3b

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0.1 CSc 84020 Neural Networks and Deep Learning, Spring 2021

Homework 2 (3b)

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0.2 Import Libraries & Load Data

Import libraries and define classes

[ ]:
```
from google.colab import drive
import glob
import os
import numpy as np
import time
import random as rn
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
from itertools import cycle
import pylab
from sklearn.model_selection import train_test_split
from sklearn.metrics import roc_curve, auc, roc_auc_score,␣
↪precision_recall_curve
from sklearn.metrics import classification_report as cr
from sklearn.metrics import confusion_matrix as cm
import tensorflow as tf
from tensorflow.keras.callbacks import Callback
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Input, Dense, BatchNormalization, Dropout,␣
↪LeakyReLU
from tensorflow.keras.regularizers import L2
from tensorflow.keras.initializers import GlorotNormal
from tensorflow.keras.optimizers import SGD, Adam
from tensorflow.keras.utils import to_categorical, plot_model

print(tf.__version__)
```

2.4.1

[ ]:
```
drive.mount('/content/drive')
```

Mounted at /content/drive

[ ]:
```
start_total_time = time.time()
```

[ ]:
```
# Different options for classes: selection to be set with constants

# critters (6 classes)
critters = ['ant', 'bee', 'butterfly', 'mosquito', 'scorpion',
            'spider']

# birds (6 classes)
birds = ['bird', 'duck', 'flamingo', 'owl', 'parrot',
            'penguin']

# ocean animals (8 classes)
ocean_animals = ['crab', 'dolphin', 'fish', 'lobster', 'octopus',
            'sea%20turtle', 'shark', 'whale']

# land mammals (22 classes)
land_mammals = ['bear', 'camel', 'cat', 'cow', 'dog',
            'elephant', 'giraffe', 'hedgehog', 'horse', 'kangaroo',
            'lion', 'monkey', 'mouse', 'panda', 'pig',
            'rabbit', 'raccoon', 'rhinoceros', 'sheep', 'squirrel',
            'tiger', 'zebra']

# all animals (47 classes)
all_animals = ['ant', 'bat', 'bear', 'bee', 'bird',
            'butterfly', 'camel', 'cat', 'cow', 'crab',
            'crocodile', 'dog', 'dolphin', 'duck', 'elephant',
            'fish', 'flamingo', 'frog', 'giraffe', 'hedgehog',
            'horse', 'kangaroo', 'lion', 'lobster', 'monkey',
            'mosquito', 'mouse', 'octopus', 'owl', 'panda',
            'parrot', 'penguin', 'pig', 'rabbit', 'raccoon',
            'rhinoceros', 'scorpion', 'sea%20turtle', 'shark', 'sheep',
            'snail', 'snake', 'spider', 'squirrel',  'tiger',
            'whale', 'zebra']
```

Set constants

[ ]:
```
classes = critters
CLASS_SAMPLE_MAX = 25000
DATA_DIR = '/content/drive/My Drive/Colab Notebooks/NNDL/HW2/data/'
```

Load data

[ ]:
```
def load_bitmaps(data_dir=DATA_DIR, class_sample_max=CLASS_SAMPLE_MAX):
    class_files = []
    for c in classes:
        print(c, end=' ')
        class_files.append(os.path.join(DATA_DIR, c + '.npy'))
    class_files.sort()

    X = np.empty([0,784])
    y = np.empty([0])

    print()
    for id, class_file in enumerate(class_files):
        print(id, end=' ')
        loaded_data = np.load(class_file)
        loaded_data = loaded_data[0:CLASS_SAMPLE_MAX, :]
        labels = np.full(loaded_data.shape[0],id)

        X = np.concatenate((X, loaded_data), axis = 0)
        y = np.append(y, labels)

    return X, y
```

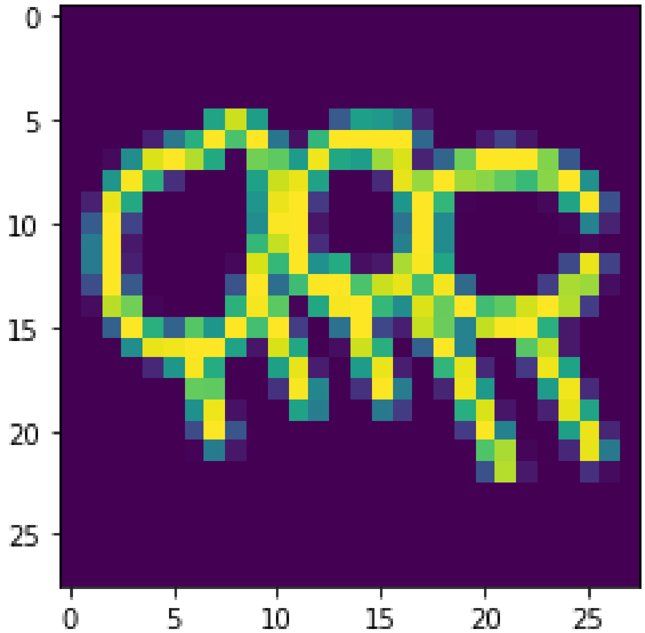
[ ]:
```
start = time.time()
X, y = load_bitmaps()
print(f'\nLoading time: %.3f' % int(time.time() - start), 'seconds')
print(y[-CLASS_SAMPLE_MAX-5:-CLASS_SAMPLE_MAX+5])
```

```
ant bee butterfly mosquito scorpion spider
0 1 2 3 4 5
Loading time: 10.000 seconds
[4. 4. 4. 4. 4. 5. 5. 5. 5. 5.]
```

Data example

[ ]:
```
id = 20000
plt.imshow(X[id].reshape(28,28))
print(classes[int(y[id].item())])
```

```
ant
```




```
[ ]: X[20000]
```

```
[ ]: array([  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0., 149., 236., 142.,   0.,   0.,   0.,  73.,
            144., 137., 113.,  21.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              0.,   0.,   0.,   0.,   0.,   0.,   0.,  22., 101., 160., 255.,
            182., 255.,  99.,  11., 169., 255., 255., 255., 255.,  86.,   0.,
              0.,  19.,  49.,  15.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
              6., 125., 242., 255., 226., 155.,   2., 201., 192., 141., 250.,
            153., 143., 218., 241.,  25.,  83., 199., 255., 255., 255., 207.,
             70.,   0.,   0.,   0.,   0.,   0., 133., 253., 163.,  35.,   0.,
              0.,   0., 146., 235., 248., 147.,   0.,   0.,  30., 246., 216.,
            255., 219., 210., 193., 172., 210., 255., 129.,   0.,   0.,   0.,
             23., 247., 154.,   0.,   0.,   0.,   0.,   0., 133., 248., 255.,
```

```
 43.,   0.,   0.,   0., 134., 255., 169.,   2.,   0.,   0.,   0.,
  5., 149., 254.,  64.,   0.,   0.,  74., 255.,  51.,   0.,   0.,
  0.,   0.,   0., 125., 254., 255.,  15.,   0.,   0.,   0.,  97.,
255., 123.,   0.,   0.,   0.,   0.,   0.,   3., 113.,  25.,   0.,
  0., 106., 255.,  17.,   0.,   0.,   0.,   0.,   0., 170., 233.,
255.,  32.,   0.,   0.,   0., 110., 255., 123.,   0.,   0.,   0.,
  0.,   0.,   0.,   5.,   0.,   0.,   0., 104., 255.,  22.,   0.,
  0.,   0.,   0.,   5., 240., 170., 255., 129., 157.,  10.,  17.,
223., 253., 150.,   0.,   0.,   0.,   0.,   0.,  57., 248.,  49.,
  0.,   0.,  60., 255.,  71.,   0.,   0.,   0.,   0.,  65., 255.,
 92., 176., 254., 255., 183., 235., 247., 179., 251.,  88.,   0.,
  0.,   0.,  46., 223., 217.,   9.,   0.,   0.,   8., 229., 201.,
  3.,   0.,   0.,   0., 164., 252., 191.,   4., 153., 252., 255.,
170., 125., 242., 196., 255., 177., 192., 238., 255., 226.,  45.,
  0.,   0.,   0.,   0.,  78., 255., 162.,  81., 188., 134., 255.,
179., 255.,  46.,   0.,  96., 255.,  55.,  21., 233., 197., 113.,
232., 253., 255., 162.,  17.,   0.,   0.,   0.,   0.,   0.,   0.,
125., 247., 250., 255., 255., 147.,  15., 240., 153.,   0.,   9.,
236., 160.,   0.,  80., 255., 113.,   0.,   1., 189., 232.,  17.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,  28., 135., 253., 158.,
  0.,   0., 145., 246.,  19.,   0., 140., 248.,  21.,   0., 168.,
246.,  28.,   0.,  42., 249., 148.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0., 195., 193.,   0.,   0.,  37., 253., 117.,
  0.,  36., 254., 108.,   0.,  26., 249., 137.,   0.,   0., 140.,
250.,  31.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0., 128.,
249.,  12.,   0.,   0., 147., 108.,   0.,   0., 103.,  45.,   0.,
  0., 160., 241.,  15.,   0.,  23., 245., 149.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,  59., 255.,  68.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,  44., 254., 112.,   0.,
  0., 145., 248.,  27.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  2., 106.,  16.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0., 185., 223.,   3.,   0.,  28., 247., 103.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,  63., 227.,
 17.,   0.,   0.,  35.,   7.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
  0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,   0.,
```

```
       0.,   0.,   0.])
```

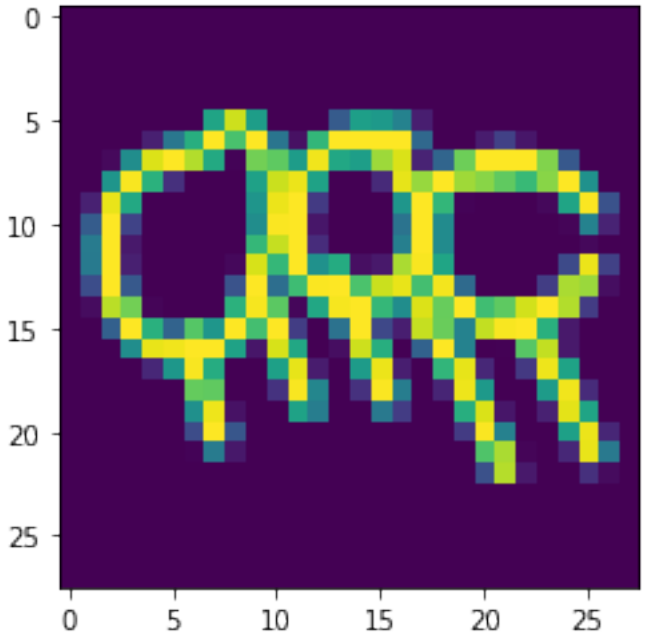
0.3 Normalization

[ ]:
```
# Normalization to range [0, 1]
X = X / 255
```

Data example after normalization

[ ]:
```
id = 20000
plt.imshow(X[id].reshape(28,28))
print(classes[int(y[id].item())])
```

```
ant
```



[ ]:
```
X[20000]
```

[ ]:
```
array([0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
```

```
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.58431373, 0.9254902 , 0.55686275,
0.        , 0.        , 0.        , 0.28627451, 0.56470588,
0.5372549 , 0.44313725, 0.08235294, 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.08627451, 0.39607843, 0.62745098,
1.        , 0.71372549, 1.        , 0.38823529, 0.04313725,
0.6627451 , 1.        , 1.        , 1.        , 1.        ,
0.3372549 , 0.        , 0.        , 0.0745098 , 0.19215686,
0.05882353, 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.02352941, 0.49019608,
0.94901961, 1.        , 0.88627451, 0.60784314, 0.00784314,
0.78823529, 0.75294118, 0.55294118, 0.98039216, 0.6       ,
0.56078431, 0.85490196, 0.94509804, 0.09803922, 0.3254902 ,
0.78039216, 1.        , 1.        , 1.        , 0.81176471,
0.2745098 , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.52156863, 0.99215686, 0.63921569, 0.1372549 ,
0.        , 0.        , 0.        , 0.57254902, 0.92156863,
0.97254902, 0.57647059, 0.        , 0.        , 0.11764706,
0.96470588, 0.84705882, 1.        , 0.85882353, 0.82352941,
0.75686275, 0.6745098 , 0.82352941, 1.        , 0.50588235,
0.        , 0.        , 0.        , 0.09019608, 0.96862745,
0.60392157, 0.        , 0.        , 0.        , 0.        ,
0.        , 0.52156863, 0.97254902, 1.        , 0.16862745,
0.        , 0.        , 0.        , 0.5254902 , 1.        ,
```

```
0.6627451 , 0.00784314, 0.        , 0.        , 0.        ,
0.01960784, 0.58431373, 0.99607843, 0.25098039, 0.        ,
0.        , 0.29019608, 1.        , 0.2       , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.49019608,
0.99607843, 1.        , 0.05882353, 0.        , 0.        ,
0.        , 0.38039216, 1.        , 0.48235294, 0.        ,
0.        , 0.        , 0.        , 0.        , 0.01176471,
0.44313725, 0.09803922, 0.        , 0.        , 0.41568627,
1.        , 0.06666667, 0.        , 0.        , 0.        ,
0.        , 0.        , 0.66666667, 0.91372549, 1.        ,
0.1254902 , 0.        , 0.        , 0.        , 0.43137255,
1.        , 0.48235294, 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.01960784, 0.        ,
0.        , 0.        , 0.40784314, 1.        , 0.08627451,
0.        , 0.        , 0.        , 0.        , 0.01960784,
0.94117647, 0.66666667, 1.        , 0.50588235, 0.61568627,
0.03921569, 0.06666667, 0.8745098 , 0.99215686, 0.58823529,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.22352941, 0.97254902, 0.19215686, 0.        , 0.        ,
0.23529412, 1.        , 0.27843137, 0.        , 0.        ,
0.        , 0.        , 0.25490196, 1.        , 0.36078431,
0.69019608, 0.99607843, 1.        , 0.71764706, 0.92156863,
0.96862745, 0.70196078, 0.98431373, 0.34509804, 0.        ,
0.        , 0.        , 0.18039216, 0.8745098 , 0.85098039,
0.03529412, 0.        , 0.        , 0.03137255, 0.89803922,
0.78823529, 0.01176471, 0.        , 0.        , 0.        ,
0.64313725, 0.98823529, 0.74901961, 0.01568627, 0.6       ,
0.98823529, 1.        , 0.66666667, 0.49019608, 0.94901961,
0.76862745, 1.        , 0.69411765, 0.75294118, 0.93333333,
1.        , 0.88627451, 0.17647059, 0.        , 0.        ,
0.        , 0.        , 0.30588235, 1.        , 0.63529412,
0.31764706, 0.7372549 , 0.5254902 , 1.        , 0.70196078,
1.        , 0.18039216, 0.        , 0.37647059, 1.        ,
0.21568627, 0.08235294, 0.91372549, 0.77254902, 0.44313725,
0.90980392, 0.99215686, 1.        , 0.63529412, 0.06666667,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.49019608, 0.96862745, 0.98039216, 1.        ,
1.        , 0.57647059, 0.05882353, 0.94117647, 0.6       ,
0.        , 0.03529412, 0.9254902 , 0.62745098, 0.        ,
0.31372549, 1.        , 0.44313725, 0.        , 0.00392157,
0.74117647, 0.90980392, 0.06666667, 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.10980392, 0.52941176, 0.99215686, 0.61960784, 0.        ,
0.        , 0.56862745, 0.96470588, 0.0745098 , 0.        ,
0.54901961, 0.97254902, 0.08235294, 0.        , 0.65882353,
0.96470588, 0.10980392, 0.        , 0.16470588, 0.97647059,
0.58039216, 0.        , 0.        , 0.        , 0.        ,
```

```
0.        , 0.        , 0.        , 0.        , 0.        ,
0.76470588, 0.75686275, 0.        , 0.        , 0.14509804,
0.99215686, 0.45882353, 0.        , 0.14117647, 0.99607843,
0.42352941, 0.        , 0.10196078, 0.97647059, 0.5372549 ,
0.        , 0.        , 0.54901961, 0.98039216, 0.12156863,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.50196078, 0.97647059,
0.04705882, 0.        , 0.        , 0.57647059, 0.42352941,
0.        , 0.        , 0.40392157, 0.17647059, 0.        ,
0.        , 0.62745098, 0.94509804, 0.05882353, 0.        ,
0.09019608, 0.96078431, 0.58431373, 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.23137255, 1.        , 0.26666667, 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.17254902,
0.99607843, 0.43921569, 0.        , 0.        , 0.56862745,
0.97254902, 0.10588235, 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.00784314,
0.41568627, 0.0627451 , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.7254902 , 0.8745098 ,
0.01176471, 0.        , 0.10980392, 0.96862745, 0.40392157,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.24705882, 0.89019608, 0.06666667, 0.        ,
0.        , 0.1372549 , 0.02745098, 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
```

```
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        ])
```

0.4 Multi-layer Perceptron Model

Set constants and parameters

[ ]:
```
RANDOM_STATE = 84020

NUM_CLASSES = len(classes)
INPUT_DIM = X.shape[1]

TEST_SIZE = 0.1
VALIDATION_SPLIT = 0.22

VERBOSE = 0          # choose from: [0, 1]
BATCH_SIZE = 128     # choose from: [32, 64, 128]
EPOCHS = 30          # choose from: [30, 40]
```

[ ]:
```
sgd = SGD(lr=0.01, decay=1e-6, momentum=0.9, nesterov=True)
optimizer = sgd      # choose from: [sgd, Adam(lr=0.001, epsilon=1e-06)]

activation = 'relu' # choose from: 'relu', LeakyReLU(alpha=0.01)

# dropout = 0         # choose from: [0, 0.1, 0.2, 0.4]

# l2_val = 0          # choose from: [0, 0.1, 0.0005]

loss = 'sparse_categorical_crossentropy'

metrics = ['sparse_categorical_accuracy']
```

Split X and y into train and test sets

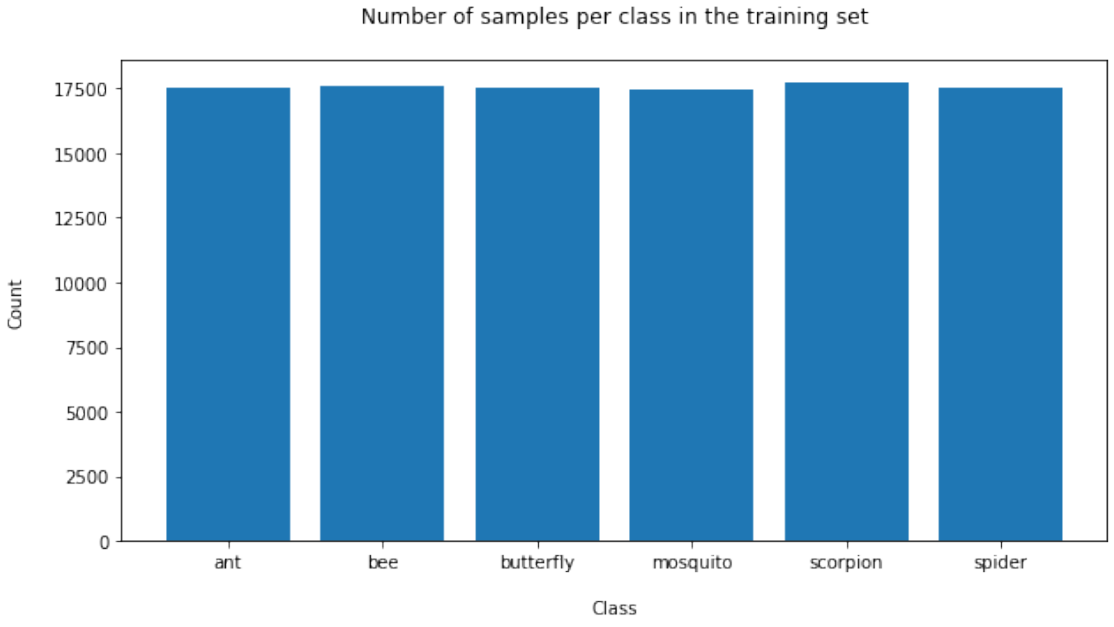
[ ]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y,
                                                    test_size=TEST_SIZE,
                                                    shuffle=True,
                                                    random_state=RANDOM_STATE)
```

[ ]:
```
print('Number of classes:', NUM_CLASSES)
print('Input dimension:', INPUT_DIM)
print('Total dataset \t\tX:\t', X.shape, '\t\ty:\t', y.shape)
print(100 * (1 - TEST_SIZE), '% train \t\tX_train:', X_train.shape,␣
↪'\t\ty_train:',y_train.shape)
print(100 * TEST_SIZE, '% test \t\tX_test:\t', X_test.shape, '\t\ty_test:
↪\t',y_test.shape)
```

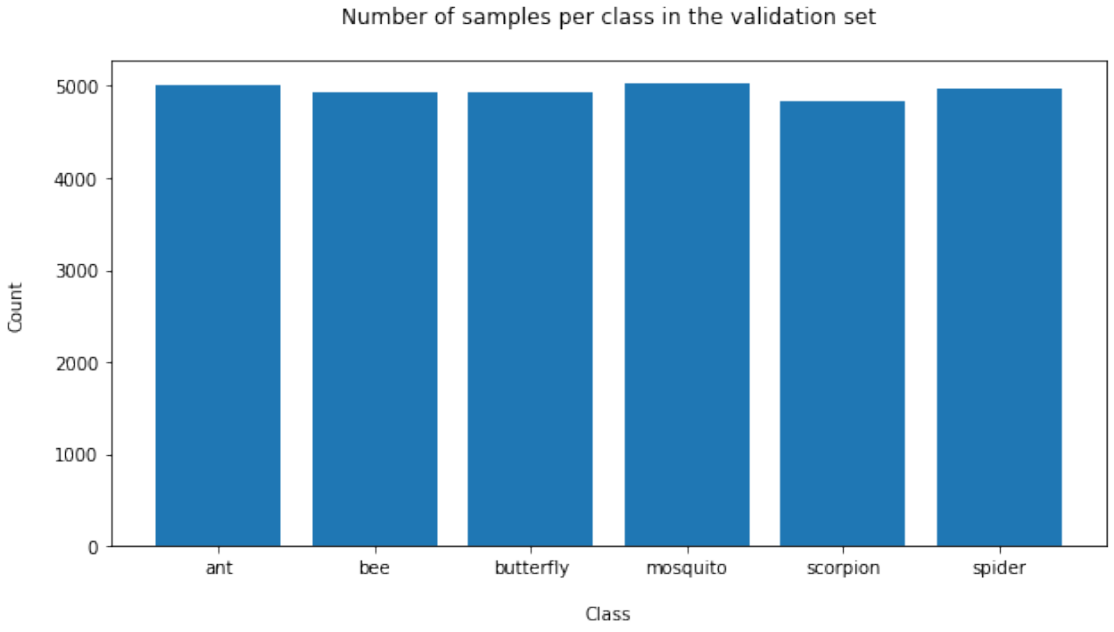
```
Number of classes: 6
Input dimension: 784
Total dataset           X:       (150000, 784)          y:       (150000,)
90.0 % train            X_train: (135000, 784)          y_train: (135000,)
10.0 % test             X_test:  (15000, 784)           y_test:  (15000,)
```

[ ]:
```
# Classification: split the dataset into train, validate and test
Xtrain, Xtest, Ytrain, Ytest = train_test_split(X, y, test_size=TEST_SIZE,␣
↪random_state=RANDOM_STATE)
Xtrain, Xval, Ytrain, Yval = train_test_split(Xtrain, Ytrain,␣
↪test_size=VALIDATION_SPLIT, random_state=RANDOM_STATE)
```

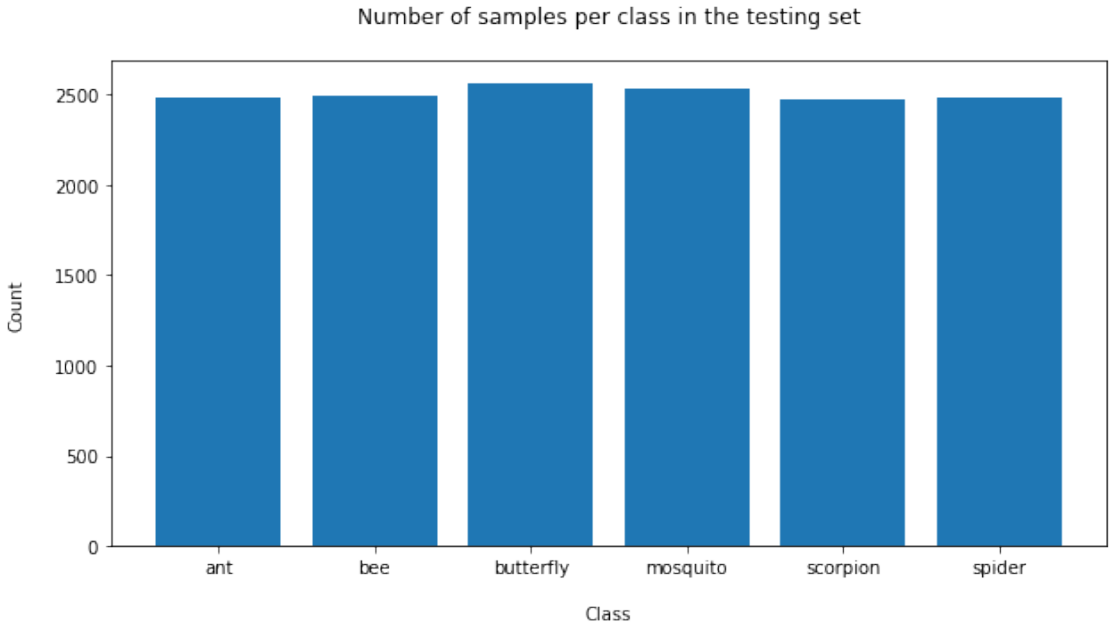
[ ]:
```
# Training data
unique, counts = np.unique(Ytrain, return_counts=True)
pylab.rcParams['figure.figsize'] = (10,5)
plt.bar(critters, counts)
plt.title('Number of samples per class in the training set\n')
plt.ylabel('Count\n')
plt.xlabel('\nClass')
plt.show()
```



[ ]:
```
# Validation data
unique, counts = np.unique(Yval, return_counts=True)
pylab.rcParams['figure.figsize'] = (10,5)
plt.bar(critters, counts)
plt.title('Number of samples per class in the validation set\n')
plt.ylabel('Count\n')
plt.xlabel('\nClass')
plt.show()
```



[ ]:
```
# Testing data
unique, counts = np.unique(Ytest, return_counts=True)
pylab.rcParams['figure.figsize'] = (10,5)
plt.bar(critters, counts)
plt.title('Number of samples per class in the testing set\n')
plt.ylabel('Count\n')
plt.xlabel('\nClass')
plt.show()
```



Model functions

[ ]:
```
def build_model(dropout, l2_val, activation=activation):

    if type(activation) != str:
        activ = 'LeakyReLU'
    else:
        activ = activation

    model = Sequential(name='Multi_Layer_Perceptron_{}_{}DO_{}L2'.format(activ,␣
↪dropout, l2_val))
    model.add(Input(shape=(INPUT_DIM,),
                    name='Input'))
    model.add(Dense(32, activation=activation,
                    kernel_initializer='glorot_normal',
                    bias_initializer='zeros',
                    kernel_regularizer=L2(l2_val),
                    name='Dense1_{}'.format(activ)))
    model.add(BatchNormalization(name='BatchNormalization1'))
    model.add(Dense(32, activation=activation,
                    kernel_initializer='glorot_normal',
                    bias_initializer='zeros',
                    kernel_regularizer=L2(l2_val),
                    name='Dense2_{}'.format(activ)))
    model.add(Dropout(dropout, name='Dropout_{}'.format(dropout)))
    model.add(Dense(32, activation=activation,
```

