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Open in Colab
(https://colab.research.google.com/github/franpanteli/Python-Machine-Learning-Cat-Dog-Image-Classifier/blob/main/Copy_of_fcc_cat_dog.ipynb)

Note: You are currently reading this using Google Colaboratory which is a cloud-hosted version of Jupyter Notebook. This is a document containng both text cells for documentation and runnable code cells. If you are unfamiliar with Jupyter Notebook, watch this 3-minute introduction before starting this challenge: https://www.youtube.com/watch?v=inN8seMm7UI (https://www.youtube.com/watch?v=inN8seMm7UI)

For this challenge, you will complete the code below to classify images of dogs and cats. You will use Tensorflow 2.0 and Keras to create a convolutional neural network that correctly classifies images of cats and dogs at least 63% of the time. (Extra credit if you get it to 70% accuracy!)

Some of the code is given to you but some code you must fill in to complete this challenge. Read the instruction in each text cell so you will know what you have to do in each code cell.

The first code cell imports the required libraries. The second code cell downloads the data and sets key variables. The third cell is the first place you will write your own code.

The structure of the dataset files that are downloaded looks like this (You will notice that the test directory has no subdirectories and the images are not labeled):

```
cats_and_dogs
|__ train:
    |______ cats: [cat.0.jpg, cat.1.jpg ...]
    |______ dogs: [dog.0.jpg, dog.1.jpg ...]
|__ validation:
    |______ cats: [cat.2000.jpg, cat.2001.jpg ...]
    |______ dogs: [dog.2000.jpg, dog.2001.jpg ...]
|__ test: [1.jpg, 2.jpg ...]
```

You can tweak epochs and batch size if you like, but it is not required.

In [1]:

```
"""
-> This task is found at
          https://www.freecodecamp.org/learn/machine-learning-with-python/machine-learning-with-python-projects/cat-and-dog-image-classifier
                                        -> These are notes on the task description found at that URL
-> Google Colaboratory -> Copy the notebook; this is the starter code
        -> They want you to submit a Google Colaboratory link, which is the submission for the project
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> And there is starter code for this
        -> Keras and TensorFlow
        -> There are instructions in each of the code cells:
                -> Importing the libraries
                -> Downloading the data, setting key variables
                -> Then writing your own code
        -> Epochs
                -> You can change the number of epochs, but this isn't required
                -> An epoch is the number of times the same piece of data is gone over when training the model
-> You have to submit your project link
-> Classifying images of dogs and cats
        -> The model has to have a 63% or higher accuracy rate
        -> The test directory has no subdirectories, and the images aren't labeled
                -> Meaning unsupervised learning (?)
-> Each of the cells has its own instructions
"""

# Importing modules -> We are using TensorFlow to train the model - this was explained in the first half of the course content
try:
  # This command only in Colab.
  %tensorflow_version 2.x
except Exception:
  pass
import tensorflow as tf

from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Conv2D, Flatten, Dropout, MaxPooling2D
from tensorflow.keras.preprocessing.image import ImageDataGenerator

import os
import numpy as np
import matplotlib.pyplot as plt
```

```
Colab only includes TensorFlow 2.x; %tensorflow_version has no effect.
```

In [2]:

```
# cell 2 <- this entire cell is importing in the files and initiali
sing the values of parameters which we will use when training the m
odel
# Get project files
    # import the file with the training images
    # we are importing the data (image files) after submitting an h
ttps request
!wget https://cdn.freecodecamp.org/project-data/cats-and-dogs/cats_
and_dogs.zip

    # unzip it
!unzip cats_and_dogs.zip

PATH = 'cats_and_dogs'

    # set the paths to the training files
train_dir = os.path.join(PATH, 'train')
validation_dir = os.path.join(PATH, 'validation')
test_dir = os.path.join(PATH, 'test')

# Get number of files in each directory. The train and validation d
irectories
# each have the subdirecories "dogs" and "cats".
total_train = sum([len(files) for r, d, files in os.walk(train_di
r)])
total_val = sum([len(files) for r, d, files in os.walk(validation_d
ir)])
total_test = len(os.listdir(test_dir))

# Variables for pre-processing and training.
batch_size = 128
epochs = 15
IMG_HEIGHT = 150
IMG_WIDTH = 150
```

Streaming output truncated to the last 5000 lines.

```
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.60.jpg
  inflating: cats_and_dogs/train/dogs/dog.858.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.858.jpg
  inflating: cats_and_dogs/train/dogs/dog.680.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.680.jpg
  inflating: cats_and_dogs/train/dogs/dog.694.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.694.jpg
  inflating: cats_and_dogs/train/dogs/dog.864.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.864.jpg
  inflating: cats_and_dogs/train/dogs/dog.870.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.870.jpg
  inflating: cats_and_dogs/train/dogs/dog.871.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.871.jpg
  inflating: cats_and_dogs/train/dogs/dog.865.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.865.jpg
  inflating: cats_and_dogs/train/dogs/dog.695.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.695.jpg
  inflating: cats_and_dogs/train/dogs/dog.681.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.681.jpg
  inflating: cats_and_dogs/train/dogs/dog.859.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.859.jpg
  inflating: cats_and_dogs/train/dogs/dog.61.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.61.jpg
  inflating: cats_and_dogs/train/dogs/dog.118.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.118.jpg
  inflating: cats_and_dogs/train/dogs/dog.75.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.75.jpg
  inflating: cats_and_dogs/train/dogs/dog.656.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.656.jpg
  inflating: cats_and_dogs/train/dogs/dog.130.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.130.jpg
  inflating: cats_and_dogs/train/dogs/dog.124.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.124.jpg
  inflating: cats_and_dogs/train/dogs/dog.642.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.642.jpg
  inflating: cats_and_dogs/train/dogs/dog.49.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.49.jpg
  inflating: cats_and_dogs/train/dogs/dog.9.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.9.jpg
  inflating: cats_and_dogs/train/dogs/dog.497.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.497.jpg
  inflating: cats_and_dogs/train/dogs/dog.483.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.483.jpg
  inflating: cats_and_dogs/train/dogs/dog.468.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.468.jpg
  inflating: cats_and_dogs/train/dogs/dog.332.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.332.jpg
  inflating: cats_and_dogs/train/dogs/dog.454.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.454.jpg
  inflating: cats_and_dogs/train/dogs/dog.440.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.440.jpg
  inflating: cats_and_dogs/train/dogs/dog.326.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.326.jpg
  inflating: cats_and_dogs/train/dogs/dog.285.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.285.jpg
  inflating: cats_and_dogs/train/dogs/dog.291.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.291.jpg
  inflating: cats_and_dogs/train/dogs/dog.508.jpg
  inflating: __MACOSX/cats_and_dogs/train/dogs/._dog.508.jpg
  inflating: cats_and_dogs/train/dogs/dog.246.jpg
```

