Importing Packages

```
import IPython
from google.colab import output

display(IPython.display.Javascript('''
 function ClickConnect(){
   btn = document.querySelector("colab-connect-button")
   if (btn != null){
     console.log("Click colab-connect-button");
     btn.click()
     }

   btn = document.getElementById('ok')
   if (btn != null){
     console.log("Click reconnect");
     btn.click()
     }
  }

setInterval(ClickConnect,60000)
'''))

print("Done.")
```

```
Done.
```

```
import pandas as pd
import matplotlib as mat
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
%matplotlib inline

pd.options.display.max_colwidth = 100

import random
import os

from numpy.random import seed
seed(42)

random.seed(42)
os.environ['PYTHONHASHSEED'] = str(42)
os.environ['TF_DETERMINISTIC_OPS'] = '1'

from sklearn.model_selection import train_test_split
from sklearn import metrics
from sklearn.metrics import accuracy_score

import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
from tensorflow.keras import callbacks
from tensorflow.keras.models import Model
from tensorflow.keras.preprocessing.image import ImageDataGenerator

import glob
import cv2

from tensorflow.random import set_seed
set_seed(42)

import warnings
warnings.filterwarnings('ignore')
```

Mount the Drive

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

```
IMG_SIZE = 224
BATCH = 32
SEED = 42
```

Importing Dataset

```
#main_path = "/content/drive/MyDrive/archive (3)/chest_xray"
main_path = "/content/drive/MyDrive/archive (3)/chest_xray"


train_path = os.path.join(main_path,"train")
test_path=os.path.join(main_path,"test")

train_normal = glob.glob(train_path+"/NORMAL/*.jpeg")
train_pneumonia = glob.glob(train_path+"/PNEUMONIA/*.jpeg")

test_normal = glob.glob(test_path+"/NORMAL/*.jpeg")
test_pneumonia = glob.glob(test_path+"/PNEUMONIA/*.jpeg")
train_list = [x for x in train_normal]
train_list.extend([x for x in train_pneumonia])


df_train = pd.DataFrame(np.concatenate([['Normal']*len(train_normal) , ['Pneumonia']*len(train_pneumonia)]), columns = ['class'])
df_train['image'] = [x for x in train_list]

test_list = [x for x in test_normal]
test_list.extend([x for x in test_pneumonia])

df_test = pd.DataFrame(np.concatenate([['Normal']*len(test_normal) , ['Pneumonia']*len(test_pneumonia)]), columns = ['class'])
df_test['image'] = [x for x in test_list]


df_train
```

	class	image
0	Normal	/content/drive/MyDrive/archive (3)/chest_xray/train/NORMAL/NORMAL-3373762-0001.jpeg
1	Normal	/content/drive/MyDrive/archive (3)/chest_xray/train/NORMAL/NORMAL-339692-0002.jpeg
2	Normal	/content/drive/MyDrive/archive (3)/chest_xray/train/NORMAL/NORMAL-3411116-0001.jpeg
3	Normal	/content/drive/MyDrive/archive (3)/chest_xray/train/NORMAL/NORMAL-3482198-0003.jpeg
4	Normal	/content/drive/MyDrive/archive (3)/chest_xray/train/NORMAL/NORMAL-332359-0001.jpeg
...	...	...
5287	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/BACTERIA-4342499-0004.jpeg
5288	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/BACTERIA-4371619-0002.jpeg

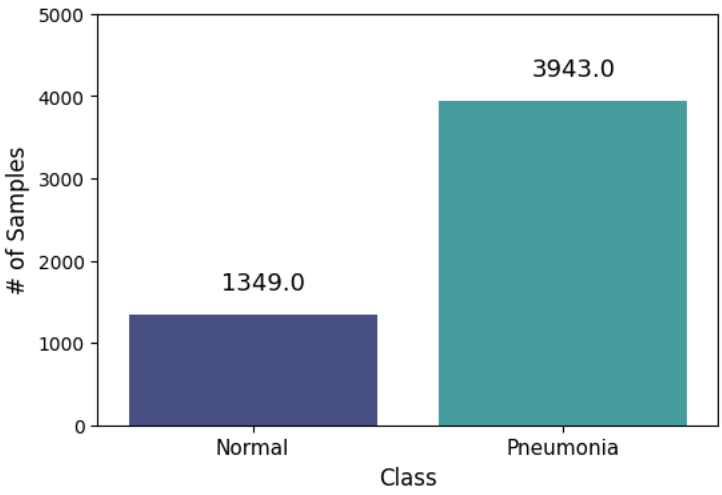
```
df_test
```

```
class                                                                image
```

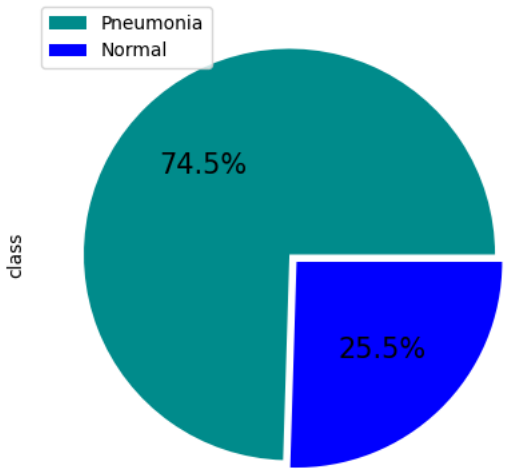
Data Exploration

```
. .. . /content/drive/MyDrive/archive (3)/chest_xray/test/NORMAL/NORMAL-1049278-
```

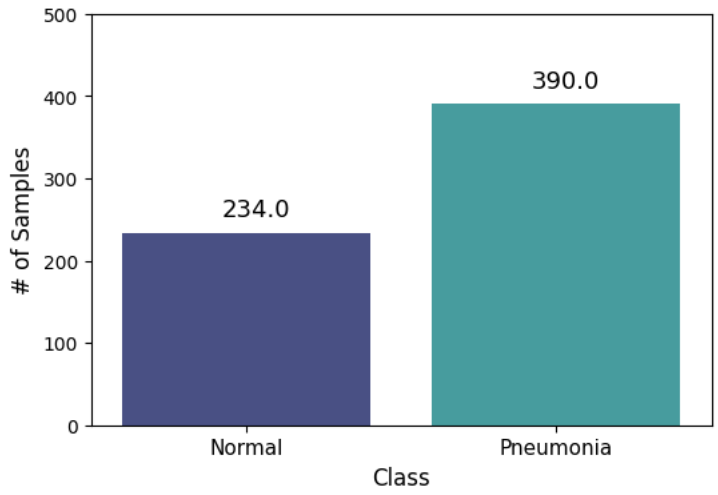
```
plt.figure(figsize=(6,4))

ax = sns.countplot(x='class', data=df_train, palette="mako")

plt.xlabel("Class", fontsize= 12)
plt.ylabel("# of Samples", fontsize= 12)
plt.ylim(0,5000)
plt.xticks([0,1], ['Normal', 'Pneumonia'], fontsize = 11)

for p in ax.patches:
    ax.annotate((p.get_height()), (p.get_x()+0.30, p.get_height()+300), fontsize = 13)

plt.show()
```



