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Initialization

load all needed libraries and functions, check the previous tutorial how to correctly load keras and other modules

In [1]:
```
import matplotlib.pyplot as plt
import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
import pandas as pd
import os
import cv2
import keras
from tqdm import tqdm
from keras.applications.vgg16 import VGG16, preprocess_input
from tensorflow.keras import datasets, layers, models
from tensorflow.keras.layers import Dense, Dropout, Activation, Flatten, Conv2D
from tensorflow.keras.models import Sequential
```

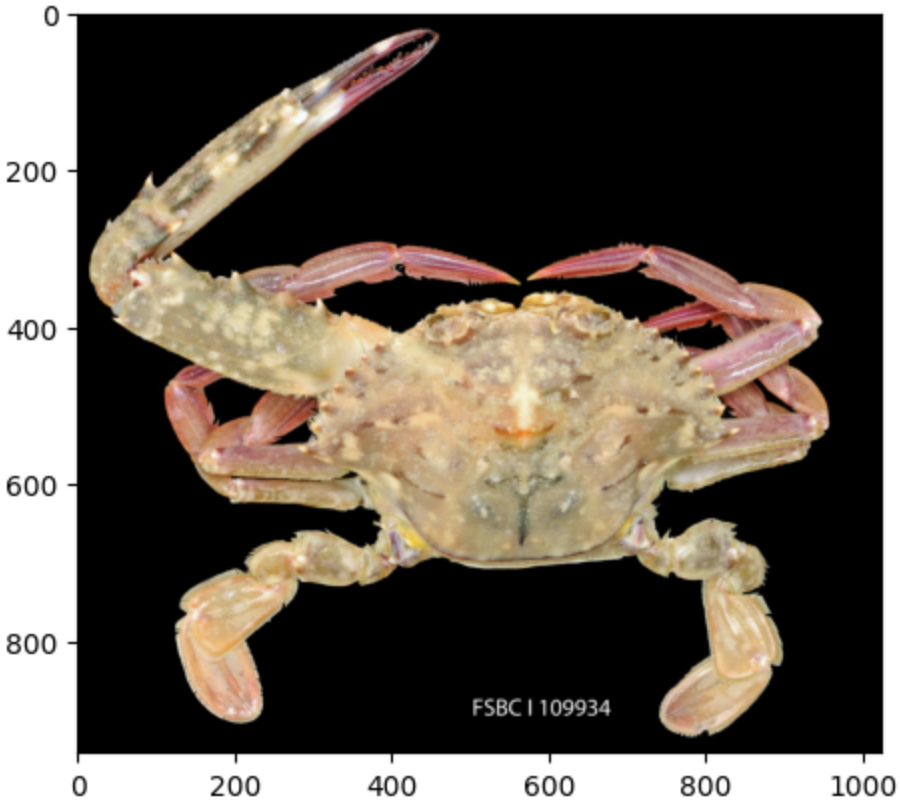
importing the libraries used in the code.

Load dataset & Plot a subset

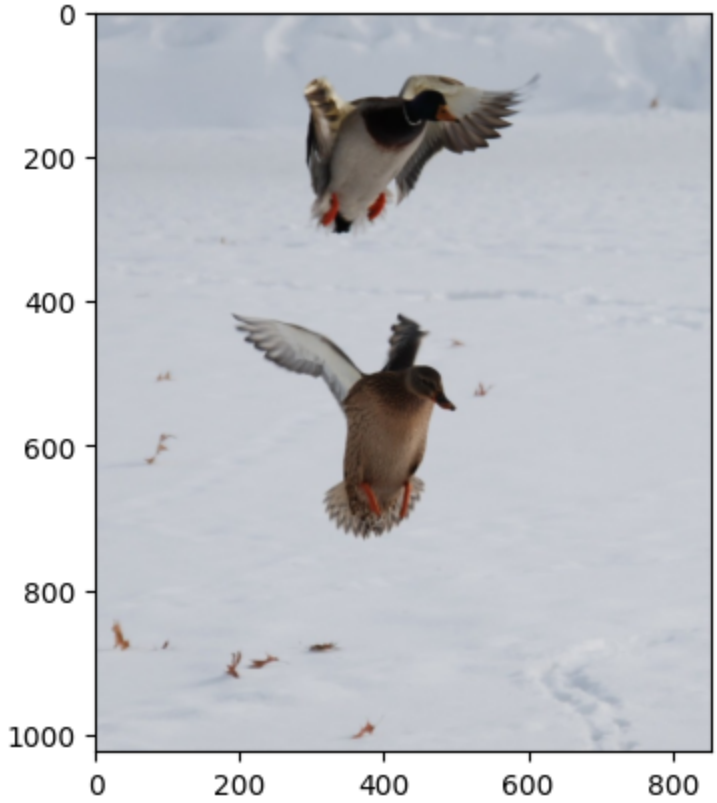
load your dataset and show a plot of the subset of your data

In [40]:
```
#felix
#DATADIR = "C:/Users/felix/Office 365 Fontys/AIS zooi - General/Ass2C/pictures/train"
#Yosha
#DATADIR = "C:/Users/yosha19/OneDrive - Office 365 Fontys/General/Ass2C/pictures/train"
#kasper
DATADIR = "C:/Users/mobie/OneDrive - Office 365 Fontys/General - AIS zooi/Ass2C/pictures

CATEGORIES = ["crab", "duck", "hedgehog", "panda", "penguin", "raccoon"]


for category in CATEGORIES:
    path = os.path.join(DATADIR,category)
    for img in os.listdir(path):
        img_arrayBGR = cv2.imread(os.path.join(path,img))  # convert to array
    #show first picture of every category
    print("Now processing", category)
    plt.imshow(img_arrayBGR[...,::-1])
    plt.show()
```

