In [9]:
```
import os
import numpy as np
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.preprocessing import image
from tensorflow.keras import layers, models
from tensorflow.keras.applications import VGG16
import matplotlib.pyplot as plt
```

In [10]:
```
from google.colab import drive
drive.mount('/content/drive/')
```
```
Drive already mounted at /content/drive/; to attempt to forcibly remount, call drive.mount("/content/drive/", force_remount=True).
```

In [11]:
```
# Define dataset paths
data_dir = "/content/drive/MyDrive/cats_vs_dogs_small/cats_vs_dogs_small"
train_dir = os.path.join(data_dir, "train")
test_dir = os.path.join(data_dir, "test")
validation_dir = os.path.join(data_dir, "validation")
```

In [12]:
```
# Image Preprocessing and Augmentation
train_datagen = ImageDataGenerator(rescale = 1./255, rotation_range = 40, width_shift_range = 0.2,
                                   height_shift_range = 0.2, shear_range = 0.2, zoom_range = 0.2, horizontal_flip = True,
                                   fill_mode = 'nearest')
validation_datagen = ImageDataGenerator(rescale = 1./255)
test_datagen = ImageDataGenerator(rescale = 1./255)
```

In [13]:
```
# Define batch size
batch_size = 32
img_size = (150,150)
```

In [14]:
```
# Load Datasets
train_generator = train_datagen.flow_from_directory(train_dir, target_size=img_size, batch_size = batch_size, class_mode = 'binary')
validation_generator = validation_datagen.flow_from_directory(validation_dir, target_size = img_size , batch_size = batch_size, class_mode = 'binary')
test_generator = validation_datagen.flow_from_directory(test_dir,target_size = img_size, batch_size = batch_size, class_mode = 'binary')
```
```
Found 2000 images belonging to 2 classes.
Found 1000 images belonging to 2 classes.
Found 779 images belonging to 2 classes.
```

Model training from Scratch

In [15]:
```
def conv_model():
    model = models.Sequential([
        layers.Conv2D(32, (3,3), activation = 'relu', input_shape = (150, 150, 3)),
        layers.MaxPooling2D(2,2),
        layers.Conv2D(64, (3,3), activation = 'relu'),
        layers.MaxPooling2D(2,2),
        layers.Conv2D(128, (3,3), activation = 'relu'),
        layers.MaxPooling2D(2,2),
        layers.Conv2D(128, (2,2), activation = 'relu'),
        layers.MaxPooling2D(2,2),
        layers.Flatten(),
        layers.Dropout(0.5),
        layers.Dense(512, activation = 'relu'),
        layers.Dense(1, activation = 'sigmoid')
    ])

    model.compile(loss = 'binary_crossentropy', optimizer = 'adam', metrics = ['accuracy'])
    return model
```