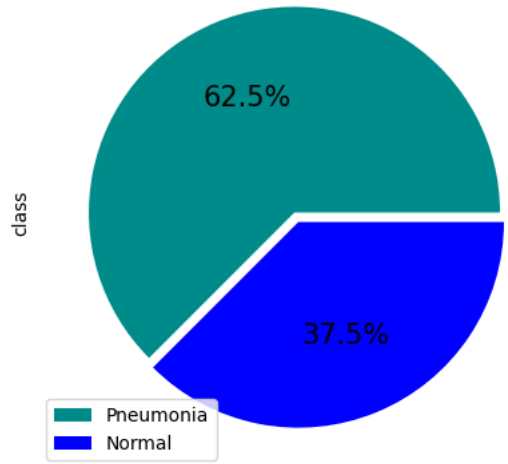

```
plt.figure(figsize=(7,5))

df_train['class'].value_counts().plot(kind='pie',labels = ['',''], autopct='%1.1f%%', colors = ['darkcyan','blue'], explode = [0,0.05],

plt.legend(labels=['Pneumonia', 'Normal'])
plt.show()
```



```
plt.figure(figsize=(6,4))

ax = sns.countplot(x='class', data=df_test, palette="mako")

plt.xlabel("Class", fontsize= 12)
plt.ylabel("# of Samples", fontsize= 12)
plt.ylim(0,500)
plt.xticks([0,1], ['Normal', 'Pneumonia'], fontsize = 11)

for p in ax.patches:
    ax.annotate((p.get_height()), (p.get_x()+0.32, p.get_height()+20), fontsize = 13)

plt.show()
```



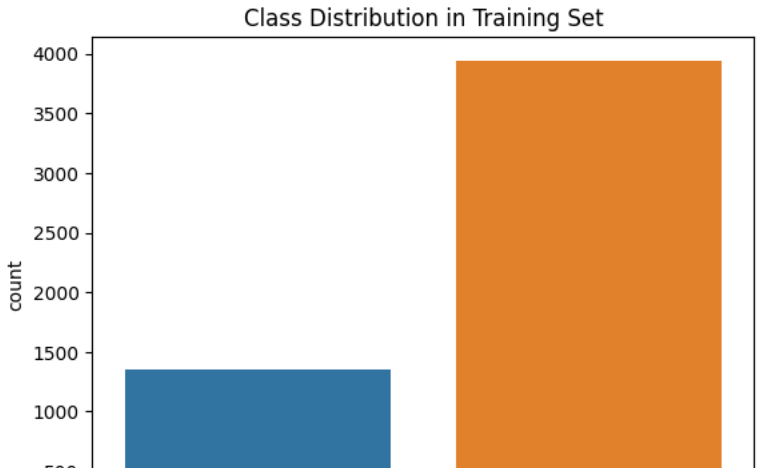

```
plt.figure(figsize=(7,5))

df_test['class'].value_counts().plot(kind='pie',labels = ['',''], autopct='%1.1f%%', colors = ['darkcyan','blue'], explode = [0,0.05], t

plt.legend(labels=['Pneumonia', 'Normal'])
plt.show()
```



The distributions from these datasets are a little different from each other. Both are slightly imbalanced, having more samples from the positive class (Pneumonia), with the training set being a little more imbalanced.

Before we move on to the next section, we will take a look at a few examples from each dataset.

```
# Explore class distribution
sns.countplot(x='class', data=df_train)
plt.title('Class Distribution in Training Set')
plt.show()
```



Data Visualization

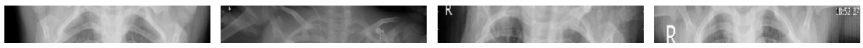
class

```
print('Train Set - Normal')

plt.figure(figsize=(12,12))

for i in range(0, 12):
    plt.subplot(3,4,i + 1)
    img = cv2.imread(train_normal[i])
    img = cv2.resize(img, (IMG_SIZE,IMG_SIZE))
    plt.imshow(img)
    plt.axis("off")

plt.tight_layout()

plt.show()
```

```
Train Set - Normal
```

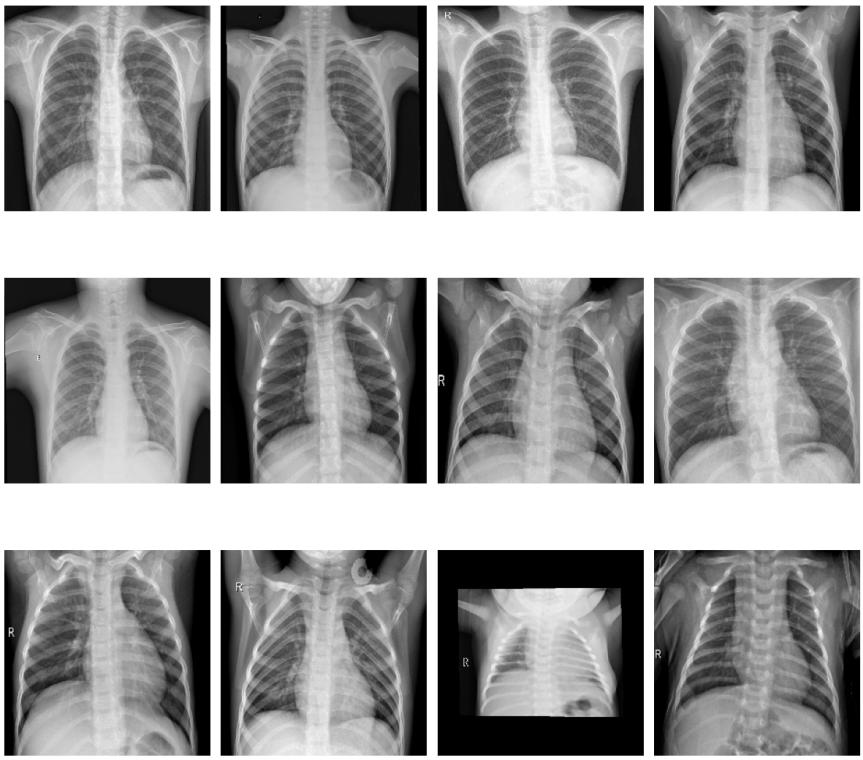
```
print('Train Set - Pneumonia')

plt.figure(figsize=(12,12))

for i in range(0, 12):
    plt.subplot(3,4,i + 1)
    img = cv2.imread(train_pneumonia[i])
    img = cv2.resize(img, (IMG_SIZE,IMG_SIZE))
    plt.imshow(img)
    plt.axis("off")

plt.tight_layout()

plt.show()
```

```
Train Set - Pneumonia
```