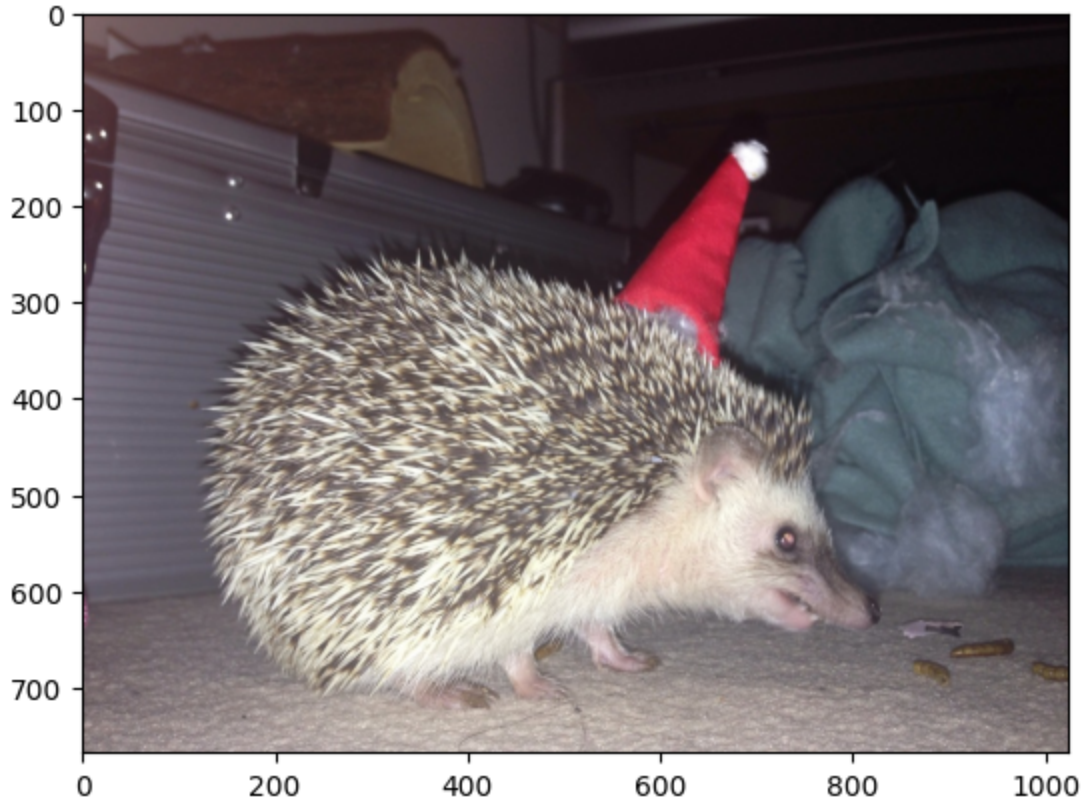
```
Now processing crab
```



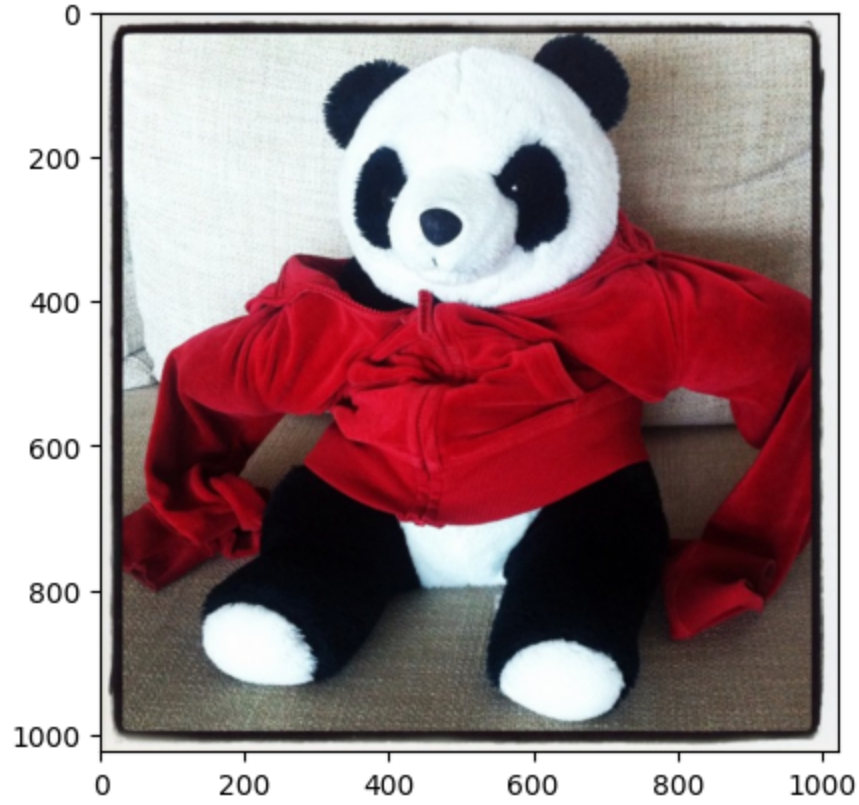

```
Now processing duck
```



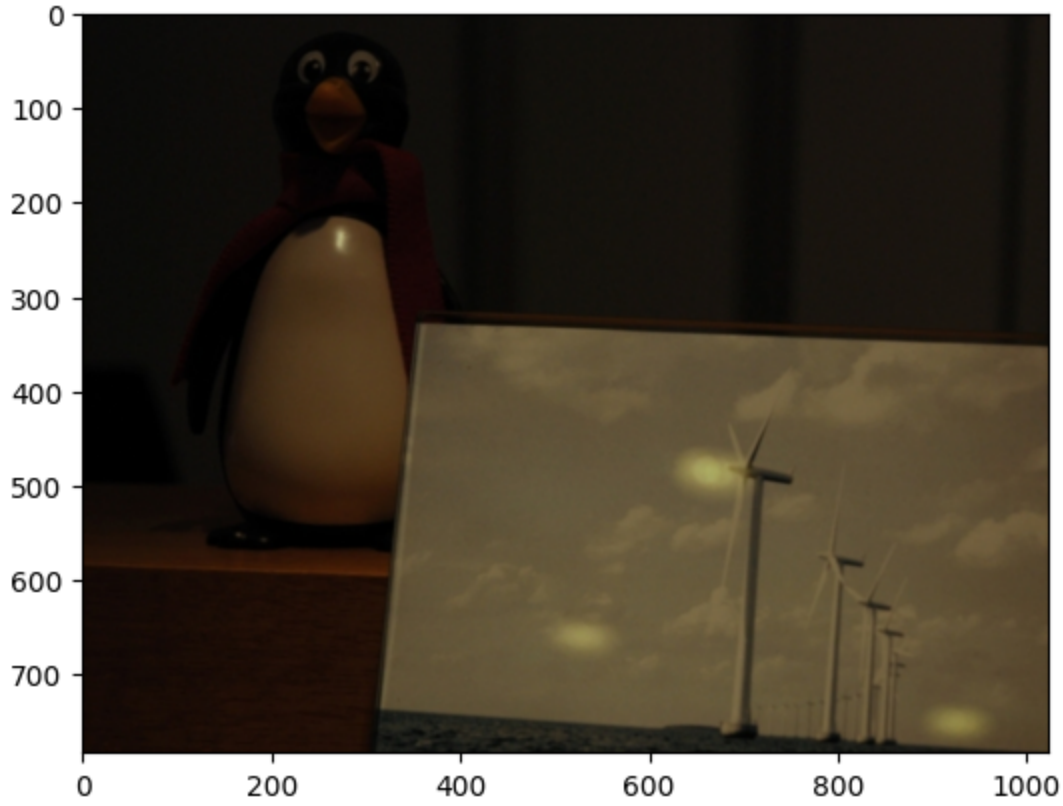

```
Now processing hedgehog
```



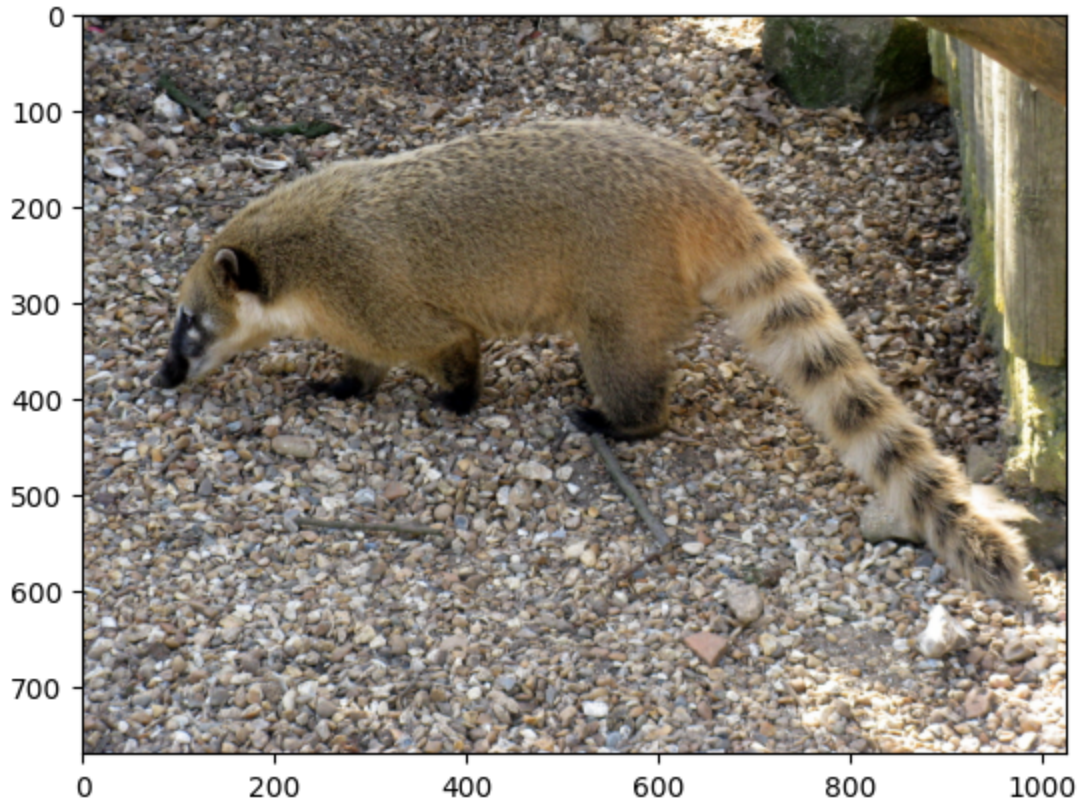

```
Now processing panda
```




```
Now processing penguin
```




```
Now processing raccoon
```



importing the images and plotting the last picture of every category.

Prepare Data

pre-process your raw input data... rescale... normalize....

In [41]:
```
img_size = 224
X_img = []
```

```
Y_class = []
#test_data = []

def create_data():
    for category in CATEGORIES:

        path = os.path.join(DATADIR,category)
        class_num = CATEGORIES.index(category)

        for img in tqdm(os.listdir(path)):
            try:
                img_arrayBGR = cv2.imread(os.path.join(path,img))  # convert to array
                preprocessed_array = cv2.resize(img_arrayBGR, (img_size, img_size))  # r
                preprocessed_array = np.expand_dims(preprocessed_array, axis=0)
                X_img.append(preprocessed_array)  # add img to array
                Y_class.append(class_num)      # add class to array
            except Exception as e:  # in the interest in keeping the output clean...
                print("Resizing not possible")
                plt.imshow(img_arrayBGR[...,::-1])
                plt.show()

create_data()

#array to numpy array
X_img = np.asarray(X_img)
Y_class = np.asarray(Y_class)

#print(X_img, Y_class)
print("IMG shape = ",X_img.shape)
print("Class shape=",Y_class.shape)

#delete 1 object from array
new_X_img = X_img[:,0,:,:]

# create a new array with 360 rows and 6 columns, filled with zeros
new_Y_class = np.zeros((2184, 6))
# copy the values from Y_class into new_Y_class
for i in range(len(Y_class)):
    new_Y_class[i, Y_class[i]] = 1


print("IMG shape = ",new_X_img.shape)
print("Class shape=",new_Y_class.shape)
print(new_X_img)
print(new_Y_class)
```

```
100%|██████████| 473/473 [00:05<00:00, 81.12it/s]
100%|██████████| 680/680 [00:08<00:00, 80.30it/s]
100%|██████████| 179/179 [00:02<00:00, 76.05it/s]
100%|██████████| 160/160 [00:01<00:00, 88.95it/s]
100%|██████████| 488/488 [00:05<00:00, 85.37it/s]
100%|██████████| 204/204 [00:02<00:00, 75.77it/s]
IMG shape =  (2184, 1, 224, 224, 3)
Class shape= (2184,)
IMG shape =  (2184, 224, 224, 3)
Class shape= (2184, 6)
[[[[ 15  14  18]
   [ 23  25  32]
   [ 20  20  26]
   ...
   [ 55  33  28]
   [ 52  32  27]
   [ 52  32  27]]

  [[ 16  15  17]
```

```
  [ 22  24  33]
  [ 19  21  29]
  ...
  [ 55  33  28]
  [ 52  32  27]
  [ 52  32  27]]

 [[ 18  18  19]
  [ 21  22  31]
  [ 20  22  30]
  ...
  [ 56  34  29]
  [ 55  33  28]
  [ 56  34  29]]

 ...

 [[ 23  42 100]
  [ 35  68 137]
  [ 33  62 141]
  ...
  [ 69  79  96]
  [ 65  73  90]
  [ 65  75  93]]

 [[ 24  46 115]
  [ 24  50 123]
  [ 30  60 138]
  ...
  [ 71  81  98]
  [ 69  79  97]
  [ 66  76  94]]

 [[ 19  55 129]
  [ 19  43 107]
  [ 24  41 114]
  ...
  [ 75  85 102]
  [ 72  84 102]
  [ 71  81  99]]]


[[[ 31  65 106]
  [ 23  54 106]
  [ 16  50 100]
  ...
  [ 18  27  23]
  [ 10  19  16]
  [ 10  16  15]]

 [[ 42  80 108]
  [ 31  66 109]
  [ 23  56 110]
  ...
  [ 20  27  21]
  [ 12  19  16]
  [  9  17  16]]

 [[ 29  64  98]
  [ 33  71 106]
  [ 30  65 108]
  ...
  [ 20  25  23]
  [ 12  17  16]
  [ 12  17  16]]
```

```
 ...

 [[ 19 148 143]
  [ 12 148 142]
  [ 20 149 144]
  ...
  [ 12  57  94]
  [ 12  54  98]
  [  9  46  96]]

 [[ 21 147 145]
  [ 21 148 143]
  [ 25 148 144]
  ...
  [  9  52  85]
  [  8  40  83]
  [ 11  52 100]]

 [[ 18 146 141]
  [ 25 146 142]
  [ 20 147 145]
  ...
  [ 11  56  88]
  [ 15  52  94]
  [ 14  54  98]]]


[[[  2   3   5]
  [ 20  12  15]
  [ 29  17  15]
  ...
  [ 58  51  50]
  [ 83  79  81]
  [249 253 252]]

 [[  4   2   3]
  [ 75  66  66]
  [ 33  18  14]
  ...
  [ 65  59  58]
  [ 66  63  64]
  [232 237 236]]

 [[  5   2   2]
  [164 154 146]
  [ 74  60  49]
  ...
  [ 84  79  76]
  [ 77  77  73]
  [229 232 230]]

 ...

 [[ 54  46  33]
  [ 63  56  47]
  [ 53  45  38]
  ...
  [ 68 117 169]
  [102 151 204]
  [ 90 149 205]]

 [[ 61  57  43]
  [ 56  53  43]
  [ 25  20  11]
  ...
  [ 47  93 147]
```

```
  [ 71 114 167]
  [ 81 127 183]]

 [[ 60  59  46]
  [ 46  46  34]
  [ 60  59  46]
  ...
  [ 61 101 159]
  [ 65 102 161]
  [ 55  94 154]]]


...


[[[129 145 151]
  [130 134 137]
  [125 123 122]
  ...
  [ 63  90 117]
  [ 61  91 110]
  [ 58  90 104]]

 [[127 146 151]
  [131 136 140]
  [132 130 129]
  ...
  [ 67  94 120]
  [ 63  91 113]
  [ 60  90 107]]

 [[126 147 152]
  [131 138 141]
  [129 130 128]
  ...
  [ 64  91 118]
  [ 62  90 114]
  [ 63  91 115]]

 ...

 [[132 149 161]
  [144 153 166]
  [145 153 166]
  ...
  [ 65  90 110]
  [ 47  72  90]
  [ 44  70  86]]

 [[135 150 162]
  [146 153 165]
  [145 152 165]
  ...
  [ 73  92 113]
  [ 66  87 105]
  [ 62  84 100]]

 [[133 147 160]
  [144 150 163]
  [146 152 165]
  ...
  [ 76  89 111]
  [ 76  91 110]
  [ 72  86 104]]]
```

```
[[[ 46  58  70]
  [ 43  58  68]
  [ 42  56  68]
  ...
  [145 167 179]
  [144 166 178]
  [144 166 178]]

 [[ 44  56  68]
  [ 44  56  66]
  [ 42  57  66]
  ...
  [144 166 178]
  [144 166 178]
  [143 165 177]]

 [[ 45  57  69]
  [ 42  56  68]
  [ 44  56  66]
  ...
  [144 167 179]
  [145 167 179]
  [142 166 178]]

 ...

 [[161 176 192]
  [157 175 189]
  [153 169 186]
  ...
  [141 164 184]
  [159 176 192]
  [161 180 193]]

 [[154 172 188]
  [156 175 191]
  [153 173 189]
  ...
  [155 175 189]
  [161 177 193]
  [151 169 185]]

 [[159 175 191]
  [152 175 192]
  [148 173 189]
  ...
  [156 175 190]
  [160 180 192]
  [159 179 197]]]


[[[104 105 105]
  [ 71  70  72]
  [102 109 106]
  ...
  [ 69  92 108]
  [ 61  83 100]
  [ 62  87  99]]

 [[122 120 119]
  [ 95  95  99]
  [135 130 123]
  ...
  [ 71  91 108]
  [ 55  86  92]
  [ 57  80  92]]
```

```
  [[156 168 172]
   [ 56  56  67]
   [142 139 144]
   ...
   [ 42  65  67]
   [ 56  80  99]
   [ 57  82  95]]

  ...

  [[117 111 112]
   [ 77  74  78]
   [ 93 103 120]
   ...
   [111 149 187]
   [114 148 196]
   [152 173 198]]

  [[115 114 123]
   [101  99  98]
   [ 81  83  85]
   ...
   [226 236 247]
   [111 107 115]
   [175 159 160]]

  [[127 118 118]
   [ 78  78  77]
   [ 59  51  56]
   ...
   [181 215 227]
   [236 249 253]
   [236 239 244]]]]
[[1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 ...
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]]
```

the images are converted from BGR to RGB, resized to 224*224, processed to fit in an array of the right shape. wich is then converted to a numpy array. this array then gets the same shape as the vgg16 model input by adding or removing columns.

Define your Model

With Transfer learning you take a given network model withouth the last layers, you can take the suggested VGG-16 model as decribed on the given website and add the additional layers.

NOTE: That the Ouput layer should match your input dataset!

- How is your model constructed, how many trainable parameters does it have, and where are they located?

