

# C1\_W1\_Lab\_3\_densenet

June 8, 2022

## 1 Densenet

In this week's assignment, you'll be using a pre-trained Densenet model for image classification.

Densenet is a convolutional network where each layer is connected to all other layers that are deeper in the network - The first layer is connected to the 3rd, 4th etc. - The second layer is connected to the 3rd, 4th, 5th etc.

Like this:

For a detailed explanation of Densenet, check out the source of the image above, a paper by Gao Huang et al. 2018 called [Densely Connected Convolutional Networks](#).

The cells below are set up to provide an exploration of the Keras densenet implementation that you'll be using in the assignment. Run these cells to gain some insight into the network architecture.

```
In [1]: # Import Densenet from Keras
        from keras.applications.densenet import DenseNet121
        from keras.layers import Dense, GlobalAveragePooling2D
        from keras.models import Model
        from keras import backend as K

        import tensorflow as tf
        tf.compat.v1.logging.set_verbosity(tf.compat.v1.logging.ERROR)
```

Using TensorFlow backend.

For your work in the assignment, you'll be loading a set of pre-trained weights to reduce training time.

```
In [2]: # Create the base pre-trained model
        base_model = DenseNet121(weights='./models/nih/densenet.hdf5', include_top=False);
```

View a summary of the model

```
In [3]: # Print the model summary
        base_model.summary()
```

Model: "densenet121"

| Layer (type)                     | Output Shape               | Param # | Connected to   |
|----------------------------------|----------------------------|---------|--|
| input_1 (InputLayer)             | (None, None, None, 3 0     |         |  |
| zero_padding2d_1 (ZeroPadding2D) | (None, None, None, 3 0     |         | input_1[0][0]  |
| conv1/conv (Conv2D)              | (None, None, None, 6 9408  |         | zero_padding2d_1[0][0]                                 |
| conv1/bn (BatchNormalization)    | (None, None, None, 6 256   |         | conv1/conv[0][0]                                       |
| conv1/relu (Activation)          | (None, None, None, 6 0     |         | conv1/bn[0][0]   |
| zero_padding2d_2 (ZeroPadding2D) | (None, None, None, 6 0     |         | conv1/relu[0][0]                                       |
| pool1 (MaxPooling2D)             | (None, None, None, 6 0     |         | zero_padding2d_2[0][0]                                 |
| conv2_block1_0_bn (BatchNormali  | (None, None, None, 6 256   |         | pool1[0][0]  |
| conv2_block1_0_relu (Activation  | (None, None, None, 6 0     |         | conv2_block1_0_bn[0][0]                                |
| conv2_block1_1_conv (Conv2D)     | (None, None, None, 1 8192  |         | conv2_block1_0_relu[0][0]                              |
| conv2_block1_1_bn (BatchNormali  | (None, None, None, 1 512   |         | conv2_block1_1_conv[0][0]                              |
| conv2_block1_1_relu (Activation  | (None, None, None, 1 0     |         | conv2_block1_1_bn[0][0]                                |
| conv2_block1_2_conv (Conv2D)     | (None, None, None, 3 36864 |         | conv2_block1_1_relu[0][0]                              |
| conv2_block1_concat (Concatenat  | (None, None, None, 9 0     |         | pool1[0][0]<br>conv2_block1_2_conv[0][0]               |
| conv2_block2_0_bn (BatchNormali  | (None, None, None, 9 384   |         | conv2_block1_concat[0][0]                              |
| conv2_block2_0_relu (Activation  | (None, None, None, 9 0     |         | conv2_block2_0_bn[0][0]                                |
| conv2_block2_1_conv (Conv2D)     | (None, None, None, 1 12288 |         | conv2_block2_0_relu[0][0]                              |
| conv2_block2_1_bn (BatchNormali  | (None, None, None, 1 512   |         | conv2_block2_1_conv[0][0]                              |
| conv2_block2_1_relu (Activation  | (None, None, None, 1 0     |         | conv2_block2_1_bn[0][0]                                |
| conv2_block2_2_conv (Conv2D)     | (None, None, None, 3 36864 |         | conv2_block2_1_relu[0][0]                              |
| conv2_block2_concat (Concatenat  | (None, None, None, 1 0     |         | conv2_block1_concat[0][0]<br>conv2_block2_2_conv[0][0] |
| conv2_block3_0_bn (BatchNormali  | (None, None, None, 1 512   |         | conv2_block2_concat[0][0]                              |

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| conv2_block3_0_relu (Activation | (None, None, None, 1 0     | conv2_block3_0_bn[0] [0]                                 |
| conv2_block3_1_conv (Conv2D)    | (None, None, None, 1 16384 | conv2_block3_0_relu[0] [0]                               |
| conv2_block3_1_bn (BatchNormali | (None, None, None, 1 512   | conv2_block3_1_conv[0] [0]                               |
| conv2_block3_1_relu (Activation | (None, None, None, 1 0     | conv2_block3_1_bn[0] [0]                                 |
| conv2_block3_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv2_block3_1_relu[0] [0]                               |
| conv2_block3_concat (Concatenat | (None, None, None, 1 0     | conv2_block2_concat[0] [0]<br>conv2_block3_2_conv[0] [0] |
| conv2_block4_0_bn (BatchNormali | (None, None, None, 1 640   | conv2_block3_concat[0] [0]                               |
| conv2_block4_0_relu (Activation | (None, None, None, 1 0     | conv2_block4_0_bn[0] [0]                                 |
| conv2_block4_1_conv (Conv2D)    | (None, None, None, 1 20480 | conv2_block4_0_relu[0] [0]                               |
| conv2_block4_1_bn (BatchNormali | (None, None, None, 1 512   | conv2_block4_1_conv[0] [0]                               |
| conv2_block4_1_relu (Activation | (None, None, None, 1 0     | conv2_block4_1_bn[0] [0]                                 |
| conv2_block4_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv2_block4_1_relu[0] [0]                               |
| conv2_block4_concat (Concatenat | (None, None, None, 1 0     | conv2_block3_concat[0] [0]<br>conv2_block4_2_conv[0] [0] |
| conv2_block5_0_bn (BatchNormali | (None, None, None, 1 768   | conv2_block4_concat[0] [0]                               |
| conv2_block5_0_relu (Activation | (None, None, None, 1 0     | conv2_block5_0_bn[0] [0]                                 |
| conv2_block5_1_conv (Conv2D)    | (None, None, None, 1 24576 | conv2_block5_0_relu[0] [0]                               |
| conv2_block5_1_bn (BatchNormali | (None, None, None, 1 512   | conv2_block5_1_conv[0] [0]                               |
| conv2_block5_1_relu (Activation | (None, None, None, 1 0     | conv2_block5_1_bn[0] [0]                                 |
| conv2_block5_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv2_block5_1_relu[0] [0]                               |
| conv2_block5_concat (Concatenat | (None, None, None, 2 0     | conv2_block4_concat[0] [0]<br>conv2_block5_2_conv[0] [0] |
| conv2_block6_0_bn (BatchNormali | (None, None, None, 2 896   | conv2_block5_concat[0] [0]                               |
| conv2_block6_0_relu (Activation | (None, None, None, 2 0     | conv2_block6_0_bn[0] [0]                                 |
| conv2_block6_1_conv (Conv2D)    | (None, None, None, 1 28672 | conv2_block6_0_relu[0] [0]                               |