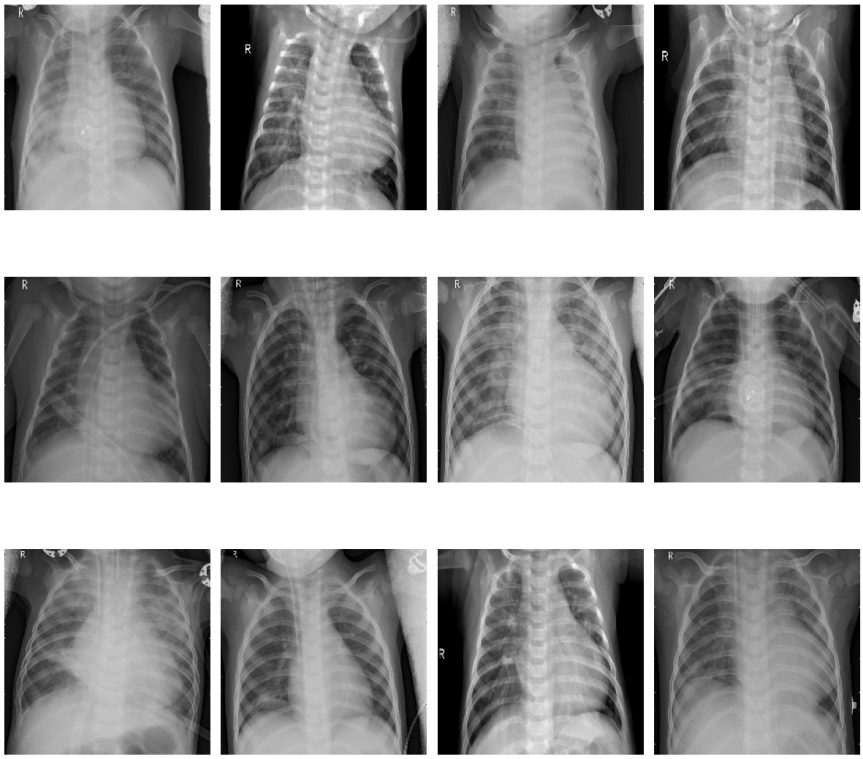
```
print('Test Set - Normal')

plt.figure(figsize=(12,12))

for i in range(0, 12):
    plt.subplot(3,4,i + 1)
    img = cv2.imread(test_normal[i])
    img = cv2.resize(img, (IMG_SIZE,IMG_SIZE))
    plt.imshow(img)
    plt.axis("off")

plt.tight_layout()

plt.show()
```

```
Test Set - Normal
```

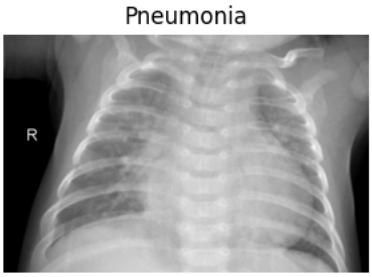


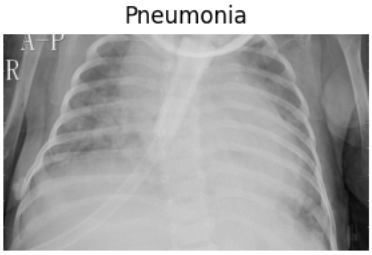
```
print('Test Set - Pneumonia')

plt.figure(figsize=(12,12))

for i in range(0, 12):
    plt.subplot(3,4,i + 1)
    img = cv2.imread(test_pneumonia[i])
    img = cv2.resize(img, (IMG_SIZE,IMG_SIZE))
    plt.imshow(img)
    plt.axis("off")

plt.tight_layout()

plt.show()
```

Test Set - Pneumonia



```
# Display sample images with both classes
normal_samples = df_train[df_train['class'] == 'Normal'].sample(3)
pneumonia_samples = df_train[df_train['class'] == 'Pneumonia'].sample(3)
sample_df = pd.concat([normal_samples, pneumonia_samples])

plt.figure(figsize=(12, 6))
for i, row in sample_df.iterrows():
    img = cv2.imread(row['image'])
    plt.subplot(2, 3, i % 6 + 1)
    plt.imshow(cv2.cvtColor(img, cv2.COLOR_BGR2RGB))
    plt.title(row['class'])
    plt.axis('off')
plt.show()
```






```
# Visualize a few images with their corresponding labels
sample_df = df_train.sample(9)

plt.figure(figsize=(12, 8))
for i, row in sample_df.iterrows():
    img = cv2.imread(row['image'])
    plt.subplot(3, 3, i % 9 + 1)
    plt.imshow(cv2.cvtColor(img, cv2.COLOR_BGR2RGB))
    plt.title(row['class'])
    plt.axis('off')

plt.show()
```

Preparing Data

First, we need to create a validation set. To do that, we apply a simple stratified split on the original train dataset, using 80% for actual training and 20% for validation purposes.

```
# Import necessary libraries for data preprocessing
from sklearn.model_selection import train_test_split
from tensorflow.keras.preprocessing.image import ImageDataGenerator
```



```
# Split the data into training and validation sets
train_df, val_df = train_test_split(df_train, test_size=0.2, random_state=42, stratify=df_train['class'])

# Data augmentation using ImageDataGenerator
datagen = ImageDataGenerator(rescale=1./255, shear_range=0.2, zoom_range=0.2, horizontal_flip=True)

# Create data generators for training and validation
train_generator = datagen.flow_from_dataframe(dataframe=train_df, x_col='image', y_col='class', target_size=(IMG_SIZE, IMG_SIZE), batch_
val_generator = datagen.flow_from_dataframe(dataframe=val_df, x_col='image', y_col='class', target_size=(IMG_SIZE, IMG_SIZE), batch_size
```

```
Found 4233 validated image filenames belonging to 2 classes.
Found 1059 validated image filenames belonging to 2 classes.
```

```
train_df, val_df = train_test_split(df_train, test_size = 0.20, random_state = SEED, stratify = df_train['class'])
```

```
train_df
```

	class	image
1911	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/VIRUS-6835737-0001.jpeg
2873	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/BACTERIA-9496210-0001.jpeg
2979	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/VIRUS-1077882-0001.jpeg
3069	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/VIRUS-1538177-0006.jpeg
708	Normal	/content/drive/MyDrive/archive (3)/chest_xray/train/NORMAL/NORMAL-8201650-0001.jpeg
...	...	...
2031	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/VIRUS-7792467-0002.jpeg
5076	Pneumonia	/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/BACTERIA-3643463-0001.jpeg

```
val_df
```

	class	image
		/content/drive/MyDrive/archive (3)/chest_xray/train/PNEUMONIA/VIRUS-
		/content/drive/MyDrive/archive (3)/chest_xray/train/NORMAL/NORMAL-
1134	Normal	

Now, we're going to load the images from the folders and prepare them to feed our models.

We begin by defining the data generators. With Keras Image Data Generator, we can rescale the pixel values and apply random transformation techniques for data augmentation on the fly. We define two different generators. The val_datagen is used to simply rescale the validation and test sets. The train_datagen includes some transformations to augment the train set.