In [5]:
```
#make vgg16 untrainable
vgg16 = VGG16(weights = "imagenet", include_top = False, input_shape = (img_size, img_si
vgg16.trainable = False

vgg16.summary()
```

```
#add vgg16 untrainable model & 3 new trainable layers
model = tf.keras.models.Sequential()
model.add(vgg16)
model.add(tf.keras.layers.Flatten())
model.add(tf.keras.layers.Dense(256, activation='relu'))
model.add(tf.keras.layers.Dense(256, activation='relu'))
model.add(tf.keras.layers.Dense(6, activation=tf.nn.softmax))

model.summary()
```

```
Model: "vgg16"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 224, 224, 3)]     0

 block1_conv1 (Conv2D)       (None, 224, 224, 64)      1792

 block1_conv2 (Conv2D)       (None, 224, 224, 64)      36928

 block1_pool (MaxPooling2D)  (None, 112, 112, 64)      0

 block2_conv1 (Conv2D)       (None, 112, 112, 128)     73856

 block2_conv2 (Conv2D)       (None, 112, 112, 128)     147584

 block2_pool (MaxPooling2D)  (None, 56, 56, 128)       0

 block3_conv1 (Conv2D)       (None, 56, 56, 256)       295168

 block3_conv2 (Conv2D)       (None, 56, 56, 256)       590080

 block3_conv3 (Conv2D)       (None, 56, 56, 256)       590080

 block3_pool (MaxPooling2D)  (None, 28, 28, 256)       0

 block4_conv1 (Conv2D)       (None, 28, 28, 512)       1180160

 block4_conv2 (Conv2D)       (None, 28, 28, 512)       2359808

 block4_conv3 (Conv2D)       (None, 28, 28, 512)       2359808

 block4_pool (MaxPooling2D)  (None, 14, 14, 512)       0

 block5_conv1 (Conv2D)       (None, 14, 14, 512)       2359808

 block5_conv2 (Conv2D)       (None, 14, 14, 512)       2359808

 block5_conv3 (Conv2D)       (None, 14, 14, 512)       2359808

 block5_pool (MaxPooling2D)  (None, 7, 7, 512)         0

=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 vgg16 (Functional)          (None, 7, 7, 512)         14714688

 flatten (Flatten)           (None, 25088)             0
```

```
 dense (Dense)               (None, 256)               6422784

 dense_1 (Dense)             (None, 256)               65792

 dense_2 (Dense)             (None, 6)                 1542

=================================================================
Total params: 21,204,806
Trainable params: 6,490,118
Non-trainable params: 14,714,688
_________________________________________________________________
```

a new model is created and the vgg16 model is added as a feature detection. after this a flattening layer, two fully connected layers and an output layer are added.

Fit the Model

Fitting the model is the time consuming part, this depend on the complexity of the model and the amount of training data. With Transfer learning a lot of pre-trained parameters are now 'frozen', this will limit training time (or enables us to train more complex networks with the same processing performance, and so achieving better results)

- Which batch size and how many epochs give a good result?

In [6]:
```
#compiling the model
#model.trainable = True
model.compile(optimizer='adam',
              loss='categorical_crossentropy',
              metrics=['accuracy'])
#
es = tf.keras.callbacks.EarlyStopping(
              monitor='val_accuracy',
              mode='max',
              patience=10,
              restore_best_weights=True)


#history = model.fit(new_X_img, new_Y_class, epochs=100)

history = model.fit(new_X_img,
              new_Y_class,
              validation_split = 0.25,
              epochs = 20,
              callbacks = es,
              batch_size = 3,
              shuffle = True)
```

```
Epoch 1/20
546/546 [==============================] - 16s 25ms/step - loss: 6.7535 - accuracy: 0.82
78 - val_loss: 78.1982 - val_accuracy: 0.1136
Epoch 2/20
546/546 [==============================] - 13s 24ms/step - loss: 2.8858 - accuracy: 0.91
94 - val_loss: 65.3611 - val_accuracy: 0.4524
Epoch 3/20
546/546 [==============================] - 13s 24ms/step - loss: 1.8256 - accuracy: 0.94
32 - val_loss: 110.5812 - val_accuracy: 0.4103
Epoch 4/20
546/546 [==============================] - 13s 24ms/step - loss: 1.7562 - accuracy: 0.96
21 - val_loss: 146.2480 - val_accuracy: 0.3974
Epoch 5/20
546/546 [==============================] - 13s 25ms/step - loss: 1.0700 - accuracy: 0.97
```

```
74 - val_loss: 153.2751 - val_accuracy: 0.4560
Epoch 6/20
546/546 [==============================] - 13s 24ms/step - loss: 0.4712 - accuracy: 0.98
84 - val_loss: 94.2703 - val_accuracy: 0.4432
Epoch 7/20
546/546 [==============================] - 13s 24ms/step - loss: 0.3046 - accuracy: 0.99
15 - val_loss: 116.5646 - val_accuracy: 0.5147
Epoch 8/20
546/546 [==============================] - 14s 25ms/step - loss: 0.4037 - accuracy: 0.99
39 - val_loss: 124.8640 - val_accuracy: 0.4725
Epoch 9/20
546/546 [==============================] - 13s 24ms/step - loss: 0.6300 - accuracy: 0.98
90 - val_loss: 120.4584 - val_accuracy: 0.4799
Epoch 10/20
546/546 [==============================] - 13s 24ms/step - loss: 0.8315 - accuracy: 0.98
60 - val_loss: 291.0923 - val_accuracy: 0.4396
Epoch 11/20
546/546 [==============================] - 13s 24ms/step - loss: 1.3838 - accuracy: 0.98
35 - val_loss: 188.1171 - val_accuracy: 0.5513
Epoch 12/20
546/546 [==============================] - 13s 24ms/step - loss: 1.7658 - accuracy: 0.98
11 - val_loss: 155.0973 - val_accuracy: 0.5275
Epoch 13/20
546/546 [==============================] - 13s 24ms/step - loss: 0.5987 - accuracy: 0.98
96 - val_loss: 275.1916 - val_accuracy: 0.5348
Epoch 14/20
546/546 [==============================] - 13s 24ms/step - loss: 0.1284 - accuracy: 0.99
76 - val_loss: 308.9723 - val_accuracy: 0.5366
Epoch 15/20
546/546 [==============================] - 13s 24ms/step - loss: 0.0173 - accuracy: 0.99
94 - val_loss: 247.0377 - val_accuracy: 0.5330
Epoch 16/20
546/546 [==============================] - 13s 24ms/step - loss: 0.0000e+00 - accuracy:
1.0000 - val_loss: 247.0377 - val_accuracy: 0.5330
Epoch 17/20
546/546 [==============================] - 13s 24ms/step - loss: 0.0000e+00 - accuracy:
1.0000 - val_loss: 247.0377 - val_accuracy: 0.5330
Epoch 18/20
546/546 [==============================] - 13s 24ms/step - loss: 0.0000e+00 - accuracy:
1.0000 - val_loss: 247.0377 - val_accuracy: 0.5330
Epoch 19/20
546/546 [==============================] - 13s 24ms/step - loss: 0.0000e+00 - accuracy:
1.0000 - val_loss: 247.0377 - val_accuracy: 0.5330
Epoch 20/20
546/546 [==============================] - 13s 24ms/step - loss: 0.0000e+00 - accuracy:
1.0000 - val_loss: 247.0377 - val_accuracy: 0.5330
```

Here the optimiser is chosen and model is trained with 20 iterations.

Evaluate Model

Show the model accuracy after the training process ...

- How accurate is your final model?

In [42]:
```
val_loss, val_acc = model.evaluate(new_X_img, new_Y_class)  # evaluate the out of sample
print(val_loss)  # model's loss (error)
print(val_acc)  # model's accuracy
```

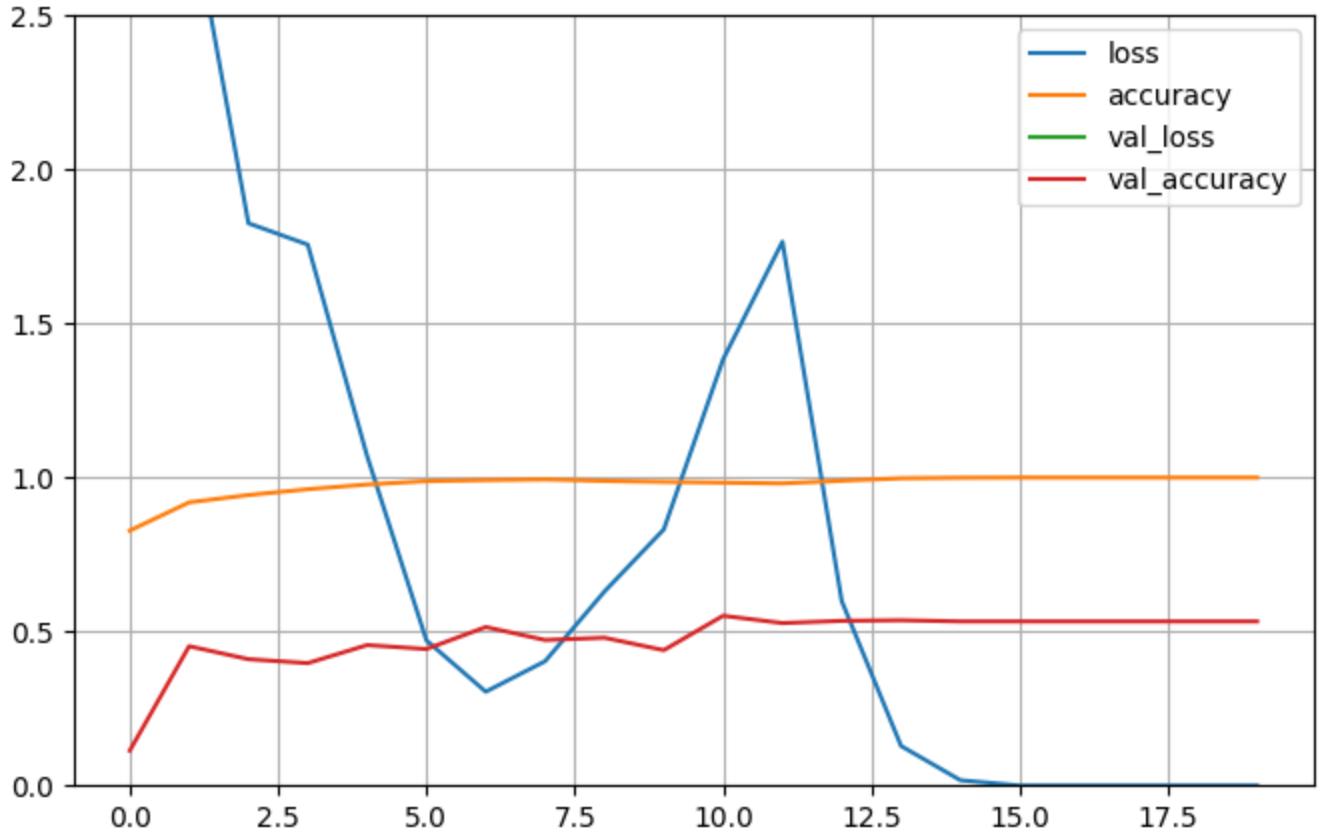
```
69/69 [==============================] - 6s 86ms/step - loss: 61.7594 - accuracy: 0.8832
61.75944900512695
0.8832417726516724
```

Here the model is tested with the given test data. The accuracy is 88.3%

learning curves

Show the learning curves of your training sequence, of accuracy, value_accuracy and loss, value_loss

In [7]:
```
pd.DataFrame(history.history).plot(figsize=(8, 5))
plt.grid(True)
plt.gca().set_ylim(0, 2.5)
plt.show()
```



the loss and accurcy during training is plotted. the graph flattens off at the end near 100%

Save model

Save the model for later usage

In [8]:
```
model.save('Ass2C')
model = tf.keras.models.load_model('Ass2C')
```

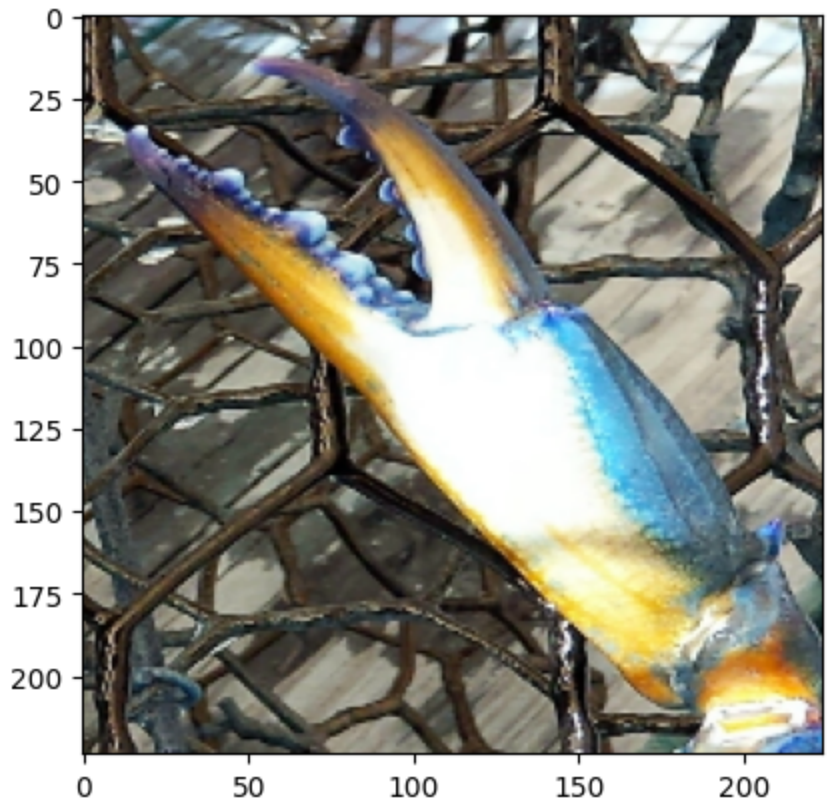
```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compile
d_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compi
led_convolution_op while saving (showing 5 of 13). These functions will not be directly
callable after loading.
INFO:tensorflow:Assets written to: Ass2C\assets
INFO:tensorflow:Assets written to: Ass2C\assets
```

Evaluate Final Model

After training and saving the model you can deploy this model on any given input image. You can start a new application in where you import this model and apply it on any given imput images, so you can just load the model and don't need the timeconsuming training anymore.