Now it is your turn! Set each of the variables below correctly. (They should no longer equal `None`.)

Create image generators for each of the three image data sets (train, validation, test). Use `ImageDataGenerator` to read / decode the images and convert them into floating point tensors. Use the `rescale` argument (and no other arguments for now) to rescale the tensors from values between 0 and 255 to values between 0 and 1.

For the `*_data_gen` variables, use the `flow_from_directory` method. Pass in the batch size, directory, target size (`(IMG_HEIGHT, IMG_WIDTH)`), class mode, and anything else required. `test_data_gen` will be the trickiest one. For `test_data_gen`, make sure to pass in `shuffle=False` to the `flow_from_directory` method. This will make sure the final predictions stay is in the order that our test expects. For `test_data_gen` it will also be helpful to observe the directory structure.

After you run the code, the output should look like this:

```
Found 2000 images belonging to 2 classes.
Found 1000 images belonging to 2 classes.
Found 50 images belonging to 1 classes.
```

In [3]:
```
"""
        -> Cell 3 <- Loading the image datasets (train, validate, t
est), with image generators -> processing that data into
                                                        tensors and
normalising it
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> The variables shouldn't equal none anymore
                -> There are three image datasets -> train, validat
ion, test
                        -> We have data and it's split into train,
validate, and test
                -> Create image generators for each of these
                        -> Once we split the data into train, valid
ate, and test, we use ImageDataGenerator to process them
                        -> We are converting the image from an imag
e into a tensor
                        -> This tensor is what we do the maths on
                        -> Then rescale to normalise them
                -> We are taking the images, converting them into t
ensors using ImageDataGenerator, and then normalising their values
                                        using rescale
                -> For the *_data_gen variables
                        -> Use the flow_from_directory method
                        -> Passing in the arguments
                                -> Batch size
                                -> Directory
                                -> Target size <- (IMG_HEIGHT, IMG_
WIDTH)
                                -> Class mode
                        -> The values which the model is trained on
                -> For test_data_gen
                        -> The flow_from_directory method should ha
ve shuffle=False <- It's not shuffling the predictions which the mo
del
                                                comes out with, so
the test knows which order to expect them in
                        -> The values which the trained model is te
sted on
                        -> The directory structure follows a specif
ic format
                -> This entire cell is about taking the image data,
splitting it into train, validate, test and then formatting it
                                        so that the images are norm
alised tensors, which can be processed
                -> We are moving the images into tensors with float
ing point numbers
"""

#normalising the tensors (higher dimensional matrices / vectors) wh
ich represent the images
        # -> ImageDataGenerator is the function which converts the
image into a tensor (vector / matrix) <- this is from the keras mod
ule
                        # -> you load in the images, and then keras
converts them into a tensor (numbers which we can proccess) using t
his method
        # -> and we are normalising them at the same time <- the pr
evious value of those tensors was between 0 and 255
  # -> we are repeating this process - once for train, once for val
idate and once for test data
```

```
train_image_generator      = ImageDataGenerator(rescale=1./255)
validation_image_generator = ImageDataGenerator(rescale=1./255)
test_image_generator       = ImageDataGenerator(rescale=1./255)

#creating image generators for the image datasets -> train
        # -> keras is also used here to convert the image files int
o different datasets -> .flow_from_directory is a method from the k
eras module
                        # and we are using it here to split the dat
aset of images into train, validate and test datasets
                                # -> after they have first been con
verted into tensors (by ImageDataGenerator, which is part of keras)
train_data_gen = train_image_generator.flow_from_directory(
                    train_dir,
                    target_size=(IMG_HEIGHT, IMG_WIDTH),
                    batch_size=batch_size,
                    class_mode='binary')

#creating image generators for the image datasets -> validate
        # -> notice how many of the arguments which we are passing
into the flow_from_directory method were defined in the second code
                                # cell of the notebook
val_data_gen   = validation_image_generator.flow_from_directory(
                    validation_dir,
                    target_size=(IMG_HEIGHT, IMG_WIDTH),
                    batch_size=batch_size,
                    class_mode='binary')

#creating image generators for the image datasets -> test
        # -> shuffling is set to false for the test data -> but not
for the other two datasets
        # -> we are splitting the larger dataset into three smaller
ones
        # -> by turning off shuffle, we are making sure the predict
ions stay in the order which the test expects
test_data_gen  = test_image_generator.flow_from_directory(
                    PATH,
                    target_size=(IMG_HEIGHT, IMG_WIDTH),
                    batch_size=batch_size,
                    classes=['test'],
                    shuffle=False)

# -> The previous cell is importing the image dataset to use
# -> This cell is normalizing the tensors that represent those imag
es
# -> Then we are splitting that data into three datasets -> train,
validate, and test
# -> We are fitting the model on one, validating it on the other to
see if it was overfit, and then testing the trained model on the th
ird

"""
The output from this cell is supposed to be:
        Found 2000 images belonging to 2 classes.
        Found 1000 images belonging to 2 classes.
        Found 50 images belonging to 1 classes.
"""

"""
In keras
        -> ImageDataGenerator <- we are using this method to genera
```

```
te data (tensors) from the images which are loaded into it
                        -> we are normalising this data as well ->
if the magnitude of the tensors is too large then it could blow up
the model
        -> flow_from_directory <- we are using this method to split
the dataset (in tensor form) into test, train and validate datasets
"""
```

```
Found 2000 images belonging to 2 classes.
Found 1000 images belonging to 2 classes.
Found 50 images belonging to 1 classes.
```