We apply those generators on each dataset using the flow_from_dataframe method. Apart from the transformations defined in each generator, the images are also resized based on the target_size set

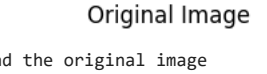
```
                                                                    1330010-0001.jpeg
train_datagen = ImageDataGenerator(rescale=1/255.,
                                   zoom_range = 0.1,
                                   #rotation_range = 0.1,
                                   width_shift_range = 0.1,
                                   height_shift_range = 0.1)

val_datagen = ImageDataGenerator(rescale=1/255.)

ds_train = train_datagen.flow_from_dataframe(train_df,
                                             #directory=train_path, #dataframe contains the full paths
                                             x_col = 'image',
                                             y_col = 'class',
                                             target_size = (IMG_SIZE, IMG_SIZE),
                                             class_mode = 'binary',
                                             batch_size = BATCH,
                                             seed = SEED)

ds_val = val_datagen.flow_from_dataframe(val_df,
                                         #directory=train_path,
                                         x_col = 'image',
                                         y_col = 'class',
                                         target_size = (IMG_SIZE, IMG_SIZE),
                                         class_mode = 'binary',
                                         batch_size = BATCH,
                                         seed = SEED)

ds_test = val_datagen.flow_from_dataframe(df_test,
                                         #directory=test_path,
                                         x_col = 'image',
                                         y_col = 'class',
                                         target_size = (IMG_SIZE, IMG_SIZE),
                                         class_mode = 'binary',
                                         batch_size = 1,
                                         shuffle = False)
```

```
Found 4233 validated image filenames belonging to 2 classes.
Found 1059 validated image filenames belonging to 2 classes.
Found 624 validated image filenames belonging to 2 classes.
```

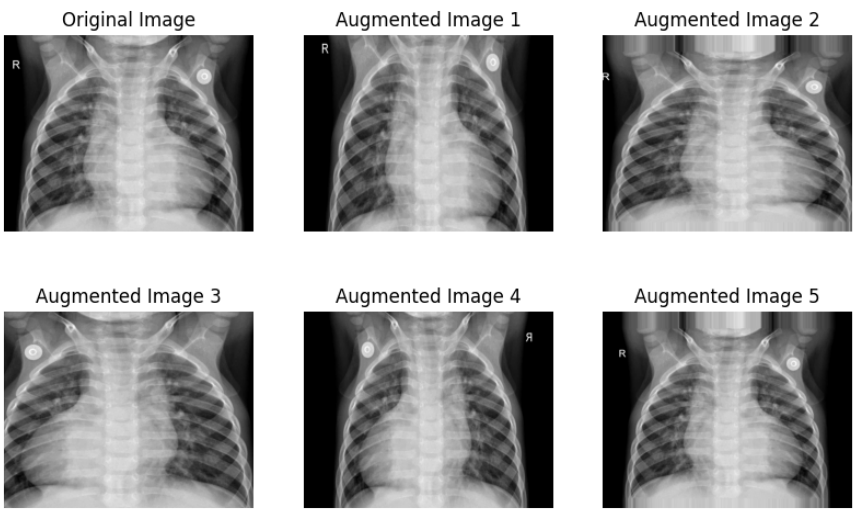
Data Augmentation

```
# Choose a random image from the training set
sample_image_path = train_df['image'].sample(1).values[0]

# Load the original image
original_image = plt.imread(sample_image_path)

# Display the original image
plt.figure(figsize=(10, 6))
plt.subplot(2, 3, 1)
plt.imshow(original_image)
plt.title('Original Image')
plt.axis('off')
```

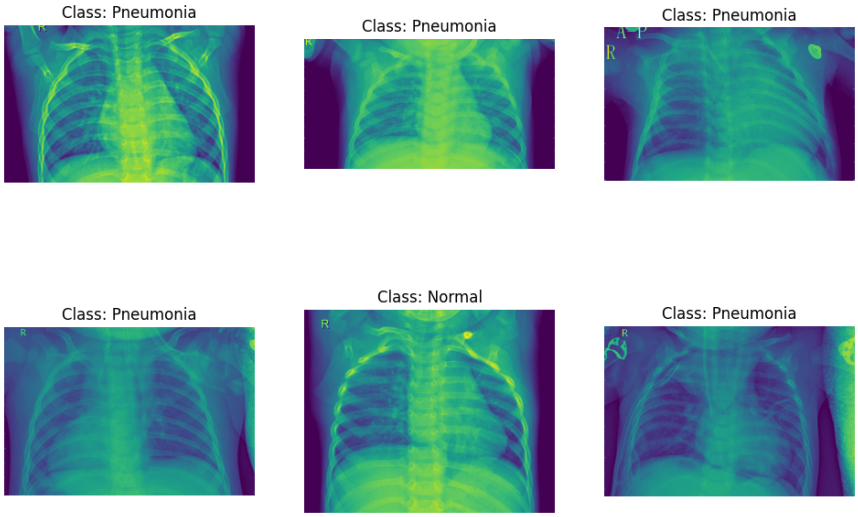
```
(-0.5, 1291.5, 1013.5, -0.5)
```



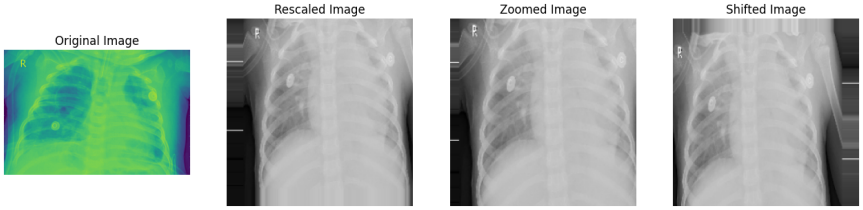

```
# Load the original image
original_image = plt.imread(sample_image_path)

# Check if the image is single-channel (grayscale)
if len(original_image.shape) == 2:
    # Add a channel dimension to make it multi-channel
    original_image = np.expand_dims(original_image, axis=-1)

# Display the original image
plt.figure(figsize=(10, 6))
plt.subplot(2, 3, 1)
plt.imshow(original_image.squeeze(), cmap='gray')  # Squeeze to remove the singleton channel dimension for display
plt.title('Original Image')
plt.axis('off')

# Display augmented images
augmented_images = [datagen.random_transform(original_image) for _ in range(5)]

for i in range(5):
    plt.subplot(2, 3, i + 2)
    plt.imshow(augmented_images[i].squeeze(), cmap='gray')  # Squeeze to remove the singleton channel dimension for display
    plt.title(f'Augmented Image {i + 1}')
    plt.axis('off')

plt.show()
```




```
# Choose a few random images from the validation set
sample_val_images = val_df.sample(6)

plt.figure(figsize=(12, 8))

for i, (_, row) in enumerate(sample_val_images.iterrows(), 1):
    img_path = row['image']
    img = plt.imread(img_path)

    plt.subplot(2, 3, i)
    plt.imshow(img)
    plt.title(f"Class: {row['class']}")
    plt.axis('off')

plt.show()
```




```
# Choose a random image from the training set
sample_image_path = train_df['image'].sample(1).values[0]

# Load the original image
original_image = plt.imread(sample_image_path)

# Rescale, zoom, and shift the original image using the data generator
rescaled_image = ds_train[0][0][0]
zoomed_image = ds_train[0][0][0]
shifted_image = ds_train[0][0][0]

# Display the original and augmented images in a single diagram
plt.figure(figsize=(16, 4))

# Original Image
plt.subplot(1, 4, 1)
plt.imshow(original_image)
plt.title('Original Image')
plt.axis('off')

# Rescaled Image
plt.subplot(1, 4, 2)
plt.imshow(rescaled_image)
plt.title('Rescaled Image')
plt.axis('off')

# Zoomed Image
plt.subplot(1, 4, 3)
plt.imshow(zoomed_image)
plt.title('Zoomed Image')
plt.axis('off')

# Shifted Image
plt.subplot(1, 4, 4)
plt.imshow(shifted_image)
plt.title('Shifted Image')
plt.axis('off')

plt.show()
```