In [11]:
```
predictions = model.predict([new_X_img])

plt.imshow(new_X_img[2], cmap=plt.cm.binary)
plt.show()
print("prediction =", CATEGORIES[np.argmax(predictions[2])])
```

```
69/69 [==============================] - 6s 86ms/step
```




```
prediction = crab
```

Here we predict one image to double check the model. this image is out of the test data. The model classifies the image as crab. as seen by the image this is correct.

Make Prediction

We can use our saved model to make a prediction on new images that are not trained on... make sure the input images receive the same pre-processing as the images you trained on.

So fetch some images from the internet (similar classes, but not from your dataset), prepare them to fit your network and classify them. Do this for **10 images per class** and show the results!

- How good is the detection on you real dataset? (show some statistics)

In [16]:
```
img_size = 224
X_img = []
Y_class = []
#test_data = []

#felix
#DATADIR = "C:/Users/felix/Office 365 Fontys/AIS zooi - General/Ass2C/pictures/test"
```

```
#Yosha
#DATADIR = "C:/Users/yosha19/OneDrive - Office 365 Fontys/General/Ass2C/pictures/test"
#kasper
DATADIR = "C:/Users/mobie/OneDrive - Office 365 Fontys/General - AIS zooi/Ass2C/pictures

def create_test_data():
    for category in CATEGORIES:

        path = os.path.join(DATADIR,category)
        class_num = CATEGORIES.index(category)

        for img in tqdm(os.listdir(path)):
            try:
                img_arrayBGR = cv2.imread(os.path.join(path,img))  # convert to array
                preprocessed_array = cv2.resize(img_arrayBGR, (img_size, img_size))  # r
                preprocessed_array = np.expand_dims(preprocessed_array, axis=0)
                X_img.append(preprocessed_array)  # add img to array
                Y_class.append(class_num)      # add class to array
            except Exception as e:  # in the interest in keeping the output clean...
                print("Resizing not possible")
                plt.imshow(img_arrayBGR[...,::-1])
                plt.show()

create_test_data()

#array to numpy array
X_img = np.asarray(X_img)
Y_class = np.asarray(Y_class)

#print(X_img, Y_class)
print("IMG shape = ",X_img.shape)
print("Class shape=",Y_class.shape)

#delete 1 object from array
new_X_img = X_img[:,0,:,:]

# create a new array with 360 rows and 6 columns, filled with zeros
new_Y_class = np.zeros((60, 6))
# copy the values from Y_class into new_Y_class
for i in range(len(Y_class)):
    new_Y_class[i, Y_class[i]] = 1


print("IMG shape = ",new_X_img.shape)
print("Class shape=",new_Y_class.shape)
print(new_X_img)
print(new_Y_class)
```

```
100%|██████████| 10/10 [00:00<00:00, 137.36it/s]
100%|██████████| 10/10 [00:00<00:00, 89.50it/s]
100%|██████████| 10/10 [00:00<00:00, 100.27it/s]
100%|██████████| 10/10 [00:00<00:00, 139.21it/s]
100%|██████████| 10/10 [00:00<00:00, 104.45it/s]
100%|██████████| 10/10 [00:00<00:00, 213.35it/s]
IMG shape =  (60, 1, 224, 224, 3)
Class shape= (60,)
IMG shape =  (60, 224, 224, 3)
Class shape= (60, 6)
[[[[171 175 176]
   [171 175 176]
   [171 175 176]
   ...
   [210 212 212]
   [210 212 212]
   [210 212 212]]
```

```
 [[171 175 176]
  [171 175 176]
  [171 176 177]
  ...
  [210 212 212]
  [210 212 212]
  [210 212 212]]

 [[172 176 177]
  [172 176 177]
  [172 176 177]
  ...
  [211 213 213]
  [211 213 213]
  [211 213 213]]

 ...

 [[149 141  87]
  [114 108  51]
  [ 88  87  26]
  ...
  [224 226 226]
  [224 226 226]
  [224 226 226]]

 [[157 146  94]
  [144 138  82]
  [131 131  71]
  ...
  [224 226 226]
  [224 226 226]
  [224 226 226]]

 [[189 178 126]
  [206 200 144]
  [198 199 139]
  ...
  [224 226 226]
  [224 226 226]
  [224 226 226]]]


[[[131 160 166]
  [ 72 103 112]
  [ 71 106 121]
  ...
  [146 158 155]
  [146 167 164]
  [181 203 201]]

 [[131 160 165]
  [ 73 104 113]
  [ 74 109 124]
  ...
  [148 161 159]
  [148 168 167]
  [178 199 199]]

 [[130 159 164]
  [ 76 106 115]
  [ 80 115 129]
  ...
  [152 164 163]
  [151 172 172]
```

```
  [173 195 196]]

 ...

 [[  4   6   7]
  [ 73  78  79]
  [158 163 164]
  ...
  [111 129 136]
  [116 132 137]
  [101 118 121]]

 [[  3   6   6]
  [ 69  73  74]
  [160 165 166]
  ...
  [111 129 136]
  [118 135 138]
  [104 121 124]]

 [[  3   5   6]
  [ 66  70  72]
  [161 166 167]
  ...
  [110 128 135]
  [116 132 136]
  [102 119 122]]]


[[[ 87 147 134]
  [ 86 149 154]
  [100 139 174]
  ...
  [152 188 190]
  [117 182 181]
  [144 194 192]]

 [[ 75 121 113]
  [ 71 114 117]
  [ 78 104 125]
  ...
  [115 192 178]
  [ 99 183 167]
  [138 180 182]]

 [[ 62  60  61]
  [ 83  68  75]
  [ 78  59  73]
  ...
  [ 83 183 158]
  [ 76 175 147]
  [152 195 195]]

 ...

 [[ 72  65  70]
  [ 76  81  86]
  [109 124 129]
  ...
  [ 95 122 137]
  [123 156 170]
  [125 175 179]]

 [[118 117 121]
  [115 127 131]
  [133 155 159]
```

```
  ...
  [128 187 188]
  [145 205 205]
  [112 197 186]]

 [[133 138 141]
  [119 139 141]
  [ 99 128 131]
  ...
  [133 218 204]
  [114 202 187]
  [ 76 168 148]]]


...


[[[ 85  96 100]
  [123 135 140]
  [ 61  73  79]
  ...
  [158 224 191]
  [134 192 164]
  [122 171 152]]

 [[ 96 108 110]
  [ 97 108 112]
  [ 43  55  61]
  ...
  [130 199 168]
  [129 191 165]
  [ 78 130 111]]

 [[140 150 150]
  [ 96 108 110]
  [ 96 108 111]
  ...
  [122 191 165]
  [114 175 154]
  [102 154 137]]

 ...

 [[ 24 102  95]
  [113 188 184]
  [ 51 125 123]
  ...
  [ 29 106  84]
  [ 50 129 106]
  [ 43 126 102]]

 [[ 34 126 117]
  [ 35 128 121]
  [ 55 121 119]
  ...
  [  5  77  55]
  [ 31 110  86]
  [ 13  96  74]]

 [[ 28 118 109]
  [ 10  97  88]
  [ 55 101 102]
  ...
  [ 27 100  78]
  [ 10  83  61]
  [ 30 113  94]]]
```

```
[[[ 81  99 107]
  [ 92 110 117]
  [ 94 112 119]
  ...
  [ 64  59  56]
  [ 64  59  56]
  [ 64  59  56]]

 [[ 82 100 107]
  [ 92 110 117]
  [ 95 113 119]
  ...
  [ 65  60  57]
  [ 65  60  57]
  [ 65  60  57]]

 [[ 82 100 107]
  [ 92 110 117]
  [ 95 113 120]
  ...
  [ 65  60  57]
  [ 65  60  57]
  [ 65  60  57]]

 ...

 [[123 166 217]
  [123 166 217]
  [124 167 218]
  ...
  [165 195 212]
  [187 212 229]
  [188 209 226]]

 [[125 168 219]
  [125 168 219]
  [126 169 220]
  ...
  [175 204 220]
  [188 212 228]
  [200 220 237]]

 [[126 169 220]
  [126 169 220]
  [127 170 221]
  ...
  [186 217 232]
  [182 207 223]
  [199 220 237]]]


[[[ 12  14  22]
  [ 12  14  22]
  [ 12  13  23]
  ...
  [ 27  41  39]
  [ 25  39  37]
  [ 23  36  33]]

 [[ 12  14  22]
  [ 12  14  22]
  [ 12  13  23]
  ...
  [ 15  28  26]
```

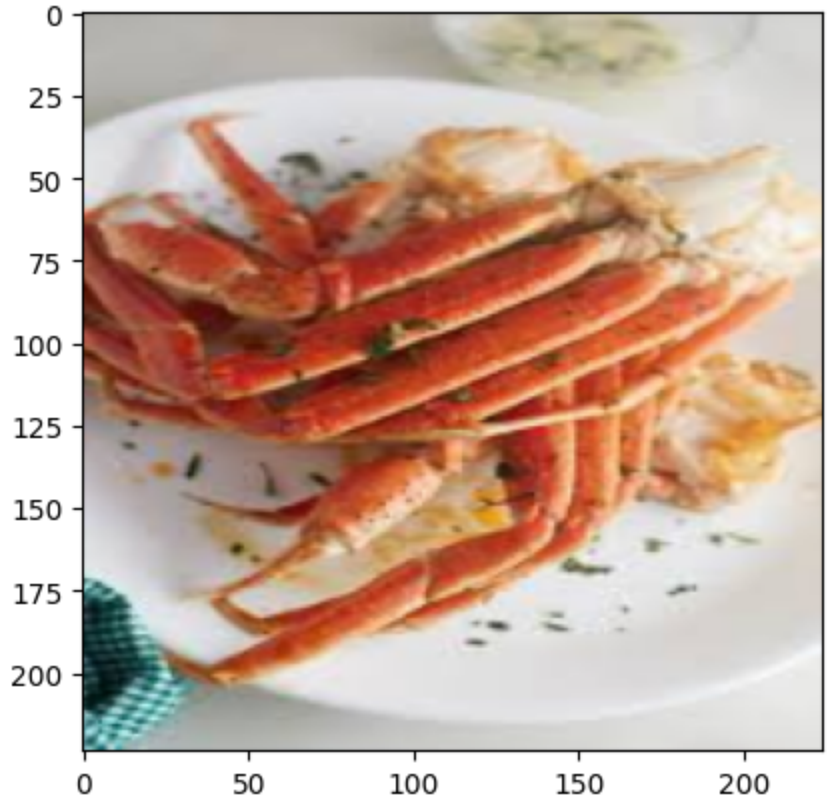
```
    [ 17  31  29]
    [ 18  30  29]]

   [[ 12  14  22]
    [ 12  14  22]
    [ 12  13  23]
    ...
    [ 14  28  26]
    [ 17  29  28]
    [ 16  29  27]]

   ...

   [[ 15  22  31]
    [ 20  27  36]
    [ 24  31  40]
    ...
    [ 88  87  91]
    [ 86  85  89]
    [ 89  88  92]]

   [[ 13  19  30]
    [ 16  22  33]
    [ 19  24  35]
    ...
    [ 88  87  91]
    [ 94  93  96]
    [ 94  93  97]]

   [[ 15  19  30]
    [ 16  20  31]
    [ 19  25  36]
    ...
    [ 93  92  96]
    [ 93  92  96]
    [ 96  96  99]]]]
[[1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0.]
```

```
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1.]]
```

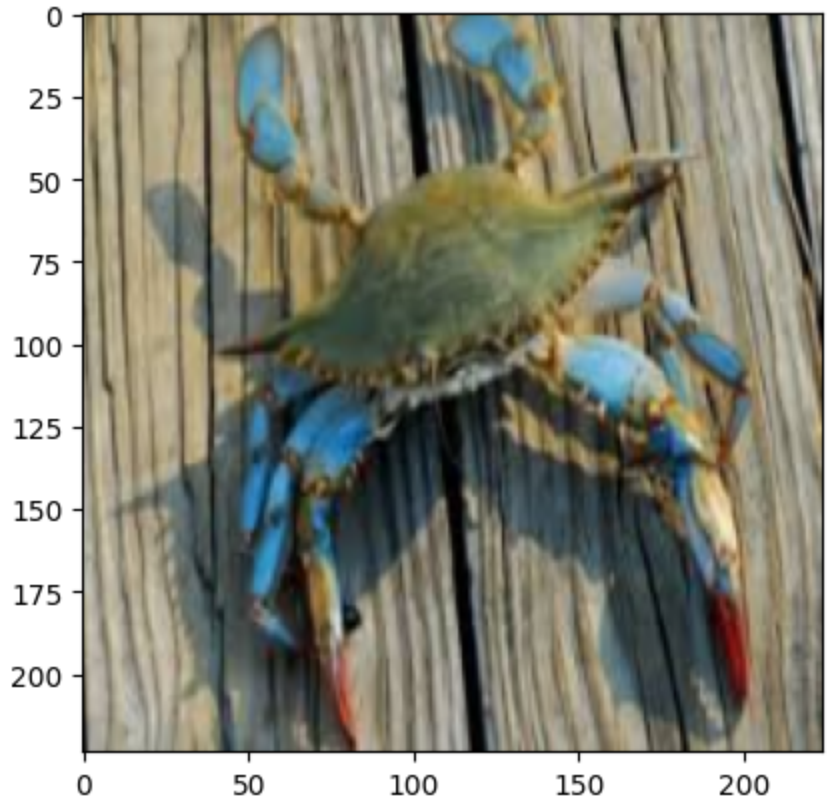
Here we import our own test data set. A for loop iterates trough all images and resizes them and adds them to an array.