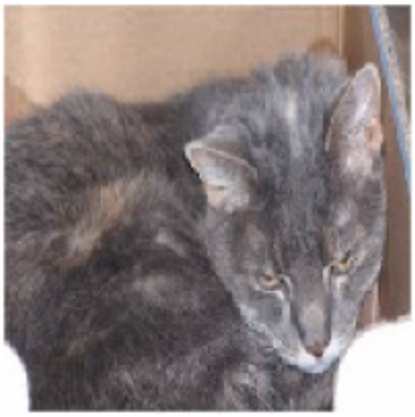
Out[3]:

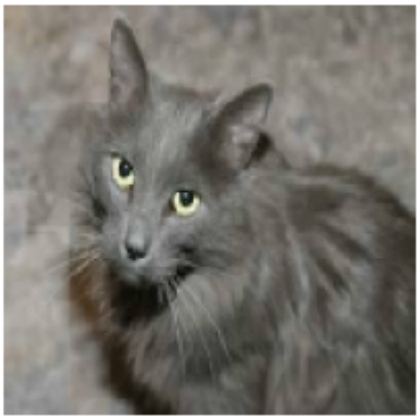
```
'\nIn keras \n\t-> ImageDataGenerator <- we are using this method t
o generate data (tensors) from the images which are loaded into it
\n\t\t\t-> we are normalising this data as well -> if the magnitude
of the tensors is too large then it could blow up the model \n\t->
flow_from_directory <- we are using this method to split the datase
t (in tensor form) into test, train and validate datasets \n'
```

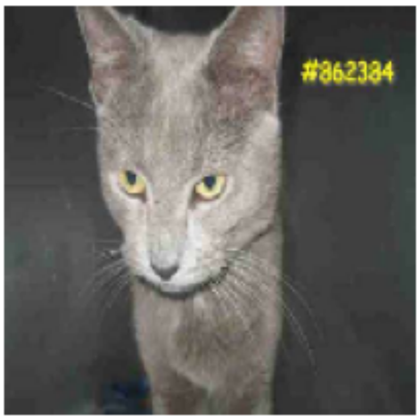
The `plotImages` function will be used a few times to plot images. It takes an array of images and a probabilities list, although the probabilities list is optional. This code is given to you. If you created the `train_data_gen` variable correctly, then running the cell below will plot five random training images.

In [4]:
```
#This one contains a function which goes from image in tensor form
to image in visual form
  #-> The previous cell went from image in visual form to image in
tensor form using keras
"""
        -> Cell 4 <- Contains a function to go from images in tenso
r form back to actual images
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> plotImages <- This is a function which takes an
array of numbers (tensor) and outputs the image which they represen
t
                -> It also takes a probability list
                -> In the starter code, it creates 5 random trainin
g images
                -> This cell essentially goes from
"""

"""
-> Defining the plotImages function
    -> We have three datasets of images in tensor form -> these wer
e derived using Keras in the previous cell
    -> We are now defining a function which can convert these image
s in tensor form back into image files
    -> One which can output / plot those images
    -> We are feeding it an array of images, and it is plotting the
m into image files
    -> It takes an array and a probability list
    -> This code is given to us
"""

#defining the funciton
def plotImages(images_arr, probabilities = False):
    fig, axes = plt.subplots(len(images_arr), 1, figsize=(5,len(ima
ges_arr) * 3))
    if probabilities is False:
      for img, ax in zip( images_arr, axes):
          ax.imshow(img)
          ax.axis('off')
    else:
      for img, probability, ax in zip( images_arr, probabilities, a
xes):
          ax.imshow(img)
          ax.axis('off')
          if probability > 0.5:
              ax.set_title("%.2f" % (probability*100) + "% dog")
          else:
              ax.set_title("%.2f" % ((1-probability)*100) + "% ca
t")
    plt.show()

#testing the function on the training dataset
"""
  How this is done/ context:
  -> The previous cell took the images and used keras to convert th
em into normalised tensors
  -> Then split them into test, training and validation datasets
  -> The code below is taking the plotImages function which was def
ined above and using the test images dataset in tensor form
      -> It is taking this array of tensors and converting it back
into images by plotting them
```

```
      -> We've used keras to go from image to tensor and now we are
using this function to go from tensor back to image
      -> And are plotting those iamges to test the function
      -> So we can go from image to tensor using keras and from ten
sor to image using this function
      -> This is important because we need to see how well the mode
l has worked by plotting the results
      -> But when the model is working on the images, it's using th
em in tensor form
"""

# This variable is storing the images we want to plot -> it is retu
rning the next item in the sequence
  # -> it is fetching batches of data, one batch of data at a time
-> to control the data flow
  # -> we aren't testing the function on the entire training datase
t, we're testing it on one batch of data from that dataset
sample_training_images, _ = next(train_data_gen)
# We are plotting the last 5 images in that dataset
plotImages(sample_training_images[:5])
```






#862384

Recreate the `train_image_generator` using `ImageDataGenerator`.

Since there are a small number of training examples there is a risk of overfitting. One way to fix this problem is by creating more training data from existing training examples by using random transformations.

Add 4-6 random transformations as arguments to `ImageDataGenerator`. Make sure to rescale the same as before.