Model - CNN

```
#Setting callbakcs

early_stopping = callbacks.EarlyStopping(
    monitor='val_loss',
    patience=5,
    min_delta=1e-7,
    restore_best_weights=True,
)

plateau = callbacks.ReduceLROnPlateau(
    monitor='val_loss',
    factor = 0.2,
    patience = 2,
    min_delt = 1e-7,
    cooldown = 0,
    verbose = 1
)


def get_model():

    #Input shape = [width, height, color channels]
    inputs = layers.Input(shape=(IMG_SIZE, IMG_SIZE, 3))

    # Block One
    x = layers.Conv2D(filters=16, kernel_size=3, padding='valid')(inputs)
    x = layers.BatchNormalization()(x)
    x = layers.Activation('relu')(x)
    x = layers.MaxPool2D()(x)
    x = layers.Dropout(0.2)(x)

    # Block Two
    x = layers.Conv2D(filters=32, kernel_size=3, padding='valid')(x)
    x = layers.BatchNormalization()(x)
    x = layers.Activation('relu')(x)
    x = layers.MaxPool2D()(x)
    x = layers.Dropout(0.2)(x)

    # Block Three
    x = layers.Conv2D(filters=64, kernel_size=3, padding='valid')(x)
    x = layers.Conv2D(filters=64, kernel_size=3, padding='valid')(x)
    x = layers.BatchNormalization()(x)
    x = layers.Activation('relu')(x)
    x = layers.MaxPool2D()(x)
    x = layers.Dropout(0.4)(x)

    # Head
    #x = layers.BatchNormalization()(x)
    x = layers.Flatten()(x)
    x = layers.Dense(64, activation='relu')(x)
    x = layers.Dropout(0.5)(x)

    #Final Layer (Output)
    output = layers.Dense(1, activation='sigmoid')(x)

    model = keras.Model(inputs=[inputs], outputs=output)

    return model


keras.backend.clear_session()

model = get_model()
model.compile(loss='binary_crossentropy'
              , optimizer = keras.optimizers.Adam(learning_rate=3e-5), metrics='binary_accuracy')

model.summary()
```

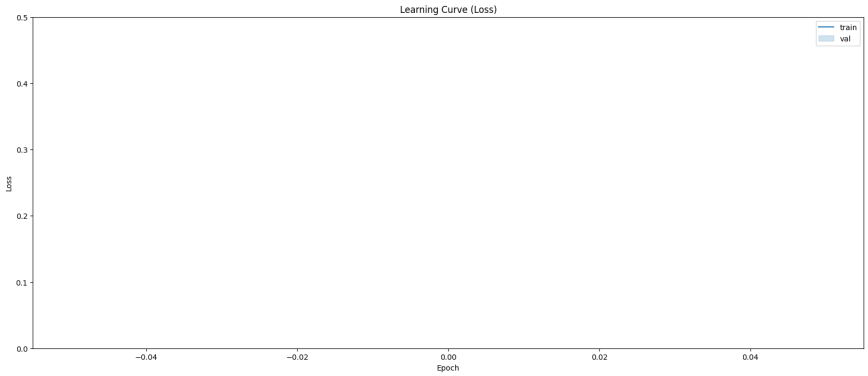
```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 224, 224, 3)]     0

 conv2d (Conv2D)             (None, 222, 222, 16)      448

 batch_normalization (BatchN  (None, 222, 222, 16)     64
 ormalization)

 activation (Activation)     (None, 222, 222, 16)      0

 max_pooling2d (MaxPooling2D  (None, 111, 111, 16)     0
```

```
)

dropout (Dropout)           (None, 111, 111, 16)      0

conv2d_1 (Conv2D)           (None, 109, 109, 32)      4640

batch_normalization_1 (Batc  (None, 109, 109, 32)     128
hNormalization)

activation_1 (Activation)   (None, 109, 109, 32)      0

max_pooling2d_1 (MaxPooling  (None, 54, 54, 32)       0
2D)

dropout_1 (Dropout)         (None, 54, 54, 32)        0

conv2d_2 (Conv2D)           (None, 52, 52, 64)        18496

conv2d_3 (Conv2D)           (None, 50, 50, 64)        36928

batch_normalization_2 (Batc  (None, 50, 50, 64)       256
hNormalization)

activation_2 (Activation)   (None, 50, 50, 64)        0

max_pooling2d_2 (MaxPooling  (None, 25, 25, 64)       0
2D)

dropout_2 (Dropout)         (None, 25, 25, 64)        0

flatten (Flatten)           (None, 40000)             0

dense (Dense)               (None, 64)                2560064

dropout_3 (Dropout)         (None, 64)                0

dense_1 (Dense)             (None, 1)                 65

=================================================================
Total params: 2,621,089
Trainable params: 2,620,865
Non-trainable params: 224
_________________________________________________________________
```