```
                    kernel_initializer='glorot_normal',
                    bias_initializer='zeros',
                    kernel_regularizer=L2(l2_val),
                    name='Dense3_{}'.format(activ)))
    model.add(Dense(32, activation=activation,
                    kernel_initializer='glorot_normal',
                    bias_initializer='zeros',
                    kernel_regularizer=L2(l2_val),
                    name='Dense4_{}'.format(activ)))
    model.add(BatchNormalization(name='BatchNormalization2'))
    model.add(Dense(16, activation=activation,
                    kernel_initializer='glorot_normal',
                    bias_initializer='zeros',
                    kernel_regularizer=L2(l2_val),
                    name='Dense5_{}'.format(activ)))
    model.add(Dense(NUM_CLASSES, activation='softmax',
                    name='Output'))

    return model
```

[ ]:
```
def compile_model(model, loss=loss, optimizer=optimizer, metrics=metrics):
    model.compile(loss=loss, optimizer=optimizer, metrics=metrics)
```

[ ]:
```
def fit_model(model):
    start_time = time.time()
    history = model.fit(X_train, y_train,
                        epochs=EPOCHS,
                        batch_size=BATCH_SIZE,
                        validation_split=VALIDATION_SPLIT,
                        verbose=VERBOSE)
    time_taken = time.time() - start_time
    print(f'Total train time for {EPOCHS} epochs = %.3f' % time_taken,␣
 ↪'seconds\n\n')

    return history
```

[ ]:
```
def evaluate_model(model):
    score = model.evaluate(X_test, y_test,
                           batch_size=BATCH_SIZE,
                           verbose=VERBOSE)

    return score
```

[ ]:
```
def predict_model(model):
    y_pred = model.predict(X_test, batch_size=BATCH_SIZE)

    return y_pred
```

[ ]:
```
def plot_accuracy(history, score, metrics=metrics):
    plt.plot(history.history[metrics[0]])
    plt.plot(history.history['val_'+metrics[0]])

    plt.title('Training and validation accuracy')
    plt.ylabel('Accuracy')
    plt.xlabel('Epoch')
    plt.yticks(ticks=[0.5, 0.6, 0.7, 0.8, 0.9, 1.0])
    plt.legend(['Training accuracy', 'Validation accuracy'], loc='best')
    plt.show()

    print(f'Test accuracy: {score[1]:.4}\n\n')
```

[ ]:
```
def plot_loss(history, score):
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])

    plt.title('Training and validation loss')
    plt.ylabel('Loss')
    plt.xlabel('Epoch')
    plt.yticks(ticks=[0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2])
    plt.legend(['Training loss', 'Validation loss'], loc='best')
    plt.show()

    print(f'Test loss: {score[0]:.4}\n\n')
```

[ ]:
```
def print_classification_report(y_pred):
    print(cr(y_test, y_pred.argmax(axis=1), target_names=classes))
```

[ ]:
```
def plot_confusion_matrix(y_pred):
    # source: https://stackoverflow.com/questions/20927368/
↪how-to-normalize-a-confusion-matrix
    cmatrix = cm(y_test, y_pred.argmax(axis=1))
    cmatrix_norm = cmatrix.astype('float') / cmatrix.sum(axis=1)[:, np.newaxis]
    fig, ax = plt.subplots(figsize=(8,4))
    sns.heatmap(cmatrix_norm, annot=True, fmt="0.3f", xticklabels=classes,␣
↪yticklabels=classes)
    plt.ylabel('Actual')
    plt.xlabel('Predicted')
    plt.title('Normalized confusion matrix')
    plt.show(block=False)
```

[ ]:
```
def plot_precision_recall_curve(y_pred):
    n_classes = len(classes)
    y_test_ohe = to_categorical(y_test, num_classes=NUM_CLASSES)
```

```
    # source: https://stackoverflow.com/questions/56090541/
↪how-to-plot-precision-and-recall-of-multiclass-classifier
    # precision recall curve
    precision = dict()
    recall = dict()
    for i in range(n_classes):
        precision[i], recall[i], _ = precision_recall_curve(y_test_ohe[:, i],
                                                            y_pred[:, i])
        plt.plot(recall[i], precision[i], lw=1, label='{}'.format(classes[i]))

    plt.xlabel("Recall")
    plt.ylabel("Precision")
    plt.legend(loc="best")
    plt.title("Precision-Recall curve")
    plt.show()
```

[ ]:
```
def plot_roc_curve(y_pred):
    # source: https://stackoverflow.com/questions/64924911/
↪plotting-multiclass-roc-curve
    # Compute ROC curve and ROC area for each class
    n_classes = len(classes)
    y_test_ohe = to_categorical(y_test, num_classes=NUM_CLASSES)
    fpr = dict()
    tpr = dict()
    roc_auc = dict()
    for i in range(n_classes):
        fpr[i], tpr[i], _ = roc_curve(y_test_ohe[:, i], y_pred[:, i])
        roc_auc[i] = auc(fpr[i], tpr[i])

    # Compute micro-average ROC curve and ROC area
    fpr["micro"], tpr["micro"], _ = roc_curve(y_test_ohe.ravel(), y_pred.
↪ravel())
    roc_auc["micro"] = auc(fpr["micro"], tpr["micro"])

    lw=1

    # First aggregate all false positive rates
    all_fpr = np.unique(np.concatenate([fpr[i] for i in range(n_classes)]))

    # Then interpolate all ROC curves at this points
    mean_tpr = np.zeros_like(all_fpr)
    for i in range(n_classes):
        mean_tpr += np.interp(all_fpr, fpr[i], tpr[i])

    # Finally average it and compute AUC
    mean_tpr /= n_classes
```

```
    fpr["macro"] = all_fpr
    tpr["macro"] = mean_tpr
    roc_auc["macro"] = auc(fpr["macro"], tpr["macro"])

    # Plot all ROC curves
    plt.figure()
    plt.plot(fpr["micro"], tpr["micro"],
             label='micro-average ROC curve (area = {0:0.2f})'
                 ''.format(roc_auc["micro"]),
             color='deeppink', linestyle=':', linewidth=4)

    plt.plot(fpr["macro"], tpr["macro"],
             label='macro-average ROC curve (area = {0:0.2f})'
                 ''.format(roc_auc["macro"]),
             color='cornflowerblue', linestyle=':', linewidth=4)

    colors = cycle(['darkgreen', 'darkorange', 'navy', 'hotpink', 'maroon',␣
↪'cyan'])
    for i, color in zip(range(n_classes), colors):
        plt.plot(fpr[i], tpr[i], color=color, lw=lw,
                 label='ROC curve of class {0} (area = {1:0.2f})'
                 ''.format(classes[i], roc_auc[i]))

    plt.plot([0, 1], [0, 1], 'k--', lw=lw)
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('Some extension of Receiver operating characteristic to␣
↪multi-class')
    plt.legend(loc="lower right")
    plt.show()
```

[ ]:
```
def print_auc_scores(y_pred):
    # source:https://scikit-learn.org/stable/auto_examples/model_selection/
↪plot_roc.html
    macro_roc_auc_ovo = roc_auc_score(y_test, y_pred, multi_class="ovo",
                                      average="macro")
    weighted_roc_auc_ovo = roc_auc_score(y_test, y_pred, multi_class="ovo",
                                         average="weighted")
    macro_roc_auc_ovr = roc_auc_score(y_test, y_pred, multi_class="ovr",
                                      average="macro")
    weighted_roc_auc_ovr = roc_auc_score(y_test, y_pred, multi_class="ovr",
                                         average="weighted")
    print("One-vs-One ROC AUC scores:\n{:.6f} (macro),\n{:.6f} "
        "(weighted by prevalence)"
        .format(macro_roc_auc_ovo, weighted_roc_auc_ovo))
```

```
    print("One-vs-Rest ROC AUC scores:\n{:.6f} (macro),\n{:.6f} "
        "(weighted by prevalence)"
        .format(macro_roc_auc_ovr, weighted_roc_auc_ovr))
```

[ ]:
```
def plot_model_png(model, dropout, l2_val, optimizer):
    if optimizer == sgd:
        plot_path = '../MLP_sgd_'+str(dropout)+'DO_'+str(l2_val)+'L2.png'
    elif type(optimizer) != str:
        plot_path = '../MLP_adam_'+str(dropout)+'DO_'+str(l2_val)+'L2.png'
    else:
        plot_path = '../MLP_'+optimizer+'_'+str(dropout)+'DO_'+str(l2_val)+'L2.
↪png'
    plot_model(model, to_file=os.path.join(DATA_DIR, plot_path),␣
↪show_shapes=True)
```

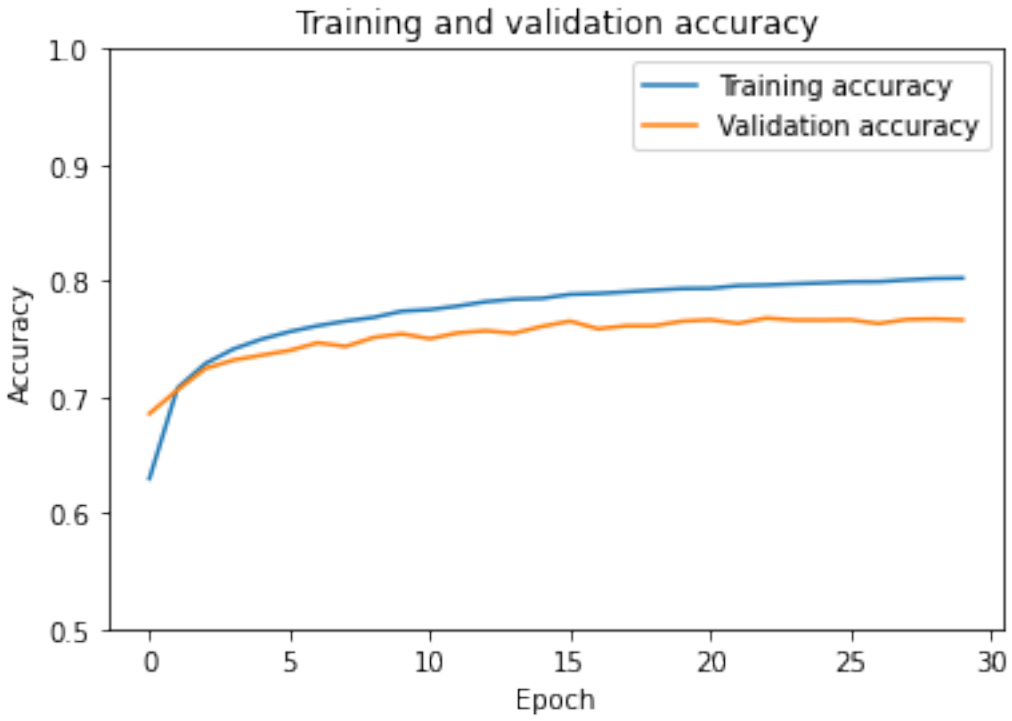
[ ]:
```
def run_model(dropout=0, l2_val=0, activation=activation,
              loss=loss, optimizer=optimizer, metrics=metrics):
    model = build_model(dropout, l2_val, activation)
    model.summary()
    plot_model_png(model, dropout, l2_val, optimizer)
    compile_model(model)
    history = fit_model(model)
    score = evaluate_model(model)
    y_pred = predict_model(model)
    plot_accuracy(history, score)
    plot_loss(history, score)
    print_classification_report(y_pred)
    print('\n\n')
    plot_confusion_matrix(y_pred)
    print('\n\n')
    plot_precision_recall_curve(y_pred)
    print('\n\n')
    plot_roc_curve(y_pred)
    print('\n\n')
    print_auc_scores(y_pred)
    print('\n\n')

    return model, history, score, y_pred
```

0.5 Run models

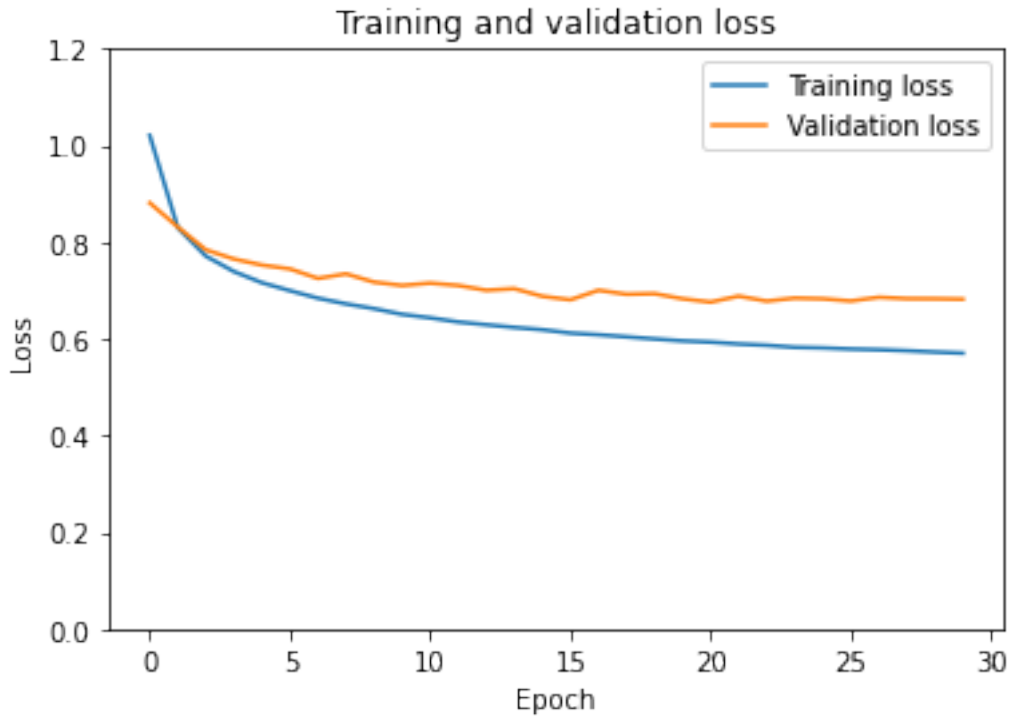
[ ]:
```
model_base, history_base, score_base, y_pred_base = run_model()
```

```
Model: "Multi_Layer_Perceptron_relu_0DO_0L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
```

```
=================================================================
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0 (Dropout)          (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 69.571 seconds
```

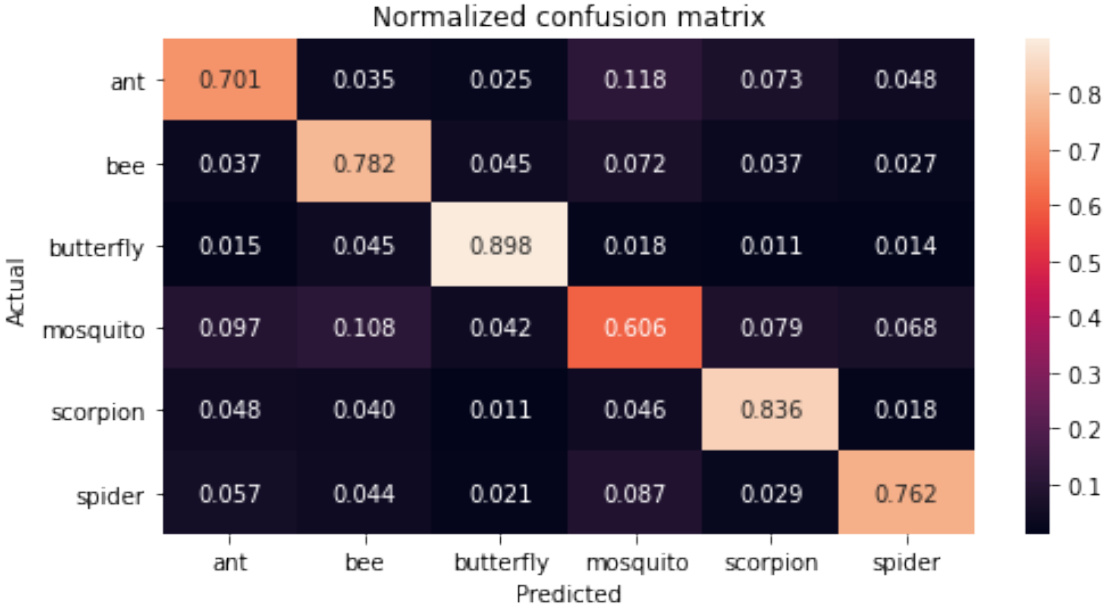


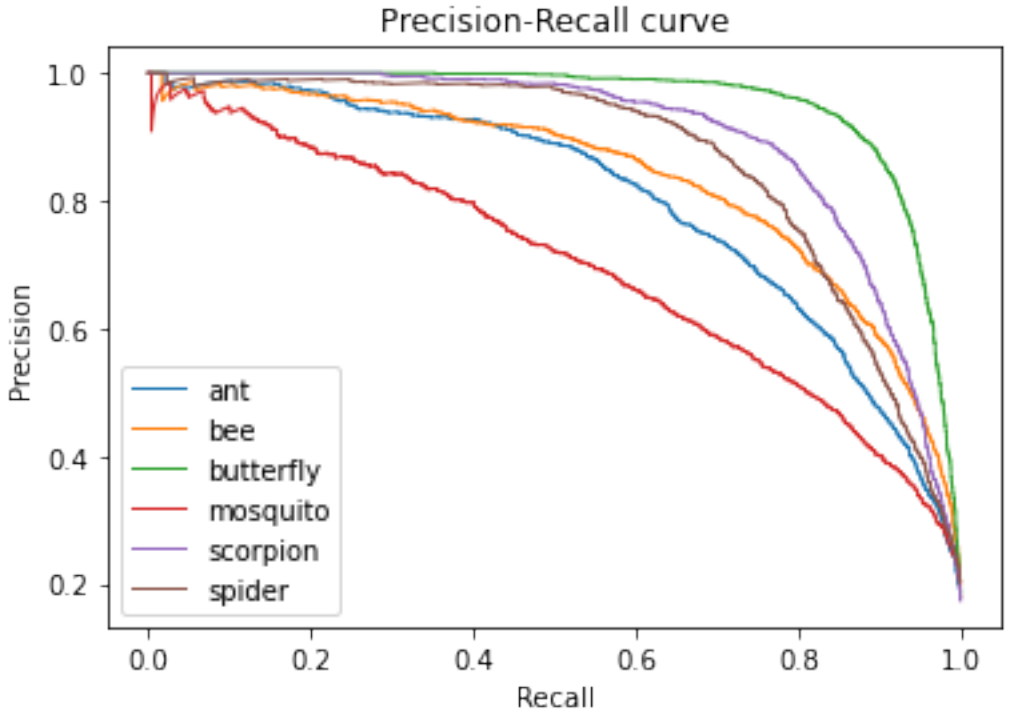
```
Test accuracy: 0.7644
```

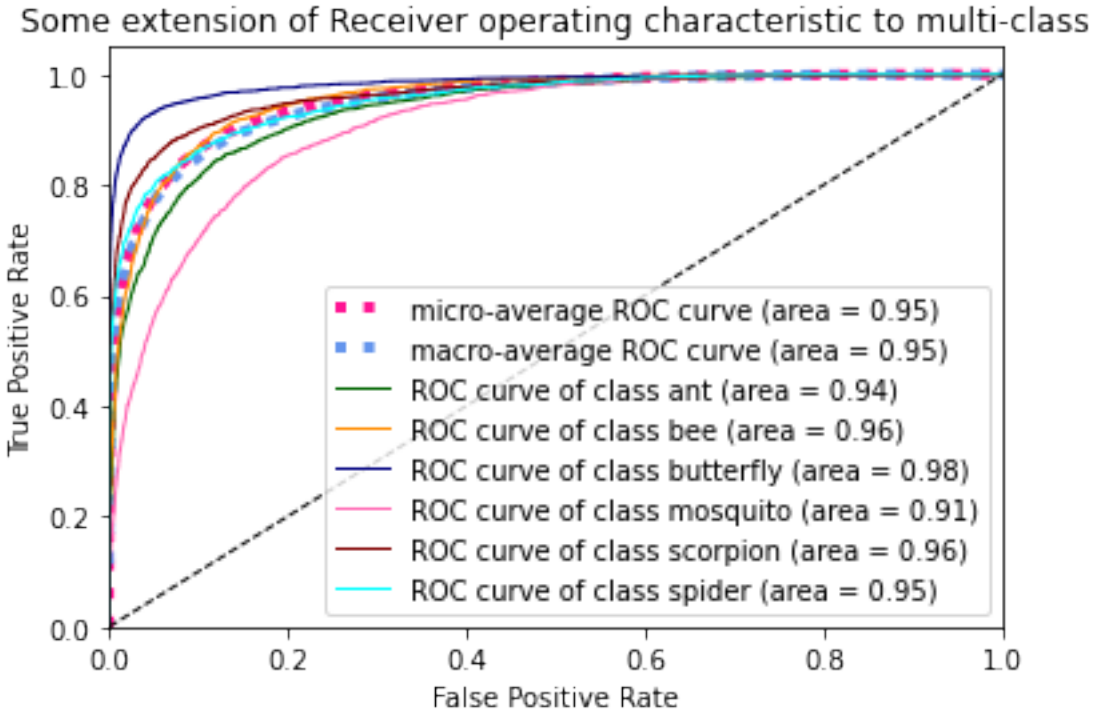