In [5]:
```
"""
        -> Cell 5 <- This runs transformations on the training imag
es so that they can be used to train the model, since we
                                                                  are
trying to avoid overfitting and there is not enough training data i
n the model's dataset
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> Recreate the train_image_generator using ImageDa
taGenerator
                -> There is not enough training data
                        -> Training the model on the same data runs
the risk of overfitting it
                        -> To get around this - creating more train
ing data by taking the same image and transforming it multiple time
s
                        -> Training it on the same image -> just tr
ansformed, because there aren't another images
                        -> Random transformations of that same imag
e
                        -> 4-6 of these random transformations
                -> This file contains a function called ImageDataGe
nerator which takes the inputted images and transforms them
                                        multiple times
                        -> So that these images can all be transfor
med and be used to train the data
                        -> Transforming the same image and training
the model on it because there isn't enough training data - and if t
he
                                                same image is used
too many times then the model could be overfit
                -> The purpose of this cell is to create new data b
y transforming the same image used to train it -> so that the model
                                                isn't overfit
"""

"""
-> Train image generator is the Keras method we used to convert dat
a into tensor form and create a dataset for
                training images
-> We aim to apply random transformations to images five times and
then utilize these augmented images for dataset
                training
-> We do not use the images directly from the dataset to train the
model; instead, we batch them into training,
                validation, and test datasets
-> The data used to train these models undergoes five transformatio
ns per image, providing five times the data to
                prevent overfitting
-> Our process involves taking images from the training dataset and
applying various transformations
-> This process is what we refer to as 'creating more training dat
a'
-> ImageDataGenerator, a Keras method, was previously employed to c
onvert images into tensors and divide them into validation,
                training, and test datasets
-> Now, we use it to apply five transformations to images in the tr
aining dataset, which constitutes image data augmentation
-> The function's arguments for these transformations include:
  - Rescaling
  - Horizontal flipping
```

```
  - Rotation
  - Zooming
  - Shifting images by a fraction of the width or height
  - Sheer transformations
-> This method can be used to process data in batches, but in our c
ase, we apply it to the entire training data at once
"""

train_image_generator = ImageDataGenerator(
    rescale=1./255,
    horizontal_flip=True,
    rotation_range=20,
    zoom_range=0.15,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.15,
    fill_mode='nearest')
```

You don't have to do anything for the next cell. `train_data_gen` is created just like before but with the new `train_image_generator`. Then, a single image is plotted five different times using different variations.

In [6]:
```
"""
        -> Cell 6 <- This cell transforms the same image five diffe
rent times - to generate an image which is used to
                                                              tra
in the model (we are increasing the amount of training data in the
model by 5x)
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> This cell is to be left alone
                -> The previous cell is taking images in the projec
t dataset and transforming them to be used to train the model
                -> This cell is taking these data and running five
random transformations on one image
                -> train_data_gen <- The training data is created,
using the train_image_generator
                -> We are taking the data which the model is being
trained on and transforming each image 5 times
                        -> To increase the amount of images which w
e have to train the model on by 5x
                -> It's plotting a single image 5 times with differ
ent transformations
"""

"""
-> Train_image_generator is the generator defined in the previous c
ell, which takes the images and transforms them
-> This is to run augmentation on the training images in the datase
t -> we are transforming them five times to increase
                the number of images in the training dataset
-> The previous cell was the one which defined the generator to tra
nsform these images in the training dataset
-> This cell is applying that generator to the train_data_gen image
s
-> We are transforming the training images five times using the gen
erator defined in the previous code cell - doing data
                augmentation on them
-> Then we are using the plotting function to plot one example of t
hem
"""

#train_image_generator is the generator which transforms the images
-> to run data augmentation
#flow_from_directory is a keras method to do this
#this is doing this for all of the data in the dataset
train_data_gen = train_image_generator.flow_from_directory(batch_si
ze=batch_size,
                                                     directory=trai
n_dir,
                                                     target_size=(I
MG_HEIGHT, IMG_WIDTH),
                                                     class_mode='bi
nary')

#the code below is extracting an example to print out using the plo
tImages function -> which takes the images in tensor form
        # and prints them out in regular form
augmented_images = [train_data_gen[0][0][0] for i in range(5)]

#this plots / outputs an example of one of them (the transformed im
ages) -> in this case it's the same image 6 times
plotImages(augmented_images)
```

```
"""
-> The previous cell defined the generator using keras, which trans
formed the image files to do data augmentation on them
-> This cell augments (transforms) the image files in the training
dataset, to increase the amount of data in the set and avoid overfi
tting
-> The last two lines of Python extracted the first image from this
and plotted it out
    -> By using plotImages -> which takes the image in tensor form
and converts it into a visible image
-> We have first loaded the data in image form, then converted it i
nto tensor form using keras, then split it into test, train and val
idate datasets
                -> Then we defined a generator to transform the dat
a in the training dataset to perform data augmentation
                -> This cell was using that generator to transform
the images in the training dataset using this augmentation
                -> Then printing out one of those augmented images
using the plotImages function to show what it's done to the data in
the training dataset
"""
```

```
Found 2000 images belonging to 2 classes.
```

Out[6]:
```
"\n-> The previous cell defined the generator using keras, which tr
ansformed the image files to do data augmentation on them \n-> This
cell augments (transforms) the image files in the training dataset,
to increase the amount of data in the set and avoid overfitting \n-
> The last two lines of Python extracted the first image from this
and plotted it out \n    -> By using plotImages -> which takes the
image in tensor form and converts it into a visible image\n-> We ha
ve first loaded the data in image form, then converted it into tens
or form using keras, then split it into test, train and validate da
tasets\n\t\t-> Then we defined a generator to transform the data in
the training dataset to perform data augmentation \n\t\t-> This cel
l was using that generator to transform the images in the training
dataset using this augmentation \n\t\t-> Then printing out one of t
hose augmented images using the plotImages function to show what i
t's done to the data in the training dataset \n"
```

In the cell below, create a model for the neural network that outputs class probabilities. It should use the Keras Sequential model. It will probably involve a stack of Conv2D and MaxPooling2D layers and then a fully connected layer on top that is activated by a ReLU activation function.

Compile the model passing the arguments to set the optimizer and loss. Also pass in `metrics=['accuracy']` to view training and validation accuracy for each training epoch.

In [7]:
```
"""
        -> Cell 7 <- This cell initialises the architecture for the
model (without training it)
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> Using the Keras Sequential model to initialise t
he architecture of the model we are going to use
                -> The output of the model
                        -> We are predicting if the images are of d
ogs or cats
                        -> These are two different classes
                        -> The final layer of the network should in
volve a 1x2 array - whose values are the probabilities that the ima
ge is either of a dog or cat
                        -> We are using a convolutional neural netw
ork -> this uses filters
                        -> Then we choose the maximum value in that
output array -> the one with the highest probability determines the
classification of the image
                        -> Because of this, we are also normalising
the values of the probabilities in that network
                -> That the model architecture should include
                        -> A stack of Conv2D and MaxPooling2D layer
s
                        -> A fully connected layer
                        -> Activated by ReLU activation function <-
it's 1 or 0 (the neuron is on or it's off, it's like a diode but fo
r a neuron)
                                -> It's getting rid of all of the n
egative values and setting them to 0 - and leaving the rest of the
values of the neuron the same
                                -> Leave ReLU -> some negative valu
es are allowed through (it's less harsh)
                                -> We are using ReLU
                        -> Optimiser and loss functions
                        -> Metrics=['accuracy'] <- so we can see th
e training and validation accuracy for each of the training epochs
                                -> For each time the model goes ove
r the same piece of data to train it -> an epoch
                                -> The model can overfit if this is
done too many times - which is why we transform the same image five
times in the training dataset
"""

"""
-> the aim of the model is to output the class probabilities
                -> we know that the image which is fead into it wil
l either be of a dog or a cat
                -> we can store this in a 1x2 array
                -> one element represents the probability that the
image is of a dog
                -> the other element represents the probability tha
t the image is of a cat
                -> which means that we need to normalise them using
a sigmoid activation funciton
                -> like a tanh funciton but between 0 and 1 (rather
than -1 and 1)
                -> this is what we want the model to ouput -> so th
ere will probably be two nodes at the end
                        -> since we are dealing with two categories
-> supervised learning (we are telling it what the categories are)
```

```
-> we are initialising the architecture of the model
                -> not actually training it (yet)
                -> we first import the data, get it into the right
form -> then initialise the architecture of the model, train the mo
del, use it
                                to make predictions and test it to
see how accurate they were
                -> we are using the Keras Sequential model to creat
e this architecture
                                -> each block represents a layer in
the neural network
                                -> each of the blocks is a layer in
the network -> we are choosing the architecture of those layers and
their activation functions
                                -> the information is flowing seque
ntially through the layers
-> we are stacking Conv2D and MaxPooling2D layers and a fully conne
cted layer with a ReLU activation function
                -> then compiling the model with the arguments to s
et the optimiser and loss
                -> we also want metrics=['accuracy'] to view the tr
aining and validation accuracy
                -> training epochs (each time the same peice of dat
a is gone over to train the model on)
                                -> and now we have engouh data beca
use of the augmentation to avoid overfitting
"""

#initialise the neural network as an empty keras sequential model
model = Sequential()
# each of these lines is adding a layer to the neural network
"""
-> The architecture of the model:
        -> This is a Convolutional Neural Network (CNN), designed f
or image classification
        -> Conv2D: this is a convolutional layer with 32 filters of
size (3,3) and utilises the ReLU activation function
        -> MaxPooling2D: Used to reduce the dimensions of matrices
from the previous layer in the network
        -> This architecture is repeated:
                -> Convolutional layer: Scans images using filters
                -> Max pooling layer: Reduces the dimensions of the
data
                -> This repetition occurs three times to capture de
eper patterns
                -> ReLU activation function ensures positive output
s and zeros for negatives. Too many negative outputs can lead to is
sues
                -> Applied in the convolutional layers of the netwo
rk
        -> Flattening layer: Converts the output of neurons into a
1-D layer. The goal is a 1D array of probabilities
        -> Densely connected layer of 64 neurons: Helps the model f
ind more complex patterns in the data
        -> The final layer of the network adds another such layer:
                -> Sigmoid function is used to squash the output in
to probabilities
                -> ReLU activation functions are needed to eliminat
e negatives. In turning them into probabilities with sigmoid in the
last
                                layer, unless we get rid of the neg
```

```
atives using a ReLU in the layer before, this could cancel out some
values we are
                                        using to calculate those pr
obabilities with the sigmoid function in the next layer
                -> The final layer consists of a single neuron for
binary classification tasks (checking if the image is of a dog or a
cat)
        -> This entire architecture is designed for image classific
ation tasks
"""

# Learning outputs
model.add(Conv2D(32, (3,3), activation="relu", input_shape=(IMG_HEI
GHT, IMG_WIDTH, 3)))
model.add(MaxPooling2D((2,2)))

model.add(Conv2D(64, (3,3), activation="relu"))
model.add(MaxPooling2D((2,2)))

model.add(Conv2D(128, (3,3), activation="relu"))
model.add(MaxPooling2D((2,2)))

# Flattening this into a vector and single output for the network
model.add(Flatten())
model.add(Dense(64, activation='relu'))
model.add(Dense(1, activation='sigmoid'))

# This line prints out a summary of the model's architecture
model.summary()

"""
-> We are defining the architecture of the model. Each layer we are
adding is a new line of code
-> Then we are printing out a summary of that architecture
-> Now the line below is compiling the model:
    -> This tells it what to optimize for (the accuracy of the mode
l)
    -> This is the loss function. Use this algorithm (Adam) to perf
orm geometry optimization
-> Why we are using binary cross-entropy:
    -> This is the loss function that we are using
    -> We are using this because we only have two classes
    -> This measures the difference between the predicted and actua
l probability distribution
    -> Cross-entropy is telling you how well the predicted probabil
ity distribution matches the actual one
"""

model.compile(optimizer='adam',
              loss=tf.keras.losses.BinaryCrossentropy(from_logits=F
alse),
              metrics=['accuracy'])
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 148, 148, 32)      896

 max_pooling2d (MaxPooling2  (None, 74, 74, 32)        0
 D)

 conv2d_1 (Conv2D)           (None, 72, 72, 64)        18496

 max_pooling2d_1 (MaxPoolin  (None, 36, 36, 64)        0
 g2D)

 conv2d_2 (Conv2D)           (None, 34, 34, 128)       73856

 max_pooling2d_2 (MaxPoolin  (None, 17, 17, 128)       0
 g2D)

 flatten (Flatten)           (None, 36992)             0

 dense (Dense)               (None, 64)                2367552

 dense_1 (Dense)             (None, 1)                 65

=================================================================
Total params: 2460865 (9.39 MB)
Trainable params: 2460865 (9.39 MB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

Use the `fit` method on your `model` to train the network. Make sure to pass in arguments for `x`, `steps_per_epoch`, `epochs`, `validation_data`, and `validation_steps`.

In [8]:
```
"""
        -> Cell 8 <- Training the model
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> We first take the training data and put it into
array format and make sure we have enough of it
                -> Then we initialize the architecture of the neura
l network
                -> Now we are training that network
                        -> We are using the fit method
                -> This will require
                        -> Arguments for
                                -> x
                                -> steps_per_epoch
                                -> epochs
                                -> validation_data
                                -> validation_steps
"""