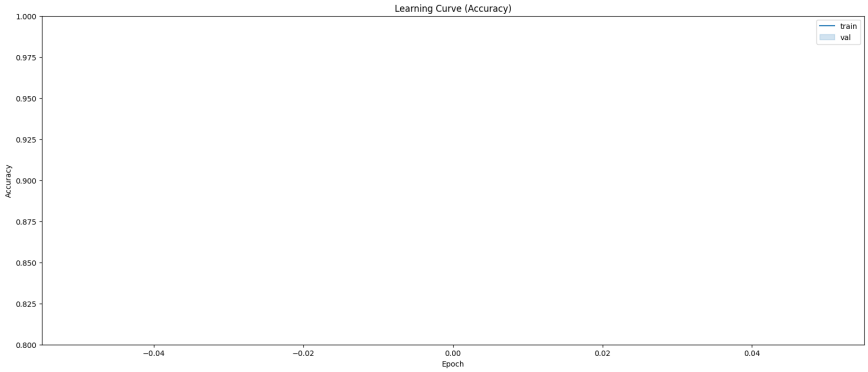
```
history = model.fit(ds_train,
          batch_size = BATCH, epochs = 1,
          validation_data=ds_val,
          callbacks=[early_stopping, plateau],
          steps_per_epoch=(len(train_df)/BATCH),
          validation_steps=(len(val_df)/BATCH));
```

```
132/132 [==============================] - 1801s 14s/step - loss: 0.4617 - binary_accuracy: 0.7987 - val_loss: 1.0181 - val_binary_a
```

```
fig, ax = plt.subplots(figsize=(20,8))
sns.lineplot(x = history.epoch, y = history.history['loss'])
sns.lineplot(x = history.epoch, y = history.history['val_loss'])
ax.set_title('Learning Curve (Loss)')
ax.set_ylabel('Loss')
ax.set_xlabel('Epoch')
ax.set_ylim(0, 0.5)
ax.legend(['train', 'val'], loc='best')
plt.show()
```




```
fig, ax = plt.subplots(figsize=(20,8))
sns.lineplot(x = history.epoch, y = history.history['binary_accuracy'])
sns.lineplot(x = history.epoch, y = history.history['val_binary_accuracy'])
ax.set_title('Learning Curve (Accuracy)')
ax.set_ylabel('Accuracy')
ax.set_xlabel('Epoch')
ax.set_ylim(0.80, 1.0)
ax.legend(['train', 'val'], loc='best')
plt.show()
```




```
score = model.evaluate(ds_val, steps = len(val_df)/BATCH, verbose = 0)
print('Val loss:', score[0])
print('Val accuracy:', score[1])
```

```
Val loss: 1.018072485923767
Val accuracy: 0.7450425028800964
```

```
score = model.evaluate(ds_test, steps = len(df_test), verbose = 0)

print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Test loss: 1.4954638481140137
Test accuracy: 0.625
```

```
num_label = {'Normal': 0, 'Pneumonia' : 1}
Y_test = df_test['class'].copy().map(num_label).astype('int')
```

VGG16

```
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications import VGG16
from tensorflow.keras import layers, models



# Define paths
test_dir = '/content/drive/MyDrive/archive (3)/chest_xray/test'
train_dir = '/content/drive/MyDrive/archive (3)/chest_xray/train'


# Set up data generators with data augmentation for the training set
train_datagen = ImageDataGenerator(
    rescale=1./255,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True
)

test_datagen = ImageDataGenerator(rescale=1./255)


# Create generators
train_generator = train_datagen.flow_from_directory(
    train_dir,
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary'  # Assuming binary classification (Normal or Pneumonia)
)

test_generator = test_datagen.flow_from_directory(
    test_dir,
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary'
)
```

```
Found 5292 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
```

```
# Load pre-trained VGG16 model
base_model = VGG16(weights='imagenet', include_top=False, input_shape=(224, 224, 3))

# Freeze the convolutional layers
for layer in base_model.layers:
    layer.trainable = False


# Build the model on top of VGG16
model = models.Sequential([
    base_model,
    layers.Flatten(),
    layers.Dense(256, activation='relu'),
    layers.Dropout(0.5),
    layers.Dense(1, activation='sigmoid')
])


# Compile the model
model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])


# Train the model
history = model.fit(
    train_generator,
    steps_per_epoch=train_generator.samples // train_generator.batch_size,
    epochs=1,
    validation_data=test_generator,
    validation_steps=test_generator.samples // test_generator.batch_size
)
```

```
165/165 [==============================] - 3726s 22s/step - loss: 0.1824 - accuracy: 0.9287 - val_loss: 0.1742 - val_accuracy: 0.932
```

```
# Evaluate the model on the test set
test_loss, test_acc = model.evaluate(test_generator, steps=test_generator.samples // test_generator.batch_size)
print(f'Test Accuracy: {test_acc}')
```

```
19/19 [==============================] - 356s 19s/step - loss: 0.1748 - accuracy: 0.9326
Test Accuracy: 0.9325658082962036
```

```
# Get predictions for the test set
y_true = test_generator.classes
y_pred_probs = model.predict(test_generator)
y_pred = np.round(y_pred_probs)
```

```
15/20 [=====================>........] - ETA: 1:47
```

```
 # Convert probabilities to class labels
print("Classification Report:")
print(classification_report(y_true, y_pred, target_names=['Normal', 'Pneumonia']))
```

```
Classification Report:
              precision    recall  f1-score   support

      Normal       0.36      0.36      0.36       234
   Pneumonia       0.61      0.61      0.61       390

    accuracy                           0.52       624
   macro avg       0.49      0.49      0.49       624
weighted avg       0.52      0.52      0.52       624
```

```
# Generate confusion matrix
conf_matrix = confusion_matrix(y_true, y_pred)
print("Confusion Matrix:")
print(conf_matrix)
```

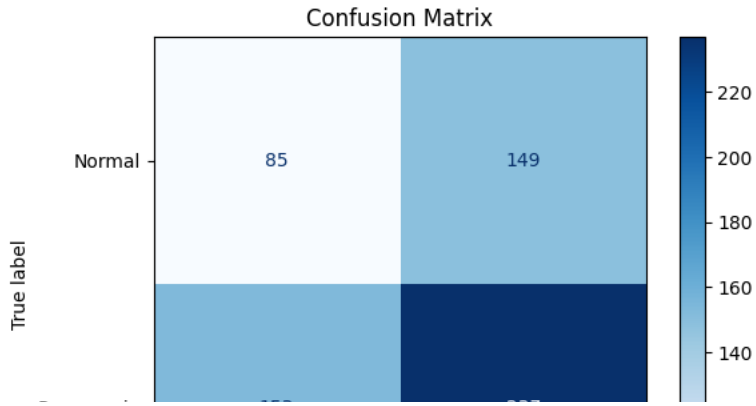
```
Confusion Matrix:
[[ 85 149]
 [153 237]]
```

```
# Extract TP, TN, FP, FN for further analysis if needed
TP = conf_matrix[1, 1]
TN = conf_matrix[0, 0]
FP = conf_matrix[0, 1]
FN = conf_matrix[1, 0]
```

```
# Calculate accuracy, precision, recall, and F1 score
accuracy = (TP + TN) / (TP + TN + FP + FN)
precision = TP / (TP + FP)
recall = TP / (TP + FN)
f1_score = 2 * (precision * recall) / (precision + recall)
print(f"Accuracy: {accuracy:.4f}")
print(f"Precision: {precision:.4f}")
print(f"Recall: {recall:.4f}")
print(f"F1 Score: {f1_score:.4f}")
```

```
Accuracy: 0.5160
Precision: 0.6140
Recall: 0.6077
F1 Score: 0.6108
```

```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.metrics import classification_report, confusion_matrix, ConfusionMatrixDisplay

# Generate confusion matrix
conf_matrix = confusion_matrix(y_true, y_pred)

# Plot confusion matrix
disp = ConfusionMatrixDisplay(confusion_matrix=conf_matrix, display_labels=['Normal', 'Pneumonia'])
disp.plot(cmap='Blues', values_format='d')
plt.title('Confusion Matrix')
plt.show()
```