```
Test loss: 0.6877
```

	precision	recall	f1-score	support
ant	0.73	0.70	0.72	2478
bee	0.74	0.78	0.76	2488
butterfly	0.87	0.90	0.88	2557
mosquito	0.64	0.61	0.62	2527
scorpion	0.78	0.84	0.81	2468
spider	0.81	0.76	0.79	2482
accuracy			0.76	15000
macro avg	0.76	0.76	0.76	15000
weighted avg	0.76	0.76	0.76	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.701 0.035 0.025 0.118 0.073 0.048
0.037 0.782 0.045 0.072 0.037 0.027
0.015 0.045 0.898 0.018 0.011 0.014
0.097 0.108 0.042 0.606 0.079 0.068
0.048 0.040 0.011 0.046 0.836 0.018
0.057 0.044 0.021 0.087 0.029 0.762
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
ant
bee
butterfly
mosquito
scorpion
spider
0.0
0.2
0.4
0.6
0.8
1.0
Recall

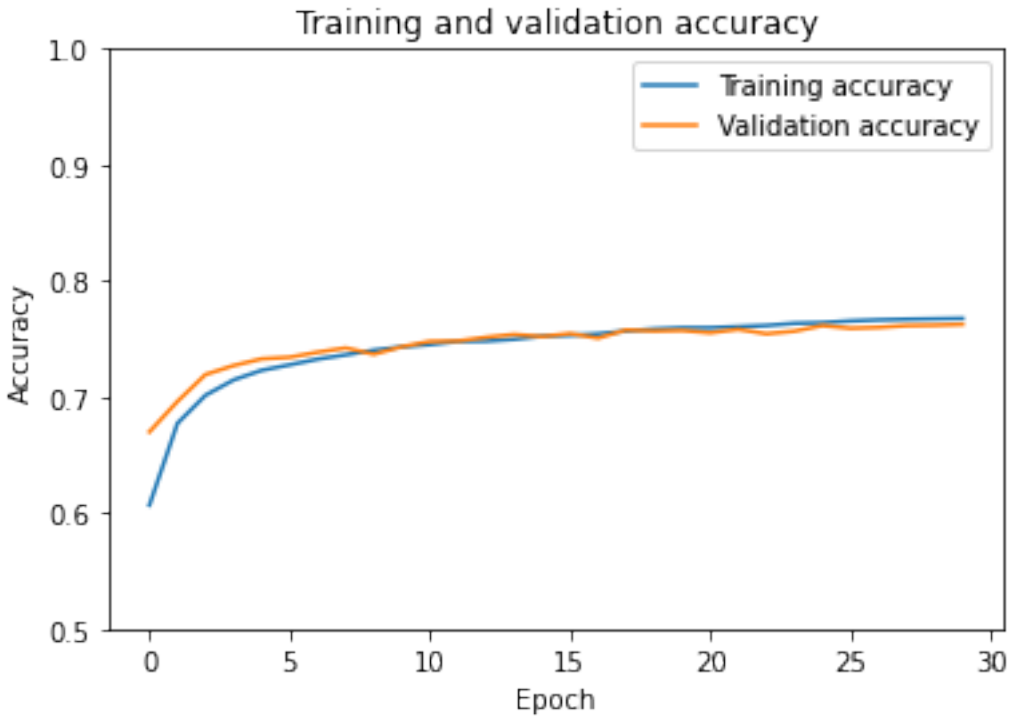



```
One-vs-One ROC AUC scores:
0.949499 (macro),
0.949544 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.949564 (macro),
0.949596 (weighted by prevalence)
```

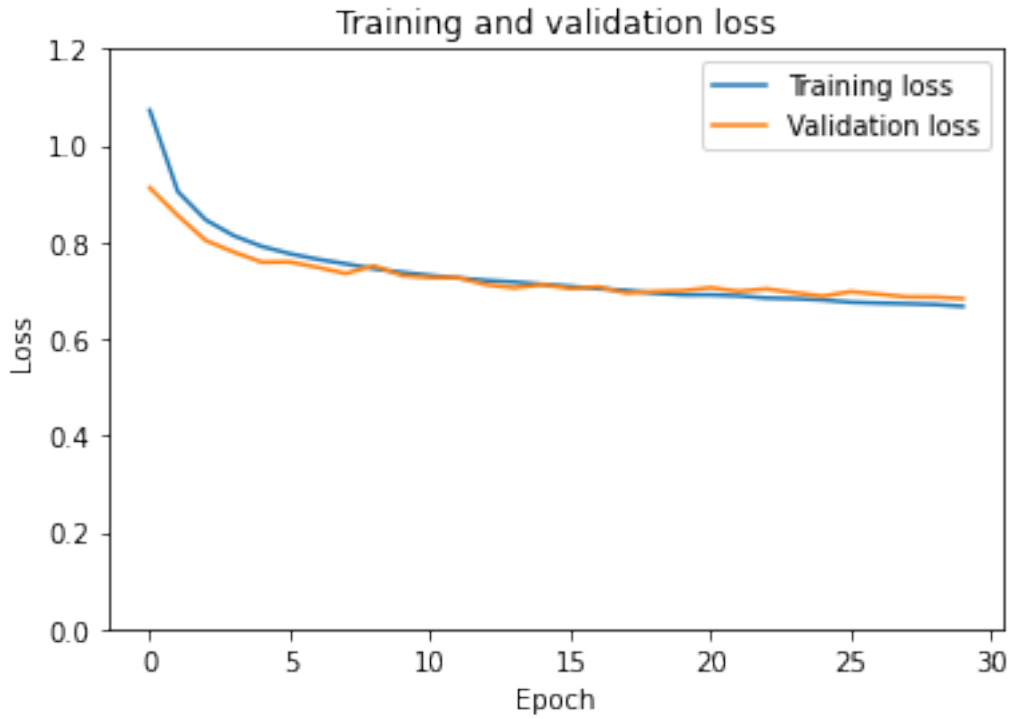
```
[ ]: model_10do, history_10do, score_10do, y_pred_10do = run_model(dropout=0.1)
```

```
Model: "Multi_Layer_Perceptron_relu_0.1DO_0L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
```

```
=================================================================
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.1 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 69.171 seconds
```

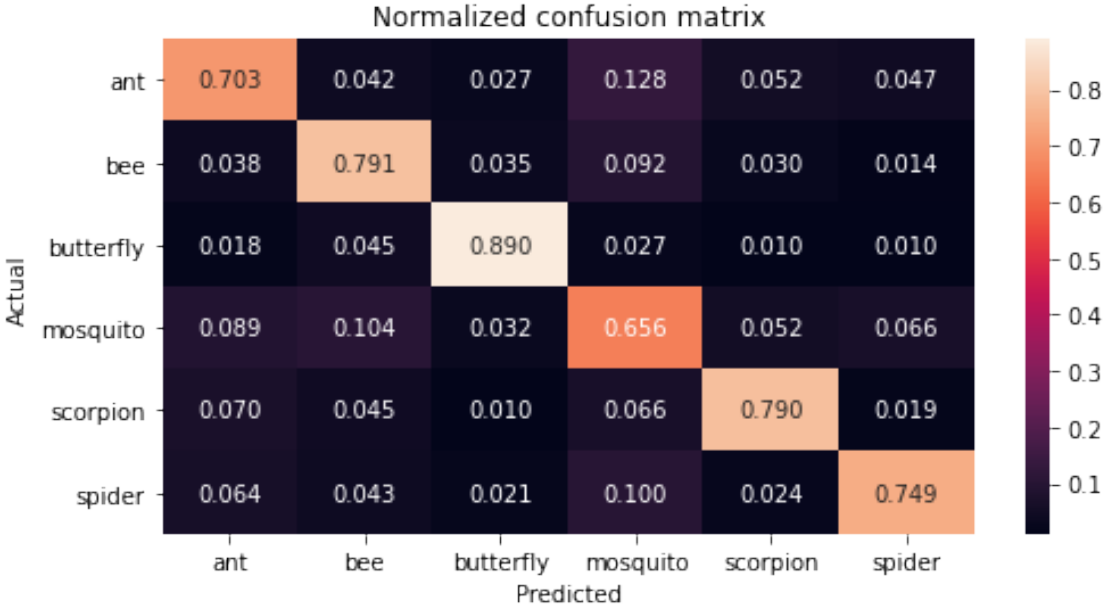


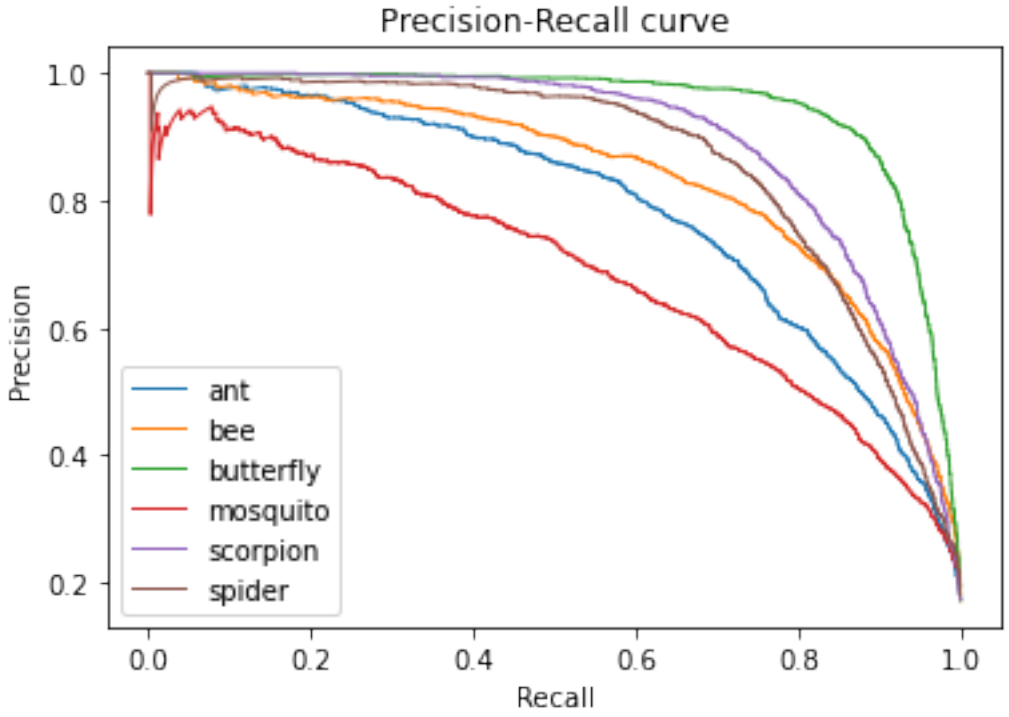
```
Test accuracy: 0.7634
```

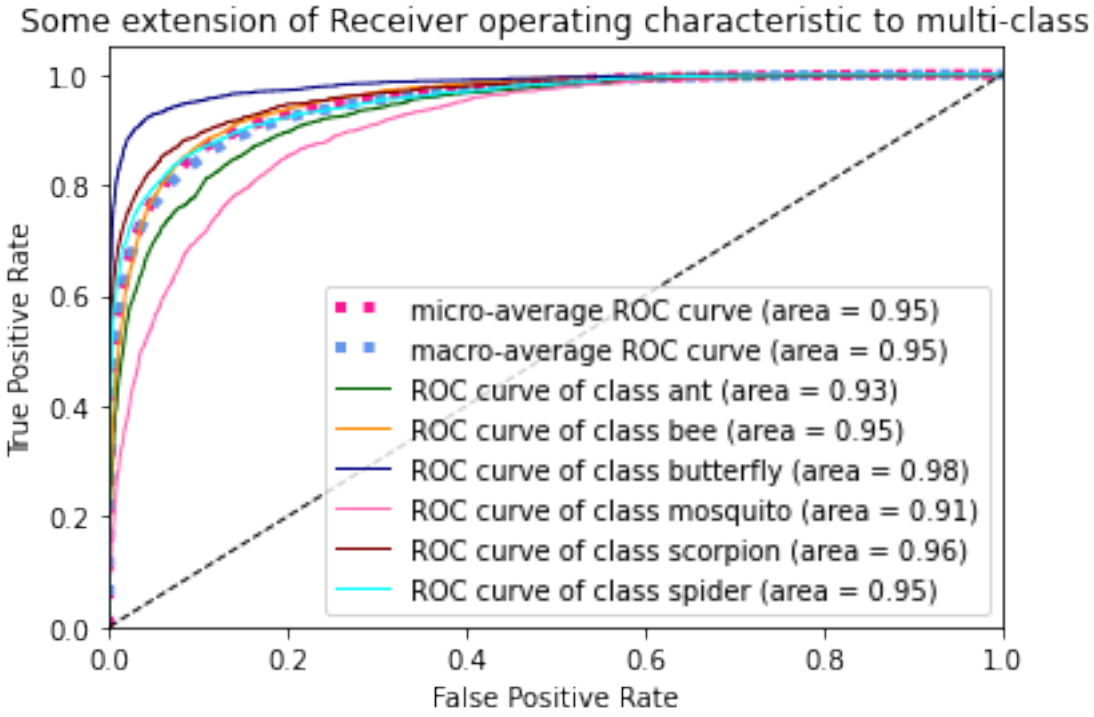



```
Test loss: 0.6928
```

	precision	recall	f1-score	support
ant	0.71	0.70	0.71	2478
bee	0.74	0.79	0.76	2488
butterfly	0.88	0.89	0.88	2557
mosquito	0.62	0.66	0.64	2527
scorpion	0.82	0.79	0.81	2468
spider	0.83	0.75	0.79	2482
accuracy			0.76	15000
macro avg	0.77	0.76	0.76	15000
weighted avg	0.77	0.76	0.76	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.703 0.042 0.027 0.128 0.052 0.047
0.038 0.791 0.035 0.092 0.030 0.014
0.018 0.045 0.890 0.027 0.010 0.010
0.089 0.104 0.032 0.656 0.052 0.066
0.070 0.045 0.010 0.066 0.790 0.019
0.064 0.043 0.021 0.100 0.024 0.749
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
ant
bee
butterfly
mosquito
scorpion
spider
0.0
0.2
0.4
0.6
0.8
1.0
Recall

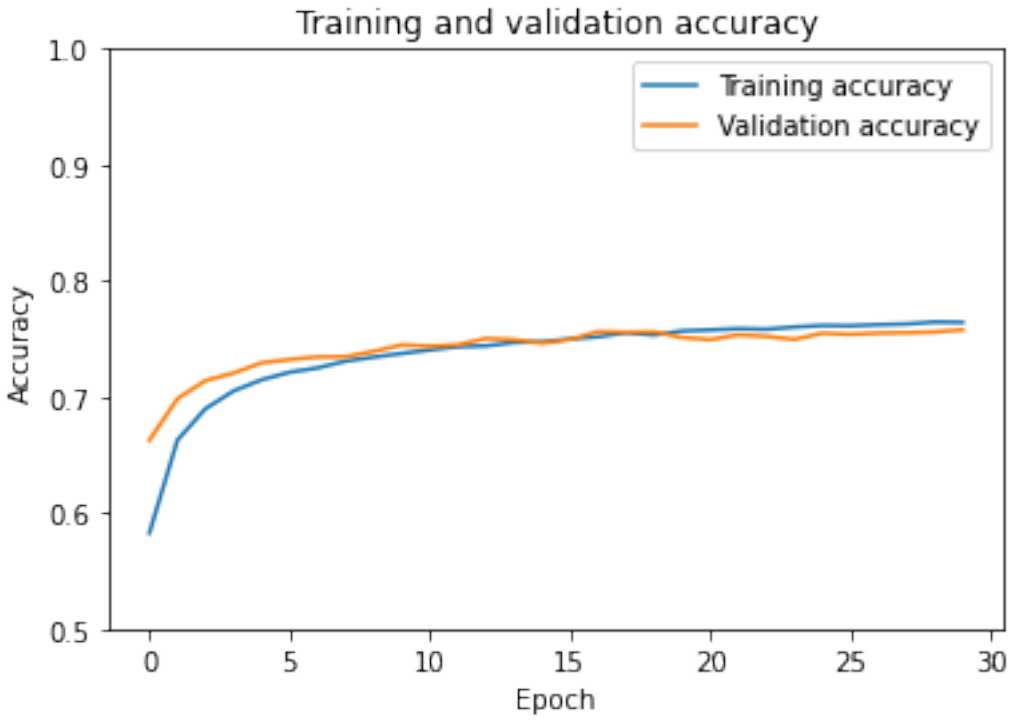



```
One-vs-One ROC AUC scores:
0.947289 (macro),
0.947341 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.947364 (macro),
0.947400 (weighted by prevalence)
```

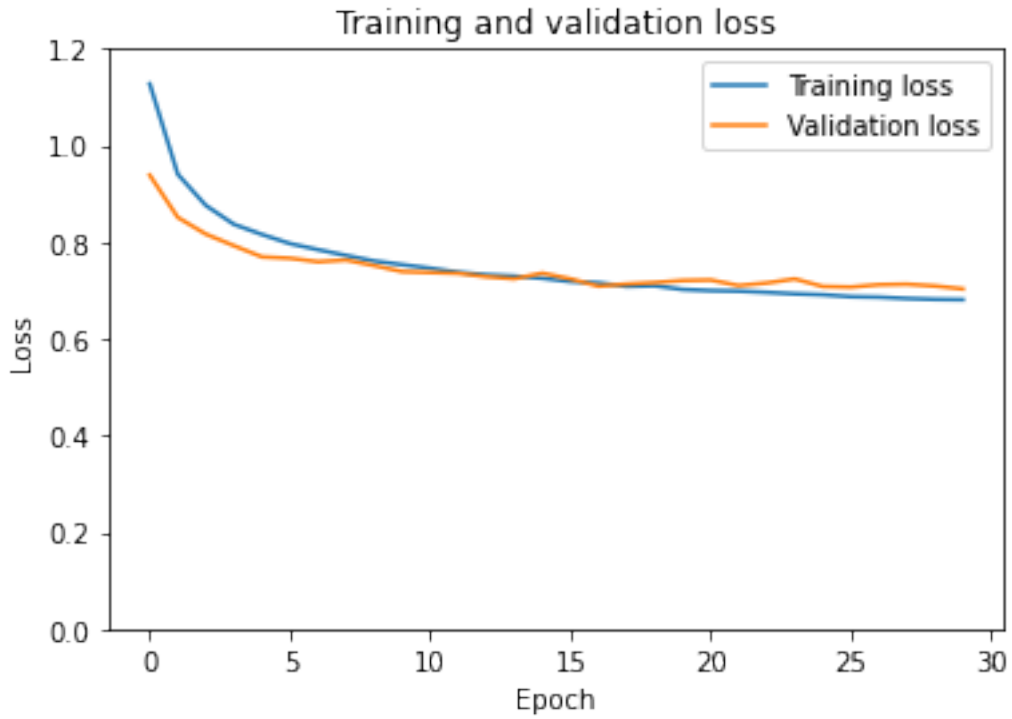
[ ]:
```
model_20do, history_20do, score_20do, y_pred_20do = run_model(dropout=0.2)
```

```
Model: "Multi_Layer_Perceptron_relu_0.2DO_0L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
```

```
=================================================================
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.2 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 68.420 seconds
```

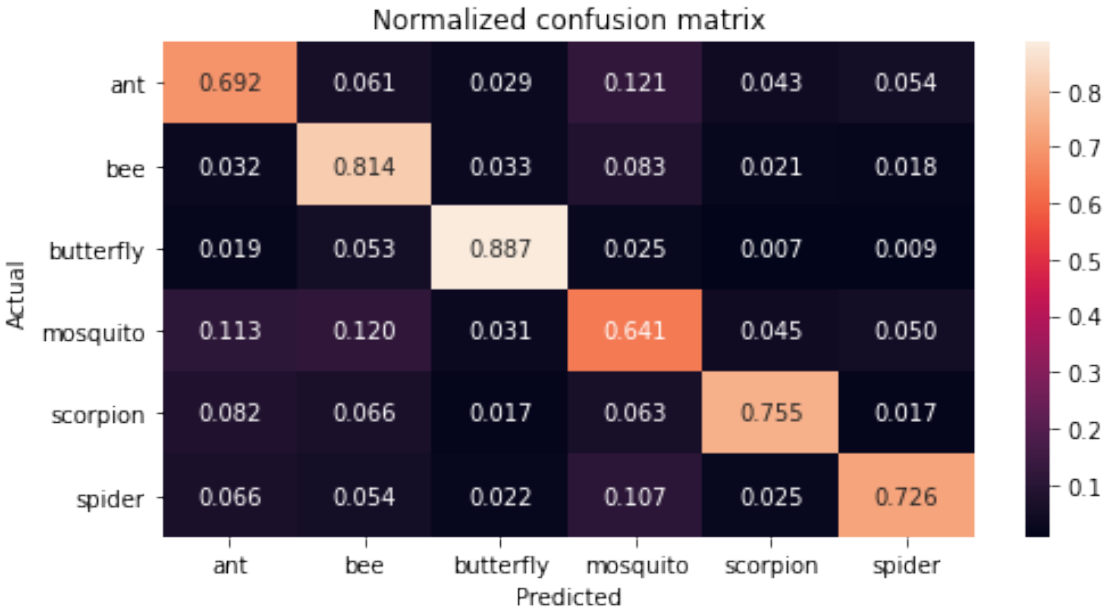


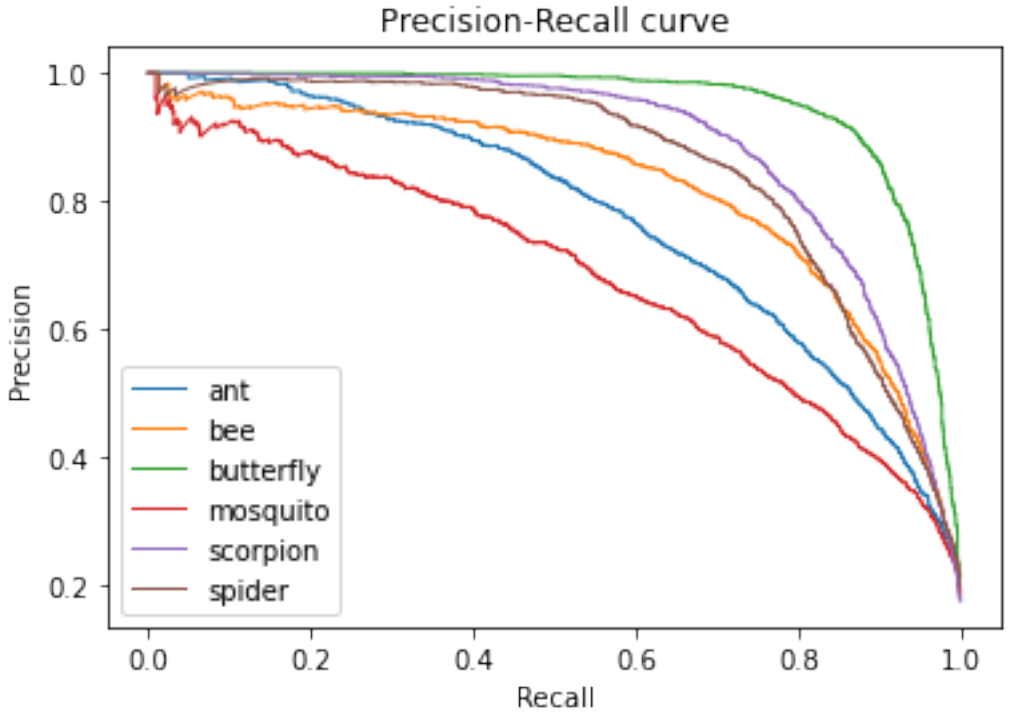
```
Test accuracy: 0.7527
```

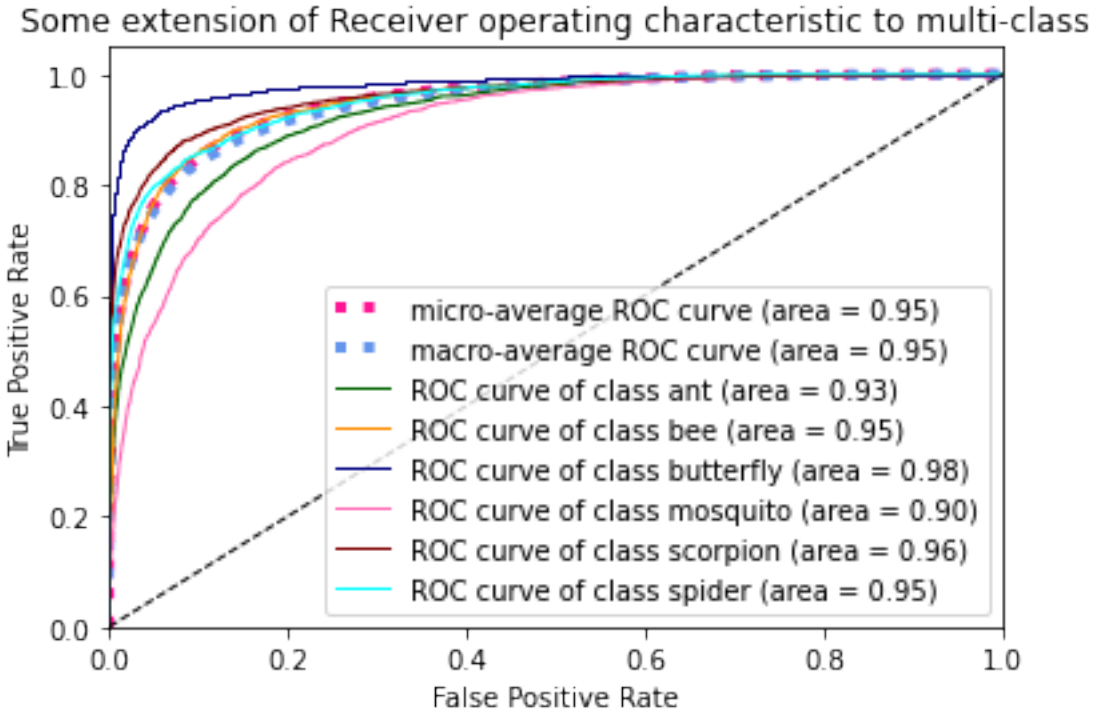