In [33]:
```
g=0
f=0

for x, y in zip(X_img, Y_class):
    print(y)
    #print(x.shape)
    #x = np.expand_dims(x, axis=0)
    print(x.shape)

    predictions = model.predict([x])
    x = x[0,:,:,:]
    plt.imshow(x [...,::-1])
    plt.show()

    print("predict =", CATEGORIES[np.argmax(predictions)])
    if (y==np.argmax(predictions)):
        g = g+1
        print("goed")
    else:
        f = f+1
        print("fout")

acc = g/(g+f)
tot = g + f
print("totaal =", tot)
print("acc =", acc*100,"%")
```

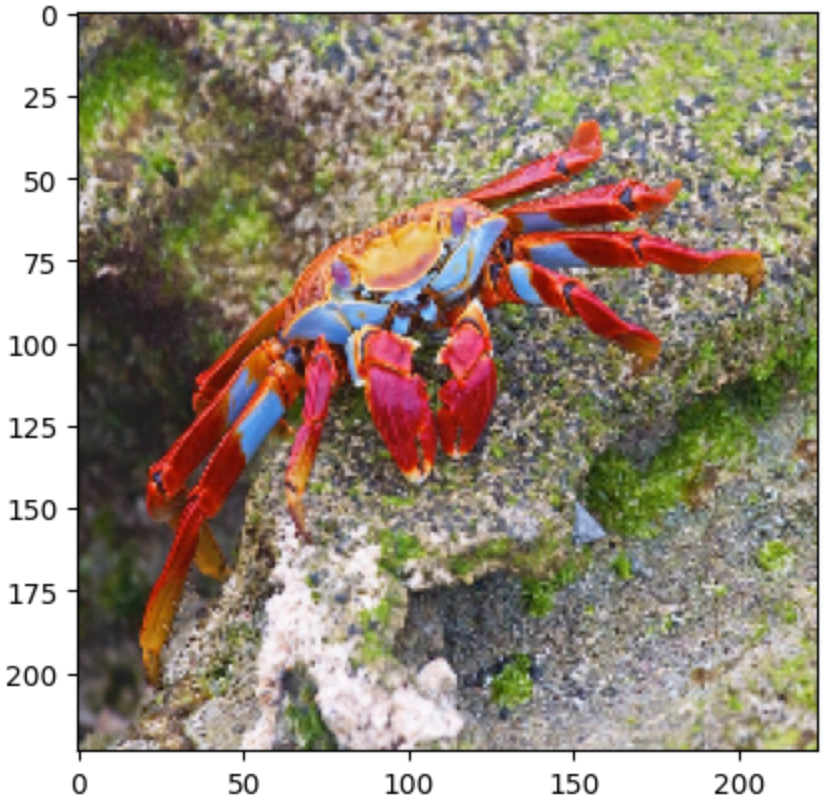
```
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```



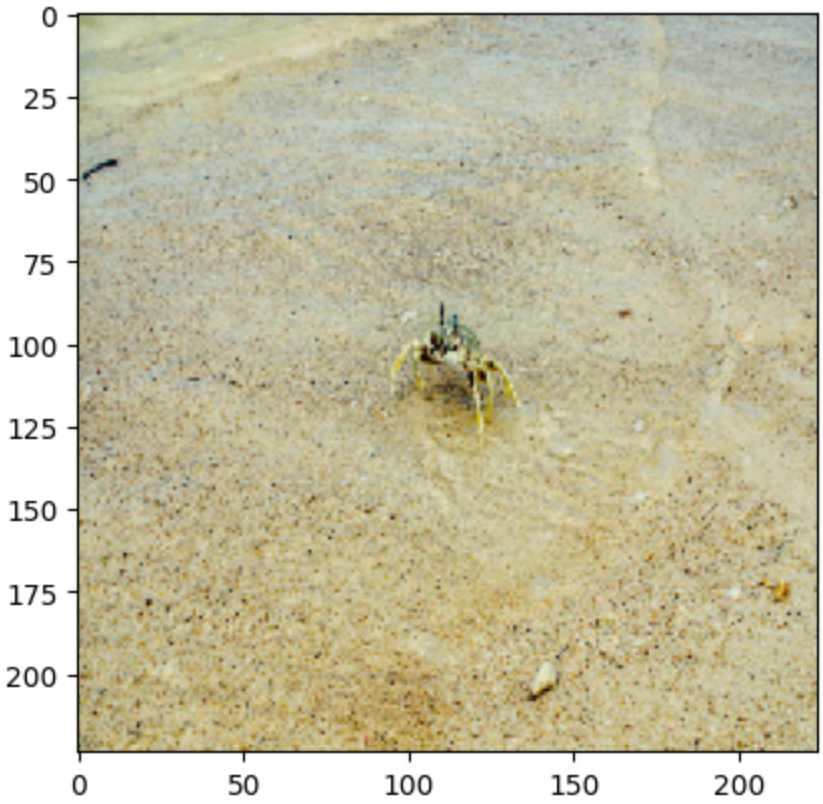

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



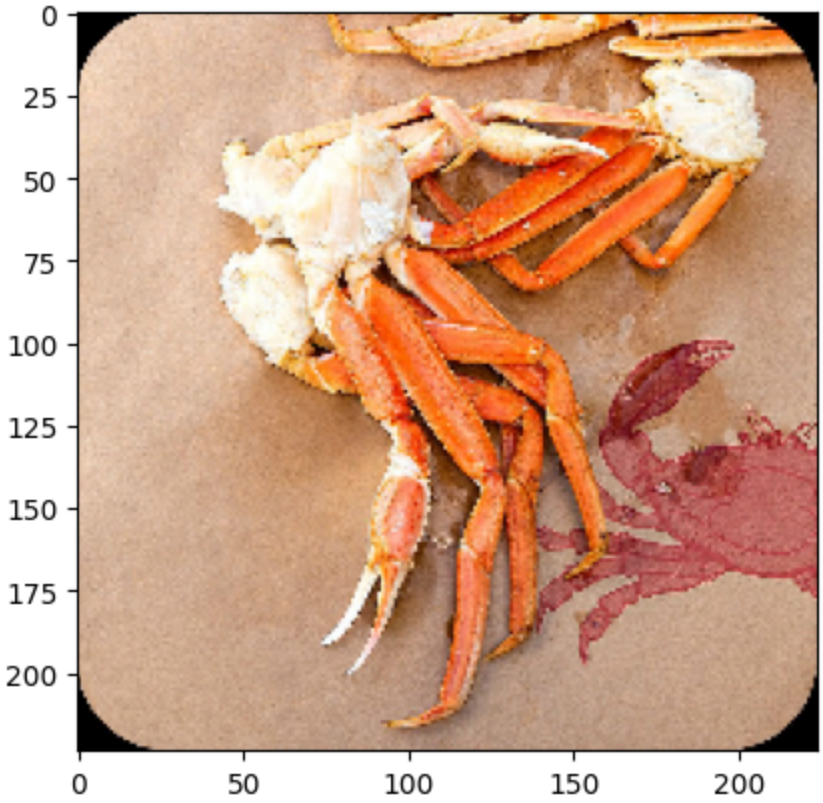

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



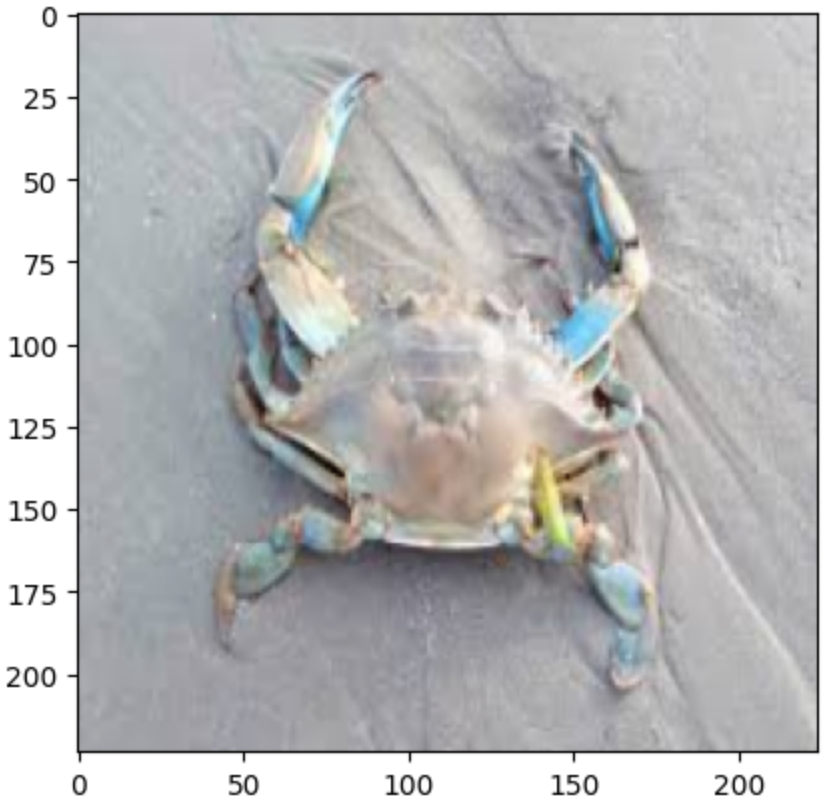

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



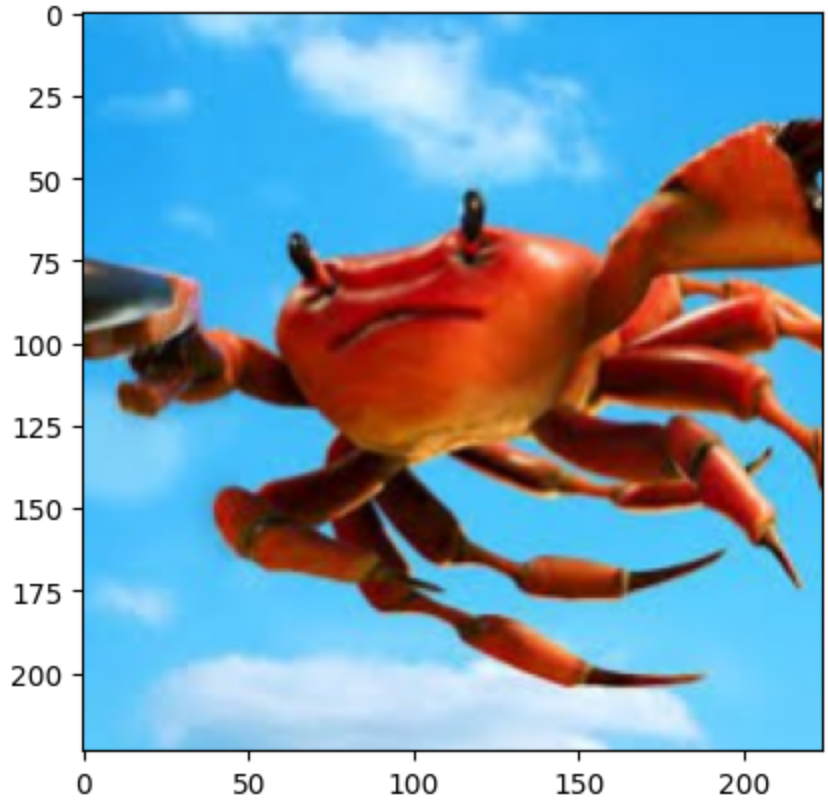

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



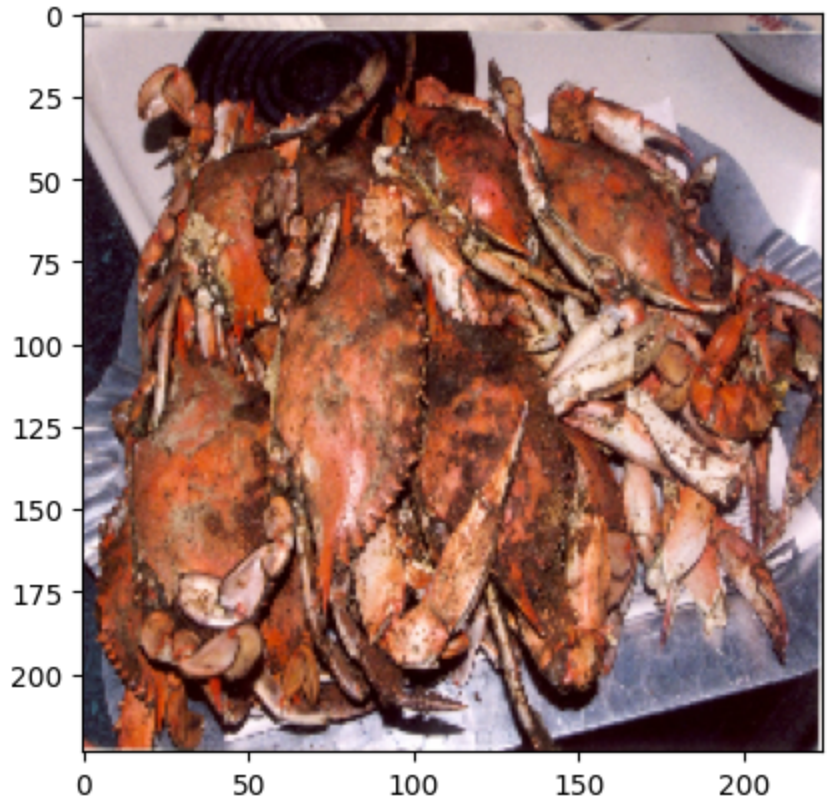

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



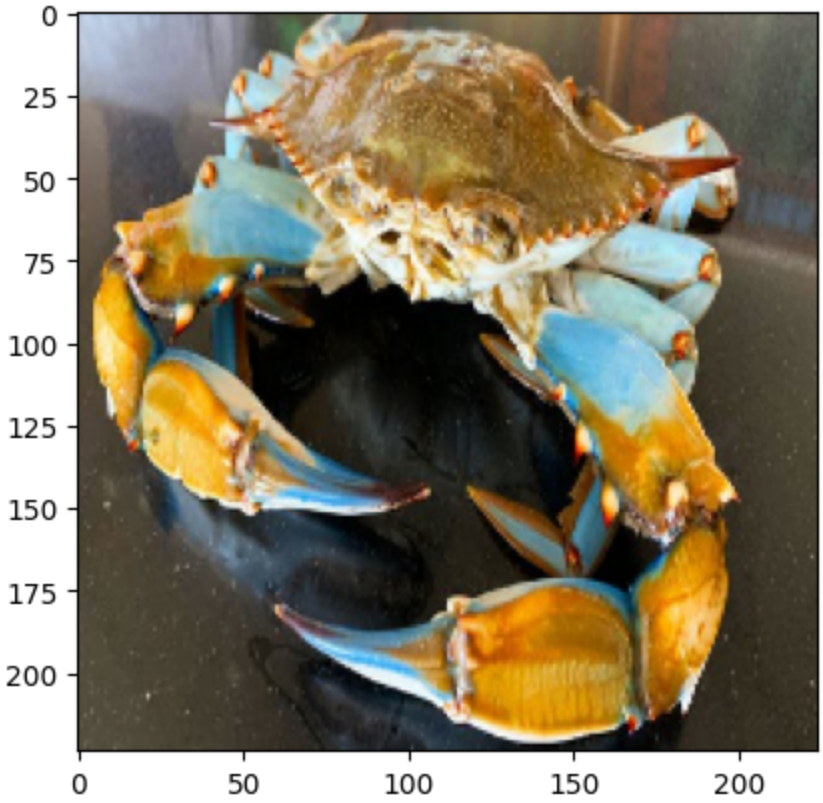

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



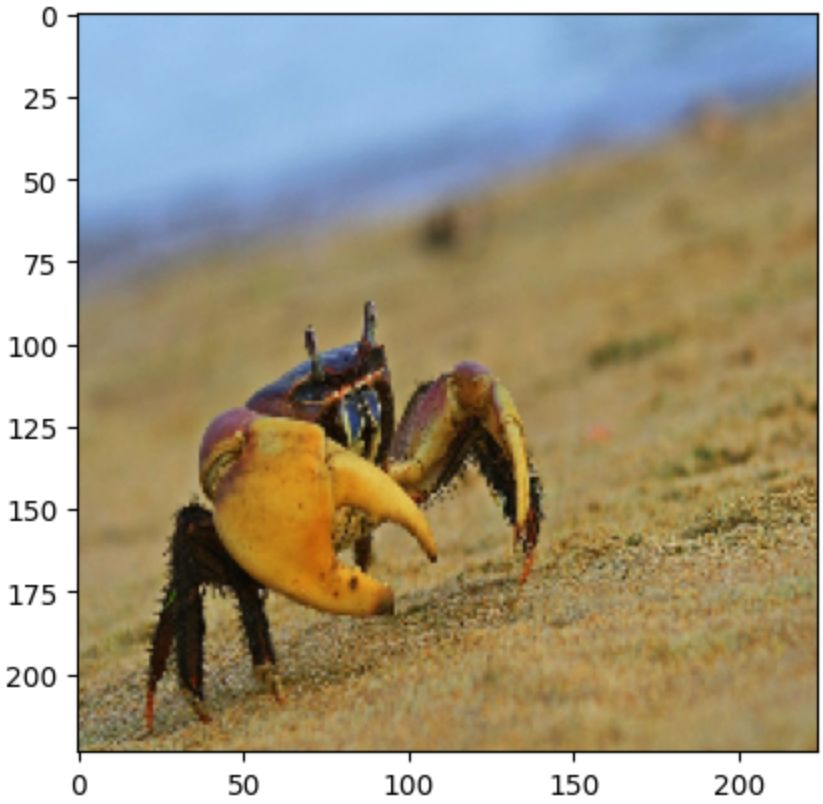

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



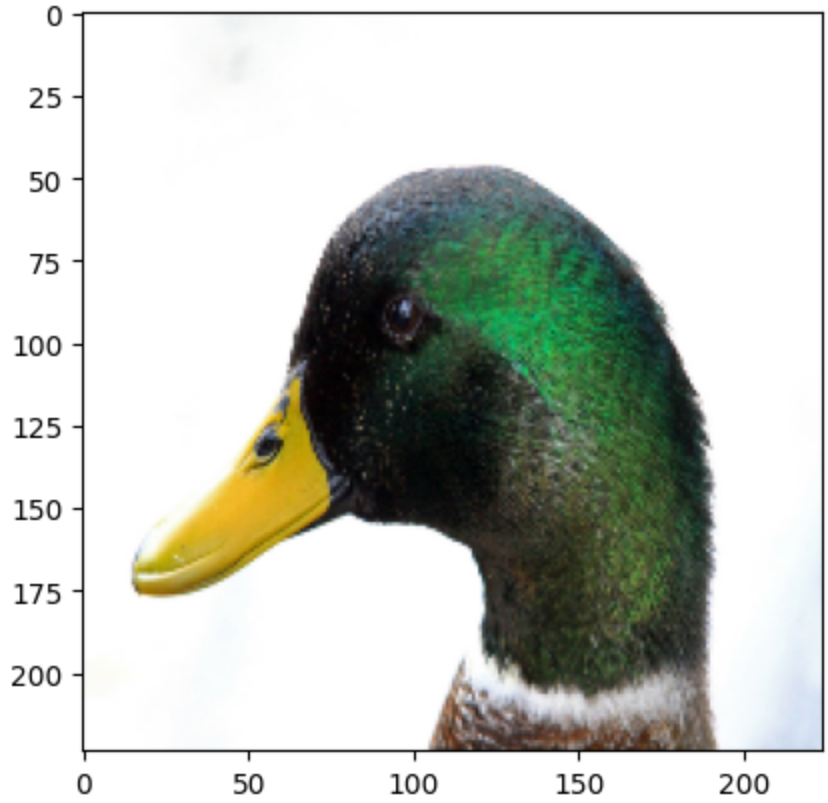

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



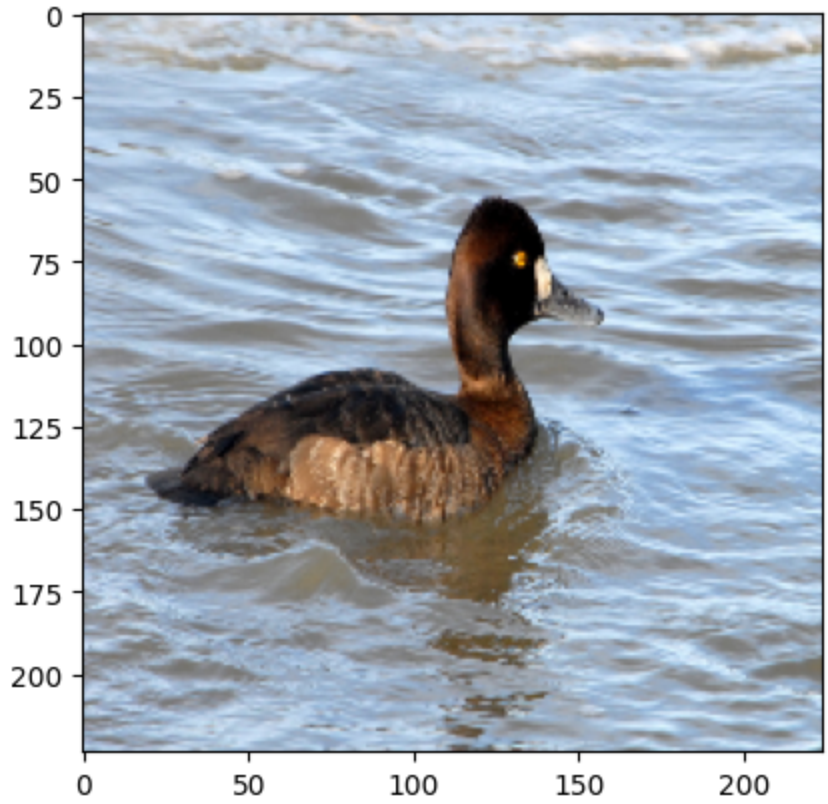

```
predict = crab
goed
0
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



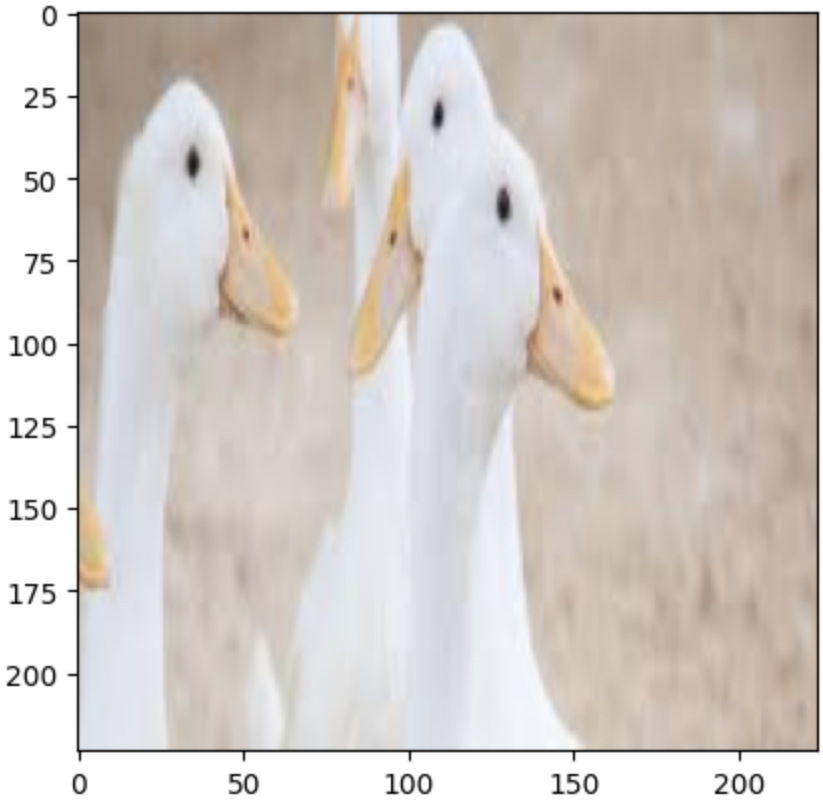

```
predict = crab
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



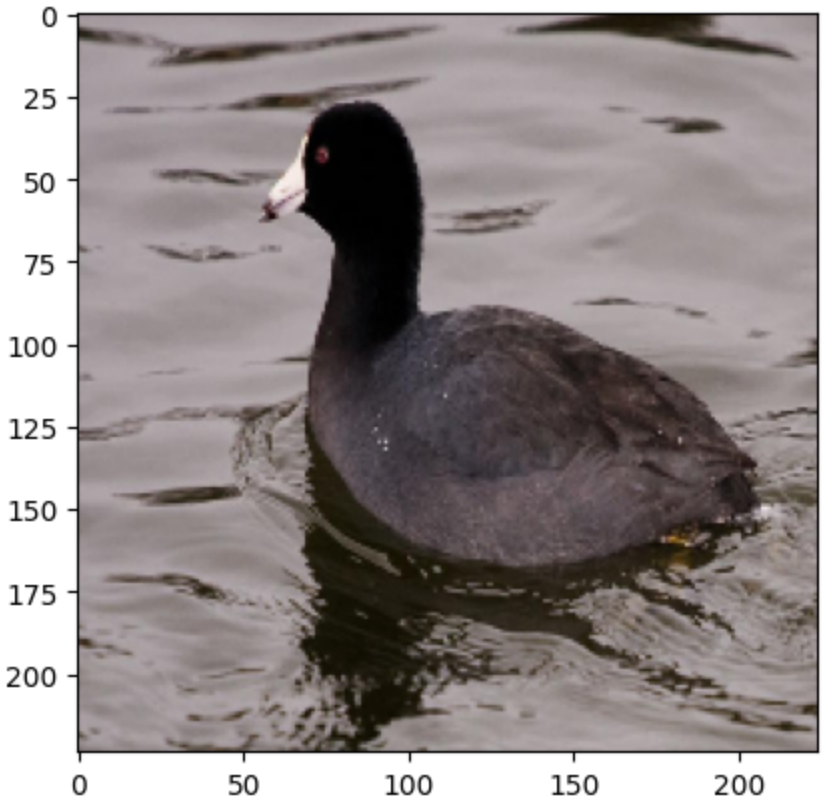

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



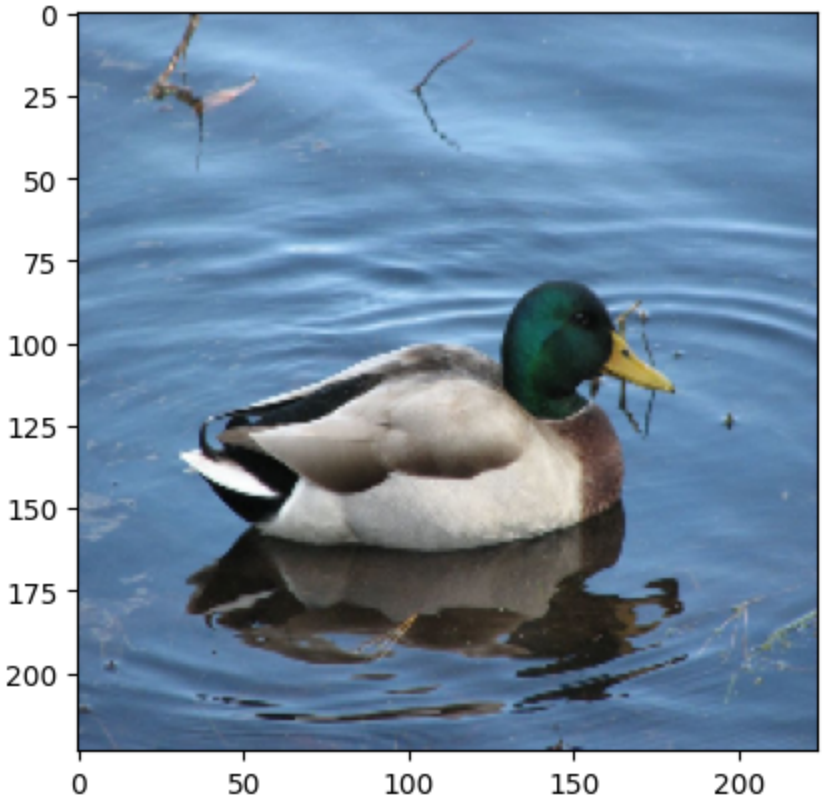

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 21ms/step
```



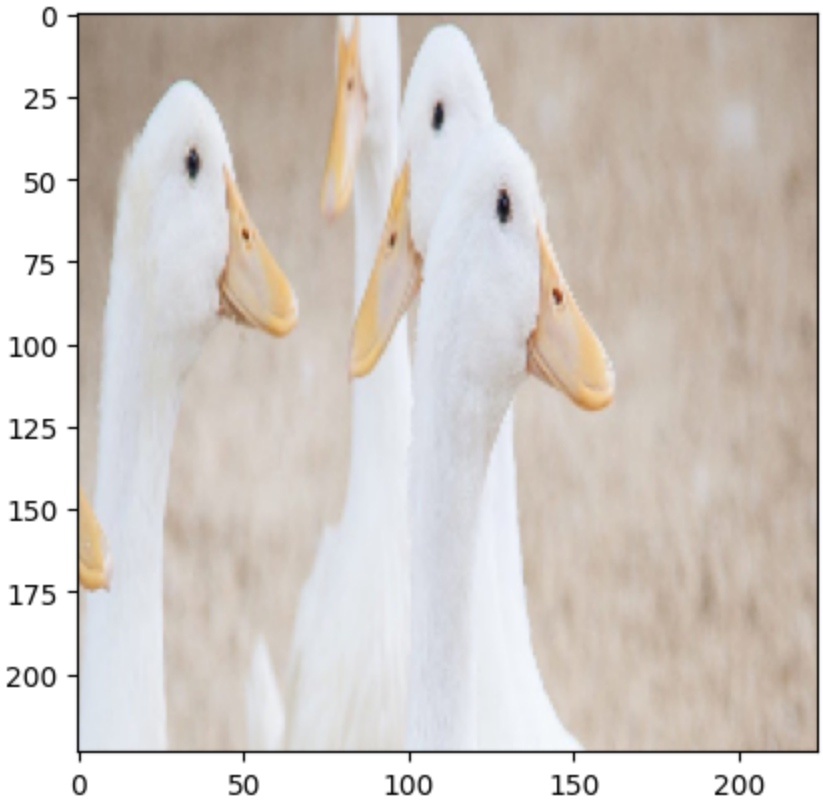

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 26ms/step
```



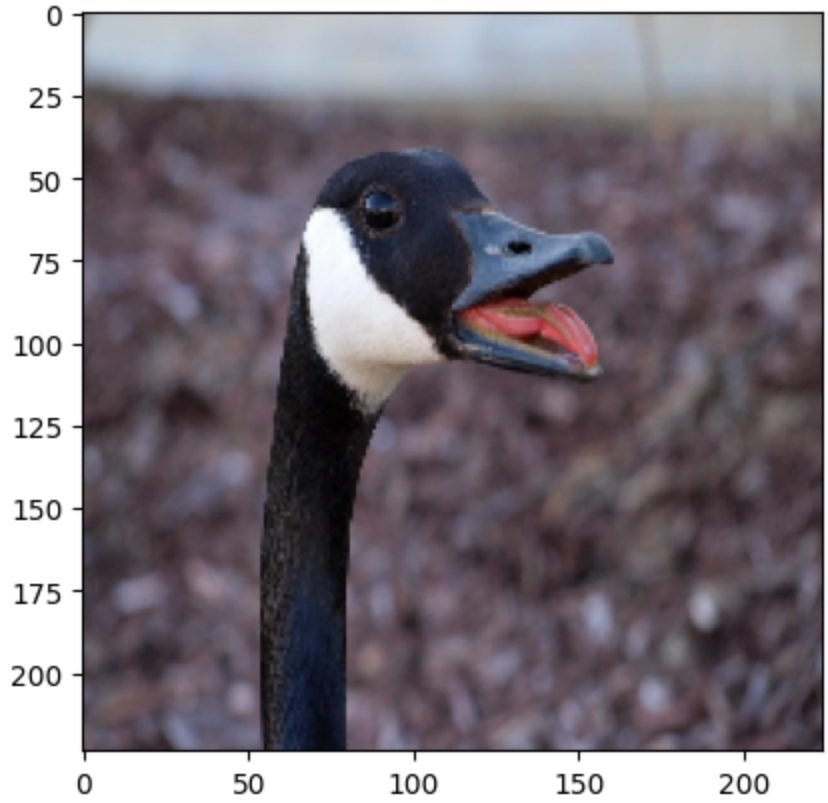

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 27ms/step
```



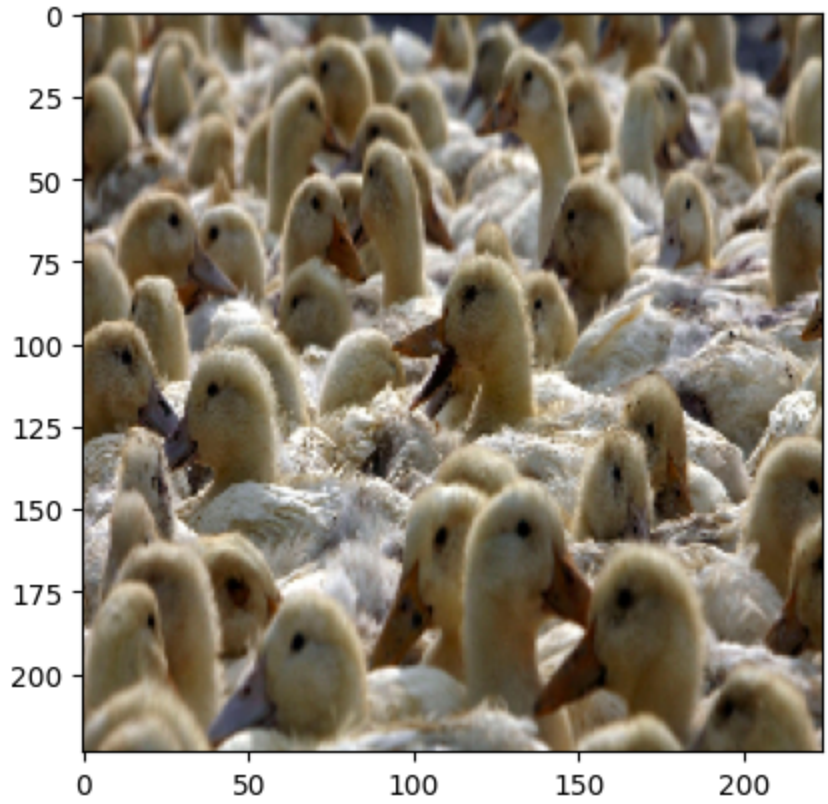

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 26ms/step
```



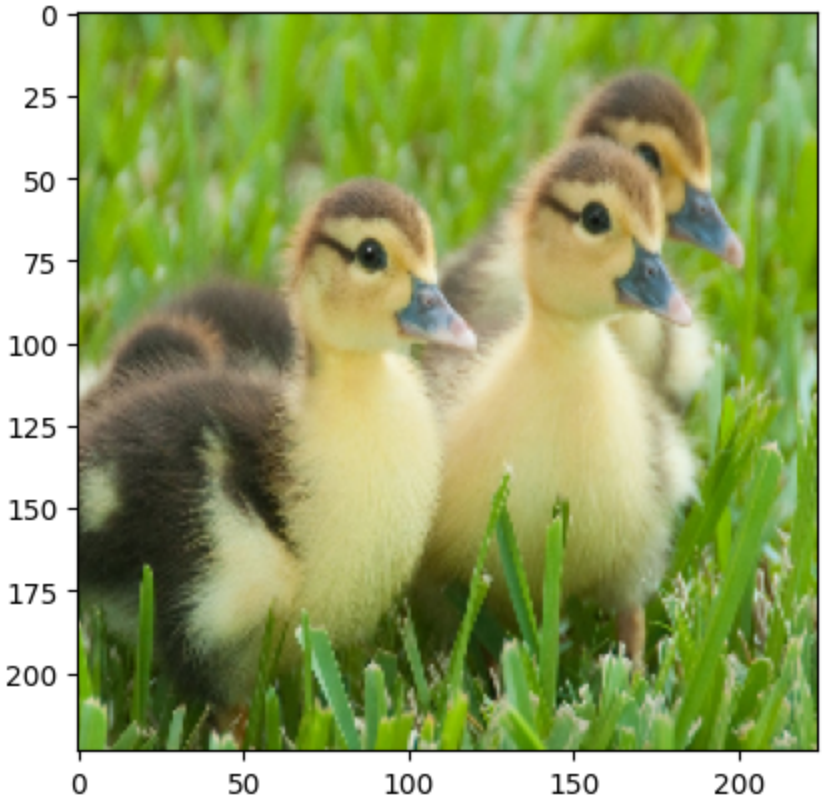

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 26ms/step
```