Transfer Learning

```
base_model = tf.keras.applications.ResNet152V2(
    weights='imagenet',
    input_shape=(IMG_SIZE, IMG_SIZE, 3),
    include_top=False)

base_model.trainable = False

def get_pretrained():

    #Input shape = [width, height, color channels]
    inputs = layers.Input(shape=(IMG_SIZE, IMG_SIZE, 3))

    x = base_model(inputs)

    # Head
    x = layers.GlobalAveragePooling2D()(x)
    x = layers.Dense(128, activation='relu')(x)
    x = layers.Dropout(0.1)(x)

    #Final Layer (Output)
    output = layers.Dense(1, activation='sigmoid')(x)

    model = keras.Model(inputs=[inputs], outputs=output)

    return model
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resnet/resnet152v2_weights_tf_dim_ordering_tf_ker
234545216/234545216 [==============================] - 5s 0us/step
```

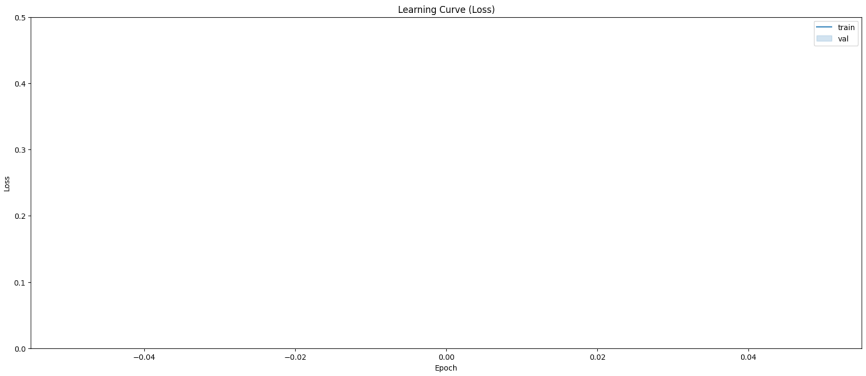
```
keras.backend.clear_session()

model_pretrained = get_pretrained()
model_pretrained.compile(loss='binary_crossentropy'
              , optimizer = keras.optimizers.Adam(learning_rate=5e-5), metrics='binary_accuracy')

model_pretrained.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 224, 224, 3)]     0

 resnet152v2 (Functional)    (None, 7, 7, 2048)        58331648

 global_average_pooling2d (G  (None, 2048)             0
 lobalAveragePooling2D)

 dense (Dense)               (None, 128)               262272

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 1)                 129

=================================================================
Total params: 58,594,049
Trainable params: 262,401
Non-trainable params: 58,331,648
_________________________________________________________________
```

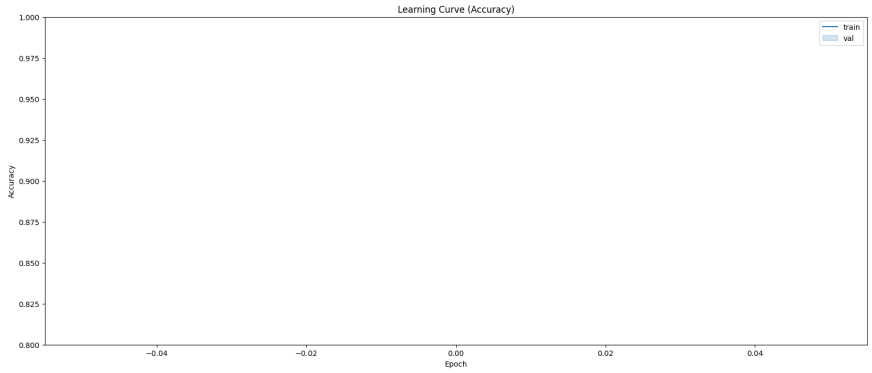
```
history = model_pretrained.fit(ds_train,
          batch_size = BATCH, epochs = 1,
          validation_data=ds_val,
          callbacks=[early_stopping, plateau],
          steps_per_epoch=(len(train_df)/BATCH),
          validation_steps=(len(val_df)/BATCH));
```

```
132/132 [==============================] - 2754s 20s/step - loss: 0.3109 - binary_accuracy: 0.8720 - val_loss: 0.1715 - val_binary_a
```

```
fig, ax = plt.subplots(figsize=(20,8))
sns.lineplot(x = history.epoch, y = history.history['loss'])
sns.lineplot(x = history.epoch, y = history.history['val_loss'])
ax.set_title('Learning Curve (Loss)')
ax.set_ylabel('Loss')
ax.set_xlabel('Epoch')
ax.set_ylim(0, 0.5)
ax.legend(['train', 'val'], loc='best')
plt.show()
```




```
fig, ax = plt.subplots(figsize=(20,8))
sns.lineplot(x = history.epoch, y = history.history['binary_accuracy'])
sns.lineplot(x = history.epoch, y = history.history['val_binary_accuracy'])
ax.set_title('Learning Curve (Accuracy)')
ax.set_ylabel('Accuracy')
ax.set_xlabel('Epoch')
ax.set_ylim(0.80, 1.0)
ax.legend(['train', 'val'], loc='best')
plt.show()
```




```
score = model_pretrained.evaluate(ds_val, steps = len(val_df)/BATCH, verbose = 0)
print('Val loss:', score[0])
print('Val accuracy:', score[1])
```

```
score = model_pretrained.evaluate(ds_test, steps = len(df_test), verbose = 0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

Fine Tuning

```
base_model.trainable = True

# Freeze all layers except for the
for layer in base_model.layers[:-13]:
    layer.trainable = False
```

```
for layer_number, layer in enumerate(base_model.layers):
    print(layer_number, layer.name, layer.trainable)
```

```
126 conv3_block8_2_relu False
127 max_pooling2d_4 False
128 conv3_block8_3_conv False
129 conv3_block8_out False
130 conv4_block1_preact_bn False
131 conv4_block1_preact_relu False
132 conv4_block1_1_conv False
133 conv4_block1_1_bn False
134 conv4_block1_1_relu False
135 conv4_block1_2_pad False
136 conv4_block1_2_conv False
137 conv4_block1_2_bn False
138 conv4_block1_2_relu False
139 conv4_block1_0_conv False
140 conv4_block1_3_conv False
141 conv4_block1_out False
142 conv4_block2_preact_bn False
143 conv4_block2_preact_relu False
144 conv4_block2_1_conv False
145 conv4_block2_1_bn False
```

```
model_pretrained.compile(loss='binary_crossentropy'
              , optimizer = keras.optimizers.Adam(learning_rate=2e-6), metrics='binary_accuracy')
```