history = model.fit(train_data_gen,
                    steps_per_epoch=train_data_gen.n//train_data_ge
n.batch_size,
                    epochs=epochs, validation_data=val_data_gen,
                    validation_steps=val_data_gen.n//val_data_gen.b
atch_size)

"""
-> We have imported and formatted the data by dividing it into trai
ning, validation, and testing datasets
-> The previous cell set the architecture for the model
-> In this cell, we are training the model
-> Keras has a fit method to do this
-> The name_of_the_model.fit <- This is how Keras is used to train
the model
-> The arguments for this method are
        -> x
        -> steps_per_epoch
        -> epochs
        -> validation_data
        -> validation_steps
-> We are setting this trained model equal to a variable called 'hi
story'
-> The previous cell initialised the architecture of the neural net
work; this cell trains the neural network
                        using the Keras fit method
-> To train models in Keras -> you use the fit method -> after init
ialising its architecture
-> The first argument when doing this is the training data -> we pr
eviously performed data augmentation for
                this, with the images in tensor form
-> Steps per epoch is the number of batches of data to process per
epoch
        -> An epoch is one time the model is trained on the same pi
ece of data
        -> This is the number of batches which that data is split i
nto each time the model is trained on it
-> We are also giving it the validation data -> when the model is t
rained, we can use this data to validate
                its training
        -> Other arguments in this process are
                        -> Training data <- to train the machine le
```