In [16]:
```
# train model from scratch
scratch_model = conv_model()
model_scratch = scratch_model.fit(train_generator, epochs = 30, validation_data = validation_generator)
```
```
Epoch 1/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 131s 2s/step - accuracy: 0.5291 - loss: 0.7117 - val_accuracy: 0.5000 - val_loss: 0.6925
Epoch 2/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 127s 2s/step - accuracy: 0.5029 - loss: 0.6968 - val_accuracy: 0.5630 - val_loss: 0.6852
Epoch 3/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 124s 2s/step - accuracy: 0.5356 - loss: 0.6885 - val_accuracy: 0.5410 - val_loss: 0.6713
Epoch 4/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 125s 2s/step - accuracy: 0.5775 - loss: 0.6764 - val_accuracy: 0.5700 - val_loss: 0.6833
Epoch 5/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 123s 2s/step - accuracy: 0.5780 - loss: 0.6788 - val_accuracy: 0.6550 - val_loss: 0.6160
Epoch 6/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 124s 2s/step - accuracy: 0.6131 - loss: 0.6645 - val_accuracy: 0.6510 - val_loss: 0.6231
Epoch 7/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 127s 2s/step - accuracy: 0.6473 - loss: 0.6381 - val_accuracy: 0.6450 - val_loss: 0.6134
Epoch 8/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 127s 2s/step - accuracy: 0.6541 - loss: 0.6388 - val_accuracy: 0.6570 - val_loss: 0.6224
Epoch 9/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.5936 - loss: 0.6692 - val_accuracy: 0.6740 - val_loss: 0.6191
Epoch 10/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 124s 2s/step - accuracy: 0.6374 - loss: 0.6368 - val_accuracy: 0.6250 - val_loss: 0.6371
Epoch 11/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.6324 - loss: 0.6326 - val_accuracy: 0.5820 - val_loss: 0.6420
Epoch 12/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 142s 2s/step - accuracy: 0.6218 - loss: 0.6548 - val_accuracy: 0.6500 - val_loss: 0.6212
Epoch 13/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 123s 2s/step - accuracy: 0.6495 - loss: 0.6241 - val_accuracy: 0.6440 - val_loss: 0.6300
Epoch 14/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.6582 - loss: 0.6239 - val_accuracy: 0.6740 - val_loss: 0.5805
Epoch 15/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 128s 2s/step - accuracy: 0.6465 - loss: 0.6254 - val_accuracy: 0.6900 - val_loss: 0.5898
Epoch 16/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 124s 2s/step - accuracy: 0.6698 - loss: 0.6051 - val_accuracy: 0.6400 - val_loss: 0.6639
Epoch 17/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.6707 - loss: 0.6086 - val_accuracy: 0.7310 - val_loss: 0.5540
Epoch 18/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 124s 2s/step - accuracy: 0.7133 - loss: 0.5831 - val_accuracy: 0.6890 - val_loss: 0.5909
Epoch 19/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.7006 - loss: 0.5697 - val_accuracy: 0.7310 - val_loss: 0.5351
Epoch 20/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 142s 2s/step - accuracy: 0.7004 - loss: 0.5725 - val_accuracy: 0.7180 - val_loss: 0.5621
Epoch 21/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 125s 2s/step - accuracy: 0.6878 - loss: 0.5738 - val_accuracy: 0.7340 - val_loss: 0.5358
Epoch 22/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 127s 2s/step - accuracy: 0.6939 - loss: 0.5581 - val_accuracy: 0.7550 - val_loss: 0.5133
Epoch 23/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.7050 - loss: 0.5599 - val_accuracy: 0.7200 - val_loss: 0.5619
Epoch 24/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 124s 2s/step - accuracy: 0.7107 - loss: 0.5679 - val_accuracy: 0.7350 - val_loss: 0.5289
Epoch 25/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.7205 - loss: 0.5489 - val_accuracy: 0.7450 - val_loss: 0.5070
Epoch 26/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 124s 2s/step - accuracy: 0.7384 - loss: 0.5382 - val_accuracy: 0.7380 - val_loss: 0.5216
Epoch 27/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.7321 - loss: 0.5455 - val_accuracy: 0.6750 - val_loss: 0.6059
Epoch 28/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 123s 2s/step - accuracy: 0.7106 - loss: 0.5529 - val_accuracy: 0.7310 - val_loss: 0.5276
Epoch 29/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 122s 2s/step - accuracy: 0.7015 - loss: 0.5582 - val_accuracy: 0.7690 - val_loss: 0.4876
Epoch 30/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 126s 2s/step - accuracy: 0.7375 - loss: 0.5247 - val_accuracy: 0.7210 - val_loss: 0.5354
```

In [17]:
```
scratch_model.summary()
```

Model: "sequential_1"

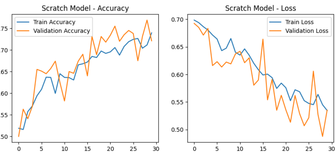
Layer (type)	Output Shape	Param #
conv2d_4 (Conv2D)	(None, 148, 148, 32)	896
max_pooling2d_4 (MaxPooling2D)	(None, 74, 74, 32)	0
conv2d_5 (Conv2D)	(None, 72, 72, 64)	18,496
max_pooling2d_5 (MaxPooling2D)	(None, 36, 36, 64)	0
conv2d_6 (Conv2D)	(None, 34, 34, 128)	73,856
max_pooling2d_6 (MaxPooling2D)	(None, 17, 17, 128)	0
conv2d_7 (Conv2D)	(None, 16, 16, 128)	65,664
max_pooling2d_7 (MaxPooling2D)	(None, 8, 8, 128)	0
flatten_1 (Flatten)	(None, 8192)	0
dropout_1 (Dropout)	(None, 8192)	0
dense_2 (Dense)	(None, 512)	4,194,816
dense_3 (Dense)	(None, 1)	513

Total params: 13,062,725 (49.83 MB)
Trainable params: 4,354,241 (16.61 MB)
Non-trainable params: 0 (0.00 B)
Optimizer params: 8,708,484 (33.22 MB)

In [18]:
```
def plot_result(history, title):
    plt.figure(figsize = (15,4))
    plt.subplot(1,2,1)
    plt.plot(history.history['accuracy'], label = 'Train Accuracy')
    plt.plot(history.history['val_accuracy'], label = 'Validation Accuracy')
    plt.title(f'{title} - Accuracy')
    plt.legend()

    plt.subplot(1,2,2)
    plt.plot(history.history['loss'], label = 'Train Loss')
    plt.plot(history.history['val_loss'], label = 'Validation Loss')
    plt.title(f'{title} - Loss')
    plt.legend()
    plt.show()
```