```
model_pretrained.summary()
```

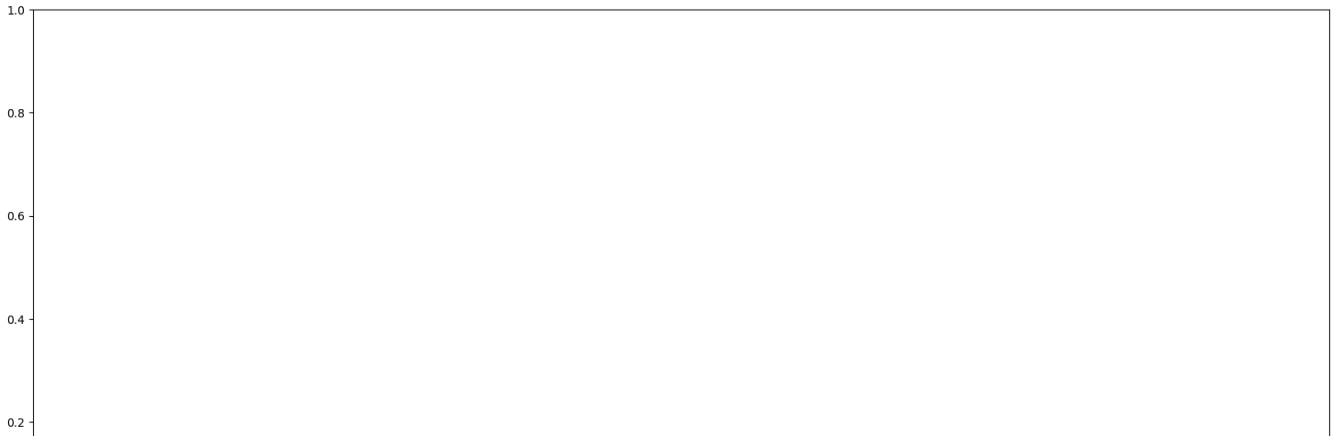
```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 224, 224, 3)]     0

 resnet152v2 (Functional)    (None, 7, 7, 2048)        58331648

 global_average_pooling2d (G  (None, 2048)             0
 lobalAveragePooling2D)

 dense (Dense)               (None, 128)               262272

 dropout (Dropout)           (None, 128)               0

 dense_1 (Dense)             (None, 1)                 129

=================================================================
Total params: 58,594,049
Trainable params: 4,731,137
Non-trainable params: 53,862,912
_________________________________________________________________
```

```
history = model_pretrained.fit(ds_train,
          batch_size = BATCH, epochs = 0,
          validation_data=ds_val,
          callbacks=[early_stopping, plateau],
          steps_per_epoch=(len(train_df)/BATCH),
          validation_steps=(len(val_df)/BATCH));
```

```
fig, ax = plt.subplots(figsize=(20,8))
sns.lineplot(x = history.epoch, y = history.history['loss'])
sns.lineplot(x = history.epoch, y = history.history['val_loss'])
ax.set_title('Learning Curve (Loss)')
ax.set_ylabel('Loss')
ax.set_xlabel('Epoch')
ax.set_ylim(0, 0.3)
ax.legend(['train', 'val'], loc='best')
plt.show()
```

```
---------------------------------------------------------------------------
KeyError                                  Traceback (most recent call last)
<ipython-input-86-643a2b1d3290> in <cell line: 2>()
      1 fig, ax = plt.subplots(figsize=(20,8))
----> 2 sns.lineplot(x = history.epoch, y = history.history['loss'])
      3 sns.lineplot(x = history.epoch, y = history.history['val_loss'])
      4 ax.set_title('Learning Curve (Loss)')
      5 ax.set_ylabel('Loss')

KeyError: 'loss'
```

SEARCH STACK OVERFLOW




```
fig, ax = plt.subplots(figsize=(20,8))
sns.lineplot(x = history.epoch, y = history.history['binary_accuracy'])
sns.lineplot(x = history.epoch, y = history.history['val_binary_accuracy'])
ax.set_title('Learning Curve (Accuracy)')
ax.set_ylabel('Accuracy')
ax.set_xlabel('Epoch')
ax.set_ylim(0.90, 1.0)
ax.legend(['train', 'val'], loc='best')
plt.show()
```

```
---------------------------------------------------------------------------
KeyError                                  Traceback (most recent call last)
<ipython-input-79-cac425c2376c> in <cell line: 2>()
      1 fig, ax = plt.subplots(figsize=(20,8))
----> 2 sns.lineplot(x = history.epoch, y = history.history['binary_accuracy'])
      3 sns.lineplot(x = history.epoch, y = history.history['val_binary_accuracy'])
```

```
score = model_pretrained.evaluate(ds_val, steps = len(val_df)/BATCH, verbose = 0)
print('Val loss:', score[0])
print('Val accuracy:', score[1])


score = model_pretrained.evaluate(ds_test, steps = len(df_test), verbose = 0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

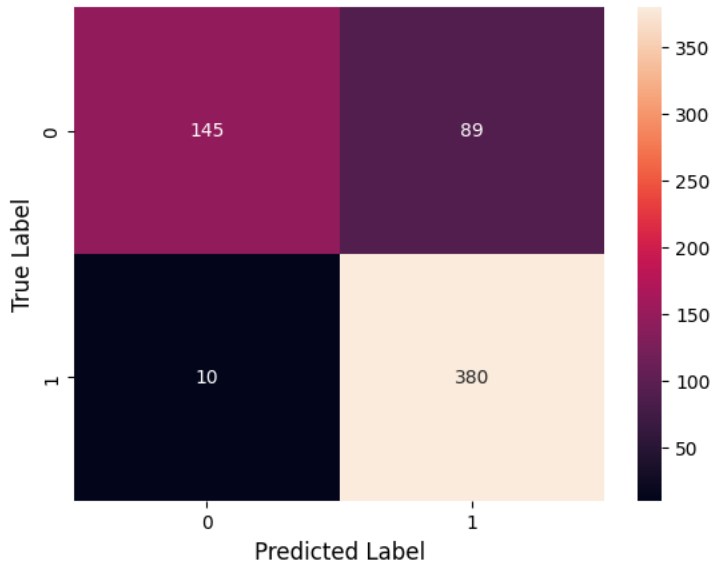
Performance Metrics

```
ds_test.reset()
predictions = model_pretrained.predict(ds_test, steps=len(ds_test), verbose=0)
pred_labels= np.where(predictions>0.5, 1, 0)
```

```
print("Test Accuracy: ", accuracy_score(Y_test, pred_labels))
```

```
Test Accuracy:  0.8413461538461539
```

```
confusion_matrix = metrics.confusion_matrix(Y_test, pred_labels)
sns.heatmap(confusion_matrix, annot=True, fmt="d")

plt.xlabel("Predicted Label", fontsize= 12)
plt.ylabel("True Label", fontsize= 12)

plt.show()
```




```
print(metrics.classification_report(Y_test, pred_labels, labels = [0, 1]))
```

```
              precision    recall  f1-score   support

           0       0.94      0.62      0.75       234
           1       0.81      0.97      0.88       390

    accuracy                           0.84       624
   macro avg       0.87      0.80      0.82       624
weighted avg       0.86      0.84      0.83       624
```

```
roc_auc = metrics.roc_auc_score(Y_test, predictions)
print('ROC_AUC: ', roc_auc)

fpr, tpr, thresholds = metrics.roc_curve(Y_test, predictions)

plt.plot(fpr, tpr, label = 'ROC_AUC = %0.3f' % roc_auc)

plt.xlabel("False Positive Rate", fontsize= 12)
plt.ylabel("True Positive Rate", fontsize= 12)
```

```
plt.legend(loc="lower right")

plt.show()
```

```
ROC_AUC:  0.9516874863028709
```