```
Test loss: 0.709
```

	precision	recall	f1-score	support
ant	0.69	0.69	0.69	2478
bee	0.69	0.81	0.75	2488
butterfly	0.87	0.89	0.88	2557
mosquito	0.62	0.64	0.63	2527
scorpion	0.84	0.76	0.80	2468
spider	0.83	0.73	0.77	2482
accuracy			0.75	15000
macro avg	0.76	0.75	0.75	15000
weighted avg	0.76	0.75	0.75	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.692 0.061 0.029 0.121 0.043 0.054
0.032 0.814 0.033 0.083 0.021 0.018
0.019 0.053 0.887 0.025 0.007 0.009
0.113 0.120 0.031 0.641 0.045 0.050
0.082 0.066 0.017 0.063 0.755 0.017
0.066 0.054 0.022 0.107 0.025 0.726
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
Recall
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
ant
bee
butterfly
mosquito
scorpion
spider

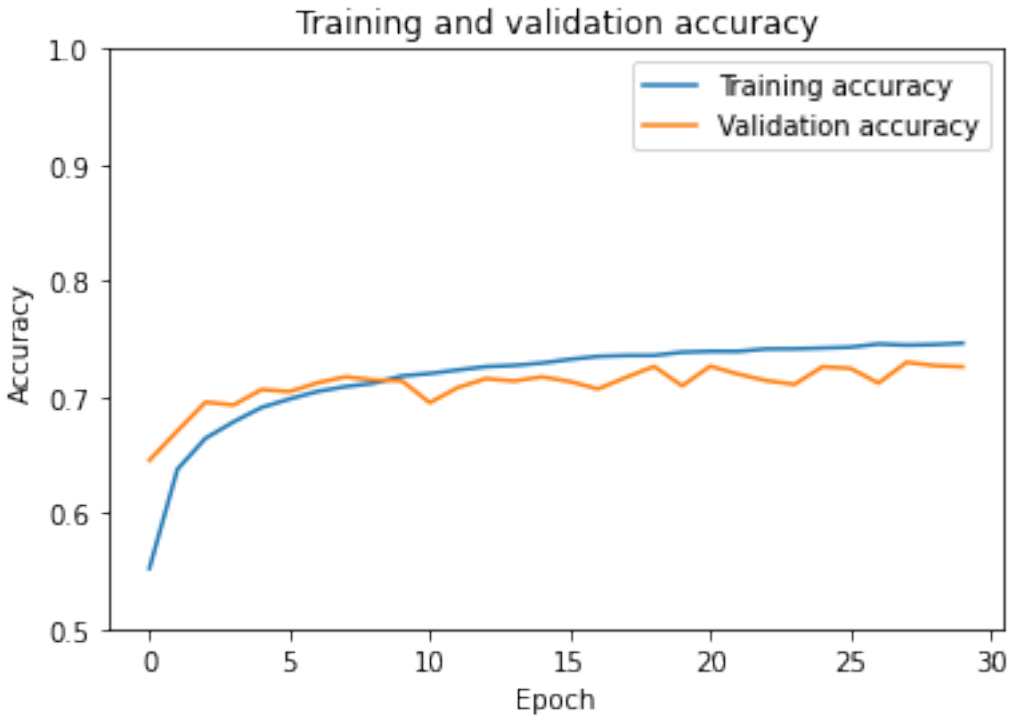



```
One-vs-One ROC AUC scores:
0.945241 (macro),
0.945309 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.945339 (macro),
0.945388 (weighted by prevalence)
```

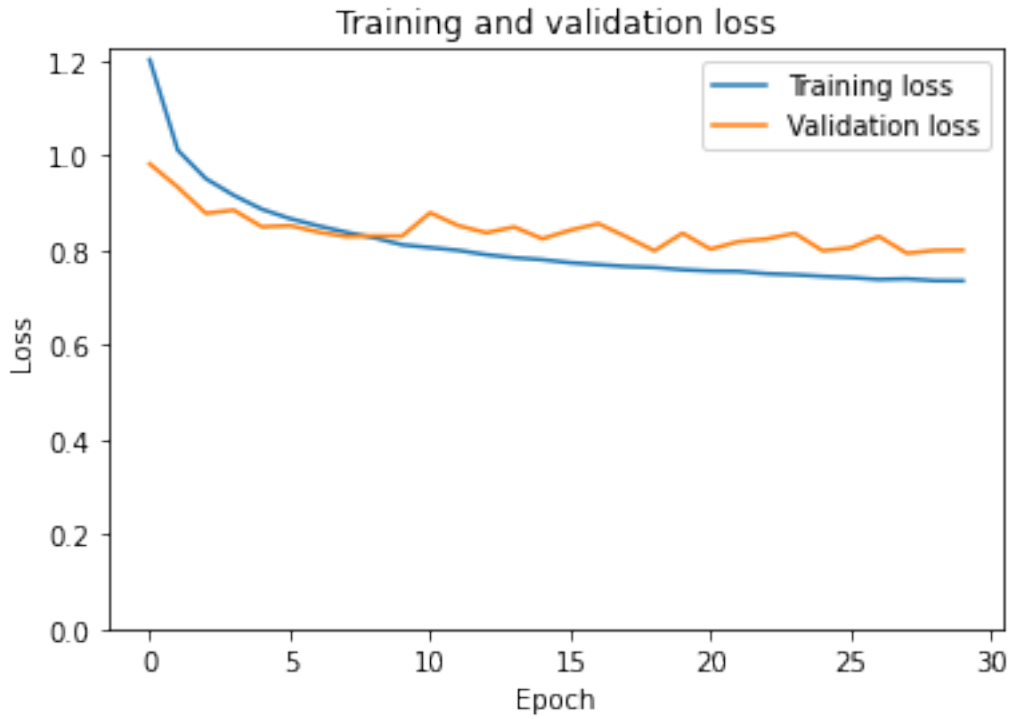
[ ]:
```
model_40do, history_40do, score_40do, y_pred_40do = run_model(dropout=0.4)
```

```
Model: "Multi_Layer_Perceptron_relu_0.4DO_0L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
```

```
=================================================================
Dense1_relu (Dense)          (None, 32)                25120
-----------------------------------------------------------------
BatchNormalization1 (BatchNo (None, 32)                128
-----------------------------------------------------------------
Dense2_relu (Dense)          (None, 32)                1056
-----------------------------------------------------------------
Dropout_0.4 (Dropout)        (None, 32)                0
-----------------------------------------------------------------
Dense3_relu (Dense)          (None, 32)                1056
-----------------------------------------------------------------
Dense4_relu (Dense)          (None, 32)                1056
-----------------------------------------------------------------
BatchNormalization2 (BatchNo (None, 32)                128
-----------------------------------------------------------------
Dense5_relu (Dense)          (None, 16)                528
-----------------------------------------------------------------
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
-----------------------------------------------------------------
Total train time for 30 epochs = 67.684 seconds
```

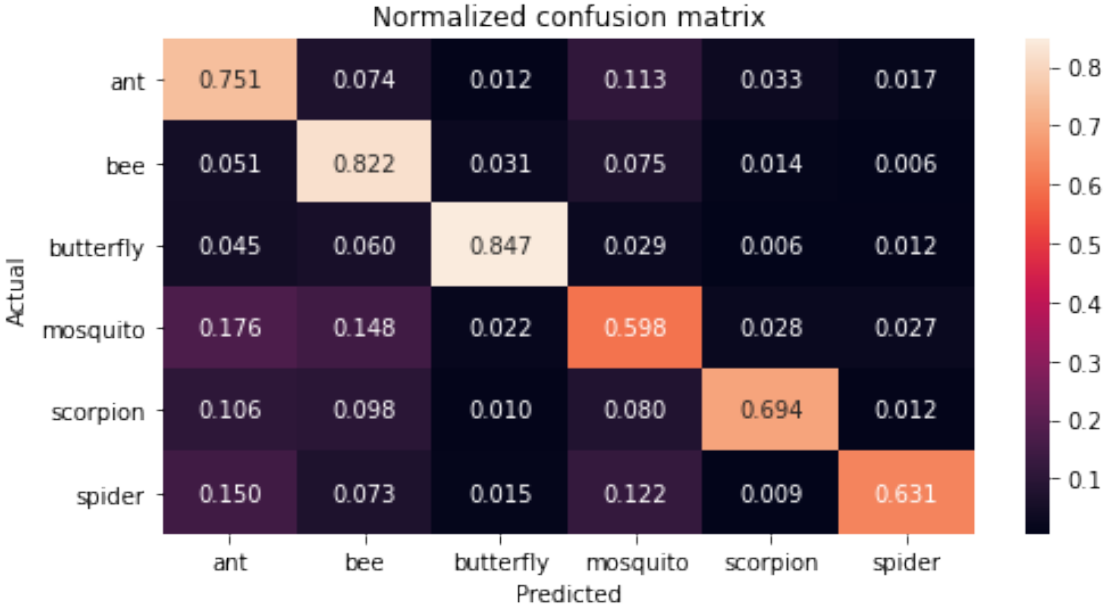


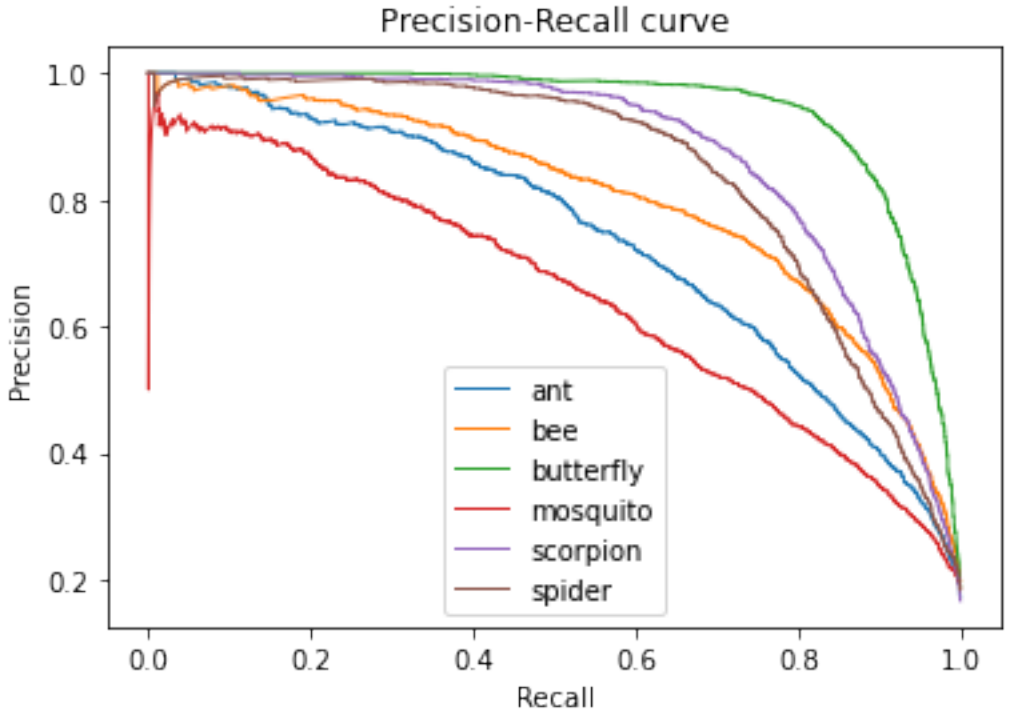
```
Test accuracy: 0.7245
```

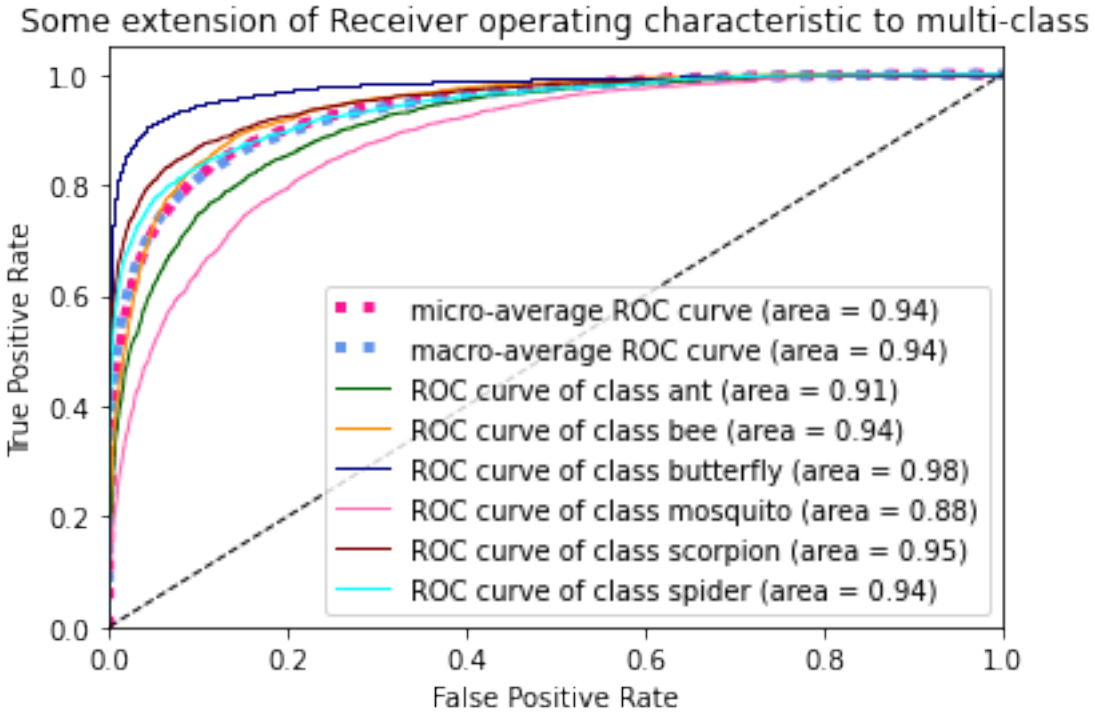



```
Test loss: 0.8019
```

	precision	recall	f1-score	support
ant	0.58	0.75	0.66	2478
bee	0.64	0.82	0.72	2488
butterfly	0.91	0.85	0.88	2557
mosquito	0.59	0.60	0.60	2527
scorpion	0.88	0.69	0.78	2468
spider	0.89	0.63	0.74	2482
accuracy			0.72	15000
macro avg	0.75	0.72	0.73	15000
weighted avg	0.75	0.72	0.73	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.751 0.074 0.012 0.113 0.033 0.017
0.051 0.822 0.031 0.075 0.014 0.006
0.045 0.060 0.847 0.029 0.006 0.012
0.176 0.148 0.022 0.598 0.028 0.027
0.106 0.098 0.010 0.080 0.694 0.012
0.150 0.073 0.015 0.122 0.009 0.631
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
Recall
ant
bee
butterfly
mosquito
scorpion
spider

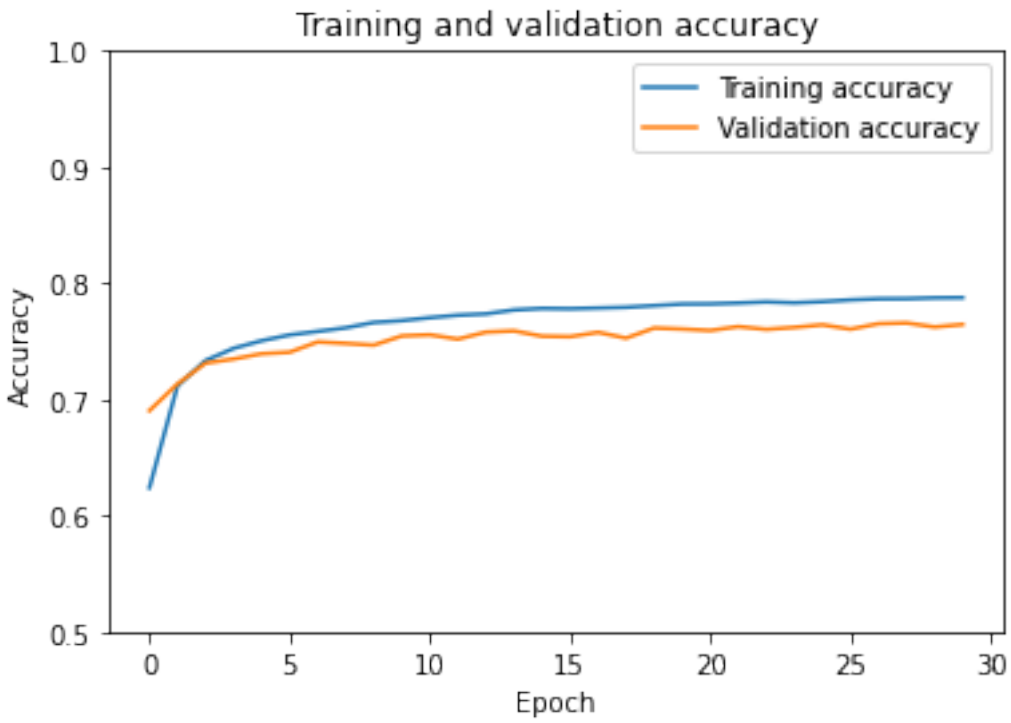



```
One-vs-One ROC AUC scores:
0.934899 (macro),
0.934966 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.934990 (macro),
0.935044 (weighted by prevalence)
```

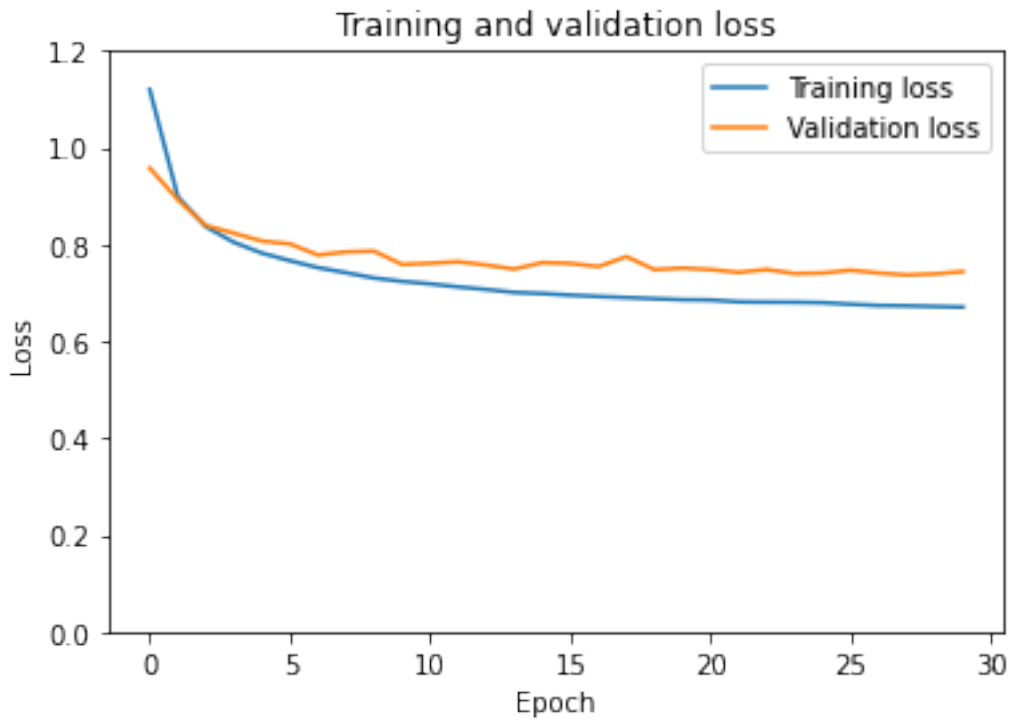
[ ]:
```
model_0005L2, history_0005L2, score_0005L2, y_pred_0005L2 = run_model(l2_val=0.
↪0005)
```

```
Model: "Multi_Layer_Perceptron_relu_0DO_0.0005L2"
_________________________________________________________________
```

```
Layer (type)                 Output Shape              Param #
=================================================================
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0 (Dropout)          (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 71.622 seconds
```

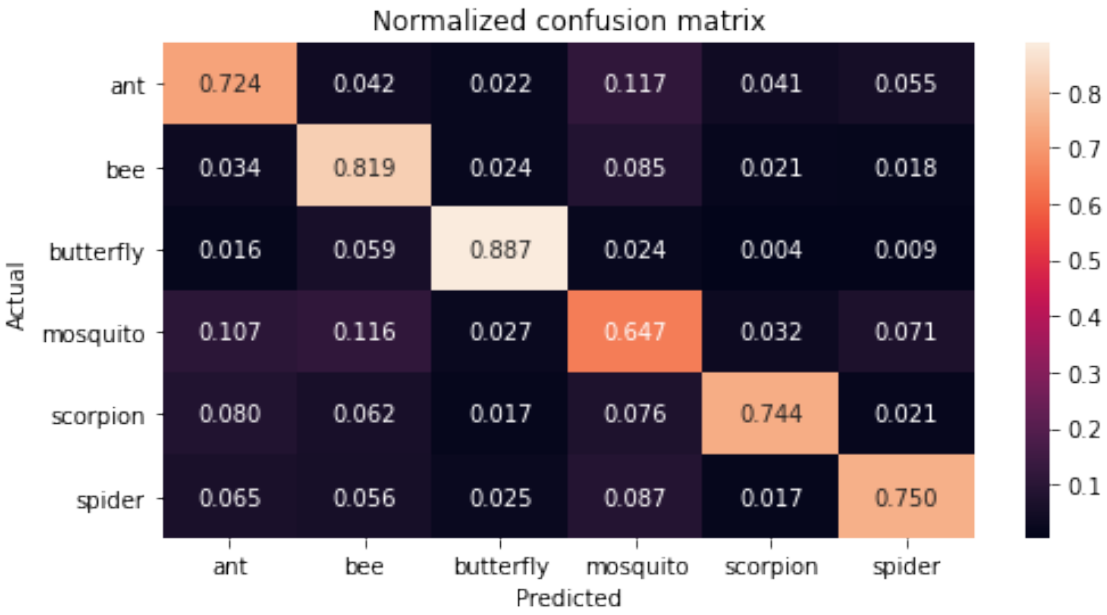


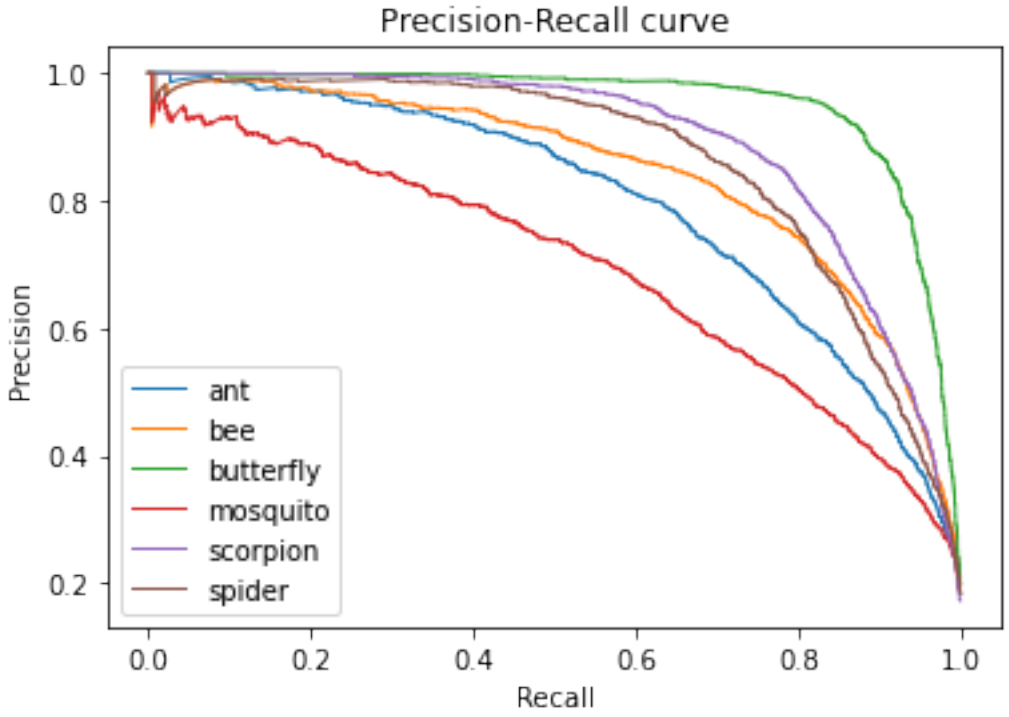

```
Test accuracy: 0.7618
```

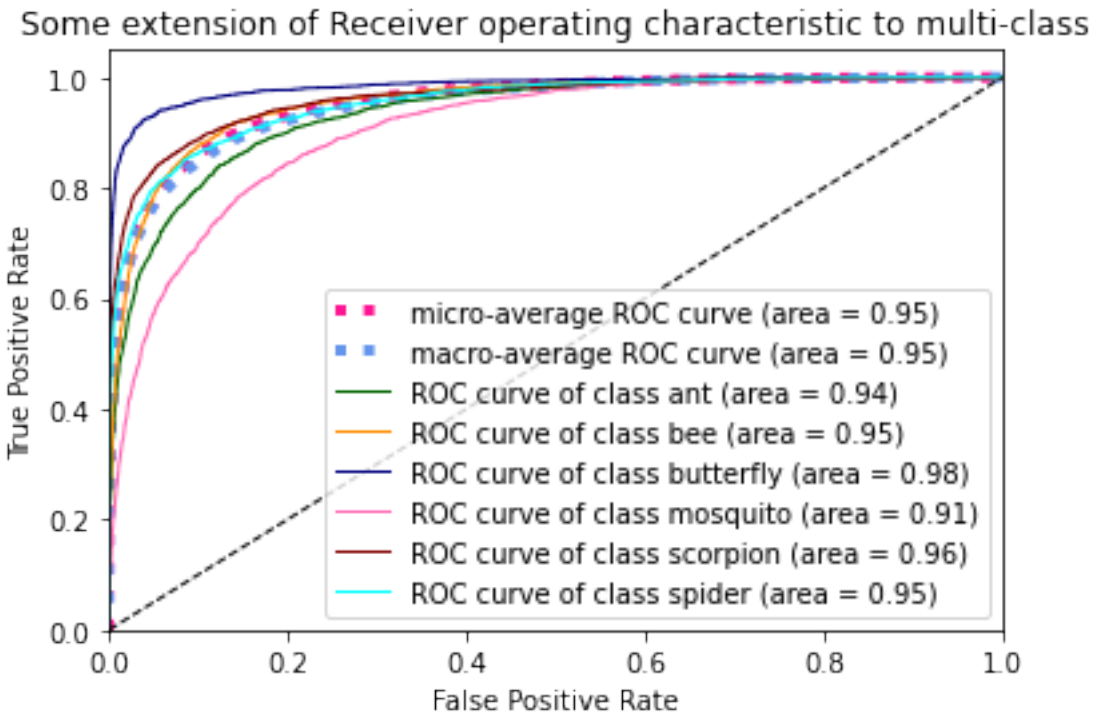


Test loss: 0.7508

	precision	recall	f1-score	support
ant	0.70	0.72	0.71	2478
bee	0.71	0.82	0.76	2488
butterfly	0.89	0.89	0.89	2557
mosquito	0.63	0.65	0.64	2527
scorpion	0.86	0.74	0.80	2468
spider	0.81	0.75	0.78	2482
accuracy			0.76	15000
macro avg	0.77	0.76	0.76	15000
weighted avg	0.77	0.76	0.76	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.724 0.042 0.022 0.117 0.041 0.055
0.034 0.819 0.024 0.085 0.021 0.018
0.016 0.059 0.887 0.024 0.004 0.009
0.107 0.116 0.027 0.647 0.032 0.071
0.080 0.062 0.017 0.076 0.744 0.021
0.065 0.056 0.025 0.087 0.017 0.750
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
Recall
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
ant
bee
butterfly
mosquito
scorpion
spider

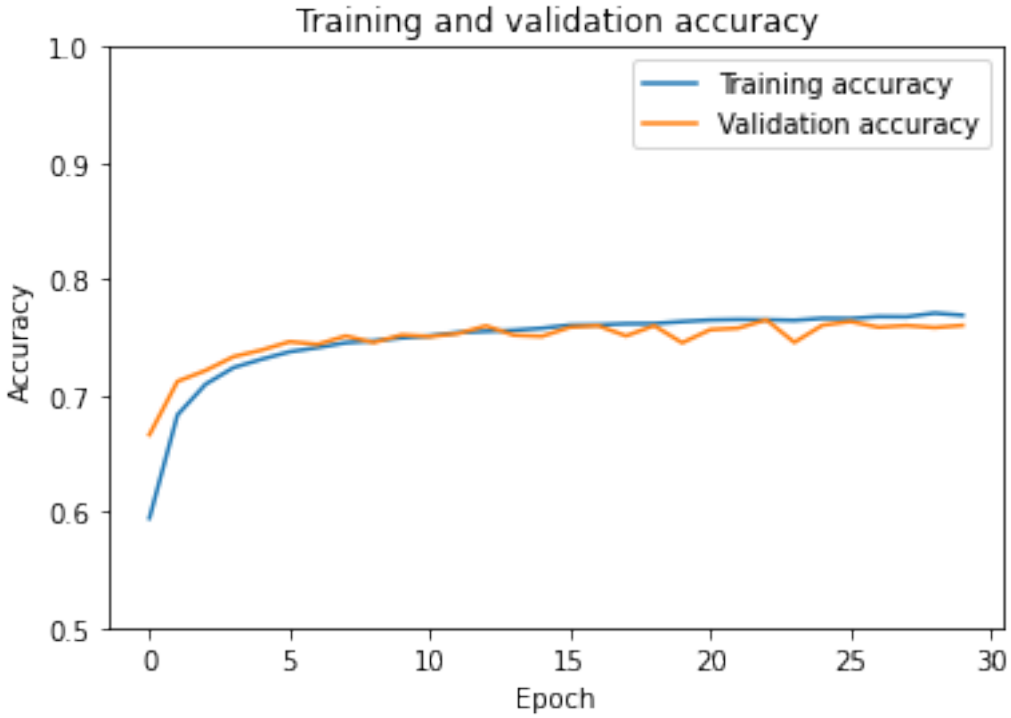



```
One-vs-One ROC AUC scores:
0.948583 (macro),
0.948645 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.948676 (macro),
0.948715 (weighted by prevalence)
```

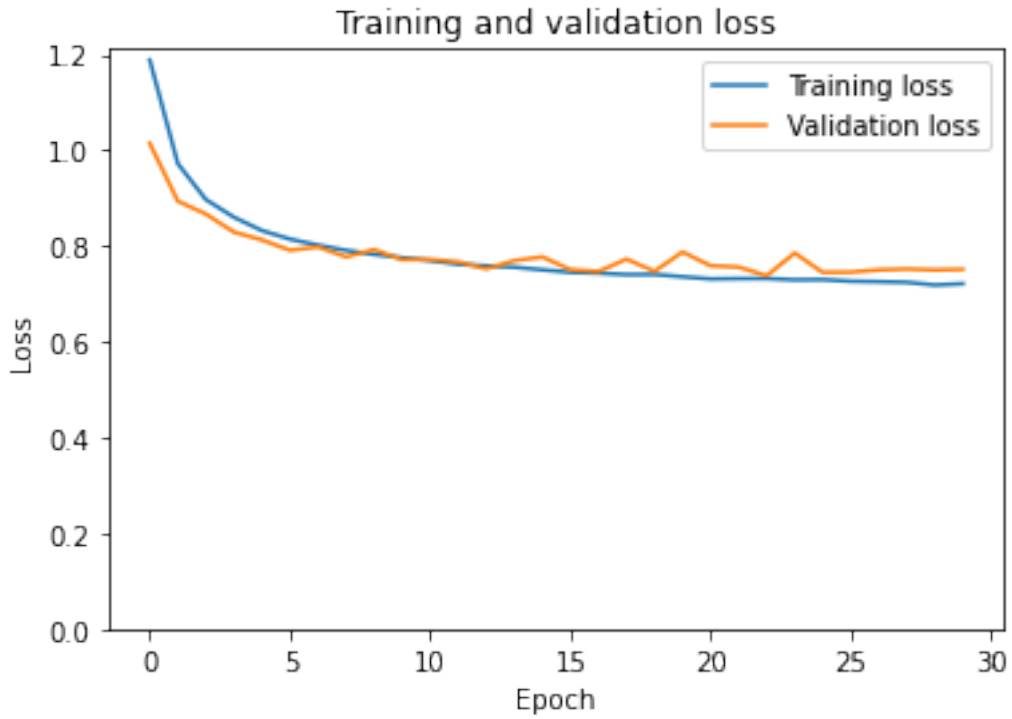
[ ]:
```
model_0005L2_10do, history_0005L2_10do, score_0005L2_10do, y_pred_0005L2_10do =␣
↪run_model(l2_val=0.0005, dropout=0.1)
```

```
Model: "Multi_Layer_Perceptron_relu_0.1DO_0.0005L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

```
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.1 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 71.933 seconds
```

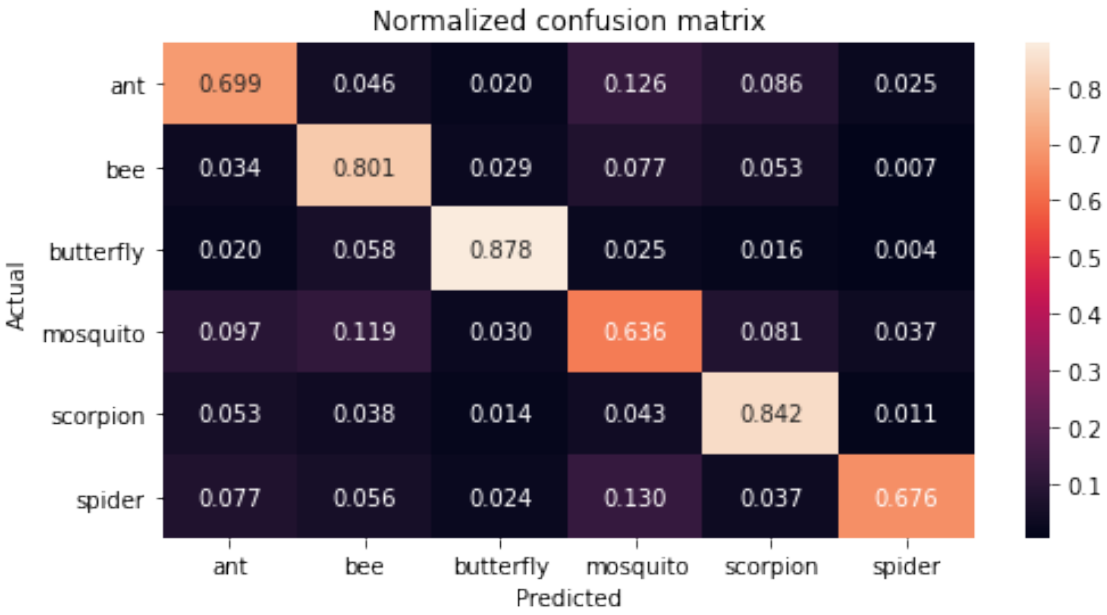


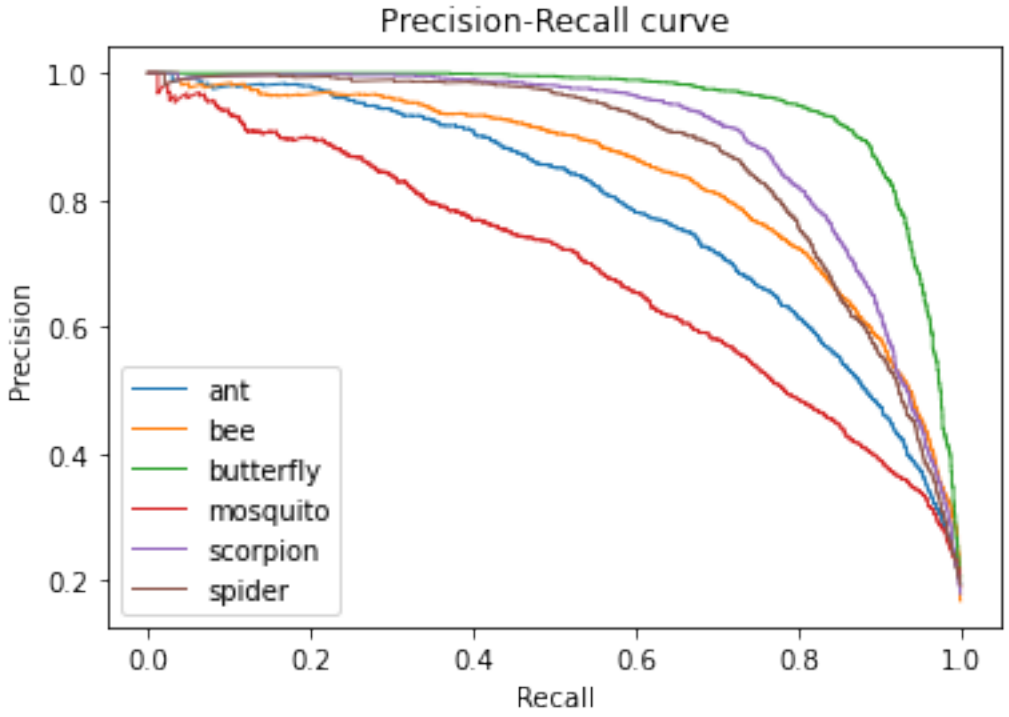
```
Test accuracy: 0.7553
```

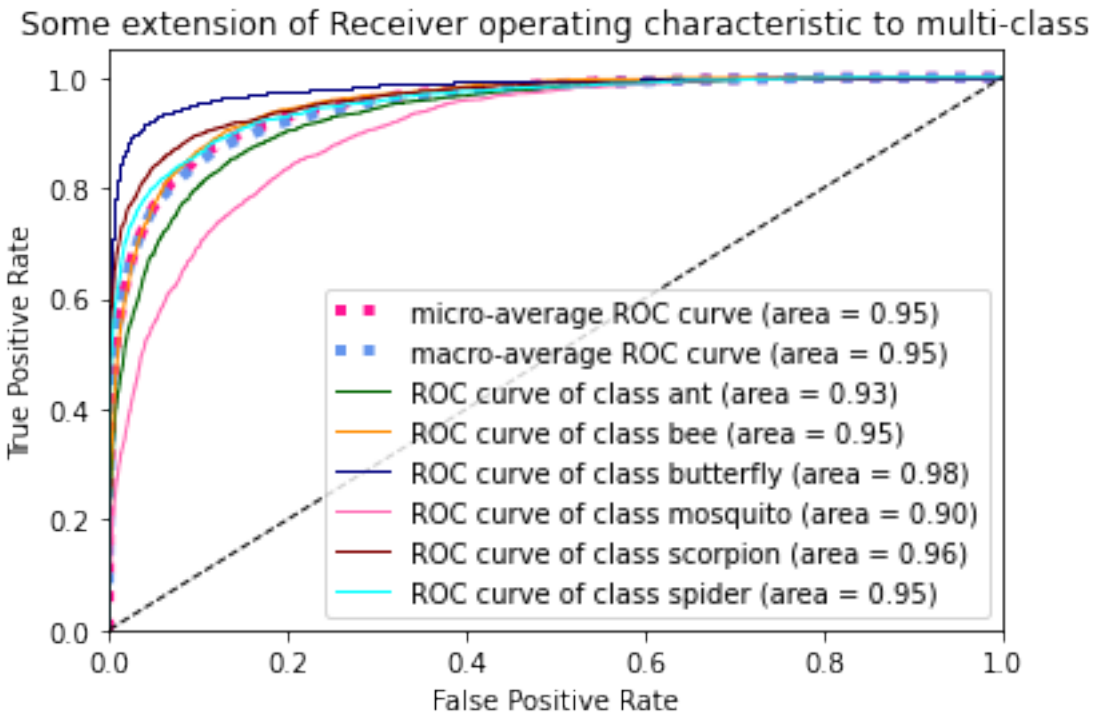



```
Test loss: 0.7567
```

	precision	recall	f1-score	support
ant	0.71	0.70	0.70	2478
bee	0.71	0.80	0.76	2488
butterfly	0.89	0.88	0.88	2557
mosquito	0.62	0.64	0.63	2527
scorpion	0.75	0.84	0.79	2468
spider	0.89	0.68	0.77	2482
accuracy			0.76	15000
macro avg	0.76	0.76	0.76	15000
weighted avg	0.76	0.76	0.76	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.699 0.046 0.020 0.126 0.086 0.025
0.034 0.801 0.029 0.077 0.053 0.007
0.020 0.058 0.878 0.025 0.016 0.004
0.097 0.119 0.030 0.636 0.081 0.037
0.053 0.038 0.014 0.043 0.842 0.011
0.077 0.056 0.024 0.130 0.037 0.676
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
ant
bee
butterfly
mosquito
scorpion
spider
0.0
0.2
0.4
0.6
0.8
1.0
Recall

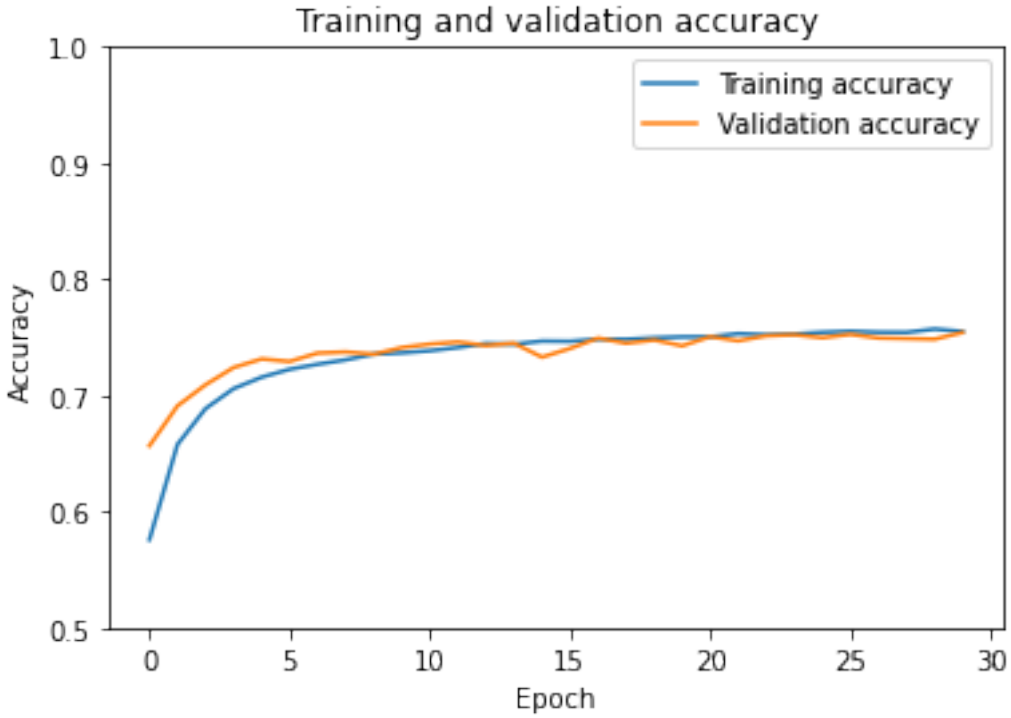



```
One-vs-One ROC AUC scores:
0.947786 (macro),
0.947824 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.947841 (macro),
0.947868 (weighted by prevalence)
```

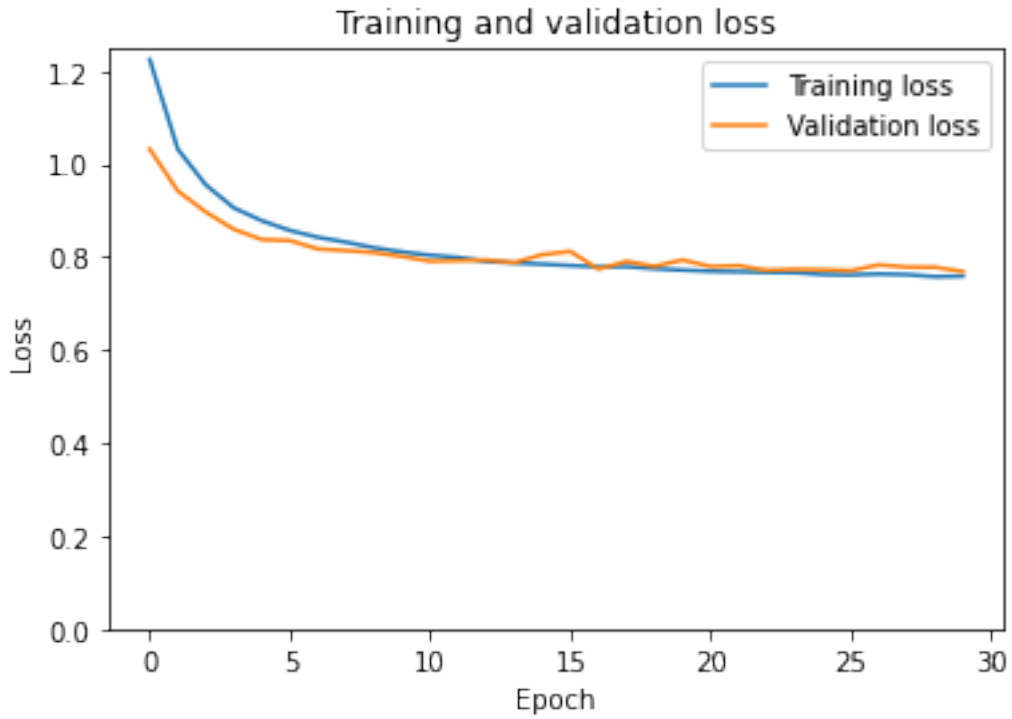
[ ]:
```
model_0005L2_20do, history_0005L2_20do, score_0005L2_20do, y_pred_0005L2_20do =␣
↪run_model(l2_val=0.0005, dropout=0.2)
```

```
Model: "Multi_Layer_Perceptron_relu_0.2DO_0.0005L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