In [19]:
```
plot_result(model_scratch, "Scratch Model")
```



In [20]:
```
# evaluate on test set
test_loss_scratch, test_acc_scratch = scratch_model.evaluate(test_generator)
print(f"Test Accuracy (Scratch Model): {test_acc_scratch:.4f}")
```
```
25/25 ━━━━━━━━━━━━━━━━━━━━ 160s 6s/step - accuracy: 0.7467 - loss: 0.5207
Test Accuracy (Scratch Model): 0.7574
```

In [21]:
```
def prepare_image(img_path):
    img = image.load_img(img_path, target_size = (150,150))
    img_array = image.img_to_array(img)
    img_array = np.expand_dims(img_array, axis = 0)
    img_array = img_array/255.0
    return img_array
```

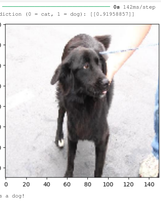
In [22]:
```
def predict_image(model, img_path):
    img_array = prepare_image(img_path)
    prediction = model.predict(img_array)
    print(f"Prediction (0 = cat, 1 = dog):", prediction)


    img = image.load_img(img_path, target_size = (150, 150))
    plt.imshow(img)
    plt.show()


    if prediction[0]<0.5:
        print("It's a cat")

    else:
        print("It's a dog")
```

In [23]:
```
img_path = "/content/drive/MyDrive/cats_vs_dogs_small/cats_vs_dogs_small/test/dogs/1549.jpg"
predict_image(scratch_model, img_path)
```
```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 142ms/step
Prediction (0 = cat, 1 = dog): [[0.9195865]]
```



```
It's a dog
```

Pretrained model

In [24]:
```
base_model = VGG16(weights = 'imagenet', include_top = False, input_shape = (150, 150, 3))
base_model.trainable = False
```
```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58889256/58889256 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
```

In [25]:
```
model_vgg16 = models.Sequential([base_model,
                                 layers.Flatten(),
                                 layers.Dense(256, activation = 'relu'),
                                 layers.Dropout(0.5),
                                 layers.Dense(1,activation = 'sigmoid')
                                ])
```

In [26]:
```
model_vgg16.compile(loss = 'binary_crossentropy', optimizer = 'adam', metrics = ['accuracy'])
```

In [ ]:
```
history_vgg16 = model_vgg16.fit(train_generator, epochs = 30, validation_data = validation_generator)
```
```
Epoch 1/30
41/63 ━━━━━━━━━━━━━━━━━━━━ 15s 8s/step - accuracy: 0.8512 - loss: 0.3293
```

In [ ]:
```
plot_result(history_vgg16, 'VGG16 Pretrained model')
```

In [29]:
```
test_loss_vgg16 ,test_acc_vgg16 = model_vgg16.evaluate(test_generator)
print(f"Test Accuracy (VGG16 Model): {test_acc_vgg16:.4f}")
```
```
25/25 ━━━━━━━━━━━━━━━━━━━━ 185s 7s/step - accuracy: 0.8931 - loss: 0.2300
Test Accuracy (VGG16 Model): 0.8870
```

In [30]:
```
img_path = "/content/drive/MyDrive/cats_vs_dogs_small/cats_vs_dogs_small/test/dogs/1549.jpg"
predict_image(model_vgg16, img_path)
```
```
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 503ms/step
Prediction (0 = cat, 1 = dog): [[0.9998295]]
```

```
It's a dog!
```

In [31]:
```
# Create a comparison table
comparison_data = {
    "Model": ["Scratch Model", "VGG16 Pretrained Model"],
    "Test Accuracy": [test_acc_scratch, test_acc_vgg16],
    "Test Loss": [test_loss_scratch, test_loss_vgg16]
}
```

In [32]:
```
import pandas as pd
comparison_df = pd.DataFrame(comparison_data)
print(comparison_df)
```
```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-32-95b4624bca4a> in <cell line: 2>()
----> 1 comparison_df = pd.DataFrame(comparison_data)
      2 print(comparison_df)

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

When evaluating loss and accuracy criteria, the Scratch Model and the VGG16 Model reveal somewhat different performance gaps. Starting fresh, the Scratch Model attained a 75.74% accuracy and a test loss of 0.5207. Both the training and validation accuracy curves show obvious ups and downs; the validation curve shows more severe swings that would suggest either overfitting or learning instability. Complementing this with different validation loss settings, the related loss curve indicates that the model finds it difficult to stretch to fresh data.

Using pretrained weights and transfer learning lowers test loss of 0.2300 much and improves performance with a test accuracy of 88.70%. Excellent feature extraction capacity of VGG16—achieved by means of strict ImageNet dataset training—allows one to attribute this great advance. Comparatively to the others, based on evaluation the VGG16 model learns fresh data faster and more precisely. Image prediction generates rather strong confidence in the classification.

Confirming the effectiveness of transfer learning in settings with limited data and computational capacity, the VGG16 model much surpasses the Scratch Model. This highlights the need of pretrained networks in reaching considerable accuracy by lowering training time and hence improving generalizability.

In [ ]: