANN training loss 0.003324
>> Epoch 111 finished   ANN training loss 0.003244
>> Epoch 112 finished   ANN training loss 0.003390
>> Epoch 113 finished   ANN training loss 0.003247
>> Epoch 114 finished   ANN training loss 0.003244
>> Epoch 115 finished   ANN training loss 0.003483
>> Epoch 116 finished   ANN training loss 0.003206
>> Epoch 117 finished   ANN training loss 0.003095
>> Epoch 118 finished   ANN training loss 0.003063
>> Epoch 119 finished   ANN training loss 0.002977
>> Epoch 120 finished   ANN training loss 0.002961
>> Epoch 121 finished   ANN training loss 0.003031
>> Epoch 122 finished   ANN training loss 0.002868
>> Epoch 123 finished   ANN training loss 0.002750
>> Epoch 124 finished   ANN training loss 0.002707
>> Epoch 125 finished   ANN training loss 0.002577
>> Epoch 126 finished   ANN training loss 0.002704
>> Epoch 127 finished   ANN training loss 0.002563
>> Epoch 128 finished   ANN training loss 0.002466
>> Epoch 129 finished   ANN training loss 0.002592
>> Epoch 130 finished   ANN training loss 0.002325
>> Epoch 131 finished   ANN training loss 0.002457
>> Epoch 132 finished   ANN training loss 0.002363
>> Epoch 133 finished   ANN training loss 0.002357
>> Epoch 134 finished   ANN training loss 0.002243
>> Epoch 135 finished   ANN training loss 0.002257
>> Epoch 136 finished   ANN training loss 0.002157
>> Epoch 137 finished   ANN training loss 0.002104
>> Epoch 138 finished   ANN training loss 0.002062
>> Epoch 139 finished   ANN training loss 0.002001
>> Epoch 140 finished   ANN training loss 0.001991
>> Epoch 141 finished   ANN training loss 0.002012
>> Epoch 142 finished   ANN training loss 0.002100
>> Epoch 143 finished   ANN training loss 0.002046
>> Epoch 144 finished   ANN training loss 0.002020
>> Epoch 145 finished   ANN training loss 0.002004
>> Epoch 146 finished   ANN training loss 0.001956
>> Epoch 147 finished   ANN training loss 0.001970
>> Epoch 148 finished   ANN training loss 0.001885
>> Epoch 149 finished   ANN training loss 0.001848
>> Epoch 150 finished   ANN training loss 0.001829
>> Epoch 151 finished   ANN training loss 0.001806
>> Epoch 152 finished   ANN training loss 0.001783
>> Epoch 153 finished   ANN training loss 0.001804
>> Epoch 154 finished   ANN training loss 0.001730
>> Epoch 155 finished   ANN training loss 0.001682
>> Epoch 156 finished   ANN training loss 0.001677
>> Epoch 157 finished   ANN training loss 0.001678
>> Epoch 158 finished   ANN training loss 0.001599
>> Epoch 159 finished   ANN training loss 0.001556
>> Epoch 160 finished   ANN training loss 0.001517
```

```
>> Epoch 161 finished    ANN training loss 0.001528
>> Epoch 162 finished    ANN training loss 0.001502
>> Epoch 163 finished    ANN training loss 0.001528
>> Epoch 164 finished    ANN training loss 0.001457
>> Epoch 165 finished    ANN training loss 0.001438
>> Epoch 166 finished    ANN training loss 0.001478
>> Epoch 167 finished    ANN training loss 0.001591
>> Epoch 168 finished    ANN training loss 0.001414
>> Epoch 169 finished    ANN training loss 0.001399
>> Epoch 170 finished    ANN training loss 0.001342
>> Epoch 171 finished    ANN training loss 0.001292
>> Epoch 172 finished    ANN training loss 0.001315
>> Epoch 173 finished    ANN training loss 0.001254
>> Epoch 174 finished    ANN training loss 0.001339
>> Epoch 175 finished    ANN training loss 0.001294
>> Epoch 176 finished    ANN training loss 0.001250
>> Epoch 177 finished    ANN training loss 0.001319
>> Epoch 178 finished    ANN training loss 0.001277
>> Epoch 179 finished    ANN training loss 0.001322
>> Epoch 180 finished    ANN training loss 0.001242
>> Epoch 181 finished    ANN training loss 0.001423
>> Epoch 182 finished    ANN training loss 0.001335
>> Epoch 183 finished    ANN training loss 0.001194
>> Epoch 184 finished    ANN training loss 0.001182
>> Epoch 185 finished    ANN training loss 0.001166
>> Epoch 186 finished    ANN training loss 0.001147
>> Epoch 187 finished    ANN training loss 0.001116
>> Epoch 188 finished    ANN training loss 0.001222
>> Epoch 189 finished    ANN training loss 0.001184
>> Epoch 190 finished    ANN training loss 0.001219
>> Epoch 191 finished    ANN training loss 0.001239
>> Epoch 192 finished    ANN training loss 0.001267
>> Epoch 193 finished    ANN training loss 0.001086
>> Epoch 194 finished    ANN training loss 0.001169
>> Epoch 195 finished    ANN training loss 0.001106
>> Epoch 196 finished    ANN training loss 0.001059
>> Epoch 197 finished    ANN training loss 0.001040
>> Epoch 198 finished    ANN training loss 0.001076
>> Epoch 199 finished    ANN training loss 0.001118
[END] Fine tuning step
Done.
```

In [131...
```python
# 2-layer
acc3 = deep_belief_net(hidden_layers_structure=[100, 500],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='relu',
                       dropout_p=0.2)
print('ACCURACY: ' + str(acc3))
```

```
[START] Pre-training step:
>> Epoch 1 finished    RBM Reconstruction error 72.365013
>> Epoch 2 finished    RBM Reconstruction error 59.222641
>> Epoch 3 finished    RBM Reconstruction error 47.150780
>> Epoch 4 finished    RBM Reconstruction error 62.283836
>> Epoch 5 finished    RBM Reconstruction error 70.769768
>> Epoch 6 finished    RBM Reconstruction error 88.854065
>> Epoch 7 finished    RBM Reconstruction error 105.223846
>> Epoch 8 finished    RBM Reconstruction error 81.825027
>> Epoch 9 finished    RBM Reconstruction error 99.801979
>> Epoch 10 finished    RBM Reconstruction error 105.395134
```

```
>> Epoch 11 finished     RBM Reconstruction error 106.450813
>> Epoch 12 finished     RBM Reconstruction error 120.503769
>> Epoch 13 finished     RBM Reconstruction error 142.858063
>> Epoch 14 finished     RBM Reconstruction error 136.069275
>> Epoch 15 finished     RBM Reconstruction error 138.071564
>> Epoch 16 finished     RBM Reconstruction error 163.779938
>> Epoch 17 finished     RBM Reconstruction error 137.830490
>> Epoch 18 finished     RBM Reconstruction error 142.365677
>> Epoch 19 finished     RBM Reconstruction error 163.303696
>> Epoch 20 finished     RBM Reconstruction error 149.320694
>> Epoch 21 finished     RBM Reconstruction error 148.039291
>> Epoch 22 finished     RBM Reconstruction error 184.989883
>> Epoch 23 finished     RBM Reconstruction error 176.896439
>> Epoch 24 finished     RBM Reconstruction error 169.834915
>> Epoch 25 finished     RBM Reconstruction error 194.992401
>> Epoch 26 finished     RBM Reconstruction error 165.127625
>> Epoch 27 finished     RBM Reconstruction error 233.850433
>> Epoch 28 finished     RBM Reconstruction error 191.004135
>> Epoch 29 finished     RBM Reconstruction error 185.259842
>> Epoch 30 finished     RBM Reconstruction error 195.047379
>> Epoch 31 finished     RBM Reconstruction error 209.788315
>> Epoch 32 finished     RBM Reconstruction error 183.105759
>> Epoch 33 finished     RBM Reconstruction error 202.009186
>> Epoch 34 finished     RBM Reconstruction error 210.700470
>> Epoch 35 finished     RBM Reconstruction error 196.206360
>> Epoch 36 finished     RBM Reconstruction error 238.192230
>> Epoch 37 finished     RBM Reconstruction error 209.537338
>> Epoch 38 finished     RBM Reconstruction error 223.371460
>> Epoch 39 finished     RBM Reconstruction error 224.429733
>> Epoch 40 finished     RBM Reconstruction error 209.946213
>> Epoch 1 finished      RBM Reconstruction error 543.722107
>> Epoch 2 finished      RBM Reconstruction error 945.417053
>> Epoch 3 finished      RBM Reconstruction error 1408.460938
>> Epoch 4 finished      RBM Reconstruction error 869.075012
>> Epoch 5 finished      RBM Reconstruction error 1830.790161
>> Epoch 6 finished      RBM Reconstruction error 1394.925049
>> Epoch 7 finished      RBM Reconstruction error 1042.788940
>> Epoch 8 finished      RBM Reconstruction error 1294.259399
>> Epoch 9 finished      RBM Reconstruction error 1514.017456
>> Epoch 10 finished     RBM Reconstruction error 1582.412842
>> Epoch 11 finished     RBM Reconstruction error 1672.300049
>> Epoch 12 finished     RBM Reconstruction error 1427.102173
>> Epoch 13 finished     RBM Reconstruction error 1698.848877
>> Epoch 14 finished     RBM Reconstruction error 1872.556152
>> Epoch 15 finished     RBM Reconstruction error 1707.910278
>> Epoch 16 finished     RBM Reconstruction error 1949.795288
>> Epoch 17 finished     RBM Reconstruction error 1834.680664
>> Epoch 18 finished     RBM Reconstruction error 1822.474487
>> Epoch 19 finished     RBM Reconstruction error 1820.377197
>> Epoch 20 finished     RBM Reconstruction error 1463.044678
>> Epoch 21 finished     RBM Reconstruction error 1730.371216
>> Epoch 22 finished     RBM Reconstruction error 1857.521851
>> Epoch 23 finished     RBM Reconstruction error 1860.320312
>> Epoch 24 finished     RBM Reconstruction error 2130.277832
>> Epoch 25 finished     RBM Reconstruction error 2084.341553
>> Epoch 26 finished     RBM Reconstruction error 1890.499268
>> Epoch 27 finished     RBM Reconstruction error 2016.219482
>> Epoch 28 finished     RBM Reconstruction error 1806.375610
>> Epoch 29 finished     RBM Reconstruction error 2028.965942
>> Epoch 30 finished     RBM Reconstruction error 2061.619873
>> Epoch 31 finished     RBM Reconstruction error 1668.918945
>> Epoch 32 finished     RBM Reconstruction error 1845.810059
>> Epoch 33 finished     RBM Reconstruction error 1987.931274
>> Epoch 34 finished     RBM Reconstruction error 1939.995728
>> Epoch 35 finished     RBM Reconstruction error 1850.166992
```

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>> Epoch 36 finished      RBM Reconstruction error 1673.720581
>> Epoch 37 finished      RBM Reconstruction error 1684.961060
>> Epoch 38 finished      RBM Reconstruction error 1742.832520
>> Epoch 39 finished      RBM Reconstruction error 1804.985352
>> Epoch 40 finished      RBM Reconstruction error 1880.997803
[END] Pre-training step
[START] Fine tuning step:
>> Epoch 0 finished      ANN training loss 0.629258
>> Epoch 1 finished      ANN training loss 0.429317
>> Epoch 2 finished      ANN training loss 0.373101
>> Epoch 3 finished      ANN training loss 0.331970
>> Epoch 4 finished      ANN training loss 0.256877
>> Epoch 5 finished      ANN training loss 0.228462
>> Epoch 6 finished      ANN training loss 0.214413
>> Epoch 7 finished      ANN training loss 0.187619
>> Epoch 8 finished      ANN training loss 0.166027
>> Epoch 9 finished      ANN training loss 0.156356
>> Epoch 10 finished      ANN training loss 0.128994
>> Epoch 11 finished      ANN training loss 0.121721
>> Epoch 12 finished      ANN training loss 0.112294
>> Epoch 13 finished      ANN training loss 0.097649
>> Epoch 14 finished      ANN training loss 0.108019
>> Epoch 15 finished      ANN training loss 0.090055
>> Epoch 16 finished      ANN training loss 0.083347
>> Epoch 17 finished      ANN training loss 0.073408
>> Epoch 18 finished      ANN training loss 0.057931
>> Epoch 19 finished      ANN training loss 0.055644
>> Epoch 20 finished      ANN training loss 0.050590
>> Epoch 21 finished      ANN training loss 0.045046
>> Epoch 22 finished      ANN training loss 0.048840
>> Epoch 23 finished      ANN training loss 0.046229
>> Epoch 24 finished      ANN training loss 0.036579
>> Epoch 25 finished      ANN training loss 0.035739
>> Epoch 26 finished      ANN training loss 0.030570
>> Epoch 27 finished      ANN training loss 0.030835
>> Epoch 28 finished      ANN training loss 0.026816
>> Epoch 29 finished      ANN training loss 0.022123
>> Epoch 30 finished      ANN training loss 0.022224
>> Epoch 31 finished      ANN training loss 0.020581
>> Epoch 32 finished      ANN training loss 0.017104
>> Epoch 33 finished      ANN training loss 0.018226
>> Epoch 34 finished      ANN training loss 0.020100
>> Epoch 35 finished      ANN training loss 0.015253
>> Epoch 36 finished      ANN training loss 0.015878
>> Epoch 37 finished      ANN training loss 0.017658
>> Epoch 38 finished      ANN training loss 0.014966
>> Epoch 39 finished      ANN training loss 0.013493
>> Epoch 40 finished      ANN training loss 0.012097
>> Epoch 41 finished      ANN training loss 0.011389
>> Epoch 42 finished      ANN training loss 0.014139
>> Epoch 43 finished      ANN training loss 0.014045
>> Epoch 44 finished      ANN training loss 0.009428
>> Epoch 45 finished      ANN training loss 0.010329
>> Epoch 46 finished      ANN training loss 0.008312
>> Epoch 47 finished      ANN training loss 0.008388
>> Epoch 48 finished      ANN training loss 0.007799
>> Epoch 49 finished      ANN training loss 0.008398
>> Epoch 50 finished      ANN training loss 0.007820
>> Epoch 51 finished      ANN training loss 0.007457
>> Epoch 52 finished      ANN training loss 0.007676
>> Epoch 53 finished      ANN training loss 0.007810
>> Epoch 54 finished      ANN training loss 0.006855
>> Epoch 55 finished      ANN training loss 0.006284
>> Epoch 56 finished      ANN training loss 0.005421
>> Epoch 57 finished      ANN training loss 0.004774
```