```
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.2 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 71.579 seconds
```

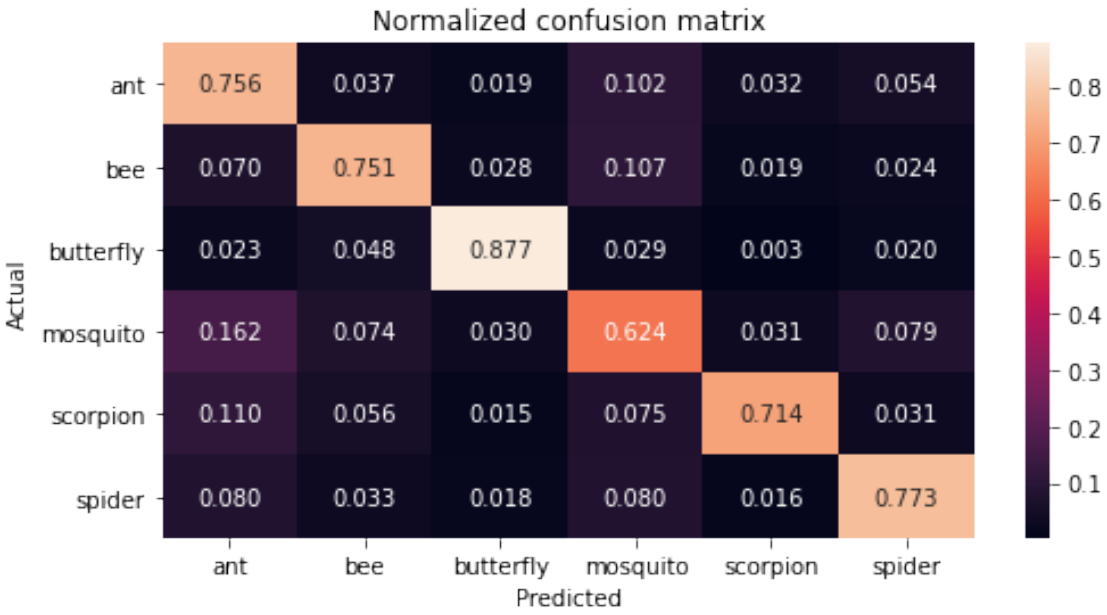


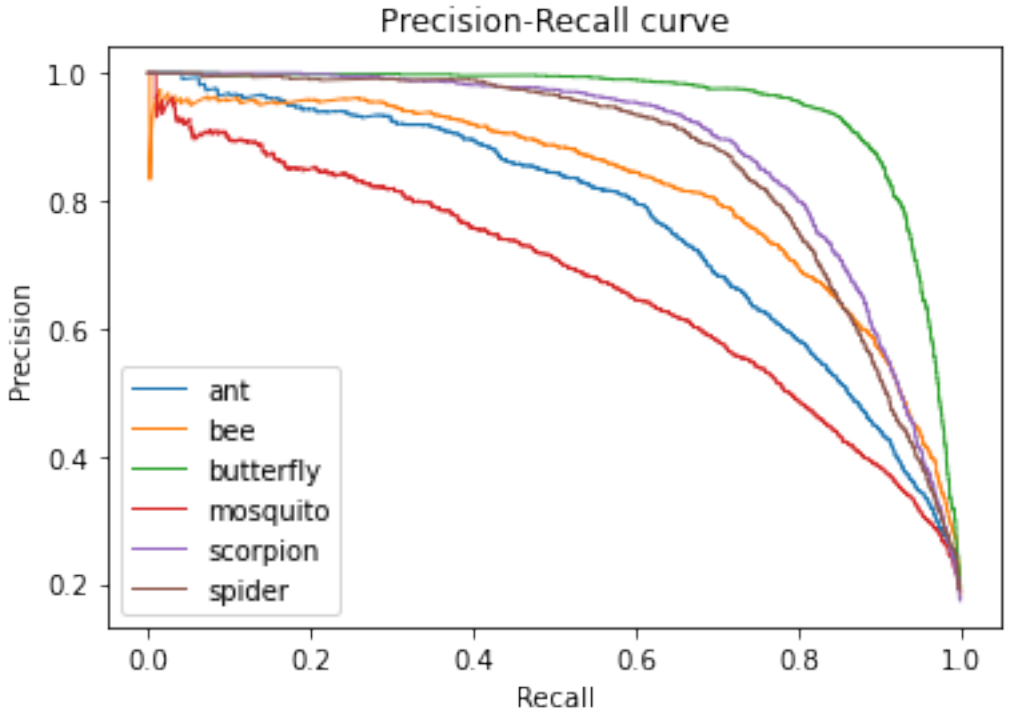
```
Test accuracy: 0.7495
```

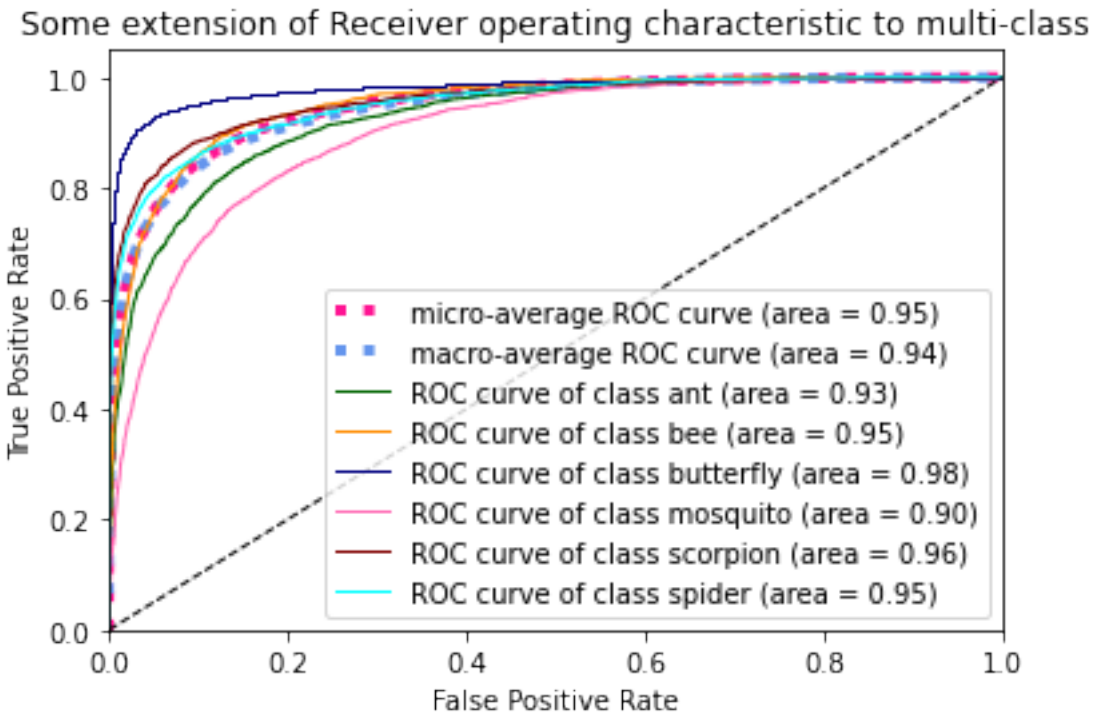



```
Test loss: 0.7769
```

	precision	recall	f1-score	support
ant	0.63	0.76	0.69	2478
bee	0.75	0.75	0.75	2488
butterfly	0.89	0.88	0.88	2557
mosquito	0.62	0.62	0.62	2527
scorpion	0.88	0.71	0.79	2468
spider	0.79	0.77	0.78	2482
accuracy			0.75	15000
macro avg	0.76	0.75	0.75	15000
weighted avg	0.76	0.75	0.75	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.756 0.037 0.019 0.102 0.032 0.054
0.070 0.751 0.028 0.107 0.019 0.024
0.023 0.048 0.877 0.029 0.003 0.020
0.162 0.074 0.030 0.624 0.031 0.079
0.110 0.056 0.015 0.075 0.714 0.031
0.080 0.033 0.018 0.080 0.016 0.773
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
Recall
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
ant
bee
butterfly
mosquito
scorpion
spider

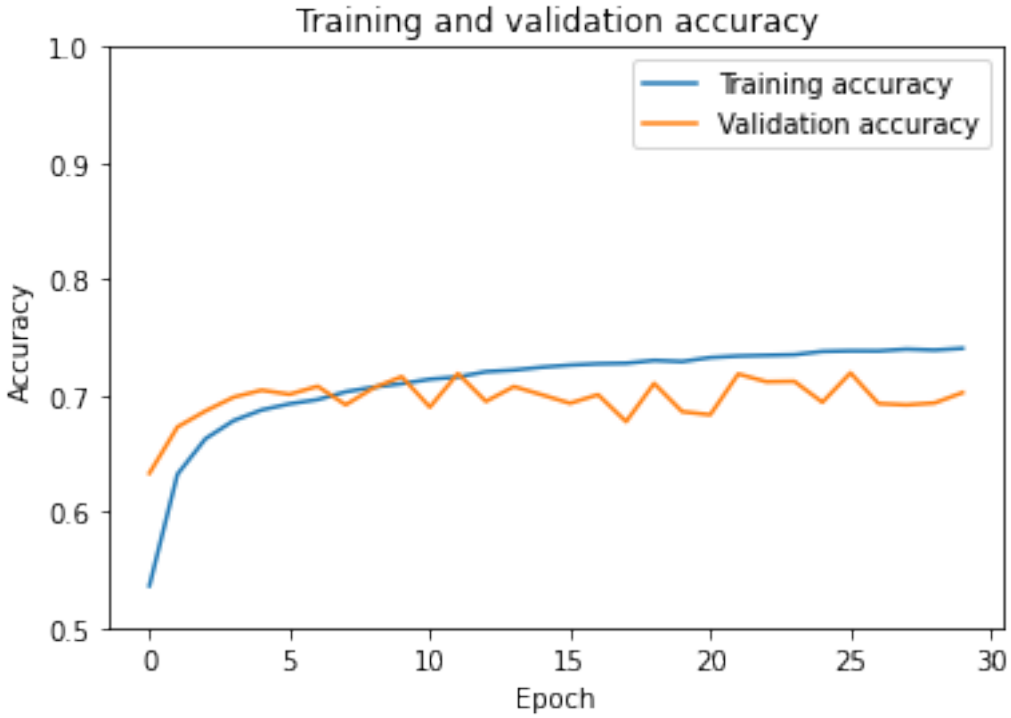



```
One-vs-One ROC AUC scores:
0.943922 (macro),
0.943984 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.944009 (macro),
0.944055 (weighted by prevalence)
```

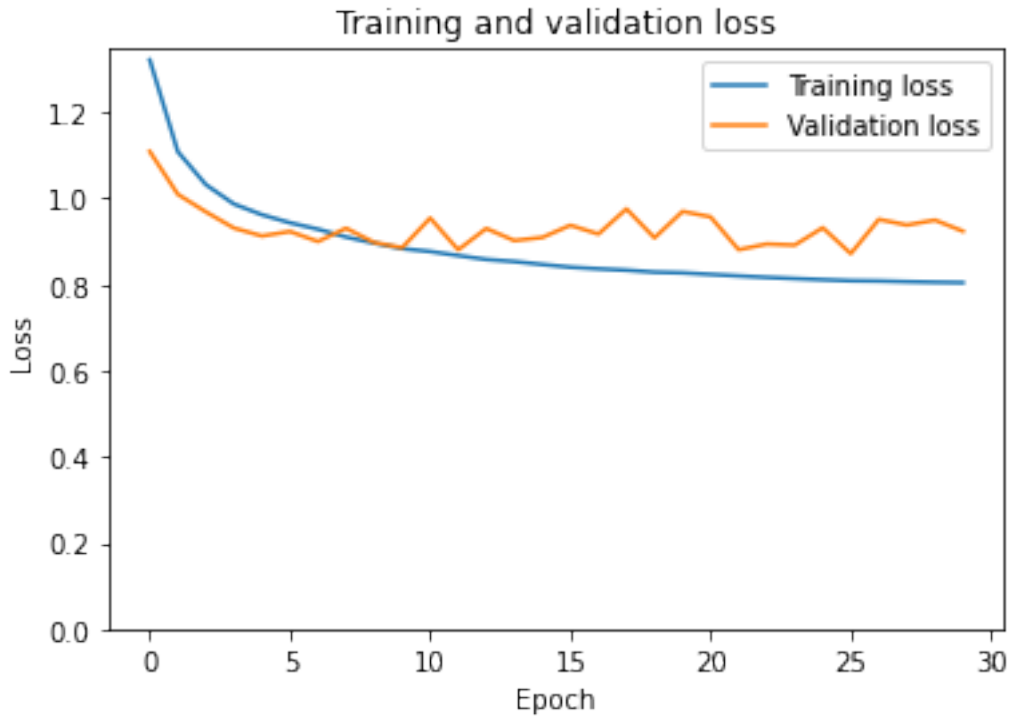
[ ]:
```
model_0005L2_40do, history_0005L2_40do, score_0005L2_40do, y_pred_0005L2_40do =␣
↪run_model(l2_val=0.0005, dropout=0.4)
```

```
Model: "Multi_Layer_Perceptron_relu_0.4DO_0.0005L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

```
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.4 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 71.995 seconds
```

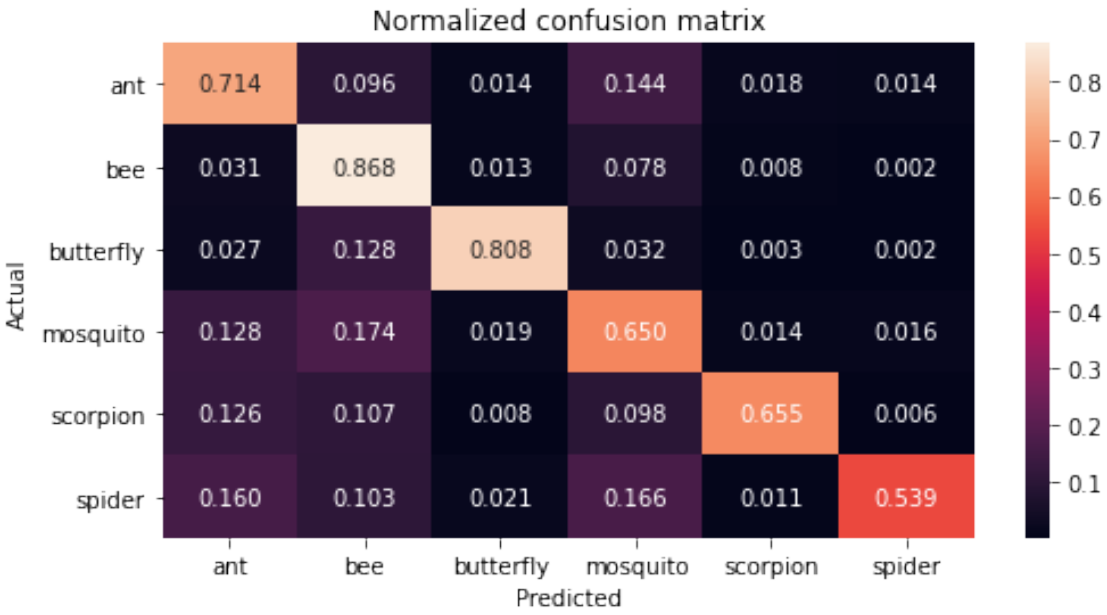


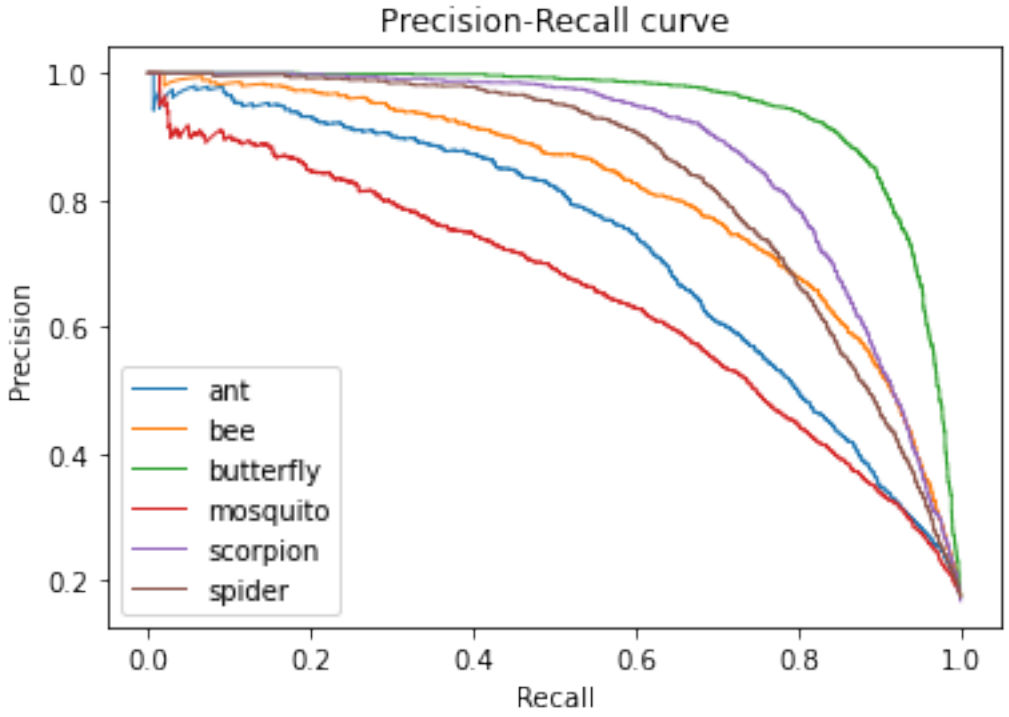
```
Test accuracy: 0.706
```

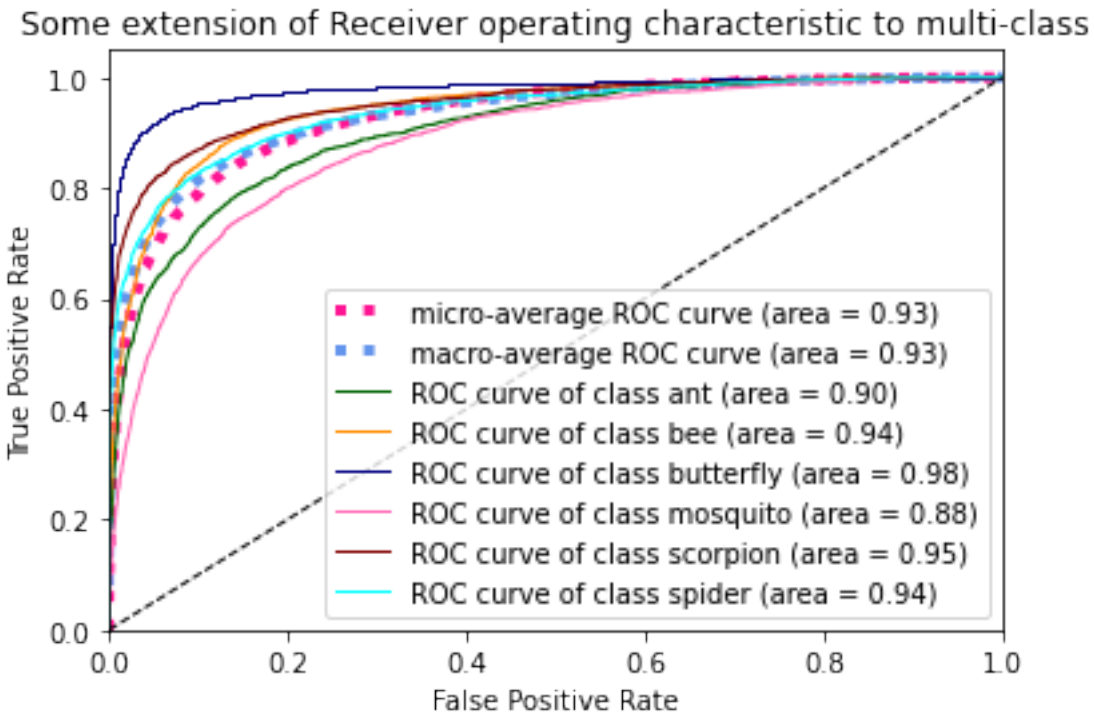



```
Test loss: 0.9156
```

	precision	recall	f1-score	support
ant	0.60	0.71	0.65	2478
bee	0.59	0.87	0.70	2488
butterfly	0.92	0.81	0.86	2557
mosquito	0.56	0.65	0.60	2527
scorpion	0.92	0.66	0.77	2468
spider	0.93	0.54	0.68	2482
accuracy			0.71	15000
macro avg	0.75	0.71	0.71	15000
weighted avg	0.75	0.71	0.71	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.714 0.096 0.014 0.144 0.018 0.014
0.031 0.868 0.013 0.078 0.008 0.002
0.027 0.128 0.808 0.032 0.003 0.002
0.128 0.174 0.019 0.650 0.014 0.016
0.126 0.107 0.008 0.098 0.655 0.006
0.160 0.103 0.021 0.166 0.011 0.539
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
ant
bee
butterfly
mosquito
scorpion
spider
0.0
0.2
0.4
0.6
0.8
1.0
Recall

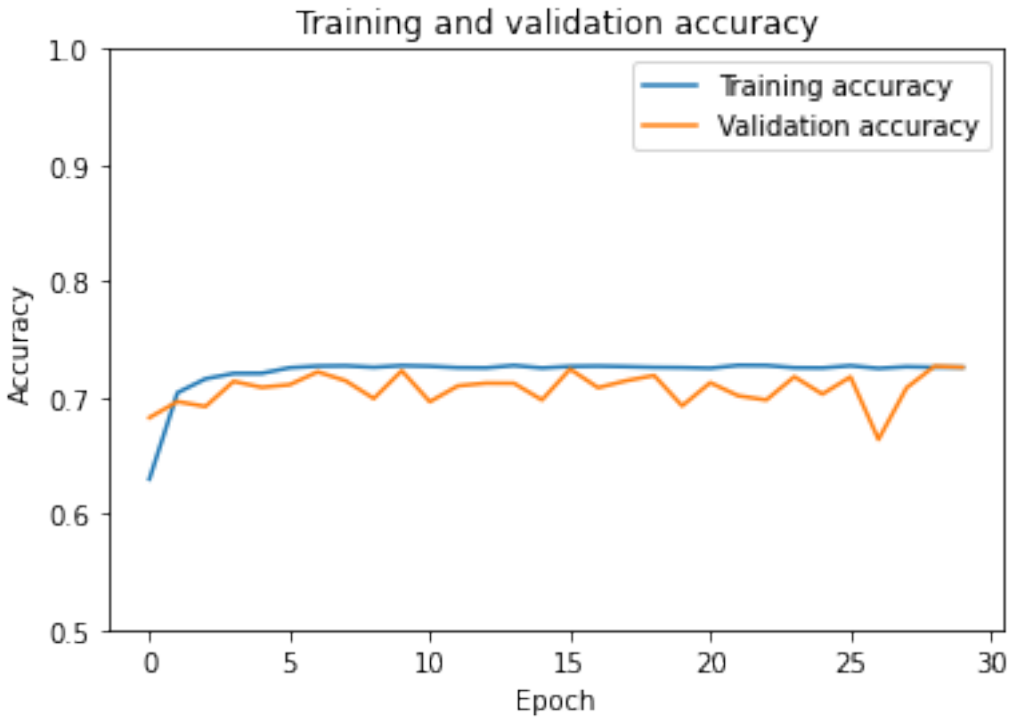



```
One-vs-One ROC AUC scores:
0.931804 (macro),
0.931897 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.931929 (macro),
0.932005 (weighted by prevalence)
```