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| conv2_block6_1_bn (BatchNormali | (None, None, None, 1 512   | conv2_block6_1_conv[0][0]                              |
| conv2_block6_1_relu (Activation | (None, None, None, 1 0     | conv2_block6_1_bn[0][0]                                |
| conv2_block6_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv2_block6_1_relu[0][0]                              |
| conv2_block6_concat (Concatenat | (None, None, None, 2 0     | conv2_block5_concat[0][0]<br>conv2_block6_2_conv[0][0] |
| pool2_bn (BatchNormalization)   | (None, None, None, 2 1024  | conv2_block6_concat[0][0]                              |
| pool2_relu (Activation)         | (None, None, None, 2 0     | pool2_bn[0][0]   |
| pool2_conv (Conv2D)             | (None, None, None, 1 32768 | pool2_relu[0][0]                                       |
| pool2_pool (AveragePooling2D)   | (None, None, None, 1 0     | pool2_conv[0][0]                                       |
| conv3_block1_0_bn (BatchNormali | (None, None, None, 1 512   | pool2_pool[0][0]                                       |
| conv3_block1_0_relu (Activation | (None, None, None, 1 0     | conv3_block1_0_bn[0][0]                                |
| conv3_block1_1_conv (Conv2D)    | (None, None, None, 1 16384 | conv3_block1_0_relu[0][0]                              |
| conv3_block1_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block1_1_conv[0][0]                              |
| conv3_block1_1_relu (Activation | (None, None, None, 1 0     | conv3_block1_1_bn[0][0]                                |
| conv3_block1_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block1_1_relu[0][0]                              |
| conv3_block1_concat (Concatenat | (None, None, None, 1 0     | pool2_pool[0][0]<br>conv3_block1_2_conv[0][0]          |
| conv3_block2_0_bn (BatchNormali | (None, None, None, 1 640   | conv3_block1_concat[0][0]                              |
| conv3_block2_0_relu (Activation | (None, None, None, 1 0     | conv3_block2_0_bn[0][0]                                |
| conv3_block2_1_conv (Conv2D)    | (None, None, None, 1 20480 | conv3_block2_0_relu[0][0]                              |
| conv3_block2_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block2_1_conv[0][0]                              |
| conv3_block2_1_relu (Activation | (None, None, None, 1 0     | conv3_block2_1_bn[0][0]                                |
| conv3_block2_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block2_1_relu[0][0]                              |
| conv3_block2_concat (Concatenat | (None, None, None, 1 0     | conv3_block1_concat[0][0]<br>conv3_block2_2_conv[0][0] |

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| conv3_block3_0_bn (BatchNormali | (None, None, None, 1 768   | conv3_block2_concat[0][0]                              |
| conv3_block3_0_relu (Activation | (None, None, None, 1 0     | conv3_block3_0_bn[0][0]                                |
| conv3_block3_1_conv (Conv2D)    | (None, None, None, 1 24576 | conv3_block3_0_relu[0][0]                              |
| conv3_block3_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block3_1_conv[0][0]                              |
| conv3_block3_1_relu (Activation | (None, None, None, 1 0     | conv3_block3_1_bn[0][0]                                |
| conv3_block3_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block3_1_relu[0][0]                              |
| conv3_block3_concat (Concatenat | (None, None, None, 2 0     | conv3_block2_concat[0][0]<br>conv3_block3_2_conv[0][0] |
| conv3_block4_0_bn (BatchNormali | (None, None, None, 2 896   | conv3_block3_concat[0][0]                              |
| conv3_block4_0_relu (Activation | (None, None, None, 2 0     | conv3_block4_0_bn[0][0]                                |
| conv3_block4_1_conv (Conv2D)    | (None, None, None, 1 28672 | conv3_block4_0_relu[0][0]                              |
| conv3_block4_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block4_1_conv[0][0]                              |
| conv3_block4_1_relu (Activation | (None, None, None, 1 0     | conv3_block4_1_bn[0][0]                                |
| conv3_block4_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block4_1_relu[0][0]                              |
| conv3_block4_concat (Concatenat | (None, None, None, 2 0     | conv3_block3_concat[0][0]<br>conv3_block4_2_conv[0][0] |
| conv3_block5_0_bn (BatchNormali | (None, None, None, 2 1024  | conv3_block4_concat[0][0]                              |
| conv3_block5_0_relu (Activation | (None, None, None, 2 0     | conv3_block5_0_bn[0][0]                                |
| conv3_block5_1_conv (Conv2D)    | (None, None, None, 1 32768 | conv3_block5_0_relu[0][0]                              |
| conv3_block5_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block5_1_conv[0][0]                              |
| conv3_block5_1_relu (Activation | (None, None, None, 1 0     | conv3_block5_1_bn[0][0]                                |
| conv3_block5_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block5_1_relu[0][0]                              |
| conv3_block5_concat (Concatenat | (None, None, None, 2 0     | conv3_block4_concat[0][0]<br>conv3_block5_2_conv[0][0] |
| conv3_block6_0_bn (BatchNormali | (None, None, None, 2 1152  | conv3_block5_concat[0][0]                              |
| conv3_block6_0_relu (Activation | (None, None, None, 2 0     | conv3_block6_0_bn[0][0]                                |

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| conv3_block6_1_conv (Conv2D)    | (None, None, None, 1 36864 | conv3_block6_0_relu[0][0]                              |
| conv3_block6_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block6_1_conv[0][0]                              |
| conv3_block6_1_relu (Activation | (None, None, None, 1 0     | conv3_block6_1_bn[0][0]                                |
| conv3_block6_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block6_1_relu[0][0]                              |
| conv3_block6_concat (Concatenat | (None, None, None, 3 0     | conv3_block5_concat[0][0]<br>conv3_block6_2_conv[0][0] |
| conv3_block7_0_bn (BatchNormali | (None, None, None, 3 1280  | conv3_block6_concat[0][0]                              |
| conv3_block7_0_relu (Activation | (None, None, None, 3 0     | conv3_block7_0_bn[0][0]                                |
| conv3_block7_1_conv (Conv2D)    | (None, None, None, 1 40960 | conv3_block7_0_relu[0][0]                              |
| conv3_block7_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block7_1_conv[0][0]                              |
| conv3_block7_1_relu (Activation | (None, None, None, 1 0     | conv3_block7_1_bn[0][0]                                |
| conv3_block7_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block7_1_relu[0][0]                              |
| conv3_block7_concat (Concatenat | (None, None, None, 3 0     | conv3_block6_concat[0][0]<br>conv3_block7_2_conv[0][0] |
| conv3_block8_0_bn (BatchNormali | (None, None, None, 3 1408  | conv3_block7_concat[0][0]                              |
| conv3_block8_0_relu (Activation | (None, None, None, 3 0     | conv3_block8_0_bn[0][0]                                |
| conv3_block8_1_conv (Conv2D)    | (None, None, None, 1 45056 | conv3_block8_0_relu[0][0]                              |
| conv3_block8_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block8_1_conv[0][0]                              |
| conv3_block8_1_relu (Activation | (None, None, None, 1 0     | conv3_block8_1_bn[0][0]                                |
| conv3_block8_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block8_1_relu[0][0]                              |
| conv3_block8_concat (Concatenat | (None, None, None, 3 0     | conv3_block7_concat[0][0]<br>conv3_block8_2_conv[0][0] |
| conv3_block9_0_bn (BatchNormali | (None, None, None, 3 1536  | conv3_block8_concat[0][0]                              |
| conv3_block9_0_relu (Activation | (None, None, None, 3 0     | conv3_block9_0_bn[0][0]                                |
| conv3_block9_1_conv (Conv2D)    | (None, None, None, 1 49152 | conv3_block9_0_relu[0][0]                              |

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| conv3_block9_1_bn (BatchNormali | (None, None, None, 1 512   | conv3_block9_1_conv[0][0]                                |
| conv3_block9_1_relu (Activation | (None, None, None, 1 0     | conv3_block9_1_bn[0][0]                                  |
| conv3_block9_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv3_block9_1_relu[0][0]                                |
| conv3_block9_concat (Concatenat | (None, None, None, 4 0     | conv3_block8_concat[0][0]<br>conv3_block9_2_conv[0][0]   |
| conv3_block10_0_bn (BatchNormal | (None, None, None, 4 1664  | conv3_block9_concat[0][0]                                |
| conv3_block10_0_relu (Activatio | (None, None, None, 4 0     | conv3_block10_0_bn[0][0]                                 |
| conv3_block10_1_conv (Conv2D)   | (None, None, None, 1 53248 | conv3_block10_0_relu[0][0]                               |
| conv3_block10_1_bn (BatchNormal | (None, None, None, 1 512   | conv3_block10_1_conv[0][0]                               |
| conv3_block10_1_relu (Activatio | (None, None, None, 1 0     | conv3_block10_1_bn[0][0]                                 |
| conv3_block10_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv3_block10_1_relu[0][0]                               |
| conv3_block10_concat (Concatena | (None, None, None, 4 0     | conv3_block9_concat[0][0]<br>conv3_block10_2_conv[0][0]  |
| conv3_block11_0_bn (BatchNormal | (None, None, None, 4 1792  | conv3_block10_concat[0][0]                               |
| conv3_block11_0_relu (Activatio | (None, None, None, 4 0     | conv3_block11_0_bn[0][0]                                 |
| conv3_block11_1_conv (Conv2D)   | (None, None, None, 1 57344 | conv3_block11_0_relu[0][0]                               |
| conv3_block11_1_bn (BatchNormal | (None, None, None, 1 512   | conv3_block11_1_conv[0][0]                               |
| conv3_block11_1_relu (Activatio | (None, None, None, 1 0     | conv3_block11_1_bn[0][0]                                 |
| conv3_block11_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv3_block11_1_relu[0][0]                               |
| conv3_block11_concat (Concatena | (None, None, None, 4 0     | conv3_block10_concat[0][0]<br>conv3_block11_2_conv[0][0] |
| conv3_block12_0_bn (BatchNormal | (None, None, None, 4 1920  | conv3_block11_concat[0][0]                               |
| conv3_block12_0_relu (Activatio | (None, None, None, 4 0     | conv3_block12_0_bn[0][0]                                 |
| conv3_block12_1_conv (Conv2D)   | (None, None, None, 1 61440 | conv3_block12_0_relu[0][0]                               |
| conv3_block12_1_bn (BatchNormal | (None, None, None, 1 512   | conv3_block12_1_conv[0][0]                               |
| conv3_block12_1_relu (Activatio | (None, None, None, 1 0     | conv3_block12_1_bn[0][0]                                 |

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| conv3_block12_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv3_block12_1_relu[0][0]                               |
| conv3_block12_concat (Concatena | (None, None, None, 5 0      | conv3_block11_concat[0][0]<br>conv3_block12_2_conv[0][0] |
| pool3_bn (BatchNormalization)   | (None, None, None, 5 2048   | conv3_block12_concat[0][0]                               |
| pool3_relu (Activation)         | (None, None, None, 5 0      | pool3_bn[0][0]   |
| pool3_conv (Conv2D)             | (None, None, None, 2 131072 | pool3_relu[0][0]   |
| pool3_pool (AveragePooling2D)   | (None, None, None, 2 0      | pool3_conv[0][0]   |
| conv4_block1_0_bn (BatchNormali | (None, None, None, 2 1024   | pool3_pool[0][0]   |
| conv4_block1_0_relu (Activation | (None, None, None, 2 0      | conv4_block1_0_bn[0][0]                                  |
| conv4_block1_1_conv (Conv2D)    | (None, None, None, 1 32768  | conv4_block1_0_relu[0][0]                                |
| conv4_block1_1_bn (BatchNormali | (None, None, None, 1 512    | conv4_block1_1_conv[0][0]                                |
| conv4_block1_1_relu (Activation | (None, None, None, 1 0      | conv4_block1_1_bn[0][0]                                  |
| conv4_block1_2_conv (Conv2D)    | (None, None, None, 3 36864  | conv4_block1_1_relu[0][0]                                |
| conv4_block1_concat (Concatenat | (None, None, None, 2 0      | pool3_pool[0][0]<br>conv4_block1_2_conv[0][0]            |
| conv4_block2_0_bn (BatchNormali | (None, None, None, 2 1152   | conv4_block1_concat[0][0]                                |
| conv4_block2_0_relu (Activation | (None, None, None, 2 0      | conv4_block2_0_bn[0][0]                                  |
| conv4_block2_1_conv (Conv2D)    | (None, None, None, 1 36864  | conv4_block2_0_relu[0][0]                                |
| conv4_block2_1_bn (BatchNormali | (None, None, None, 1 512    | conv4_block2_1_conv[0][0]                                |
| conv4_block2_1_relu (Activation | (None, None, None, 1 0      | conv4_block2_1_bn[0][0]                                  |
| conv4_block2_2_conv (Conv2D)    | (None, None, None, 3 36864  | conv4_block2_1_relu[0][0]                                |
| conv4_block2_concat (Concatenat | (None, None, None, 3 0      | conv4_block1_concat[0][0]<br>conv4_block2_2_conv[0][0]   |
| conv4_block3_0_bn (BatchNormali | (None, None, None, 3 1280   | conv4_block2_concat[0][0]                                |
| conv4_block3_0_relu (Activation | (None, None, None, 3 0      | conv4_block3_0_bn[0][0]                                  |



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| conv4_block3_1_conv (Conv2D)    | (None, None, None, 1 40960 | conv4_block3_0_relu[0][0]                              |
| conv4_block3_1_bn (BatchNormali | (None, None, None, 1 512   | conv4_block3_1_conv[0][0]                              |
| conv4_block3_1_relu (Activation | (None, None, None, 1 0     | conv4_block3_1_bn[0][0]                                |
| conv4_block3_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv4_block3_1_relu[0][0]                              |
| conv4_block3_concat (Concatenat | (None, None, None, 3 0     | conv4_block2_concat[0][0]<br>conv4_block3_2_conv[0][0] |
| conv4_block4_0_bn (BatchNormali | (None, None, None, 3 1408  | conv4_block3_concat[0][0]                              |
| conv4_block4_0_relu (Activation | (None, None, None, 3 0     | conv4_block4_0_bn[0][0]                                |
| conv4_block4_1_conv (Conv2D)    | (None, None, None, 1 45056 | conv4_block4_0_relu[0][0]                              |
| conv4_block4_1_bn (BatchNormali | (None, None, None, 1 512   | conv4_block4_1_conv[0][0]                              |
| conv4_block4_1_relu (Activation | (None, None, None, 1 0     | conv4_block4_1_bn[0][0]                                |
| conv4_block4_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv4_block4_1_relu[0][0]                              |
| conv4_block4_concat (Concatenat | (None, None, None, 3 0     | conv4_block3_concat[0][0]<br>conv4_block4_2_conv[0][0] |
| conv4_block5_0_bn (BatchNormali | (None, None, None, 3 1536  | conv4_block4_concat[0][0]                              |
| conv4_block5_0_relu (Activation | (None, None, None, 3 0     | conv4_block5_0_bn[0][0]                                |
| conv4_block5_1_conv (Conv2D)    | (None, None, None, 1 49152 | conv4_block5_0_relu[0][0]                              |
| conv4_block5_1_bn (BatchNormali | (None, None, None, 1 512   | conv4_block5_1_conv[0][0]                              |
| conv4_block5_1_relu (Activation | (None, None, None, 1 0     | conv4_block5_1_bn[0][0]                                |
| conv4_block5_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv4_block5_1_relu[0][0]                              |
| conv4_block5_concat (Concatenat | (None, None, None, 4 0     | conv4_block4_concat[0][0]<br>conv4_block5_2_conv[0][0] |
| conv4_block6_0_bn (BatchNormali | (None, None, None, 4 1664  | conv4_block5_concat[0][0]                              |
| conv4_block6_0_relu (Activation | (None, None, None, 4 0     | conv4_block6_0_bn[0][0]                                |
| conv4_block6_1_conv (Conv2D)    | (None, None, None, 1 53248 | conv4_block6_0_relu[0][0]                              |
| conv4_block6_1_bn (BatchNormali | (None, None, None, 1 512   | conv4_block6_1_conv[0][0]                              |

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| conv4_block6_1_relu (Activation | (None, None, None, 1 0     | conv4_block6_1_bn[0][0]                                |
| conv4_block6_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv4_block6_1_relu[0][0]                              |
| conv4_block6_concat (Concatenat | (None, None, None, 4 0     | conv4_block5_concat[0][0]<br>conv4_block6_2_conv[0][0] |
| conv4_block7_0_bn (BatchNormali | (None, None, None, 4 1792  | conv4_block6_concat[0][0]                              |
| conv4_block7_0_relu (Activation | (None, None, None, 4 0     | conv4_block7_0_bn[0][0]                                |
| conv4_block7_1_conv (Conv2D)    | (None, None, None, 1 57344 | conv4_block7_0_relu[0][0]                              |
| conv4_block7_1_bn (BatchNormali | (None, None, None, 1 512   | conv4_block7_1_conv[0][0]                              |
| conv4_block7_1_relu (Activation | (None, None, None, 1 0     | conv4_block7_1_bn[0][0]                                |
| conv4_block7_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv4_block7_1_relu[0][0]                              |
| conv4_block7_concat (Concatenat | (None, None, None, 4 0     | conv4_block6_concat[0][0]<br>conv4_block7_2_conv[0][0] |
| conv4_block8_0_bn (BatchNormali | (None, None, None, 4 1920  | conv4_block7_concat[0][0]                              |
| conv4_block8_0_relu (Activation | (None, None, None, 4 0     | conv4_block8_0_bn[0][0]                                |
| conv4_block8_1_conv (Conv2D)    | (None, None, None, 1 61440 | conv4_block8_0_relu[0][0]                              |
| conv4_block8_1_bn (BatchNormali | (None, None, None, 1 512   | conv4_block8_1_conv[0][0]                              |
| conv4_block8_1_relu (Activation | (None, None, None, 1 0     | conv4_block8_1_bn[0][0]                                |
| conv4_block8_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv4_block8_1_relu[0][0]                              |
| conv4_block8_concat (Concatenat | (None, None, None, 5 0     | conv4_block7_concat[0][0]<br>conv4_block8_2_conv[0][0] |
| conv4_block9_0_bn (BatchNormali | (None, None, None, 5 2048  | conv4_block8_concat[0][0]                              |
| conv4_block9_0_relu (Activation | (None, None, None, 5 0     | conv4_block9_0_bn[0][0]                                |
| conv4_block9_1_conv (Conv2D)    | (None, None, None, 1 65536 | conv4_block9_0_relu[0][0]                              |
| conv4_block9_1_bn (BatchNormali | (None, None, None, 1 512   | conv4_block9_1_conv[0][0]                              |
| conv4_block9_1_relu (Activation | (None, None, None, 1 0     | conv4_block9_1_bn[0][0]                                |

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| conv4_block9_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv4_block9_1_relu[0][0]                                |
| conv4_block9_concat (Concatenat | (None, None, None, 5 0     | conv4_block8_concat[0][0]<br>conv4_block9_2_conv[0][0]   |
| conv4_block10_0_bn (BatchNormal | (None, None, None, 5 2176  | conv4_block9_concat[0][0]                                |
| conv4_block10_0_relu (Activatio | (None, None, None, 5 0     | conv4_block10_0_bn[0][0]                                 |
| conv4_block10_1_conv (Conv2D)   | (None, None, None, 1 69632 | conv4_block10_0_relu[0][0]                               |
| conv4_block10_1_bn (BatchNormal | (None, None, None, 1 512   | conv4_block10_1_conv[0][0]                               |
| conv4_block10_1_relu (Activatio | (None, None, None, 1 0     | conv4_block10_1_bn[0][0]                                 |
| conv4_block10_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv4_block10_1_relu[0][0]                               |
| conv4_block10_concat (Concatena | (None, None, None, 5 0     | conv4_block9_concat[0][0]<br>conv4_block10_2_conv[0][0]  |
| conv4_block11_0_bn (BatchNormal | (None, None, None, 5 2304  | conv4_block10_concat[0][0]                               |
| conv4_block11_0_relu (Activatio | (None, None, None, 5 0     | conv4_block11_0_bn[0][0]                                 |
| conv4_block11_1_conv (Conv2D)   | (None, None, None, 1 73728 | conv4_block11_0_relu[0][0]                               |
| conv4_block11_1_bn (BatchNormal | (None, None, None, 1 512   | conv4_block11_1_conv[0][0]                               |
| conv4_block11_1_relu (Activatio | (None, None, None, 1 0     | conv4_block11_1_bn[0][0]                                 |
| conv4_block11_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv4_block11_1_relu[0][0]                               |
| conv4_block11_concat (Concatena | (None, None, None, 6 0     | conv4_block10_concat[0][0]<br>conv4_block11_2_conv[0][0] |
| conv4_block12_0_bn (BatchNormal | (None, None, None, 6 2432  | conv4_block11_concat[0][0]                               |
| conv4_block12_0_relu (Activatio | (None, None, None, 6 0     | conv4_block12_0_bn[0][0]                                 |
| conv4_block12_1_conv (Conv2D)   | (None, None, None, 1 77824 | conv4_block12_0_relu[0][0]                               |
| conv4_block12_1_bn (BatchNormal | (None, None, None, 1 512   | conv4_block12_1_conv[0][0]                               |
| conv4_block12_1_relu (Activatio | (None, None, None, 1 0     | conv4_block12_1_bn[0][0]                                 |
| conv4_block12_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv4_block12_1_relu[0][0]                               |
| conv4_block12_concat (Concatena | (None, None, None, 6 0     | conv4_block11_concat[0][0]                               |

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|                                 |                            | conv4_block12_2_conv[0][0]                               |
| conv4_block13_0_bn (BatchNormal | (None, None, None, 6 2560  | conv4_block12_concat[0][0]                               |
| conv4_block13_0_relu (Activatio | (None, None, None, 6 0     | conv4_block13_0_bn[0][0]                                 |
| conv4_block13_1_conv (Conv2D)   | (None, None, None, 1 81920 | conv4_block13_0_relu[0][0]                               |
| conv4_block13_1_bn (BatchNormal | (None, None, None, 1 512   | conv4_block13_1_conv[0][0]                               |
| conv4_block13_1_relu (Activatio | (None, None, None, 1 0     | conv4_block13_1_bn[0][0]                                 |
| conv4_block13_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv4_block13_1_relu[0][0]                               |
| conv4_block13_concat (Concatena | (None, None, None, 6 0     | conv4_block12_concat[0][0]<br>conv4_block13_2_conv[0][0] |
| conv4_block14_0_bn (BatchNormal | (None, None, None, 6 2688  | conv4_block13_concat[0][0]                               |
| conv4_block14_0_relu (Activatio | (None, None, None, 6 0     | conv4_block14_0_bn[0][0]                                 |
| conv4_block14_1_conv (Conv2D)   | (None, None, None, 1 86016 | conv4_block14_0_relu[0][0]                               |
| conv4_block14_1_bn (BatchNormal | (None, None, None, 1 512   | conv4_block14_1_conv[0][0]                               |
| conv4_block14_1_relu (Activatio | (None, None, None, 1 0     | conv4_block14_1_bn[0][0]                                 |
| conv4_block14_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv4_block14_1_relu[0][0]                               |
| conv4_block14_concat (Concatena | (None, None, None, 7 0     | conv4_block13_concat[0][0]<br>conv4_block14_2_conv[0][0] |
| conv4_block15_0_bn (BatchNormal | (None, None, None, 7 2816  | conv4_block14_concat[0][0]                               |
| conv4_block15_0_relu (Activatio | (None, None, None, 7 0     | conv4_block15_0_bn[0][0]                                 |
| conv4_block15_1_conv (Conv2D)   | (None, None, None, 1 90112 | conv4_block15_0_relu[0][0]                               |
| conv4_block15_1_bn (BatchNormal | (None, None, None, 1 512   | conv4_block15_1_conv[0][0]                               |
| conv4_block15_1_relu (Activatio | (None, None, None, 1 0     | conv4_block15_1_bn[0][0]                                 |
| conv4_block15_2_conv (Conv2D)   | (None, None, None, 3 36864 | conv4_block15_1_relu[0][0]                               |
| conv4_block15_concat (Concatena | (None, None, None, 7 0     | conv4_block14_concat[0][0]<br>conv4_block15_2_conv[0][0] |
| conv4_block16_0_bn (BatchNormal | (None, None, None, 7 2944  | conv4_block15_concat[0][0]                               |

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| conv4_block16_0_relu (Activatio | (None, None, None, 7 0      | conv4_block16_0_bn[0][0]                                 |
| conv4_block16_1_conv (Conv2D)   | (None, None, None, 1 94208  | conv4_block16_0_relu[0][0]                               |
| conv4_block16_1_bn (BatchNormal | (None, None, None, 1 512    | conv4_block16_1_conv[0][0]                               |
| conv4_block16_1_relu (Activatio | (None, None, None, 1 0      | conv4_block16_1_bn[0][0]                                 |
| conv4_block16_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv4_block16_1_relu[0][0]                               |
| conv4_block16_concat (Concatena | (None, None, None, 7 0      | conv4_block15_concat[0][0]<br>conv4_block16_2_conv[0][0] |
| conv4_block17_0_bn (BatchNormal | (None, None, None, 7 3072   | conv4_block16_concat[0][0]                               |
| conv4_block17_0_relu (Activatio | (None, None, None, 7 0      | conv4_block17_0_bn[0][0]                                 |
| conv4_block17_1_conv (Conv2D)   | (None, None, None, 1 98304  | conv4_block17_0_relu[0][0]                               |
| conv4_block17_1_bn (BatchNormal | (None, None, None, 1 512    | conv4_block17_1_conv[0][0]                               |
| conv4_block17_1_relu (Activatio | (None, None, None, 1 0      | conv4_block17_1_bn[0][0]                                 |
| conv4_block17_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv4_block17_1_relu[0][0]                               |
| conv4_block17_concat (Concatena | (None, None, None, 8 0      | conv4_block16_concat[0][0]<br>conv4_block17_2_conv[0][0] |
| conv4_block18_0_bn (BatchNormal | (None, None, None, 8 3200   | conv4_block17_concat[0][0]                               |
| conv4_block18_0_relu (Activatio | (None, None, None, 8 0      | conv4_block18_0_bn[0][0]                                 |
| conv4_block18_1_conv (Conv2D)   | (None, None, None, 1 102400 | conv4_block18_0_relu[0][0]                               |
| conv4_block18_1_bn (BatchNormal | (None, None, None, 1 512    | conv4_block18_1_conv[0][0]                               |
| conv4_block18_1_relu (Activatio | (None, None, None, 1 0      | conv4_block18_1_bn[0][0]                                 |
| conv4_block18_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv4_block18_1_relu[0][0]                               |
| conv4_block18_concat (Concatena | (None, None, None, 8 0      | conv4_block17_concat[0][0]<br>conv4_block18_2_conv[0][0] |
| conv4_block19_0_bn (BatchNormal | (None, None, None, 8 3328   | conv4_block18_concat[0][0]                               |
| conv4_block19_0_relu (Activatio | (None, None, None, 8 0      | conv4_block19_0_bn[0][0]                                 |

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| conv4_block19_1_conv (Conv2D)   | (None, None, None, 1 106496 | conv4_block19_0_relu[0][0]                               |
| conv4_block19_1_bn (BatchNormal | (None, None, None, 1 512    | conv4_block19_1_conv[0][0]                               |
| conv4_block19_1_relu (Activatio | (None, None, None, 1 0      | conv4_block19_1_bn[0][0]                                 |
| conv4_block19_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv4_block19_1_relu[0][0]                               |
| conv4_block19_concat (Concatena | (None, None, None, 8 0      | conv4_block18_concat[0][0]<br>conv4_block19_2_conv[0][0] |
| conv4_block20_0_bn (BatchNormal | (None, None, None, 8 3456   | conv4_block19_concat[0][0]                               |
| conv4_block20_0_relu (Activatio | (None, None, None, 8 0      | conv4_block20_0_bn[0][0]                                 |
| conv4_block20_1_conv (Conv2D)   | (None, None, None, 1 110592 | conv4_block20_0_relu[0][0]                               |
| conv4_block20_1_bn (BatchNormal | (None, None, None, 1 512    | conv4_block20_1_conv[0][0]                               |
| conv4_block20_1_relu (Activatio | (None, None, None, 1 0      | conv4_block20_1_bn[0][0]                                 |
| conv4_block20_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv4_block20_1_relu[0][0]                               |
| conv4_block20_concat (Concatena | (None, None, None, 8 0      | conv4_block19_concat[0][0]<br>conv4_block20_2_conv[0][0] |
| conv4_block21_0_bn (BatchNormal | (None, None, None, 8 3584   | conv4_block20_concat[0][0]                               |
| conv4_block21_0_relu (Activatio | (None, None, None, 8 0      | conv4_block21_0_bn[0][0]                                 |
| conv4_block21_1_conv (Conv2D)   | (None, None, None, 1 114688 | conv4_block21_0_relu[0][0]                               |
| conv4_block21_1_bn (BatchNormal | (None, None, None, 1 512    | conv4_block21_1_conv[0][0]                               |
| conv4_block21_1_relu (Activatio | (None, None, None, 1 0      | conv4_block21_1_bn[0][0]                                 |
| conv4_block21_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv4_block21_1_relu[0][0]                               |
| conv4_block21_concat (Concatena | (None, None, None, 9 0      | conv4_block20_concat[0][0]<br>conv4_block21_2_conv[0][0] |
| conv4_block22_0_bn (BatchNormal | (None, None, None, 9 3712   | conv4_block21_concat[0][0]                               |
| conv4_block22_0_relu (Activatio | (None, None, None, 9 0      | conv4_block22_0_bn[0][0]                                 |
| conv4_block22_1_conv (Conv2D)   | (None, None, None, 1 118784 | conv4_block22_0_relu[0][0]                               |
| conv4_block22_1_bn (BatchNormal | (None, None, None, 1 512    | conv4_block22_1_conv[0][0]                               |

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| conv4_block22_1_relu (Activation)    | (None, None, None, 1 0      | conv4_block22_1_bn[0][0]                                 |
| conv4_block22_2_conv (Conv2D)        | (None, None, None, 3 36864  | conv4_block22_1_relu[0][0]                               |
| conv4_block22_concat (Concatenation) | (None, None, None, 9 0      | conv4_block21_concat[0][0]<br>conv4_block22_2_conv[0][0] |
| conv4_block23_0_bn (BatchNormal      | (None, None, None, 9 3840   | conv4_block22_concat[0][0]                               |
| conv4_block23_0_relu (Activation)    | (None, None, None, 9 0      | conv4_block23_0_bn[0][0]                                 |
| conv4_block23_1_conv (Conv2D)        | (None, None, None, 1 122880 | conv4_block23_0_relu[0][0]                               |
| conv4_block23_1_bn (BatchNormal      | (None, None, None, 1 512    | conv4_block23_1_conv[0][0]                               |
| conv4_block23_1_relu (Activation)    | (None, None, None, 1 0      | conv4_block23_1_bn[0][0]                                 |
| conv4_block23_2_conv (Conv2D)        | (None, None, None, 3 36864  | conv4_block23_1_relu[0][0]                               |
| conv4_block23_concat (Concatenation) | (None, None, None, 9 0      | conv4_block22_concat[0][0]<br>conv4_block23_2_conv[0][0] |
| conv4_block24_0_bn (BatchNormal      | (None, None, None, 9 3968   | conv4_block23_concat[0][0]                               |
| conv4_block24_0_relu (Activation)    | (None, None, None, 9 0      | conv4_block24_0_bn[0][0]                                 |
| conv4_block24_1_conv (Conv2D)        | (None, None, None, 1 126976 | conv4_block24_0_relu[0][0]                               |
| conv4_block24_1_bn (BatchNormal      | (None, None, None, 1 512    | conv4_block24_1_conv[0][0]                               |
| conv4_block24_1_relu (Activation)    | (None, None, None, 1 0      | conv4_block24_1_bn[0][0]                                 |
| conv4_block24_2_conv (Conv2D)        | (None, None, None, 3 36864  | conv4_block24_1_relu[0][0]                               |
| conv4_block24_concat (Concatenation) | (None, None, None, 1 0      | conv4_block23_concat[0][0]<br>conv4_block24_2_conv[0][0] |
| pool4_bn (BatchNormalization)        | (None, None, None, 1 4096   | conv4_block24_concat[0][0]                               |
| pool4_relu (Activation)              | (None, None, None, 1 0      | pool4_bn[0][0]   |
| pool4_conv (Conv2D)                  | (None, None, None, 5 524288 | pool4_relu[0][0]   |
| pool4_pool (AveragePooling2D)        | (None, None, None, 5 0      | pool4_conv[0][0]   |
| conv5_block1_0_bn (BatchNormali      | (None, None, None, 5 2048   | pool4_pool[0][0]   |

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| conv5_block1_0_relu (Activation (None, None, None, 5 0    | conv5_block1_0_bn[0] [0]                                 |
| conv5_block1_1_conv (Conv2D) (None, None, None, 1 65536   | conv5_block1_0_relu[0] [0]                               |
| conv5_block1_1_bn (BatchNormali (None, None, None, 1 512  | conv5_block1_1_conv[0] [0]                               |
| conv5_block1_1_relu (Activation (None, None, None, 1 0    | conv5_block1_1_bn[0] [0]                                 |
| conv5_block1_2_conv (Conv2D) (None, None, None, 3 36864   | conv5_block1_1_relu[0] [0]                               |
| conv5_block1_concat (Concatenat (None, None, None, 5 0    | pool4_pool[0] [0]<br>conv5_block1_2_conv[0] [0]          |
| conv5_block2_0_bn (BatchNormali (None, None, None, 5 2176 | conv5_block1_concat[0] [0]                               |
| conv5_block2_0_relu (Activation (None, None, None, 5 0    | conv5_block2_0_bn[0] [0]                                 |
| conv5_block2_1_conv (Conv2D) (None, None, None, 1 69632   | conv5_block2_0_relu[0] [0]                               |
| conv5_block2_1_bn (BatchNormali (None, None, None, 1 512  | conv5_block2_1_conv[0] [0]                               |
| conv5_block2_1_relu (Activation (None, None, None, 1 0    | conv5_block2_1_bn[0] [0]                                 |
| conv5_block2_2_conv (Conv2D) (None, None, None, 3 36864   | conv5_block2_1_relu[0] [0]                               |
| conv5_block2_concat (Concatenat (None, None, None, 5 0    | conv5_block1_concat[0] [0]<br>conv5_block2_2_conv[0] [0] |
| conv5_block3_0_bn (BatchNormali (None, None, None, 5 2304 | conv5_block2_concat[0] [0]                               |
| conv5_block3_0_relu (Activation (None, None, None, 5 0    | conv5_block3_0_bn[0] [0]                                 |
| conv5_block3_1_conv (Conv2D) (None, None, None, 1 73728   | conv5_block3_0_relu[0] [0]                               |
| conv5_block3_1_bn (BatchNormali (None, None, None, 1 512  | conv5_block3_1_conv[0] [0]                               |
| conv5_block3_1_relu (Activation (None, None, None, 1 0    | conv5_block3_1_bn[0] [0]                                 |
| conv5_block3_2_conv (Conv2D) (None, None, None, 3 36864   | conv5_block3_1_relu[0] [0]                               |
| conv5_block3_concat (Concatenat (None, None, None, 6 0    | conv5_block2_concat[0] [0]<br>conv5_block3_2_conv[0] [0] |
| conv5_block4_0_bn (BatchNormali (None, None, None, 6 2432 | conv5_block3_concat[0] [0]                               |
| conv5_block4_0_relu (Activation (None, None, None, 6 0    | conv5_block4_0_bn[0] [0]                                 |
| conv5_block4_1_conv (Conv2D) (None, None, None, 1 77824   | conv5_block4_0_relu[0] [0]                               |



|                                 |                            |  |
|---------------------------------|----------------------------|--|
| conv5_block4_1_bn (BatchNormali | (None, None, None, 1 512   | conv5_block4_1_conv[0][0]                              |
| conv5_block4_1_relu (Activation | (None, None, None, 1 0     | conv5_block4_1_bn[0][0]                                |
| conv5_block4_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv5_block4_1_relu[0][0]                              |
| conv5_block4_concat (Concatenat | (None, None, None, 6 0     | conv5_block3_concat[0][0]<br>conv5_block4_2_conv[0][0] |
| conv5_block5_0_bn (BatchNormali | (None, None, None, 6 2560  | conv5_block4_concat[0][0]                              |
| conv5_block5_0_relu (Activation | (None, None, None, 6 0     | conv5_block5_0_bn[0][0]                                |
| conv5_block5_1_conv (Conv2D)    | (None, None, None, 1 81920 | conv5_block5_0_relu[0][0]                              |
| conv5_block5_1_bn (BatchNormali | (None, None, None, 1 512   | conv5_block5_1_conv[0][0]                              |
| conv5_block5_1_relu (Activation | (None, None, None, 1 0     | conv5_block5_1_bn[0][0]                                |
| conv5_block5_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv5_block5_1_relu[0][0]                              |
| conv5_block5_concat (Concatenat | (None, None, None, 6 0     | conv5_block4_concat[0][0]<br>conv5_block5_2_conv[0][0] |
| conv5_block6_0_bn (BatchNormali | (None, None, None, 6 2688  | conv5_block5_concat[0][0]                              |
| conv5_block6_0_relu (Activation | (None, None, None, 6 0     | conv5_block6_0_bn[0][0]                                |
| conv5_block6_1_conv (Conv2D)    | (None, None, None, 1 86016 | conv5_block6_0_relu[0][0]                              |
| conv5_block6_1_bn (BatchNormali | (None, None, None, 1 512   | conv5_block6_1_conv[0][0]                              |
| conv5_block6_1_relu (Activation | (None, None, None, 1 0     | conv5_block6_1_bn[0][0]                                |
| conv5_block6_2_conv (Conv2D)    | (None, None, None, 3 36864 | conv5_block6_1_relu[0][0]                              |
| conv5_block6_concat (Concatenat | (None, None, None, 7 0     | conv5_block5_concat[0][0]<br>conv5_block6_2_conv[0][0] |
| conv5_block7_0_bn (BatchNormali | (None, None, None, 7 2816  | conv5_block6_concat[0][0]                              |
| conv5_block7_0_relu (Activation | (None, None, None, 7 0     | conv5_block7_0_bn[0][0]                                |
| conv5_block7_1_conv (Conv2D)    | (None, None, None, 1 90112 | conv5_block7_0_relu[0][0]                              |
| conv5_block7_1_bn (BatchNormali | (None, None, None, 1 512   | conv5_block7_1_conv[0][0]                              |

|                                 |                             |  |
|---------------------------------|-----------------------------|--|
| conv5_block7_1_relu (Activation | (None, None, None, 1 0      | conv5_block7_1_bn[0][0]                                |
| conv5_block7_2_conv (Conv2D)    | (None, None, None, 3 36864  | conv5_block7_1_relu[0][0]                              |
| conv5_block7_concat (Concatenat | (None, None, None, 7 0      | conv5_block6_concat[0][0]<br>conv5_block7_2_conv[0][0] |
| conv5_block8_0_bn (BatchNormali | (None, None, None, 7 2944   | conv5_block7_concat[0][0]                              |
| conv5_block8_0_relu (Activation | (None, None, None, 7 0      | conv5_block8_0_bn[0][0]                                |
| conv5_block8_1_conv (Conv2D)    | (None, None, None, 1 94208  | conv5_block8_0_relu[0][0]                              |
| conv5_block8_1_bn (BatchNormali | (None, None, None, 1 512    | conv5_block8_1_conv[0][0]                              |
| conv5_block8_1_relu (Activation | (None, None, None, 1 0      | conv5_block8_1_bn[0][0]                                |
| conv5_block8_2_conv (Conv2D)    | (None, None, None, 3 36864  | conv5_block8_1_relu[0][0]                              |
| conv5_block8_concat (Concatenat | (None, None, None, 7 0      | conv5_block7_concat[0][0]<br>conv5_block8_2_conv[0][0] |
| conv5_block9_0_bn (BatchNormali | (None, None, None, 7 3072   | conv5_block8_concat[0][0]                              |
| conv5_block9_0_relu (Activation | (None, None, None, 7 0      | conv5_block9_0_bn[0][0]                                |
| conv5_block9_1_conv (Conv2D)    | (None, None, None, 1 98304  | conv5_block9_0_relu[0][0]                              |
| conv5_block9_1_bn (BatchNormali | (None, None, None, 1 512    | conv5_block9_1_conv[0][0]                              |
| conv5_block9_1_relu (Activation | (None, None, None, 1 0      | conv5_block9_1_bn[0][0]                                |
| conv5_block9_2_conv (Conv2D)    | (None, None, None, 3 36864  | conv5_block9_1_relu[0][0]                              |
| conv5_block9_concat (Concatenat | (None, None, None, 8 0      | conv5_block8_concat[0][0]<br>conv5_block9_2_conv[0][0] |
| conv5_block10_0_bn (BatchNormal | (None, None, None, 8 3200   | conv5_block9_concat[0][0]                              |
| conv5_block10_0_relu (Activatio | (None, None, None, 8 0      | conv5_block10_0_bn[0][0]                               |
| conv5_block10_1_conv (Conv2D)   | (None, None, None, 1 102400 | conv5_block10_0_relu[0][0]                             |
| conv5_block10_1_bn (BatchNormal | (None, None, None, 1 512    | conv5_block10_1_conv[0][0]                             |
| conv5_block10_1_relu (Activatio | (None, None, None, 1 0      | conv5_block10_1_bn[0][0]                               |
| conv5_block10_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv5_block10_1_relu[0][0]                             |

|                                 |                             |  |
|---------------------------------|-----------------------------|--|
| conv5_block10_concat (Concatena | (None, None, None, 8 0      | conv5_block9_concat[0][0]<br>conv5_block10_2_conv[0][0]  |
| conv5_block11_0_bn (BatchNormal | (None, None, None, 8 3328   | conv5_block10_concat[0][0]                               |
| conv5_block11_0_relu (Activatio | (None, None, None, 8 0      | conv5_block11_0_bn[0][0]                                 |
| conv5_block11_1_conv (Conv2D)   | (None, None, None, 1 106496 | conv5_block11_0_relu[0][0]                               |
| conv5_block11_1_bn (BatchNormal | (None, None, None, 1 512    | conv5_block11_1_conv[0][0]                               |
| conv5_block11_1_relu (Activatio | (None, None, None, 1 0      | conv5_block11_1_bn[0][0]                                 |
| conv5_block11_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv5_block11_1_relu[0][0]                               |
| conv5_block11_concat (Concatena | (None, None, None, 8 0      | conv5_block10_concat[0][0]<br>conv5_block11_2_conv[0][0] |
| conv5_block12_0_bn (BatchNormal | (None, None, None, 8 3456   | conv5_block11_concat[0][0]                               |
| conv5_block12_0_relu (Activatio | (None, None, None, 8 0      | conv5_block12_0_bn[0][0]                                 |
| conv5_block12_1_conv (Conv2D)   | (None, None, None, 1 110592 | conv5_block12_0_relu[0][0]                               |
| conv5_block12_1_bn (BatchNormal | (None, None, None, 1 512    | conv5_block12_1_conv[0][0]                               |
| conv5_block12_1_relu (Activatio | (None, None, None, 1 0      | conv5_block12_1_bn[0][0]                                 |
| conv5_block12_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv5_block12_1_relu[0][0]                               |
| conv5_block12_concat (Concatena | (None, None, None, 8 0      | conv5_block11_concat[0][0]<br>conv5_block12_2_conv[0][0] |
| conv5_block13_0_bn (BatchNormal | (None, None, None, 8 3584   | conv5_block12_concat[0][0]                               |
| conv5_block13_0_relu (Activatio | (None, None, None, 8 0      | conv5_block13_0_bn[0][0]                                 |
| conv5_block13_1_conv (Conv2D)   | (None, None, None, 1 114688 | conv5_block13_0_relu[0][0]                               |
| conv5_block13_1_bn (BatchNormal | (None, None, None, 1 512    | conv5_block13_1_conv[0][0]                               |
| conv5_block13_1_relu (Activatio | (None, None, None, 1 0      | conv5_block13_1_bn[0][0]                                 |
| conv5_block13_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv5_block13_1_relu[0][0]                               |
| conv5_block13_concat (Concatena | (None, None, None, 9 0      | conv5_block12_concat[0][0]<br>conv5_block13_2_conv[0][0] |

|                                 |                             |  |
|---------------------------------|-----------------------------|--|
| conv5_block14_0_bn (BatchNormal | (None, None, None, 9 3712   | conv5_block13_concat[0][0]                               |
| conv5_block14_0_relu (Activatio | (None, None, None, 9 0      | conv5_block14_0_bn[0][0]                                 |
| conv5_block14_1_conv (Conv2D)   | (None, None, None, 1 118784 | conv5_block14_0_relu[0][0]                               |
| conv5_block14_1_bn (BatchNormal | (None, None, None, 1 512    | conv5_block14_1_conv[0][0]                               |
| conv5_block14_1_relu (Activatio | (None, None, None, 1 0      | conv5_block14_1_bn[0][0]                                 |
| conv5_block14_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv5_block14_1_relu[0][0]                               |
| conv5_block14_concat (Concatena | (None, None, None, 9 0      | conv5_block13_concat[0][0]<br>conv5_block14_2_conv[0][0] |
| conv5_block15_0_bn (BatchNormal | (None, None, None, 9 3840   | conv5_block14_concat[0][0]                               |
| conv5_block15_0_relu (Activatio | (None, None, None, 9 0      | conv5_block15_0_bn[0][0]                                 |
| conv5_block15_1_conv (Conv2D)   | (None, None, None, 1 122880 | conv5_block15_0_relu[0][0]                               |
| conv5_block15_1_bn (BatchNormal | (None, None, None, 1 512    | conv5_block15_1_conv[0][0]                               |
| conv5_block15_1_relu (Activatio | (None, None, None, 1 0      | conv5_block15_1_bn[0][0]                                 |
| conv5_block15_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv5_block15_1_relu[0][0]                               |
| conv5_block15_concat (Concatena | (None, None, None, 9 0      | conv5_block14_concat[0][0]<br>conv5_block15_2_conv[0][0] |
| conv5_block16_0_bn (BatchNormal | (None, None, None, 9 3968   | conv5_block15_concat[0][0]                               |
| conv5_block16_0_relu (Activatio | (None, None, None, 9 0      | conv5_block16_0_bn[0][0]                                 |
| conv5_block16_1_conv (Conv2D)   | (None, None, None, 1 126976 | conv5_block16_0_relu[0][0]                               |
| conv5_block16_1_bn (BatchNormal | (None, None, None, 1 512    | conv5_block16_1_conv[0][0]                               |
| conv5_block16_1_relu (Activatio | (None, None, None, 1 0      | conv5_block16_1_bn[0][0]                                 |
| conv5_block16_2_conv (Conv2D)   | (None, None, None, 3 36864  | conv5_block16_1_relu[0][0]                               |
| conv5_block16_concat (Concatena | (None, None, None, 1 0      | conv5_block15_concat[0][0]<br>conv5_block16_2_conv[0][0] |
| bn (BatchNormalization)         | (None, None, None, 1 4096   | conv5_block16_concat[0][0]                               |

```
relu (Activation)                (None, None, None, 1 0          bn[0] [0]
```

```
=====
Total params: 7,037,504
Trainable params: 6,953,856
Non-trainable params: 83,648
-----
```

```
In [4]: # Print out the first five layers
        layers_l = base_model.layers

        print("First 5 layers")
        layers_l[0:5]
```

First 5 layers

```
Out[4]: [<keras.engine.input_layer.InputLayer at 0x7f47aed52e80>,
        <keras.layers.convolutional.ZeroPadding2D at 0x7f47aecec0f0>,
        <keras.layers.convolutional.Conv2D at 0x7f480014e470>,
        <keras.layers.normalization.BatchNormalization at 0x7f47aecec7f0>,
        <keras.layers.core.Activation at 0x7f47aececcc0>]
```

```
In [5]: # Print out the last five layers
        print("Last 5 layers")
        layers_l[-6:-1]
```

Last 5 layers

```
Out[5]: [<keras.layers.normalization.BatchNormalization at 0x7f475c163518>,
        <keras.layers.core.Activation at 0x7f475c163630>,
        <keras.layers.convolutional.Conv2D at 0x7f475c16dd30>,
        <keras.layers.merge.Concatenate at 0x7f475c11fd68>,
        <keras.layers.normalization.BatchNormalization at 0x7f475c11f160>]
```

```
In [6]: # Get the convolutional layers and print the first 5
        conv2D_layers = [layer for layer in base_model.layers
                          if str(type(layer)).find('Conv2D') > -1]
        print("The first five conv2D layers")
        conv2D_layers[0:5]
```

The first five conv2D layers

```
Out[6]: [<keras.layers.convolutional.Conv2D at 0x7f480014e470>,
        <keras.layers.convolutional.Conv2D at 0x7f47ac47ca20>,
        <keras.layers.convolutional.Conv2D at 0x7f47ac42ecf8>,
        <keras.layers.convolutional.Conv2D at 0x7f47ac3e9240>,
        <keras.layers.convolutional.Conv2D at 0x7f47ac39e470>]
```

```
In [7]: # Print out the total number of convolutional layers
        print(f"There are {len(conv2D_layers)} convolutional layers")
```

There are 120 convolutional layers

```
In [8]: # Print the number of channels in the input
        print("The input has 3 channels")
        base_model.input
```

The input has 3 channels

```
Out[8]: <tf.Tensor 'input_1:0' shape=(?, ?, ?, 3) dtype=float32>
```

```
In [9]: # Print the number of output channels
        print("The output has 1024 channels")
        x = base_model.output
        x
```

The output has 1024 channels

```
Out[9]: <tf.Tensor 'relu/Relu:0' shape=(?, ?, ?, 1024) dtype=float32>
```

```
In [10]: # Add a global spatial average pooling layer
          x_pool = GlobalAveragePooling2D()(x)
          x_pool
```

```
Out[10]: <tf.Tensor 'global_average_pooling2d_1/Mean:0' shape=(?, 1024) dtype=float32>
```

```
In [11]: # Define a set of five class labels to use as an example
          labels = ['Emphysema',
                    'Hernia',
                    'Mass',
                    'Pneumonia',
                    'Edema']
          n_classes = len(labels)
          print(f"In this example, you want your model to identify {n_classes} classes")
```

In this example, you want your model to identify 5 classes

```
In [12]: # Add a logistic layer the same size as the number of classes you're trying to predict
          predictions = Dense(n_classes, activation="sigmoid")(x_pool)
          print("Predictions have {n_classes} units, one for each class")
          predictions
```

Predictions have {n\_classes} units, one for each class

```
Out[12]: <tf.Tensor 'dense_1/Sigmoid:0' shape=(?, 5) dtype=float32>
```

```
In [13]: # Create an updated model
         model = Model(inputs=base_model.input, outputs=predictions)
```

```
In [14]: # Compile the model
         model.compile(optimizer='adam',
                       loss='categorical_crossentropy')
         # (You'll customize the loss function in the assignment!)
```

**This has been a brief exploration of the Densenet architecture you'll use in this week's graded assignment!**