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>> Epoch 58 finished    ANN training loss 0.005584
>> Epoch 59 finished    ANN training loss 0.004808
>> Epoch 60 finished    ANN training loss 0.004793
>> Epoch 61 finished    ANN training loss 0.004343
>> Epoch 62 finished    ANN training loss 0.003867
>> Epoch 63 finished    ANN training loss 0.003697
>> Epoch 64 finished    ANN training loss 0.003253
>> Epoch 65 finished    ANN training loss 0.003236
>> Epoch 66 finished    ANN training loss 0.003513
>> Epoch 67 finished    ANN training loss 0.004076
>> Epoch 68 finished    ANN training loss 0.003507
>> Epoch 69 finished    ANN training loss 0.003666
>> Epoch 70 finished    ANN training loss 0.003498
>> Epoch 71 finished    ANN training loss 0.003197
>> Epoch 72 finished    ANN training loss 0.002908
>> Epoch 73 finished    ANN training loss 0.004324
>> Epoch 74 finished    ANN training loss 0.003147
>> Epoch 75 finished    ANN training loss 0.002689
>> Epoch 76 finished    ANN training loss 0.002451
>> Epoch 77 finished    ANN training loss 0.002586
>> Epoch 78 finished    ANN training loss 0.002539
>> Epoch 79 finished    ANN training loss 0.002470
>> Epoch 80 finished    ANN training loss 0.002465
>> Epoch 81 finished    ANN training loss 0.002282
>> Epoch 82 finished    ANN training loss 0.002167
>> Epoch 83 finished    ANN training loss 0.001901
>> Epoch 84 finished    ANN training loss 0.001833
>> Epoch 85 finished    ANN training loss 0.002186
>> Epoch 86 finished    ANN training loss 0.002160
>> Epoch 87 finished    ANN training loss 0.001880
>> Epoch 88 finished    ANN training loss 0.002421
>> Epoch 89 finished    ANN training loss 0.002259
>> Epoch 90 finished    ANN training loss 0.001771
>> Epoch 91 finished    ANN training loss 0.001740
>> Epoch 92 finished    ANN training loss 0.001633
>> Epoch 93 finished    ANN training loss 0.001626
>> Epoch 94 finished    ANN training loss 0.001579
>> Epoch 95 finished    ANN training loss 0.001497
>> Epoch 96 finished    ANN training loss 0.001836
>> Epoch 97 finished    ANN training loss 0.001736
>> Epoch 98 finished    ANN training loss 0.001330
>> Epoch 99 finished    ANN training loss 0.001416
>> Epoch 100 finished   ANN training loss 0.001555
>> Epoch 101 finished   ANN training loss 0.001364
>> Epoch 102 finished   ANN training loss 0.001353
>> Epoch 103 finished   ANN training loss 0.001653
>> Epoch 104 finished   ANN training loss 0.001402
>> Epoch 105 finished   ANN training loss 0.001267
>> Epoch 106 finished   ANN training loss 0.001332
>> Epoch 107 finished   ANN training loss 0.001148
>> Epoch 108 finished   ANN training loss 0.001158
>> Epoch 109 finished   ANN training loss 0.001060
>> Epoch 110 finished   ANN training loss 0.001089
>> Epoch 111 finished   ANN training loss 0.001210
>> Epoch 112 finished   ANN training loss 0.001148
>> Epoch 113 finished   ANN training loss 0.001055
>> Epoch 114 finished   ANN training loss 0.001126
>> Epoch 115 finished   ANN training loss 0.001171
>> Epoch 116 finished   ANN training loss 0.000989
>> Epoch 117 finished   ANN training loss 0.000891
>> Epoch 118 finished   ANN training loss 0.000807
>> Epoch 119 finished   ANN training loss 0.000935
>> Epoch 120 finished   ANN training loss 0.001082
>> Epoch 121 finished   ANN training loss 0.001025
>> Epoch 122 finished   ANN training loss 0.001047
```

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>> Epoch 123 finished    ANN training loss 0.000896
>> Epoch 124 finished    ANN training loss 0.000831
>> Epoch 125 finished    ANN training loss 0.000701
>> Epoch 126 finished    ANN training loss 0.000712
>> Epoch 127 finished    ANN training loss 0.000609
>> Epoch 128 finished    ANN training loss 0.000599
>> Epoch 129 finished    ANN training loss 0.000632
>> Epoch 130 finished    ANN training loss 0.000606
>> Epoch 131 finished    ANN training loss 0.000753
>> Epoch 132 finished    ANN training loss 0.000767
>> Epoch 133 finished    ANN training loss 0.000644
>> Epoch 134 finished    ANN training loss 0.000725
>> Epoch 135 finished    ANN training loss 0.000890
>> Epoch 136 finished    ANN training loss 0.000667
>> Epoch 137 finished    ANN training loss 0.000659
>> Epoch 138 finished    ANN training loss 0.000660
>> Epoch 139 finished    ANN training loss 0.000583
>> Epoch 140 finished    ANN training loss 0.000650
>> Epoch 141 finished    ANN training loss 0.000640
>> Epoch 142 finished    ANN training loss 0.000774
>> Epoch 143 finished    ANN training loss 0.000590
>> Epoch 144 finished    ANN training loss 0.000728
>> Epoch 145 finished    ANN training loss 0.000583
>> Epoch 146 finished    ANN training loss 0.000546
>> Epoch 147 finished    ANN training loss 0.000508
>> Epoch 148 finished    ANN training loss 0.000740
>> Epoch 149 finished    ANN training loss 0.000626
>> Epoch 150 finished    ANN training loss 0.000530
>> Epoch 151 finished    ANN training loss 0.000709
>> Epoch 152 finished    ANN training loss 0.000679
>> Epoch 153 finished    ANN training loss 0.000624
>> Epoch 154 finished    ANN training loss 0.000562
>> Epoch 155 finished    ANN training loss 0.000548
>> Epoch 156 finished    ANN training loss 0.000413
>> Epoch 157 finished    ANN training loss 0.000440
>> Epoch 158 finished    ANN training loss 0.000397
>> Epoch 159 finished    ANN training loss 0.000483
>> Epoch 160 finished    ANN training loss 0.000650
>> Epoch 161 finished    ANN training loss 0.000528
>> Epoch 162 finished    ANN training loss 0.000450
>> Epoch 163 finished    ANN training loss 0.000446
>> Epoch 164 finished    ANN training loss 0.000472
>> Epoch 165 finished    ANN training loss 0.000417
>> Epoch 166 finished    ANN training loss 0.000424
>> Epoch 167 finished    ANN training loss 0.000383
>> Epoch 168 finished    ANN training loss 0.000440
>> Epoch 169 finished    ANN training loss 0.000372
>> Epoch 170 finished    ANN training loss 0.000369
>> Epoch 171 finished    ANN training loss 0.000340
>> Epoch 172 finished    ANN training loss 0.000459
>> Epoch 173 finished    ANN training loss 0.000389
>> Epoch 174 finished    ANN training loss 0.000318
>> Epoch 175 finished    ANN training loss 0.000348
>> Epoch 176 finished    ANN training loss 0.000397
>> Epoch 177 finished    ANN training loss 0.000457
>> Epoch 178 finished    ANN training loss 0.000349
>> Epoch 179 finished    ANN training loss 0.000331
>> Epoch 180 finished    ANN training loss 0.000295
>> Epoch 181 finished    ANN training loss 0.000296
>> Epoch 182 finished    ANN training loss 0.000256
>> Epoch 183 finished    ANN training loss 0.000309
>> Epoch 184 finished    ANN training loss 0.000256
>> Epoch 185 finished    ANN training loss 0.000314
>> Epoch 186 finished    ANN training loss 0.000301
>> Epoch 187 finished    ANN training loss 0.000290
```

```
>> Epoch 188 finished    ANN training loss 0.000301
>> Epoch 189 finished    ANN training loss 0.000274
>> Epoch 190 finished    ANN training loss 0.000272
>> Epoch 191 finished    ANN training loss 0.000251
>> Epoch 192 finished    ANN training loss 0.000276
>> Epoch 193 finished    ANN training loss 0.000258
>> Epoch 194 finished    ANN training loss 0.000236
>> Epoch 195 finished    ANN training loss 0.000221
>> Epoch 196 finished    ANN training loss 0.000230
>> Epoch 197 finished    ANN training loss 0.000191
>> Epoch 198 finished    ANN training loss 0.000245
>> Epoch 199 finished    ANN training loss 0.000186
[END] Fine tuning step
Done.
```

In [132...

```python
# 3-layer
acc4 = deep_belief_net(hidden_layers_structure=[500, 200, 300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='relu',
                       dropout_p=0.2)
print('ACCURACY: ' + str(acc4))
```

```
[START] Pre-training step:
>> Epoch 1 finished     RBM Reconstruction error 49.976906
>> Epoch 2 finished     RBM Reconstruction error 39.193859
>> Epoch 3 finished     RBM Reconstruction error 60.738590
>> Epoch 4 finished     RBM Reconstruction error 40.068138
>> Epoch 5 finished     RBM Reconstruction error 36.381416
>> Epoch 6 finished     RBM Reconstruction error 27.695738
>> Epoch 7 finished     RBM Reconstruction error 31.692266
>> Epoch 8 finished     RBM Reconstruction error 22.926769
>> Epoch 9 finished     RBM Reconstruction error 26.704662
>> Epoch 10 finished    RBM Reconstruction error 50.590729
>> Epoch 11 finished    RBM Reconstruction error 43.781010
>> Epoch 12 finished    RBM Reconstruction error 44.857765
>> Epoch 13 finished    RBM Reconstruction error 27.561945
>> Epoch 14 finished    RBM Reconstruction error 41.463779
>> Epoch 15 finished    RBM Reconstruction error 26.169941
>> Epoch 16 finished    RBM Reconstruction error 37.501453
>> Epoch 17 finished    RBM Reconstruction error 29.253149
>> Epoch 18 finished    RBM Reconstruction error 33.052502
>> Epoch 19 finished    RBM Reconstruction error 32.312393
>> Epoch 20 finished    RBM Reconstruction error 31.389067
>> Epoch 21 finished    RBM Reconstruction error 21.296227
>> Epoch 22 finished    RBM Reconstruction error 26.187267
>> Epoch 23 finished    RBM Reconstruction error 39.849171
>> Epoch 24 finished    RBM Reconstruction error 29.634150
>> Epoch 25 finished    RBM Reconstruction error 40.812279
>> Epoch 26 finished    RBM Reconstruction error 42.959599
>> Epoch 27 finished    RBM Reconstruction error 37.425438
>> Epoch 28 finished    RBM Reconstruction error 30.140884
>> Epoch 29 finished    RBM Reconstruction error 33.903286
>> Epoch 30 finished    RBM Reconstruction error 34.914486
>> Epoch 31 finished    RBM Reconstruction error 26.608259
>> Epoch 32 finished    RBM Reconstruction error 37.091728
>> Epoch 33 finished    RBM Reconstruction error 39.818306
>> Epoch 34 finished    RBM Reconstruction error 35.382458
>> Epoch 35 finished    RBM Reconstruction error 38.537567
>> Epoch 36 finished    RBM Reconstruction error 38.315800
>> Epoch 37 finished    RBM Reconstruction error 33.588486
```

```
>> Epoch 38 finished      RBM Reconstruction error 35.622738
>> Epoch 39 finished      RBM Reconstruction error 48.679142
>> Epoch 40 finished      RBM Reconstruction error 35.314220
>> Epoch 1 finished       RBM Reconstruction error 180.476089
>> Epoch 2 finished       RBM Reconstruction error 225.567886
>> Epoch 3 finished       RBM Reconstruction error 176.648941
>> Epoch 4 finished       RBM Reconstruction error 180.464844
>> Epoch 5 finished       RBM Reconstruction error 264.905151
>> Epoch 6 finished       RBM Reconstruction error 196.203964
>> Epoch 7 finished       RBM Reconstruction error 277.745758
>> Epoch 8 finished       RBM Reconstruction error 271.667419
>> Epoch 9 finished       RBM Reconstruction error 338.135193
>> Epoch 10 finished      RBM Reconstruction error 307.140900
>> Epoch 11 finished      RBM Reconstruction error 297.623383
>> Epoch 12 finished      RBM Reconstruction error 277.545502
>> Epoch 13 finished      RBM Reconstruction error 390.069855
>> Epoch 14 finished      RBM Reconstruction error 337.505005
>> Epoch 15 finished      RBM Reconstruction error 350.964569
>> Epoch 16 finished      RBM Reconstruction error 329.049530
>> Epoch 17 finished      RBM Reconstruction error 360.897736
>> Epoch 18 finished      RBM Reconstruction error 334.683167
>> Epoch 19 finished      RBM Reconstruction error 379.955933
>> Epoch 20 finished      RBM Reconstruction error 422.093048
>> Epoch 21 finished      RBM Reconstruction error 406.426361
>> Epoch 22 finished      RBM Reconstruction error 390.894775
>> Epoch 23 finished      RBM Reconstruction error 415.112335
>> Epoch 24 finished      RBM Reconstruction error 404.142120
>> Epoch 25 finished      RBM Reconstruction error 474.451324
>> Epoch 26 finished      RBM Reconstruction error 381.996643
>> Epoch 27 finished      RBM Reconstruction error 425.734283
>> Epoch 28 finished      RBM Reconstruction error 412.326019
>> Epoch 29 finished      RBM Reconstruction error 437.668915
>> Epoch 30 finished      RBM Reconstruction error 437.440704
>> Epoch 31 finished      RBM Reconstruction error 444.260712
>> Epoch 32 finished      RBM Reconstruction error 491.722565
>> Epoch 33 finished      RBM Reconstruction error 417.637238
>> Epoch 34 finished      RBM Reconstruction error 461.670319
>> Epoch 35 finished      RBM Reconstruction error 483.363373
>> Epoch 36 finished      RBM Reconstruction error 484.862549
>> Epoch 37 finished      RBM Reconstruction error 491.169739
>> Epoch 38 finished      RBM Reconstruction error 495.012146
>> Epoch 39 finished      RBM Reconstruction error 423.387970
>> Epoch 40 finished      RBM Reconstruction error 428.286041
>> Epoch 1 finished       RBM Reconstruction error 2934.960938
>> Epoch 2 finished       RBM Reconstruction error 5030.222656
>> Epoch 3 finished       RBM Reconstruction error 6104.488281
>> Epoch 4 finished       RBM Reconstruction error 8854.126953
>> Epoch 5 finished       RBM Reconstruction error 8653.106445
>> Epoch 6 finished       RBM Reconstruction error 11379.825195
>> Epoch 7 finished       RBM Reconstruction error 12570.495117
>> Epoch 8 finished       RBM Reconstruction error 13759.152344
>> Epoch 9 finished       RBM Reconstruction error 14209.438477
>> Epoch 10 finished      RBM Reconstruction error 19051.427734
>> Epoch 11 finished      RBM Reconstruction error 17329.632812
>> Epoch 12 finished      RBM Reconstruction error 20735.753906
>> Epoch 13 finished      RBM Reconstruction error 21200.845703
>> Epoch 14 finished      RBM Reconstruction error 21008.546875
>> Epoch 15 finished      RBM Reconstruction error 25367.699219
>> Epoch 16 finished      RBM Reconstruction error 24598.609375
>> Epoch 17 finished      RBM Reconstruction error 25335.789062
>> Epoch 18 finished      RBM Reconstruction error 27463.523438
>> Epoch 19 finished      RBM Reconstruction error 27770.546875
>> Epoch 20 finished      RBM Reconstruction error 26145.570312
>> Epoch 21 finished      RBM Reconstruction error 27050.550781
>> Epoch 22 finished      RBM Reconstruction error 26424.250000
```

```
            >> Epoch 23 finished     RBM Reconstruction error 28078.681641
            >> Epoch 24 finished     RBM Reconstruction error 27537.992188
            >> Epoch 25 finished     RBM Reconstruction error 27005.591797
            >> Epoch 26 finished     RBM Reconstruction error 30757.904297
            >> Epoch 27 finished     RBM Reconstruction error 26916.005859
            >> Epoch 28 finished     RBM Reconstruction error 29909.357422
            >> Epoch 29 finished     RBM Reconstruction error 28604.019531
            >> Epoch 30 finished     RBM Reconstruction error 31249.949219
            >> Epoch 31 finished     RBM Reconstruction error 31314.730469
            >> Epoch 32 finished     RBM Reconstruction error 30333.994141
            >> Epoch 33 finished     RBM Reconstruction error 29864.095703
            >> Epoch 34 finished     RBM Reconstruction error 32253.339844
            >> Epoch 35 finished     RBM Reconstruction error 31815.750000
            >> Epoch 36 finished     RBM Reconstruction error 31666.410156
            >> Epoch 37 finished     RBM Reconstruction error 32227.132812
            >> Epoch 38 finished     RBM Reconstruction error 32283.505859
            >> Epoch 39 finished     RBM Reconstruction error 34032.593750
            >> Epoch 40 finished     RBM Reconstruction error 32990.699219
            [END] Pre-training step
            [START] Fine tuning step:
            >> Epoch 0 finished      ANN training loss 0.911362
            >> Epoch 1 finished      ANN training loss 0.604457
            >> Epoch 2 finished      ANN training loss 0.474070
            >> Epoch 3 finished      ANN training loss 0.381709
            >> Epoch 4 finished      ANN training loss 0.319585
            >> Epoch 5 finished      ANN training loss 0.259750
            >> Epoch 6 finished      ANN training loss 0.199558
            >> Epoch 7 finished      ANN training loss 0.184357
            >> Epoch 8 finished      ANN training loss 0.173245
            >> Epoch 9 finished      ANN training loss 0.129617
            >> Epoch 10 finished     ANN training loss 0.109312
            >> Epoch 11 finished     ANN training loss 0.108086
            >> Epoch 12 finished     ANN training loss 0.092397
            >> Epoch 13 finished     ANN training loss 0.084253
            >> Epoch 14 finished     ANN training loss 0.071196
            >> Epoch 15 finished     ANN training loss 0.060142
            >> Epoch 16 finished     ANN training loss 0.042267
            >> Epoch 17 finished     ANN training loss 0.040446
            >> Epoch 18 finished     ANN training loss 0.039330
            >> Epoch 19 finished     ANN training loss 0.032213
            >> Epoch 20 finished     ANN training loss 0.034231
            >> Epoch 21 finished     ANN training loss 0.028234
            >> Epoch 22 finished     ANN training loss 0.023979
            >> Epoch 23 finished     ANN training loss 0.019085
            >> Epoch 24 finished     ANN training loss 0.015687
            >> Epoch 25 finished     ANN training loss 0.015189
            >> Epoch 26 finished     ANN training loss 0.012369
            >> Epoch 27 finished     ANN training loss 0.014277
            >> Epoch 28 finished     ANN training loss 0.016163
            >> Epoch 29 finished     ANN training loss 0.011858
            >> Epoch 30 finished     ANN training loss 0.008881
            >> Epoch 31 finished     ANN training loss 0.009524
            >> Epoch 32 finished     ANN training loss 0.006928
            >> Epoch 33 finished     ANN training loss 0.006045
            >> Epoch 34 finished     ANN training loss 0.007251
            >> Epoch 35 finished     ANN training loss 0.009590
            >> Epoch 36 finished     ANN training loss 0.010445
            >> Epoch 37 finished     ANN training loss 0.005224
            >> Epoch 38 finished     ANN training loss 0.006138
            >> Epoch 39 finished     ANN training loss 0.007295
            >> Epoch 40 finished     ANN training loss 0.004161
            >> Epoch 41 finished     ANN training loss 0.004550
            >> Epoch 42 finished     ANN training loss 0.003801
            >> Epoch 43 finished     ANN training loss 0.003151
            >> Epoch 44 finished     ANN training loss 0.002783
```

```
>> Epoch 45 finished    ANN training loss 0.001878
>> Epoch 46 finished    ANN training loss 0.002939
>> Epoch 47 finished    ANN training loss 0.001946
>> Epoch 48 finished    ANN training loss 0.001881
>> Epoch 49 finished    ANN training loss 0.003158
>> Epoch 50 finished    ANN training loss 0.001818
>> Epoch 51 finished    ANN training loss 0.002380
>> Epoch 52 finished    ANN training loss 0.001708
>> Epoch 53 finished    ANN training loss 0.002065
>> Epoch 54 finished    ANN training loss 0.001669
>> Epoch 55 finished    ANN training loss 0.001336
>> Epoch 56 finished    ANN training loss 0.001100
>> Epoch 57 finished    ANN training loss 0.001639
>> Epoch 58 finished    ANN training loss 0.001091
>> Epoch 59 finished    ANN training loss 0.002623
>> Epoch 60 finished    ANN training loss 0.001415
>> Epoch 61 finished    ANN training loss 0.001250
>> Epoch 62 finished    ANN training loss 0.003194
>> Epoch 63 finished    ANN training loss 0.001029
>> Epoch 64 finished    ANN training loss 0.001206
>> Epoch 65 finished    ANN training loss 0.001571
>> Epoch 66 finished    ANN training loss 0.000823
>> Epoch 67 finished    ANN training loss 0.001452
>> Epoch 68 finished    ANN training loss 0.000900
>> Epoch 69 finished    ANN training loss 0.001003
>> Epoch 70 finished    ANN training loss 0.000786
>> Epoch 71 finished    ANN training loss 0.000559
>> Epoch 72 finished    ANN training loss 0.000766
>> Epoch 73 finished    ANN training loss 0.000535
>> Epoch 74 finished    ANN training loss 0.001324
>> Epoch 75 finished    ANN training loss 0.000568
>> Epoch 76 finished    ANN training loss 0.000446
>> Epoch 77 finished    ANN training loss 0.000498
>> Epoch 78 finished    ANN training loss 0.000413
>> Epoch 79 finished    ANN training loss 0.000584
>> Epoch 80 finished    ANN training loss 0.000383
>> Epoch 81 finished    ANN training loss 0.000410
>> Epoch 82 finished    ANN training loss 0.000377
>> Epoch 83 finished    ANN training loss 0.000473
>> Epoch 84 finished    ANN training loss 0.000485
>> Epoch 85 finished    ANN training loss 0.000427
>> Epoch 86 finished    ANN training loss 0.000452
>> Epoch 87 finished    ANN training loss 0.000637
>> Epoch 88 finished    ANN training loss 0.000297
>> Epoch 89 finished    ANN training loss 0.000217
>> Epoch 90 finished    ANN training loss 0.000573
>> Epoch 91 finished    ANN training loss 0.000367
>> Epoch 92 finished    ANN training loss 0.000492
>> Epoch 93 finished    ANN training loss 0.000587
>> Epoch 94 finished    ANN training loss 0.000256
>> Epoch 95 finished    ANN training loss 0.000250
>> Epoch 96 finished    ANN training loss 0.000207
>> Epoch 97 finished    ANN training loss 0.000202
>> Epoch 98 finished    ANN training loss 0.000232
>> Epoch 99 finished    ANN training loss 0.000192
>> Epoch 100 finished   ANN training loss 0.000242
>> Epoch 101 finished   ANN training loss 0.000321
>> Epoch 102 finished   ANN training loss 0.000187
>> Epoch 103 finished   ANN training loss 0.000168
>> Epoch 104 finished   ANN training loss 0.000418
>> Epoch 105 finished   ANN training loss 0.000531
>> Epoch 106 finished   ANN training loss 0.000366
>> Epoch 107 finished   ANN training loss 0.000313
>> Epoch 108 finished   ANN training loss 0.000286
>> Epoch 109 finished   ANN training loss 0.000196
```

```
>> Epoch 110 finished    ANN training loss 0.000224
>> Epoch 111 finished    ANN training loss 0.000352
>> Epoch 112 finished    ANN training loss 0.000328
>> Epoch 113 finished    ANN training loss 0.000191
>> Epoch 114 finished    ANN training loss 0.000180
>> Epoch 115 finished    ANN training loss 0.000125
>> Epoch 116 finished    ANN training loss 0.000097
>> Epoch 117 finished    ANN training loss 0.000133
>> Epoch 118 finished    ANN training loss 0.000189
>> Epoch 119 finished    ANN training loss 0.000162
>> Epoch 120 finished    ANN training loss 0.000135
>> Epoch 121 finished    ANN training loss 0.000114
>> Epoch 122 finished    ANN training loss 0.000105
>> Epoch 123 finished    ANN training loss 0.000098
>> Epoch 124 finished    ANN training loss 0.000085
>> Epoch 125 finished    ANN training loss 0.000197
>> Epoch 126 finished    ANN training loss 0.000093
>> Epoch 127 finished    ANN training loss 0.000074
>> Epoch 128 finished    ANN training loss 0.000100
>> Epoch 129 finished    ANN training loss 0.001002
>> Epoch 130 finished    ANN training loss 0.000132
>> Epoch 131 finished    ANN training loss 0.000183
>> Epoch 132 finished    ANN training loss 0.000185
>> Epoch 133 finished    ANN training loss 0.000232
>> Epoch 134 finished    ANN training loss 0.000079
>> Epoch 135 finished    ANN training loss 0.000088
>> Epoch 136 finished    ANN training loss 0.000097
>> Epoch 137 finished    ANN training loss 0.000116
>> Epoch 138 finished    ANN training loss 0.000078
>> Epoch 139 finished    ANN training loss 0.000074
>> Epoch 140 finished    ANN training loss 0.000153
>> Epoch 141 finished    ANN training loss 0.000051
>> Epoch 142 finished    ANN training loss 0.000045
>> Epoch 143 finished    ANN training loss 0.000048
>> Epoch 144 finished    ANN training loss 0.000051
>> Epoch 145 finished    ANN training loss 0.000080
>> Epoch 146 finished    ANN training loss 0.000079
>> Epoch 147 finished    ANN training loss 0.000043
>> Epoch 148 finished    ANN training loss 0.000034
>> Epoch 149 finished    ANN training loss 0.000042
>> Epoch 150 finished    ANN training loss 0.000042
>> Epoch 151 finished    ANN training loss 0.000136
>> Epoch 152 finished    ANN training loss 0.000193
>> Epoch 153 finished    ANN training loss 0.000091
>> Epoch 154 finished    ANN training loss 0.000147
>> Epoch 155 finished    ANN training loss 0.000091
>> Epoch 156 finished    ANN training loss 0.000239
>> Epoch 157 finished    ANN training loss 0.000163
>> Epoch 158 finished    ANN training loss 0.000071
>> Epoch 159 finished    ANN training loss 0.000062
>> Epoch 160 finished    ANN training loss 0.000055
>> Epoch 161 finished    ANN training loss 0.000058
>> Epoch 162 finished    ANN training loss 0.000099
>> Epoch 163 finished    ANN training loss 0.000056
>> Epoch 164 finished    ANN training loss 0.000047
>> Epoch 165 finished    ANN training loss 0.000042
>> Epoch 166 finished    ANN training loss 0.000055
>> Epoch 167 finished    ANN training loss 0.000059
>> Epoch 168 finished    ANN training loss 0.000044
>> Epoch 169 finished    ANN training loss 0.000068
>> Epoch 170 finished    ANN training loss 0.000049
>> Epoch 171 finished    ANN training loss 0.000059
>> Epoch 172 finished    ANN training loss 0.000048
>> Epoch 173 finished    ANN training loss 0.000059
>> Epoch 174 finished    ANN training loss 0.000065
```

```
>> Epoch 175 finished    ANN training loss 0.000062
>> Epoch 176 finished    ANN training loss 0.000048
>> Epoch 177 finished    ANN training loss 0.000059
>> Epoch 178 finished    ANN training loss 0.000102
>> Epoch 179 finished    ANN training loss 0.000066
>> Epoch 180 finished    ANN training loss 0.000049
>> Epoch 181 finished    ANN training loss 0.000048
>> Epoch 182 finished    ANN training loss 0.000054
>> Epoch 183 finished    ANN training loss 0.000033
>> Epoch 184 finished    ANN training loss 0.000050
>> Epoch 185 finished    ANN training loss 0.000054
>> Epoch 186 finished    ANN training loss 0.000053
>> Epoch 187 finished    ANN training loss 0.000047
>> Epoch 188 finished    ANN training loss 0.000031
>> Epoch 189 finished    ANN training loss 0.000041
>> Epoch 190 finished    ANN training loss 0.000074
>> Epoch 191 finished    ANN training loss 0.000069
>> Epoch 192 finished    ANN training loss 0.000039
>> Epoch 193 finished    ANN training loss 0.000027
>> Epoch 194 finished    ANN training loss 0.000044
>> Epoch 195 finished    ANN training loss 0.000042
>> Epoch 196 finished    ANN training loss 0.000080
>> Epoch 197 finished    ANN training loss 0.000035
>> Epoch 198 finished    ANN training loss 0.000022
>> Epoch 199 finished    ANN training loss 0.000021
[END] Fine tuning step
Done.
```

In [133...

```python
# Create bar graph
plt.clf()
objects = ('[200]', '[300]', '[100, 500]', '[500, 200, 300]')
y_pos = np.arange(len(objects))
performance = [0.9, 0.92, 0.905, 0.905]
plt.bar(y_pos, performance, align='center', alpha=0.5)
plt.xticks(y_pos, objects, rotation=30)
plt.xlabel('Settings')
plt.ylabel('Accuracy')
plt.title('Benchmark 1 Settings')

plt.show()
plt.clf()
```
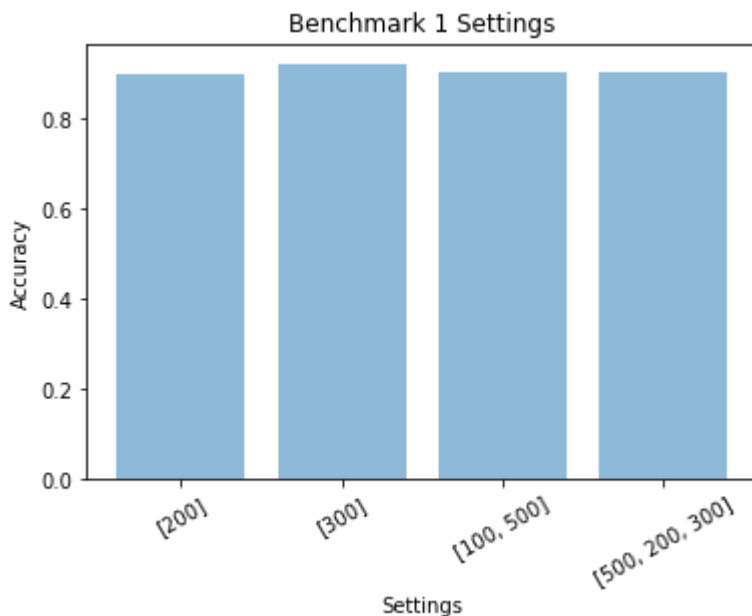
Benchmark 2:

Take the best performing one from benchmark 1 and test with the sigmoidal activation function and various dropouts.

In [1]:
```python
# Sigmoidal activation, dropout = 0
acc1 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='sigmoid',
                       dropout_p=0.)
print('ACCURACY: ' + str(acc1))
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-1-f90a10155deb> in <module>
      1 # Sigmoidal activation, dropout = 0
----> 2 acc1 = deep_belief_net(hidden_layers_structure=[300],
      3                        learning_rate_rbm=0.05,
      4                        learning_rate=0.1,
      5                        n_epochs_rbm=40,

NameError: name 'deep_belief_net' is not defined
```

In [ ]:
```python
# Sigmoidal activation, dropout = 0.1
acc2 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='sigmoid',
                       dropout_p=0.1)
print('ACCURACY: ' + str(acc2))
```

In [ ]:
```python
# Sigmoidal activation, dropout = 0.2
acc3 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='sigmoid',
                       dropout_p=0.2)
print('ACCURACY: ' + str(acc3))
```

```python
In [ ]:   # Sigmoidal activation, dropout=0.3
          acc4 = deep_belief_net(hidden_layers_structure=[300],
                                  learning_rate_rbm=0.05,
                                  learning_rate=0.1,
                                  n_epochs_rbm=40,
                                  n_iter_backprop=200,
                                  batch_size=32,
                                  activation_function='sigmoid',
                                  dropout_p=0.3)
          print('ACCURACY: ' + str(acc4))
```

```python
In [ ]:   # Sigmoidal activation, dropout=0.4
          acc5 = deep_belief_net(hidden_layers_structure=[300],
                                  learning_rate_rbm=0.05,
                                  learning_rate=0.1,
                                  n_epochs_rbm=40,
                                  n_iter_backprop=200,
                                  batch_size=32,
                                  activation_function='sigmoid',
                                  dropout_p=0.4)
          print('ACCURACY: ' + str(acc5))
```

```python
In [ ]:   # Sigmoidal activation, dropout=0.5
          acc6 = deep_belief_net(hidden_layers_structure=[300],
                                  learning_rate_rbm=0.05,
                                  learning_rate=0.1,
                                  n_epochs_rbm=40,
                                  n_iter_backprop=200,
                                  batch_size=32,
                                  activation_function='sigmoid',
                                  dropout_p=0.5)
          print('ACCURACY: ' + str(acc6))
```

```python
In [ ]:   # Sigmoidal activation, dropout=0.6
          acc7 = deep_belief_net(hidden_layers_structure=[300],
                                  learning_rate_rbm=0.05,
                                  learning_rate=0.1,
                                  n_epochs_rbm=40,
                                  n_iter_backprop=200,
                                  batch_size=32,
                                  activation_function='sigmoid',
                                  dropout_p=0.6)
          print('ACCURACY: ' + str(acc7))
```

```python
In [ ]:   # Sigmoidal activation, dropout=0.7
          acc8 = deep_belief_net(hidden_layers_structure=[300],
                                  learning_rate_rbm=0.05,
                                  learning_rate=0.1,
                                  n_epochs_rbm=40,
                                  n_iter_backprop=200,
                                  batch_size=32,
                                  activation_function='sigmoid',
                                  dropout_p=0.7)
          print('ACCURACY: ' + str(acc8))
```

```python
In [ ]:  # Sigmoidal activation, dropout=0.8
         acc9 = deep_belief_net(hidden_layers_structure=[300],
                                learning_rate_rbm=0.05,
                                learning_rate=0.1,
                                n_epochs_rbm=40,
                                n_iter_backprop=200,
                                batch_size=32,
                                activation_function='sigmoid',
                                dropout_p=0.8)
         print('ACCURACY: ' + str(acc9))
```

```python
In [ ]:  # Sigmoidal activation, dropout=0.9
         acc10 = deep_belief_net(hidden_layers_structure=[300],
                                 learning_rate_rbm=0.05,
                                 learning_rate=0.1,
                                 n_epochs_rbm=40,
                                 n_iter_backprop=200,
                                 batch_size=32,
                                 activation_function='sigmoid',
                                 dropout_p=0.9)
         print('ACCURACY: ' + str(acc10))
```

```python
In [ ]:  # Sigmoidal activation, dropout=1
         acc11 = deep_belief_net(hidden_layers_structure=[300],
                                 learning_rate_rbm=0.05,
                                 learning_rate=0.1,
                                 n_epochs_rbm=40,
                                 n_iter_backprop=200,
                                 batch_size=32,
                                 activation_function='sigmoid',
                                 dropout_p=1.)
         print('ACCURACY: ' + str(acc11))
```

```python
In [ ]:  # Create bar graph
         plt.clf()
         objects = ('0', '0.1', '0.2', '0.3', '0.4', '0.5', '0.6', '0.7', '0.8', '0.9',
         y_pos = np.arange(len(objects))
         performance = [0.885, 0.92, 0.895, 0.885, 0.885, 0.875, 0.88, 0.85, 0.845, 0.
         plt.bar(y_pos, performance, align='center', alpha=1)
         plt.xticks(y_pos, objects, rotation=30)
         plt.xlabel('dropout_p')
         plt.ylabel('Accuracy')
         plt.title('Benchmark 2, sigmoid Settings')

         plt.show()
         plt.clf()
```

Benchmark 2 (ReLu)

Same benchmark as benchmark 2 but with the ReLu function

```python
In [ ]:   # ReLu, dropout = 0
          acc0 = deep_belief_net(hidden_layers_structure=[300],
                                 learning_rate_rbm=0.05,
                                 learning_rate=0.1,
                                 n_epochs_rbm=40,
                                 n_iter_backprop=200,
                                 batch_size=32,
                                 activation_function='relu',
                                 dropout_p=0.)
          print('ACCURACY: ' + str(acc0))
```

```python
In [ ]:   # ReLu, dropout = 0.1
          acc1 = deep_belief_net(hidden_layers_structure=[300],
                                 learning_rate_rbm=0.05,
                                 learning_rate=0.1,
                                 n_epochs_rbm=40,
                                 n_iter_backprop=200,
                                 batch_size=32,
                                 activation_function='relu',
                                 dropout_p=0.1)
          print('ACCURACY: ' + str(acc1))
```

```python
In [ ]:   # ReLu, dropout = 0.3
          acc3 = deep_belief_net(hidden_layers_structure=[300],
                                 learning_rate_rbm=0.05,
                                 learning_rate=0.1,
                                 n_epochs_rbm=40,
                                 n_iter_backprop=200,
                                 batch_size=32,
                                 activation_function='relu',
                                 dropout_p=0.3)
          print('ACCURACY: ' + str(acc3))
```

```python
In [ ]:   # ReLu, dropout = 0.4
          acc4 = deep_belief_net(hidden_layers_structure=[300],
                                 learning_rate_rbm=0.05,
                                 learning_rate=0.1,
                                 n_epochs_rbm=40,
                                 n_iter_backprop=200,
                                 batch_size=32,
                                 activation_function='relu',
                                 dropout_p=0.4)
          print('ACCURACY: ' + str(acc4))
```

```python
In [ ]:   # ReLu, dropout = 0.5
          acc5 = deep_belief_net(hidden_layers_structure=[300],
                                 learning_rate_rbm=0.05,
                                 learning_rate=0.1,
                                 n_epochs_rbm=40,
                                 n_iter_backprop=200,
                                 batch_size=32,
                                 activation_function='relu',
                                 dropout_p=0.5)
          print('ACCURACY: ' + str(acc5))
```

In [ ]:
```python
# ReLu, dropout = 0.6
acc6 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='relu',
                       dropout_p=0.6)
print('ACCURACY: ' + str(acc6))
```

In [ ]:
```python
# ReLu, dropout = 0.7
acc7 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='relu',
                       dropout_p=0.7)
print('ACCURACY: ' + str(acc7))
```

In [ ]:
```python
# ReLu, dropout = 0.8
acc8 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='relu',
                       dropout_p=0.8)
print('ACCURACY: ' + str(acc8))
```

In [ ]:
```python
# ReLu, dropout = 0.9
acc9 = deep_belief_net(hidden_layers_structure=[300],
                       learning_rate_rbm=0.05,
                       learning_rate=0.1,
                       n_epochs_rbm=40,
                       n_iter_backprop=200,
                       batch_size=32,
                       activation_function='relu',
                       dropout_p=0.9)
print('ACCURACY: ' + str(acc9))
```

In [ ]:
```python
# ReLu, dropout = 1
acc10 = deep_belief_net(hidden_layers_structure=[300],
                        learning_rate_rbm=0.05,
                        learning_rate=0.1,
                        n_epochs_rbm=40,
                        n_iter_backprop=200,
                        batch_size=32,
                        activation_function='relu',
                        dropout_p=1.)
print('ACCURACY: ' + str(acc10))
```

```
In [ ]:    # Create bar graph
           plt.clf()
           objects = ('0', '0.1', '0.2', '0.3', '0.4', '0.5', '0.6', '0.7', '0.8', '0.9',
           y_pos = np.arange(len(objects))
           performance = [0.88, 0.89, 0.92, 0.90, 0.89, 0.89, 0.87, 0.90, 0.80, 0.155, 0
           plt.bar(y_pos, performance, align='center', alpha=1)
           plt.xticks(y_pos, objects, rotation=30)
           plt.xlabel('dropout_p')
           plt.ylabel('Accuracy')
           plt.title('Benchmark 2, relu Settings')

           plt.show()
           plt.clf()
```

SVM Tests:

```
In [ ]:    # Import SVM modules
           from sklearn.svm import LinearSVC
           from sklearn.tree import DecisionTreeClassifier
           from sklearn.ensemble import AdaBoostClassifier
           from sklearn.ensemble import RandomForestClassifier
           from sklearn.svm import SVC
```

```
In [ ]:    # Linear SVC Performance
           def linSVC(C):
               X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2,
               clf = LinearSVC(C=C)
               clf.fit(X_train, Y_train)
               Y_pred = clf.predict(X_test)
               correct = 0
               for i in range(0, len(Y_test)):
                   if Y_pred[i] == Y_test[i]:
                       correct += 1
               return float(correct / len(Y_test))
```

```
In [ ]:    linSVC_acc1 = linSVC(C=0.1)
           print('ACCURACY: ' + str(linSVC_acc1))
```

```
In [ ]:    linSVC_acc2 = linSVC(C=1.)
           print('ACCURACY: ' + str(linSVC_acc2))
```

```
In [ ]:    linSVC_acc3 = linSVC(C=10)
           print('ACCURACY: ' + str(linSVC_acc3))
```

```
In [ ]:    linSVC_acc4 = linSVC(C=100)
           print('ACCURACY: ' + str(linSVC_acc4))
```

In [ ]:
```python
# Decision Tree Performance
def decision_tree():
    X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2,
    clf = DecisionTreeClassifier()
    clf.fit(X_train, Y_train)
    Y_pred = clf.predict(X_test)
    correct = 0
    for i in range(0, len(Y_test)):
        if Y_pred[i] == Y_test[i]:
            correct += 1
    return float(correct / len(Y_test))

decision_tree_acc = decision_tree()
print('ACCURACY: ' + str(decision_tree_acc))
```

In [ ]:
```python
# Boosting Performance
def boosting():
    X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2,
    clf = AdaBoostClassifier()
    clf.fit(X_train, Y_train)
    Y_pred = clf.predict(X_test)
    correct = 0
    for i in range(0, len(Y_test)):
        if Y_pred[i] == Y_test[i]:
            correct += 1
    return float(correct / len(Y_test))

boosting_acc = boosting()
print('ACCURACY: ' + str(boosting_acc))
```

In [ ]:
```python
# Random Forest Performance
def random_forest():
    X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2,
    clf = RandomForestClassifier()
    clf.fit(X_train, Y_train)
    Y_pred = clf.predict(X_test)
    correct = 0
    for i in range(0, len(Y_test)):
        if Y_pred[i] == Y_test[i]:
            correct += 1
    return float(correct / len(Y_test))

random_forest_acc = random_forest()
print('ACCURACY: ' + str(random_forest_acc))
```

In [ ]:
```python
# SVC, 3rd degree rbf
def svc_classifier(C):
    X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2,
    clf = SVC(C=C, max_iter=-1)
    clf.fit(X_train, Y_train)
    Y_pred = clf.predict(X_test)
    correct = 0
    for i in range(0, len(Y_test)):
        if Y_pred[i] == Y_test[i]:
            correct += 1
    return float(correct / len(Y_test))
```

```
In [ ]:   svc1_acc = svc_classifier(0.1)
```

```
In [ ]:   svc2_acc = svc_classifier(1.0)
          print('ACCURACY: ' + str(svc2_acc))
```

```
In [ ]:   svc3_acc = svc_classifier(10.)
          print('ACCURACY: ' + str(svc3_acc))
```

```
In [ ]:   svc4_acc = svc_classifier(100.)
          print('ACCURACY: ' + str(svc4_acc))
```

```
In [ ]:   # Create bar graph
          plt.clf()
          objects = ('ReLu (0.2)', 'Sigmoid (0.1)',
                     'LinearSVC (0.1)', 'LinearSVC (1)', 'LinearSVC (10)', 'LinearSVC (
                     'DecisionTree', 'AdaBoost', 'RandomForest',
                     'SVC (0.1)', 'SVC (1)', 'SVC (10)', 'SVC (100)')

          y_pos = np.arange(len(objects))
          performance = [0.92, 0.92,
                         0.86, 0.845, 0.84, 0.84,
                         0.665, 0.395, 0.795,
                         0.115, 0.805, 0.885, 0.895]
          plt.bar(y_pos, performance, align='center', alpha=1)
          plt.xticks(y_pos, objects, rotation=90)
          plt.xlabel('Model')
          plt.ylabel('Accuracy, Performance')
          plt.title('Model Comparisons')

          plt.show()
          plt.clf()
```

```
In [ ]:
```