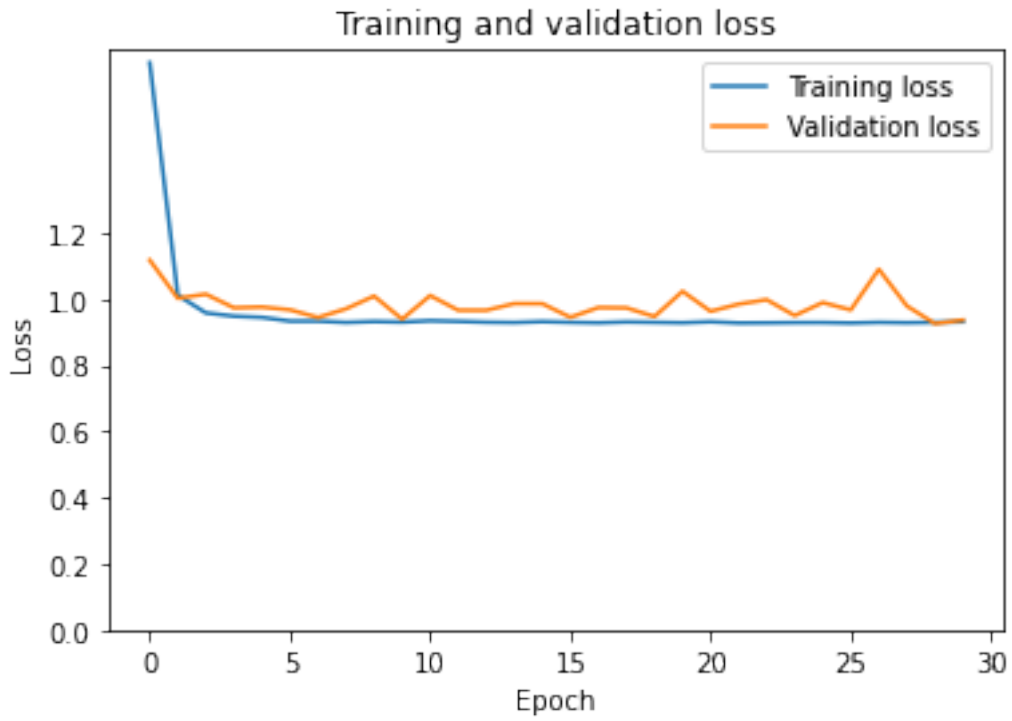
[ ]:
```
model_01L2, history_01L2, score_01L2, y_pred_01L2 = run_model(l2_val=0.01)
```

```
Model: "Multi_Layer_Perceptron_relu_0DO_0.01L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
Dense1_relu (Dense)          (None, 32)                25120
```

```
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0 (Dropout)          (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 71.368 seconds
```

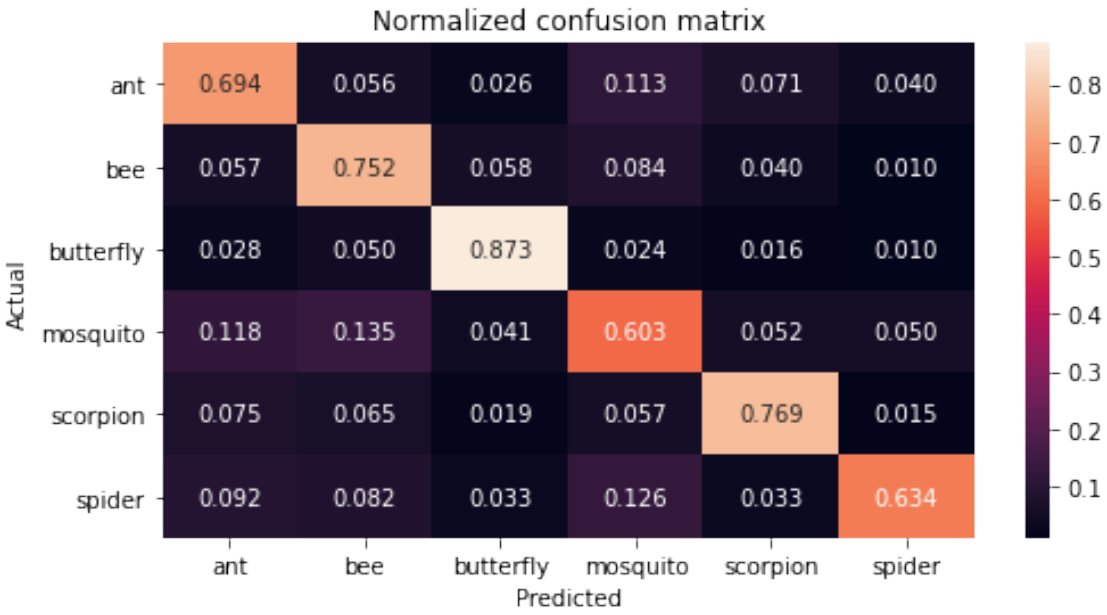


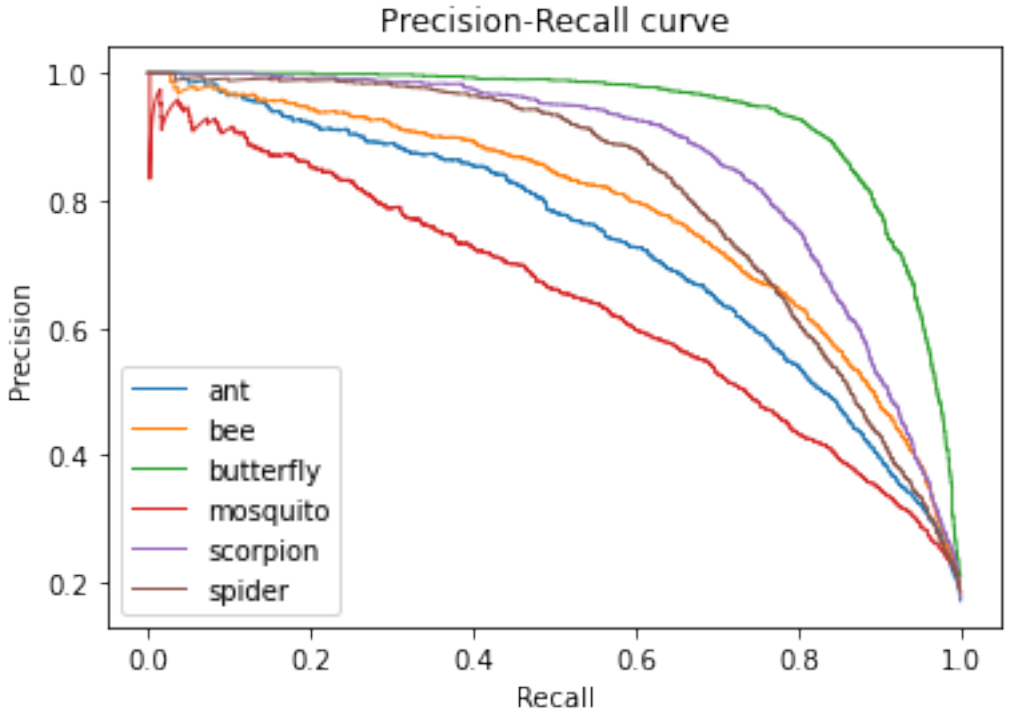
```
Test accuracy: 0.7211
```

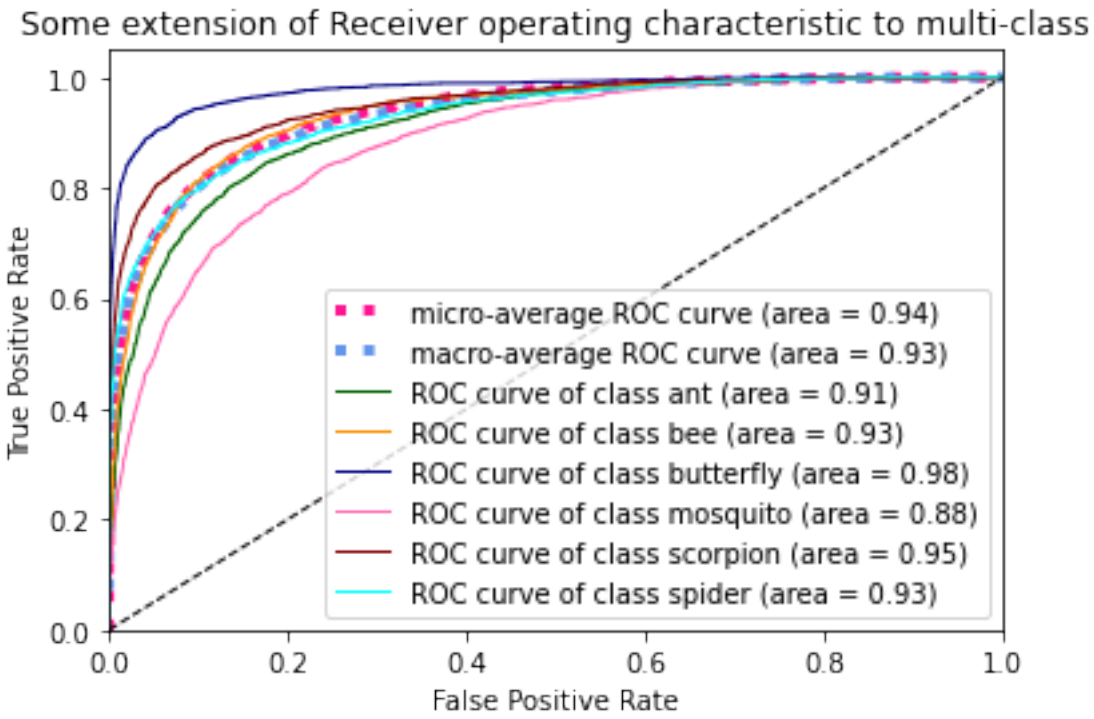



```
Test loss: 0.9464
```

	precision	recall	f1-score	support
ant	0.65	0.69	0.67	2478
bee	0.66	0.75	0.70	2488
butterfly	0.83	0.87	0.85	2557
mosquito	0.60	0.60	0.60	2527
scorpion	0.78	0.77	0.78	2468
spider	0.84	0.63	0.72	2482
accuracy			0.72	15000
macro avg	0.73	0.72	0.72	15000
weighted avg	0.73	0.72	0.72	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.694 0.056 0.026 0.113 0.071 0.040
0.057 0.752 0.058 0.084 0.040 0.010
0.028 0.050 0.873 0.024 0.016 0.010
0.118 0.135 0.041 0.603 0.052 0.050
0.075 0.065 0.019 0.057 0.769 0.015
0.092 0.082 0.033 0.126 0.033 0.634
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
ant
bee
butterfly
mosquito
scorpion
spider
0.0
0.2
0.4
0.6
0.8
1.0
Recall

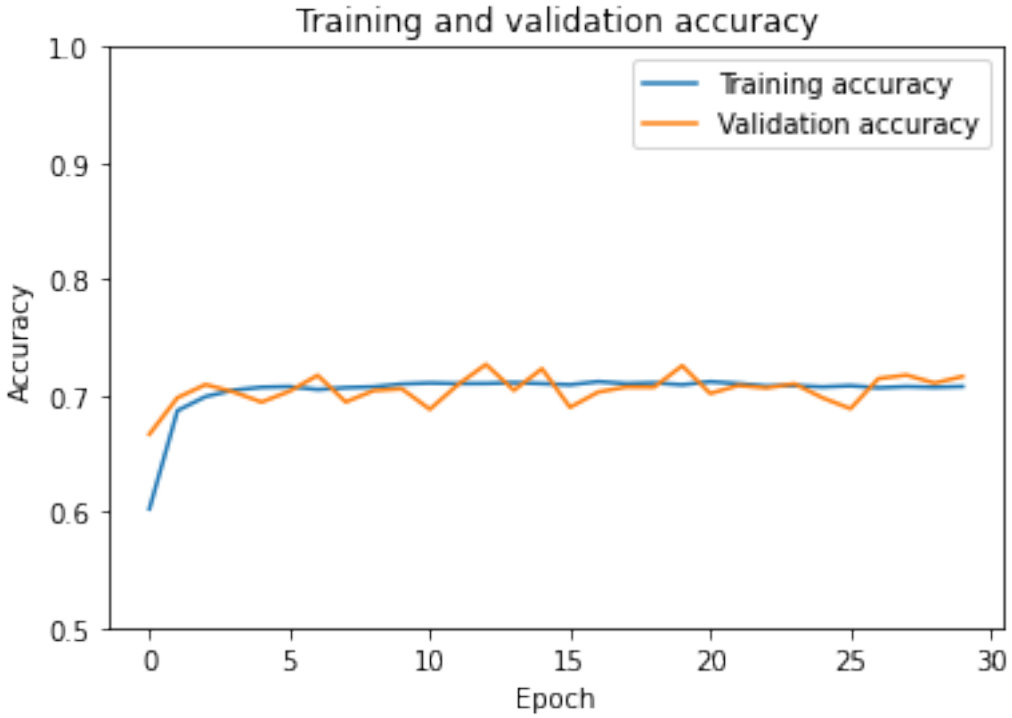



```
One-vs-One ROC AUC scores:
0.931122 (macro),
0.931203 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.931225 (macro),
0.931300 (weighted by prevalence)
```

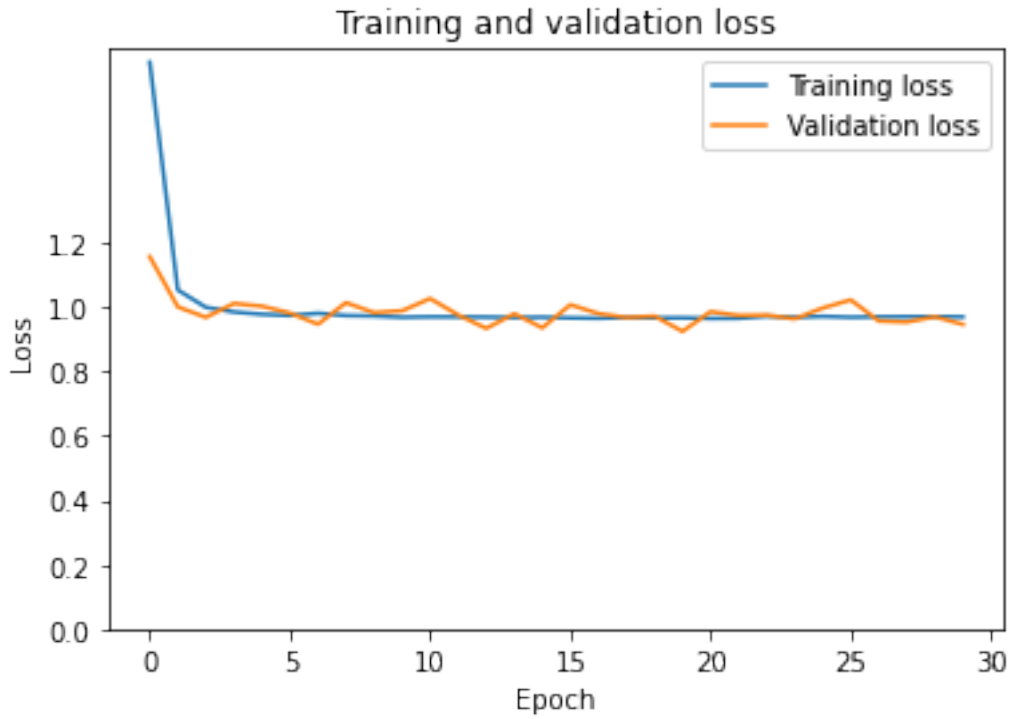
[ ]:
```
model_01L2_10do, history_01L2_10do, score_01L2_10do, y_pred_01L2_10do =␣
↪run_model(l2_val=0.01, dropout=0.1)
```

```
Model: "Multi_Layer_Perceptron_relu_0.1DO_0.01L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

```
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.1 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 71.366 seconds
```

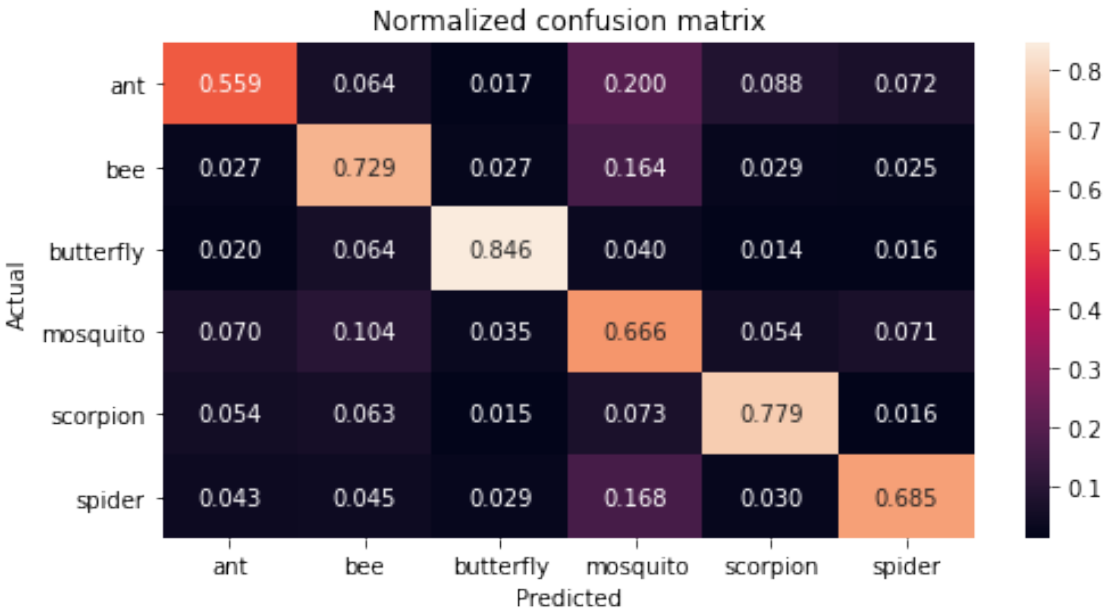


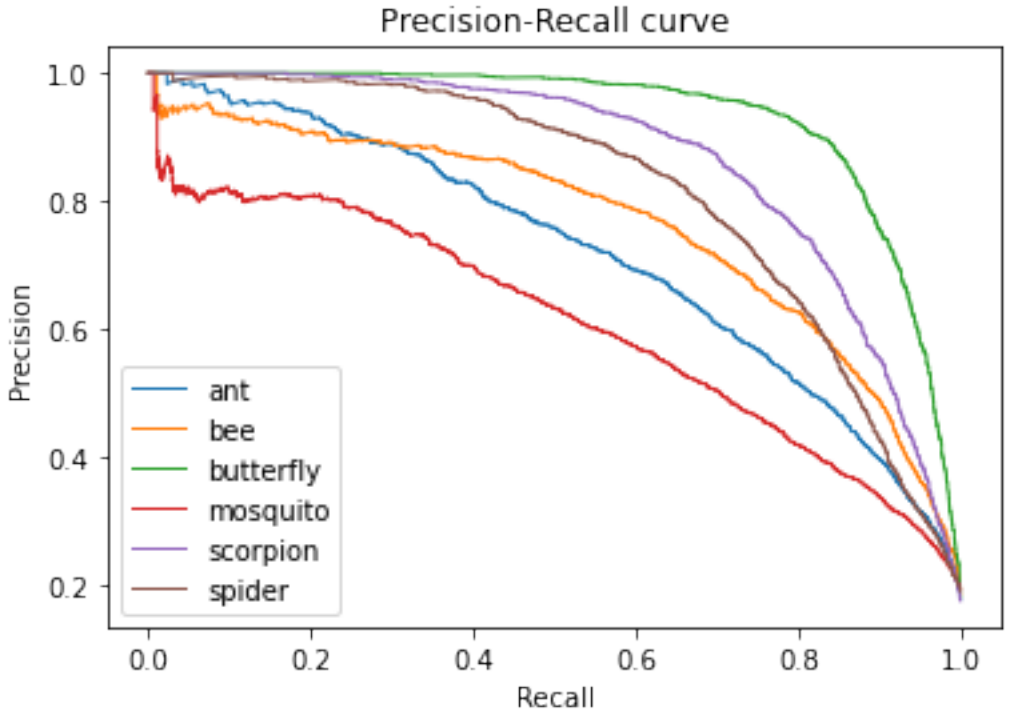
```
Test accuracy: 0.7111
```

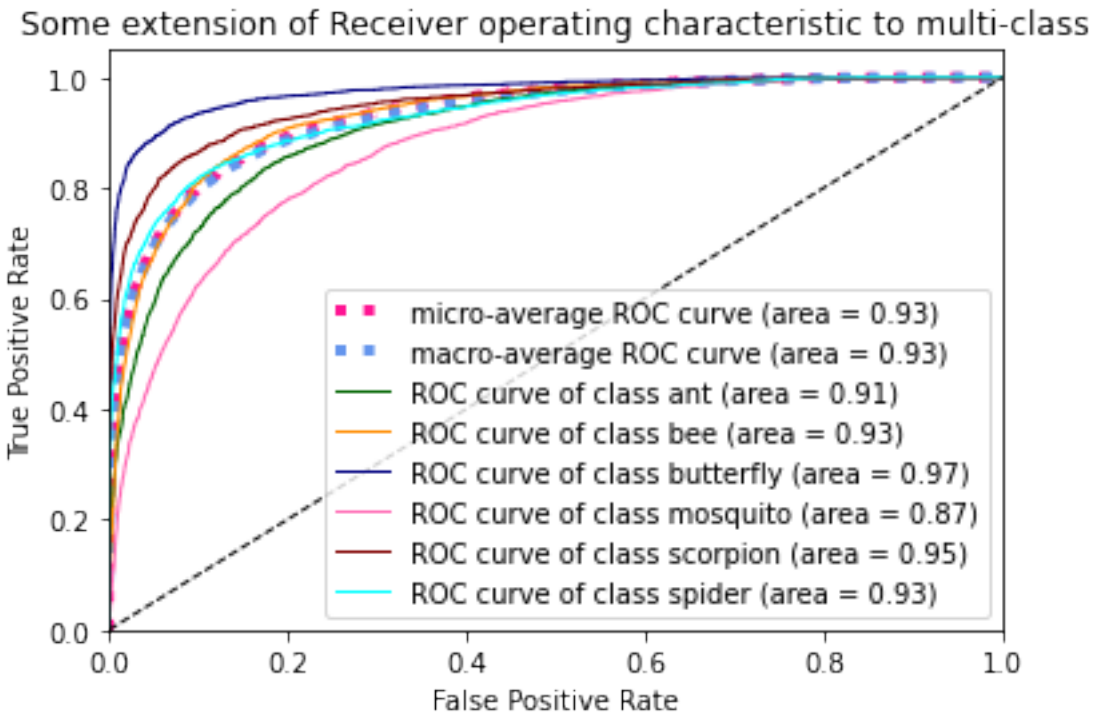



```
Test loss: 0.9581
```

	precision	recall	f1-score	support
ant	0.72	0.56	0.63	2478
bee	0.68	0.73	0.70	2488
butterfly	0.88	0.85	0.86	2557
mosquito	0.51	0.67	0.58	2527
scorpion	0.78	0.78	0.78	2468
spider	0.77	0.68	0.73	2482
accuracy			0.71	15000
macro avg	0.72	0.71	0.71	15000
weighted avg	0.72	0.71	0.71	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.559 0.064 0.017 0.200 0.088 0.072
0.027 0.729 0.027 0.164 0.029 0.025
0.020 0.064 0.846 0.040 0.014 0.016
0.070 0.104 0.035 0.666 0.054 0.071
0.054 0.063 0.015 0.073 0.779 0.016
0.043 0.045 0.029 0.168 0.030 0.685
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
ant
bee
butterfly
mosquito
scorpion
spider
0.0
0.2
0.4
0.6
0.8
1.0
Recall

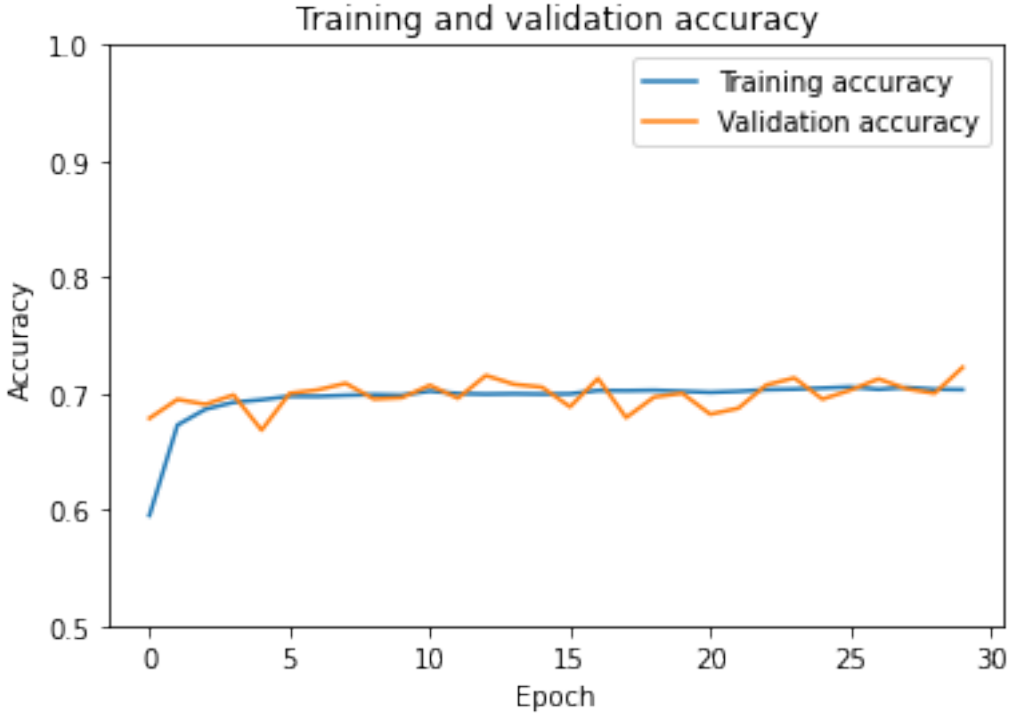



```
One-vs-One ROC AUC scores:
0.928403 (macro),
0.928467 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.928488 (macro),
0.928543 (weighted by prevalence)
```

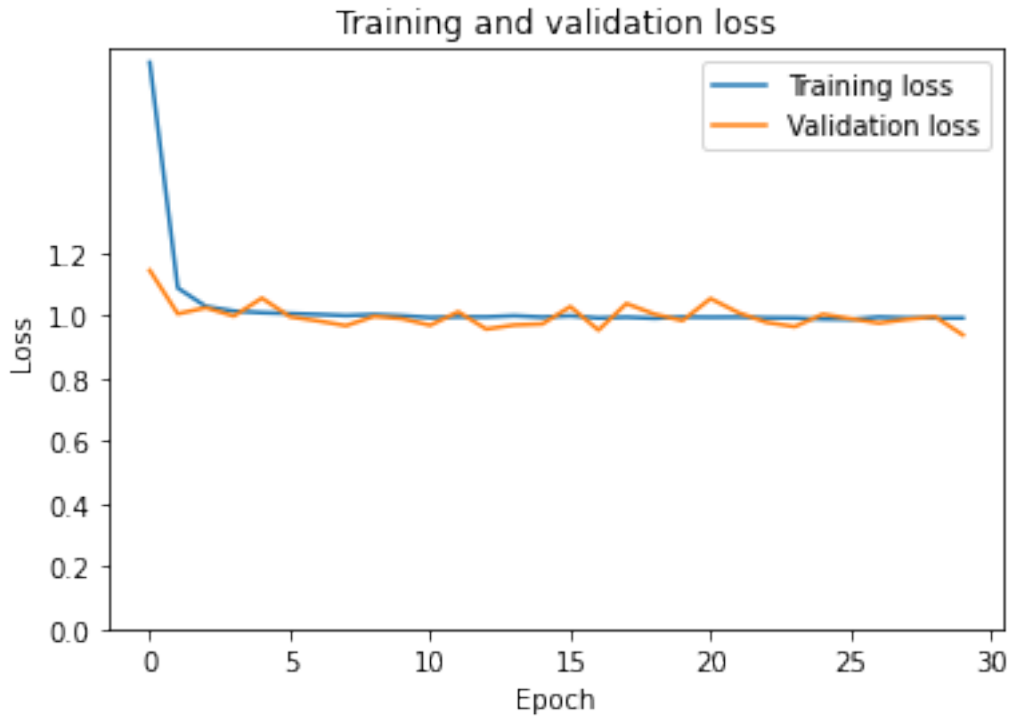
[ ]:
```
model_01L2_20do, history_01L2_20do, score_01L2_20do, y_pred_01L2_20do =␣
↪run_model(l2_val=0.01, dropout=0.2)
```

```
Model: "Multi_Layer_Perceptron_relu_0.2DO_0.01L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

```
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.2 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 70.964 seconds
```

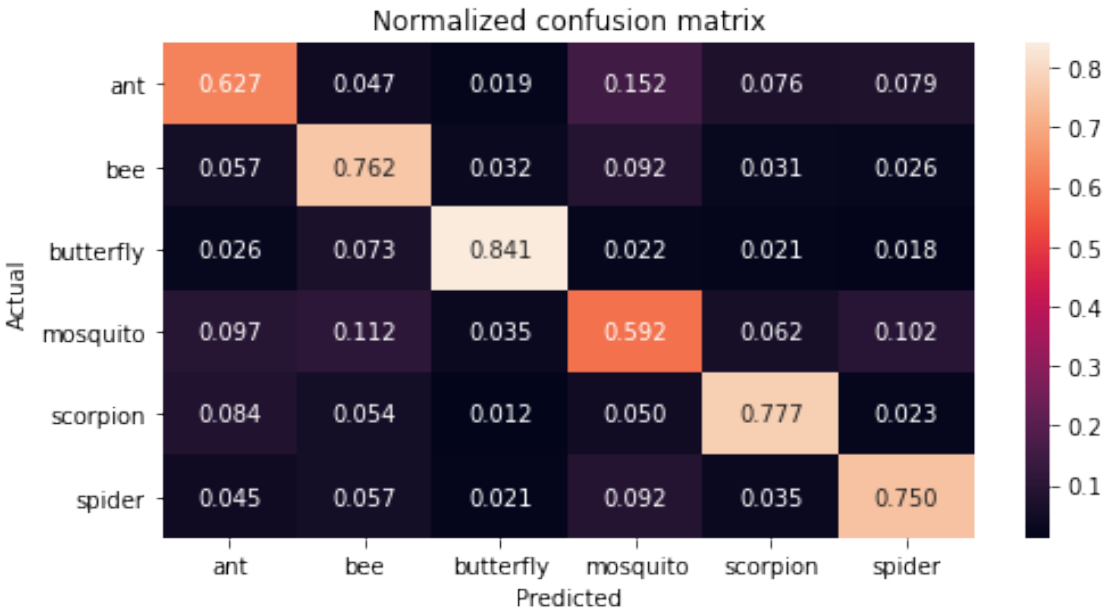


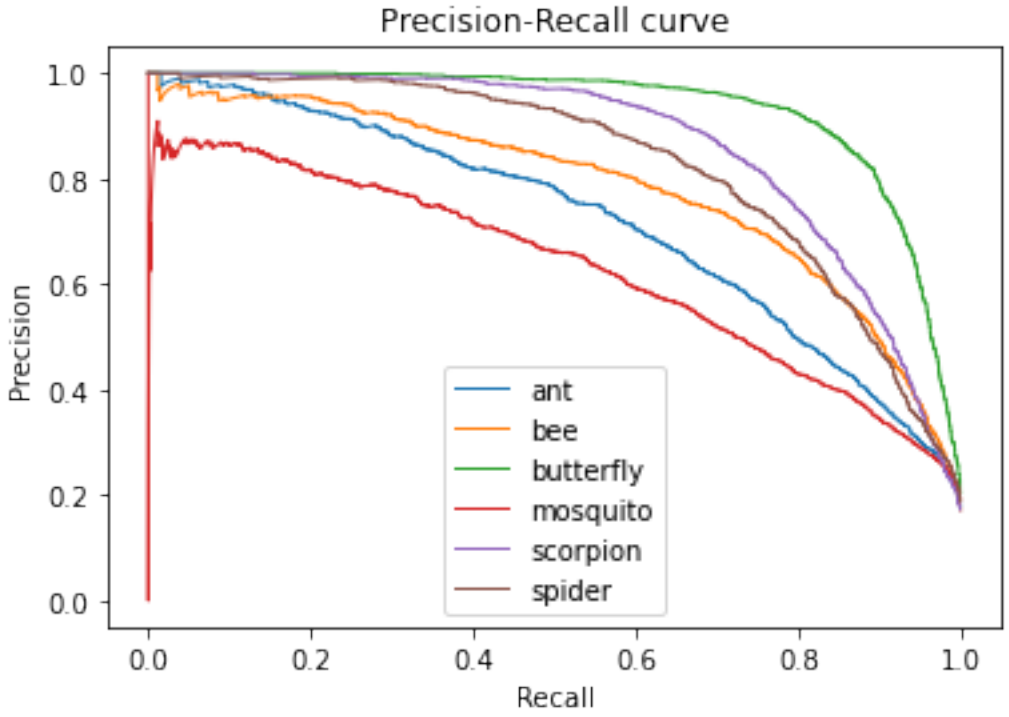
```
Test accuracy: 0.7249
```

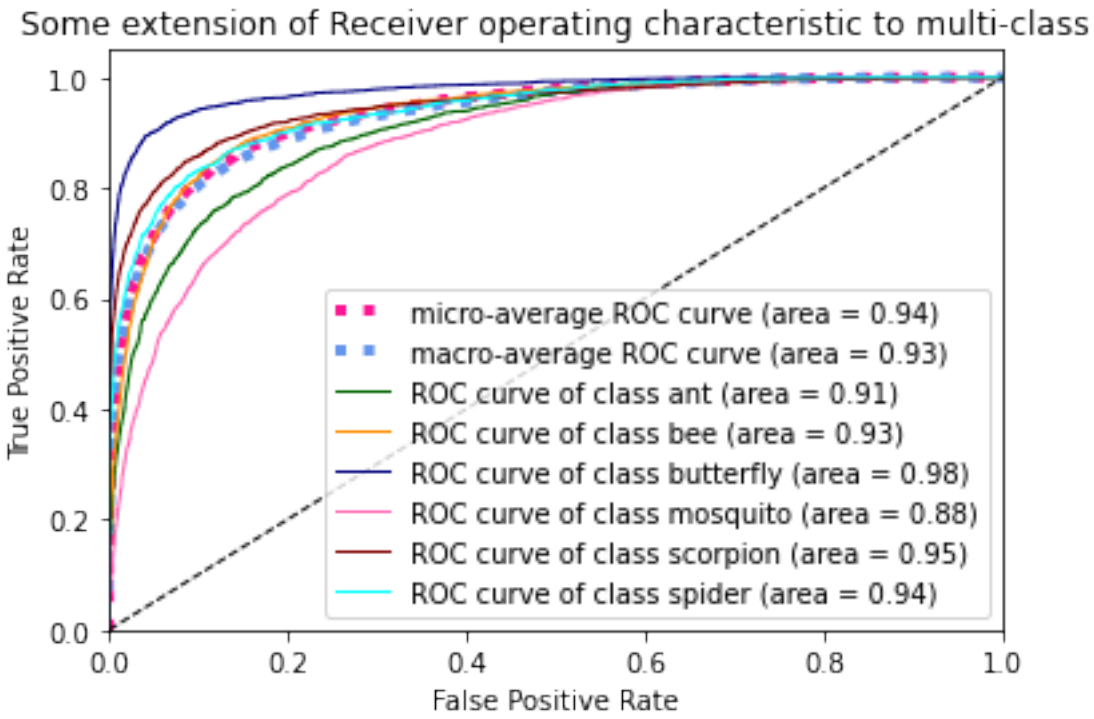



```
Test loss: 0.9387
```

	precision	recall	f1-score	support
ant	0.67	0.63	0.65	2478
bee	0.69	0.76	0.72	2488
butterfly	0.88	0.84	0.86	2557
mosquito	0.60	0.59	0.59	2527
scorpion	0.77	0.78	0.78	2468
spider	0.75	0.75	0.75	2482
accuracy			0.72	15000
macro avg	0.73	0.72	0.72	15000
weighted avg	0.73	0.72	0.72	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.627 0.047 0.019 0.152 0.076 0.079
0.057 0.762 0.032 0.092 0.031 0.026
0.026 0.073 0.841 0.022 0.021 0.018
0.097 0.112 0.035 0.592 0.062 0.102
0.084 0.054 0.012 0.050 0.777 0.023
0.045 0.057 0.021 0.092 0.035 0.750
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
Recall
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
ant
bee
butterfly
mosquito
scorpion
spider

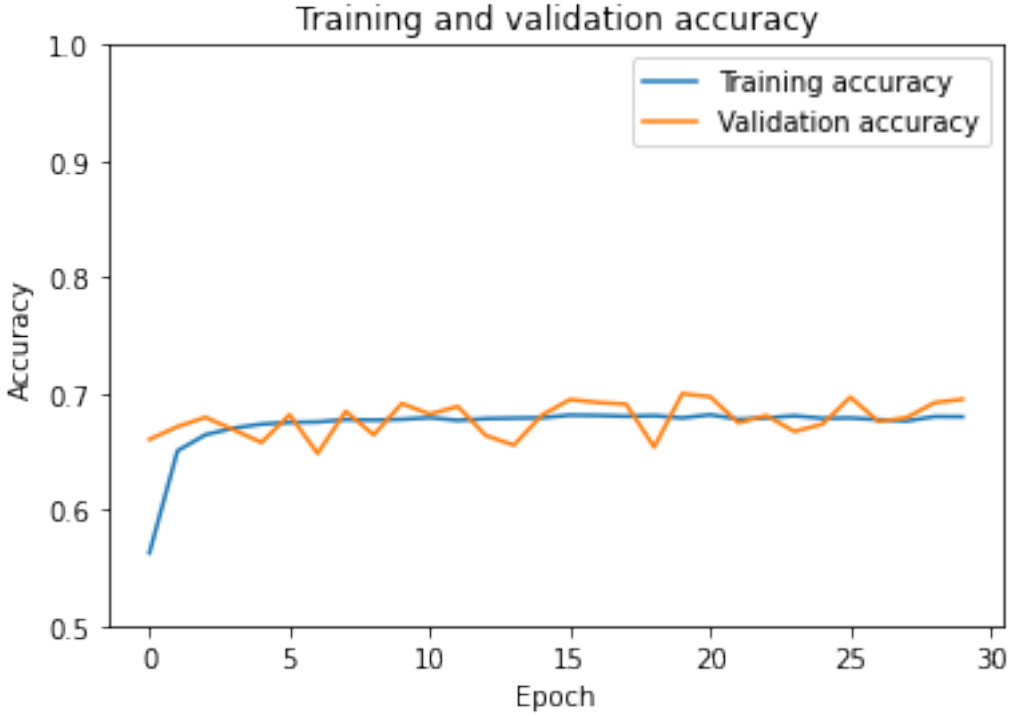



```
One-vs-One ROC AUC scores:
0.930630 (macro),
0.930700 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.930711 (macro),
0.930785 (weighted by prevalence)
```

[ ]:
```
model_01L2_40do, history_01L2_40do, score_01L2_40do, y_pred_01L2_40do =␣
↪run_model(l2_val=0.01, dropout=0.4)
```

```
Model: "Multi_Layer_Perceptron_relu_0.4DO_0.01L2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

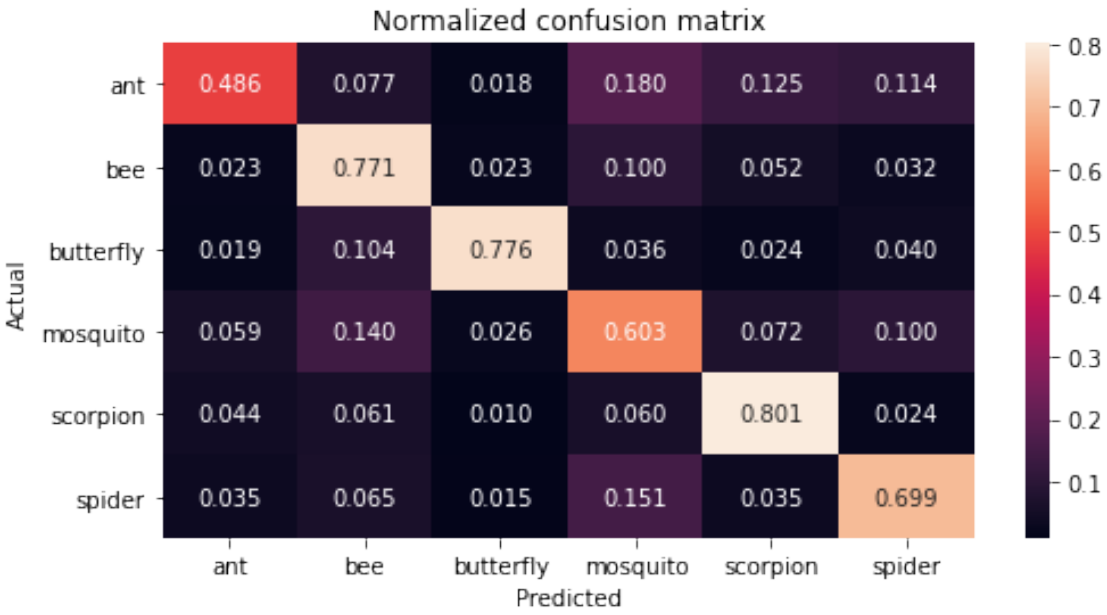
```
Dense1_relu (Dense)          (None, 32)                25120
_________________________________________________________________
BatchNormalization1 (BatchNo (None, 32)                128
_________________________________________________________________
Dense2_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dropout_0.4 (Dropout)        (None, 32)                0
_________________________________________________________________
Dense3_relu (Dense)          (None, 32)                1056
_________________________________________________________________
Dense4_relu (Dense)          (None, 32)                1056
_________________________________________________________________
BatchNormalization2 (BatchNo (None, 32)                128
_________________________________________________________________
Dense5_relu (Dense)          (None, 16)                528
_________________________________________________________________
Output (Dense)               (None, 6)                 102
=================================================================
Total params: 29,174
Trainable params: 29,046
Non-trainable params: 128
_________________________________________________________________
Total train time for 30 epochs = 72.090 seconds
```

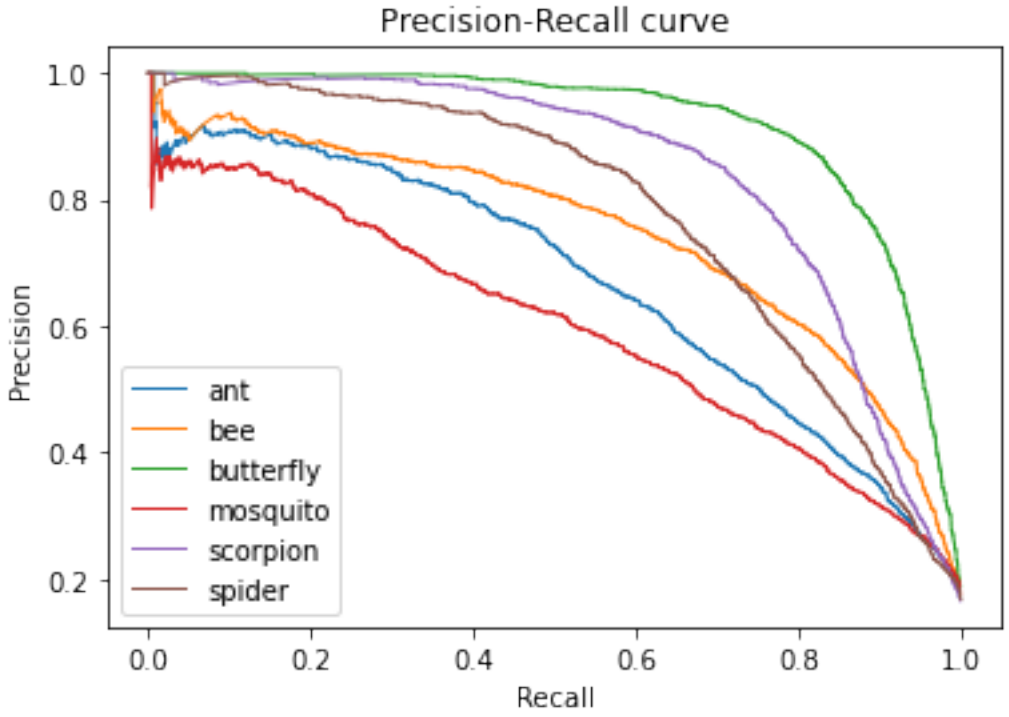


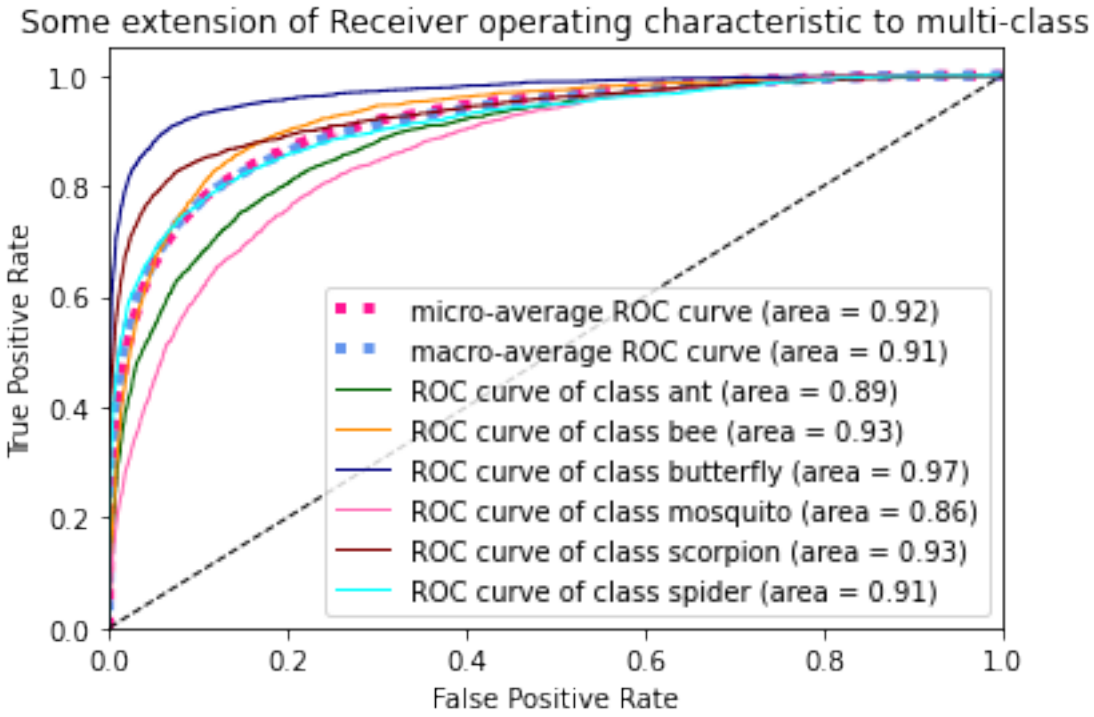
```
Test accuracy: 0.6897
```


```
Test loss: 1.039
```

	precision	recall	f1-score	support
ant	0.73	0.49	0.58	2478
bee	0.63	0.77	0.69	2488
butterfly	0.90	0.78	0.83	2557
mosquito	0.54	0.60	0.57	2527
scorpion	0.72	0.80	0.76	2468
spider	0.69	0.70	0.70	2482
accuracy			0.69	15000
macro avg	0.70	0.69	0.69	15000
weighted avg	0.70	0.69	0.69	15000


Normalized confusion matrix
ant
bee
butterfly
mosquito
scorpion
spider
Actual
0.486 0.077 0.018 0.180 0.125 0.114
0.023 0.771 0.023 0.100 0.052 0.032
0.019 0.104 0.776 0.036 0.024 0.040
0.059 0.140 0.026 0.603 0.072 0.100
0.044 0.061 0.010 0.060 0.801 0.024
0.035 0.065 0.015 0.151 0.035 0.699
ant
bee
butterfly
mosquito
scorpion
spider
Predicted
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


Precision-Recall curve
Precision
1.0
0.8
0.6
0.4
0.2
ant
bee
butterfly
mosquito
scorpion
spider
0.0
0.2
0.4
0.6
0.8
1.0
Recall




```
One-vs-One ROC AUC scores:
0.914622 (macro),
0.914684 (weighted by prevalence)
One-vs-Rest ROC AUC scores:
0.914652 (macro),
0.914769 (weighted by prevalence)
```

0.5.1 Time taken

[ ]:
```
total_time = (time.time() - start_total_time) / 60
print(f"Total time %.3f" % total_time, "minutes")
```

```
Total time 14.549 minutes
```