```
arning model
                                -> This is the one the model adjust
s its weights on
                        -> Validation
                                -> To make decisions about the mode
l's architecture
                        -> Test data
                                -> To evaluate the performance of t
he trained model
                        -> We are also telling it the number of ste
ps to perform validation in -> how many batches we should put
                                        that data into during the t
raining process - per epoch (one time the validation is gone over d
uring training)
-> History is used to store the values which the model outputs duri
ng this training
-> The parameters need to be properly initialised because the model
takes time to train -> you can also use a GPU in Colab
"""
```

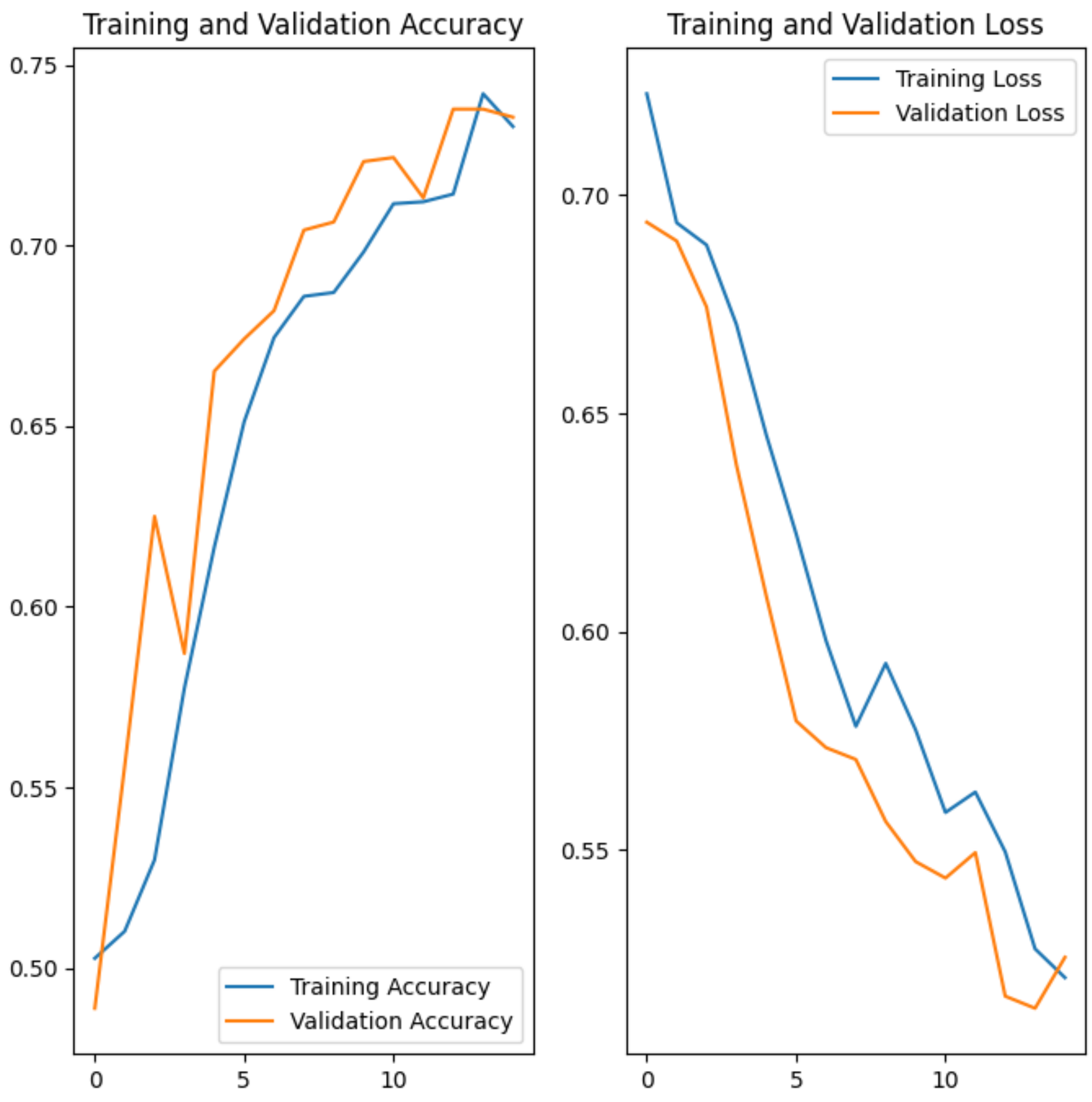
```
Epoch 1/15
15/15 [==============================] - 117s 8s/step - loss: 0.723
2 - accuracy: 0.5027 - val_loss: 0.6938 - val_accuracy: 0.4888
Epoch 2/15
15/15 [==============================] - 113s 7s/step - loss: 0.693
7 - accuracy: 0.5101 - val_loss: 0.6895 - val_accuracy: 0.5558
Epoch 3/15
15/15 [==============================] - 113s 7s/step - loss: 0.688
6 - accuracy: 0.5299 - val_loss: 0.6744 - val_accuracy: 0.6250
Epoch 4/15
15/15 [==============================] - 113s 7s/step - loss: 0.670
4 - accuracy: 0.5775 - val_loss: 0.6382 - val_accuracy: 0.5871
Epoch 5/15
15/15 [==============================] - 120s 8s/step - loss: 0.645
1 - accuracy: 0.6165 - val_loss: 0.6082 - val_accuracy: 0.6652
Epoch 6/15
15/15 [==============================] - 106s 7s/step - loss: 0.622
4 - accuracy: 0.6512 - val_loss: 0.5795 - val_accuracy: 0.6741
Epoch 7/15
15/15 [==============================] - 117s 8s/step - loss: 0.598
0 - accuracy: 0.6745 - val_loss: 0.5734 - val_accuracy: 0.6819
Epoch 8/15
15/15 [==============================] - 107s 7s/step - loss: 0.578
3 - accuracy: 0.6859 - val_loss: 0.5707 - val_accuracy: 0.7042
Epoch 9/15
15/15 [==============================] - 114s 8s/step - loss: 0.592
7 - accuracy: 0.6870 - val_loss: 0.5565 - val_accuracy: 0.7065
Epoch 10/15
15/15 [==============================] - 107s 7s/step - loss: 0.577
5 - accuracy: 0.6982 - val_loss: 0.5473 - val_accuracy: 0.7232
Epoch 11/15
15/15 [==============================] - 114s 8s/step - loss: 0.558
6 - accuracy: 0.7115 - val_loss: 0.5435 - val_accuracy: 0.7243
Epoch 12/15
15/15 [==============================] - 107s 7s/step - loss: 0.563
2 - accuracy: 0.7121 - val_loss: 0.5494 - val_accuracy: 0.7132
Epoch 13/15
15/15 [==============================] - 128s 8s/step - loss: 0.549
6 - accuracy: 0.7142 - val_loss: 0.5165 - val_accuracy: 0.7377
Epoch 14/15
15/15 [==============================] - 122s 8s/step - loss: 0.527
3 - accuracy: 0.7420 - val_loss: 0.5137 - val_accuracy: 0.7377
Epoch 15/15
15/15 [==============================] - 111s 7s/step - loss: 0.520
7 - accuracy: 0.7329 - val_loss: 0.5254 - val_accuracy: 0.7355
```

Out[8]:
```
"\n-> We have imported and formatted the data by dividing it into t
raining, validation, and testing datasets\n-> The previous cell set
the architecture for the model \n-> In this cell, we are training t
he model \n-> Keras has a fit method to do this \n-> The name_of_th
e_model.fit <- This is how Keras is used to train the model \n-> Th
e arguments for this method are \n\t-> x\n\t-> steps_per_epoch\n\t-
> epochs\n\t-> validation_data\n\t-> validation_steps\n-> We are se
tting this trained model equal to a variable called 'history'\n-> T
he previous cell initialised the architecture of the neural networ
k; this cell trains the neural network \n\t\t\tusing the Keras fit
method  \n-> To train models in Keras -> you use the fit method ->
after initialising its architecture \n-> The first argument when do
ing this is the training data -> we previously performed data augme
ntation for \n\t\tthis, with the images in tensor form \n-> Steps p
er epoch is the number of batches of data to process per epoch \n\t
-> An epoch is one time the model is trained on the same piece of d
ata\n\t-> This is the number of batches which that data is split in
to each time the model is trained on it \n-> We are also giving it
the validation data -> when the model is trained, we can use this d
ata to validate \n\t\tits training \n\t-> Other arguments in this p
rocess are \n\t\t\t-> Training data <- to train the machine learnin
g model \n\t\t\t\t-> This is the one the model adjusts its weights
on \n\t\t\t-> Validation \n\t\t\t\t-> To make decisions about the m
odel's architecture\n\t\t\t-> Test data\n\t\t\t\t-> To evaluate the
performance of the trained model\n\t\t\t-> We are also telling it t
he number of steps to perform validation in -> how many batches we
should put \n\t\t\t\t\tthat data into during the training process -
per epoch (one time the validation is gone over during training)\n-
> History is used to store the values which the model outputs durin
g this training \n-> The parameters need to be properly initialised
because the model takes time to train -> you can also use a GPU in
Colab \n"
```

Run the next cell to visualize the accuracy and loss of the model.

In [9]:
```
"""
        -> Cell 9 <- Outputs graphs about the accuracy and loss of the training model
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> The previous cell trains the model
                -> This cell is telling us about the performance of its loss function
                -> We are trying to maximize the accuracy of the function
                        -> This is the same as trying to minimize the loss function by performing gradient descent
"""

# Extracting Metrics from History
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']

# Setting up Epochs Range
epochs_range = range(epochs)

# Creating a Figure
plt.figure(figsize=(8, 8))

# Plotting Training and Validation Accuracy
plt.subplot(1, 2, 1)
plt.plot(epochs_range, acc, label='Training Accuracy')
plt.plot(epochs_range, val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

# Plotting Training and Validation Loss
plt.subplot(1, 2, 2)
plt.plot(epochs_range, loss, label='Training Loss')
plt.plot(epochs_range, val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.title('Training and Validation Loss')

# Displaying the Plots
plt.show()

"""
                -> This entire cell creates plots which show how accurate the model is with the number of epochs used to
                                train it
                -> This code is provided to us and we are using it to visualise the accuracy of the model after it's been
                                trained
                -> This is both for the training and for the validation of the neural network
                -> History stores the trained model -> the first block of code in this cell extracts the different metrics
                                from this (e.g the accuracy of the model and the loss function which we are going to use to make predictions with)
                -> We are then creating a range object for the number of epochs
                        -> Each time the model is trained on the same piece of data, this is an epoch
```

```
                        -> We are looking at the accuracy and loss
function of the model and predicting how this changes with the amou
nt
                                        of times we train the model
on the same peice of data
                        -> Too many times and we can overfit the da
ta
                        -> Not enough times and it won't be as accu
rate
                -> We are then creating the graphs to plot
                        -> The first blocks of code in this cell ar
e defining the arrays which we are going to plot
                        -> The next is for creating these plots
                        -> We are creating two subplots -> plotting
the training and validation loss over epochs
                        -> This is used to determine the architectu
re of the model which optimises the accuracy of its predictions
"""
```



Now it is time to use your model to predict whether a brand new image is a cat or a dog.

In this final cell, get the probability that each test image (from `test_data_gen`) is a dog or a cat. `probabilities` should be a list of integers.

Call the `plotImages` function and pass in the test images and the probabilities corresponding to each test image.

After your run the cell, you should see all 50 test images with a label showing the percentage sure that the image is a cat or a dog. The accuracy will correspond to the accuracy shown in the graph above (after running the previous cell). More training images could lead to a higher accuracy.

In [10]:
```
"""
        -> Cell 10 <- Using the model to make a prediction and seei
ng if it works
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                -> So we
                        -> Put the data into a specific format
                        -> Make sure there is enough of it
                        -> Initialize the architecture of the model
                        -> Train the model
                -> Now we are using the model to make predictions a
nd see if they work
                -> We are predicting if the image is a cat or a dog
                -> There are 50 test images -> running this cell wi
ll output the accuracy of the model
                        -> More training images mean the model will
become more accurate
                -> test_data_gen <- This contains the test data
                -> The output of this model is a list of probabilit
ies
                -> The plotImages function
                        -> Passing the test images into this will g
ive the probabilities for each of these images
                        -> The probability each of those images is
of a dog or a cat (how "sure" it is)
                        -> Running this cell will do this with 50 t
est images
                        -> This "sure" score corresponds to the acc
uracy of the model
                        -> The previous cell output this accuracy f
or the entire model -> this does it for each of the pieces of test
data in the model
"""

probabilities = model.predict(test_data_gen)[:,0]
plotImages(test_data_gen[0][0], probabilities)

"""
        -> Now we are using the model to make predictions
        -> We are taking the trained model and testing it on test d
ata it hasn't seen before
        -> The validation data was to optimise the number of epochs
and for the architecture of the model -> outputting graphs
                                for these metrics and the performan
ce of the model
        -> The model had been trained in the previous cell
                -> This outputs graphs which were used to validate
it and the number of epochs used to train it
                                        -> Going over the same piec
e of data more than once when training the model makes it more accu
rate
        -> Now we have the trained model, we are using it to make p
redictions on the test data to see how accurate it is
        -> These are images of cats and dogs in tensor form -> whic
h this cell runs the model on
        -> It hasn't seen these images before -> and it is predicti
ng whether they are of cats or dogs
        -> We are running the model on an entire dataset of these f
iles to make predictions
        -> Each prediction which it makes is a 1x1 array -> which i
s the probability that the image which has been passed through
```

```
                                it in tensor form is a cat or dog
                -> test_data_gen is the array which contains this l
ist of its probabilities / guesses for all 50 images in the dataset
which are being passed
                                through our model
        -> The plotImages function is then used to plot these image
s, which combines them with the predictions which the model makes
                                about whether the image is of a dog
or cat
                -> This takes both the predictions which the model
output and the probabilities which correspond to each image
                -> There are 50 test images -> more training images
could have been used to increase the accuracy of the model
                -> When the model is trained, it goes through (in t
his case) one batch of data and trains itself on it 15 times -> it
does
                                this for all of the data in the tra
ining dataset
                        -> And you can see its accuracy as it train
s -> too accurate and there may be overfitting because of an epoch
count which is
                                        too high
"""

"""
        How this code works:
                -> There are two lines of code
                                -> The first uses the trained model
to make predictions using the Keras predict method
                                                -> This is done on
the test images stored in test_data_gen
                                                -> We are then sele
cting the probability that the image is of a dog, by using [:,0]
                                                -> This is done for
all 50 images in the test dataset and storing the output from each
prediction in the array called probabilities
                                -> The second line uses the plottin
g function to plot these probabilities (the predictions of the mode
l on the training dataset), but
                                                for the first batch
of training data
                                                -> This converts th
e tensors that represent those images back into visible images for
the first 50 images
                                                -> We are doing thi
s so we can visibly compare the predictions of the model to the ima
ges which it is trying to classify
"""
```

```
1/1 [==============================] - 1s 793ms/step
```