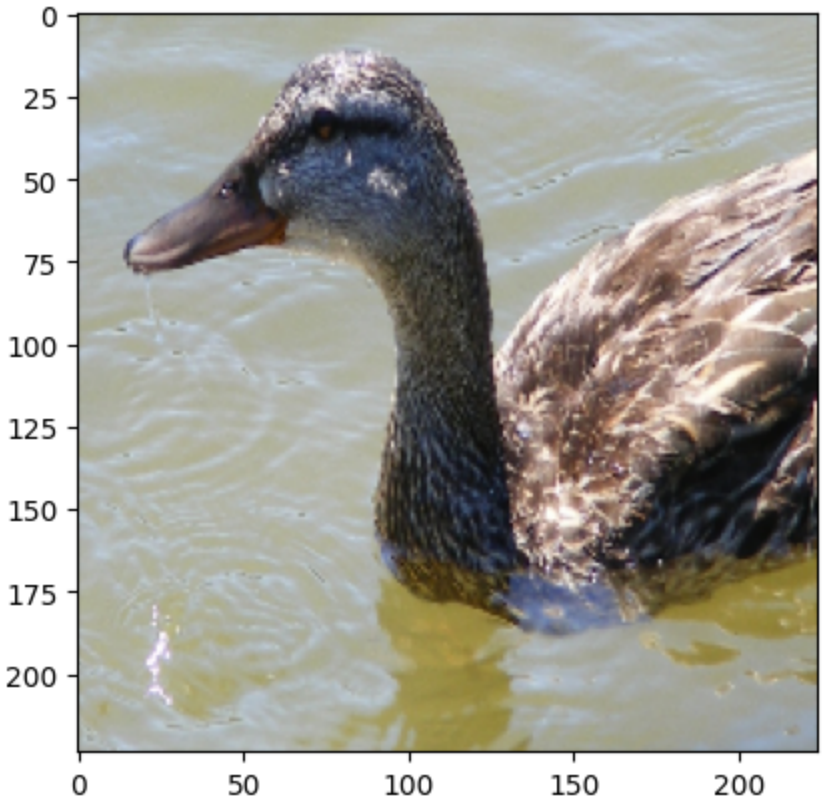

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 29ms/step
```



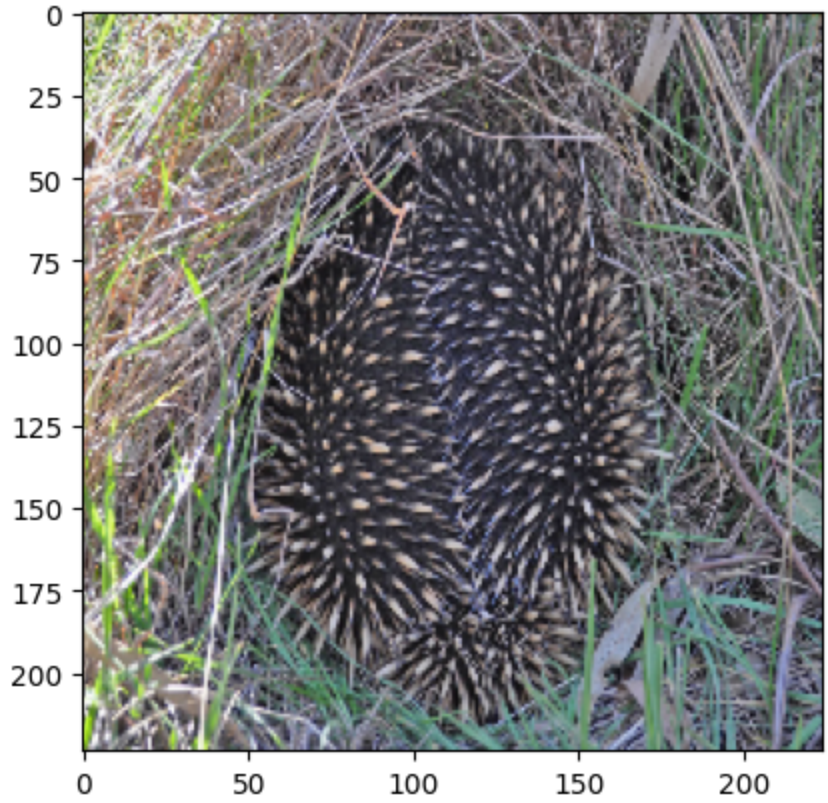

```
predict = duck
goed
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



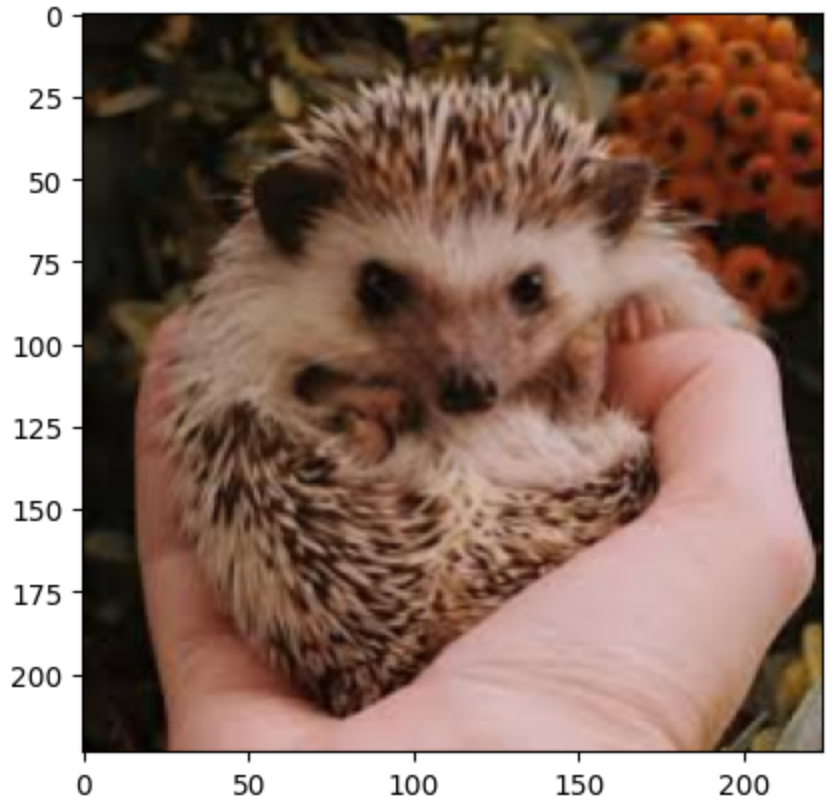

```
predict = panda
fout
1
(1, 224, 224, 3)
1/1 [==============================] - 0s 26ms/step
```



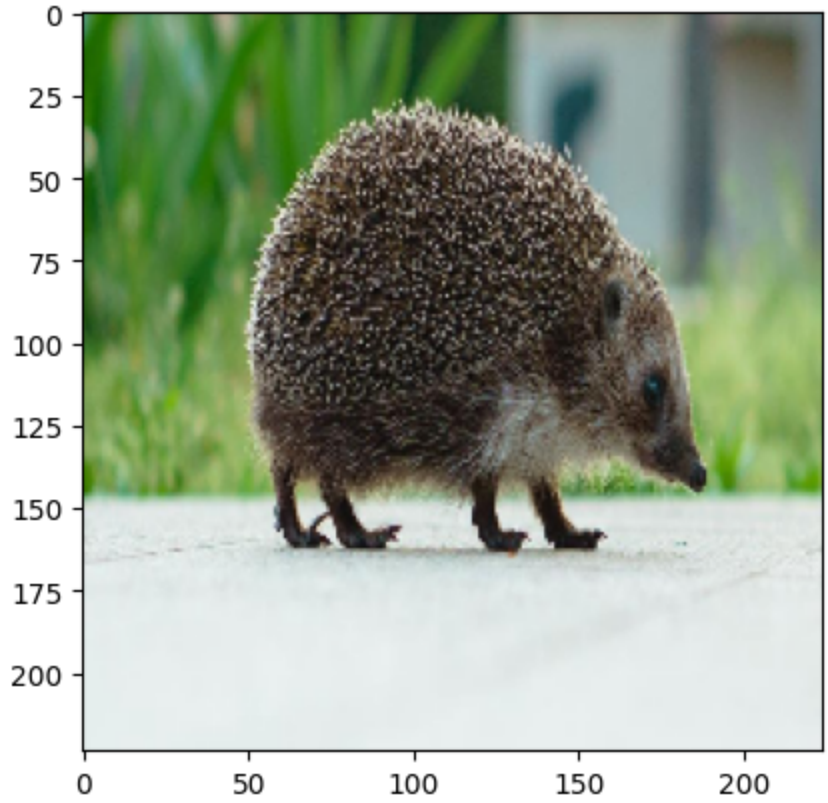

```
predict = duck
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 26ms/step
```



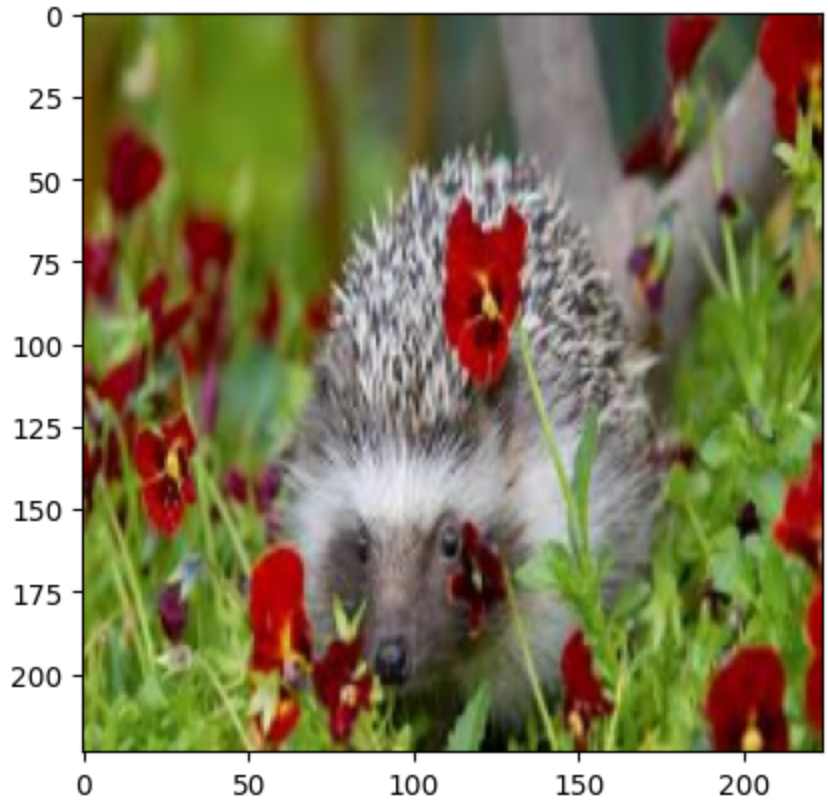

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



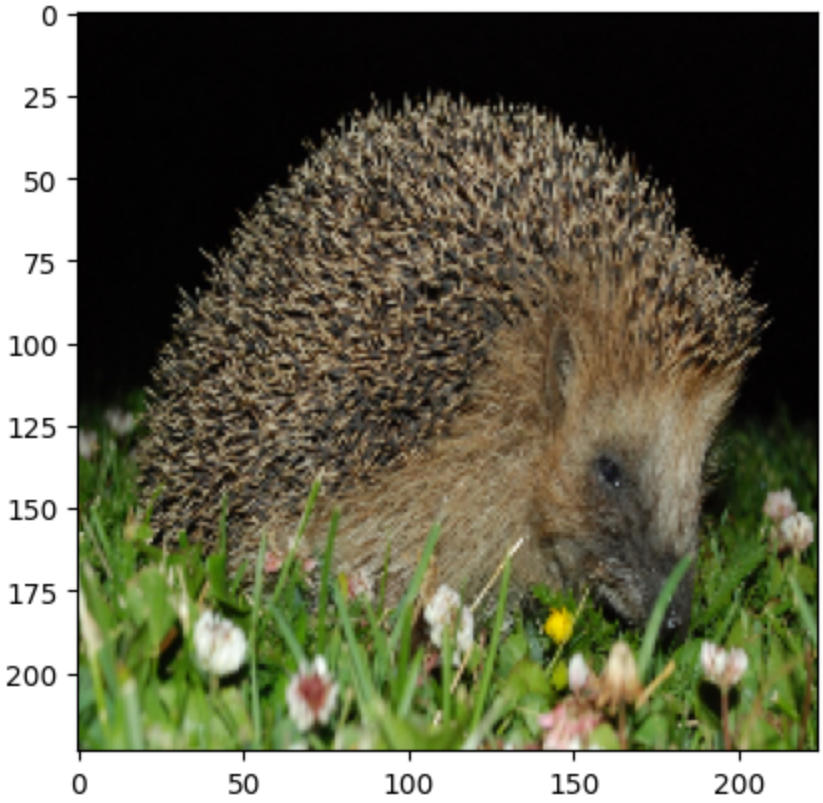

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



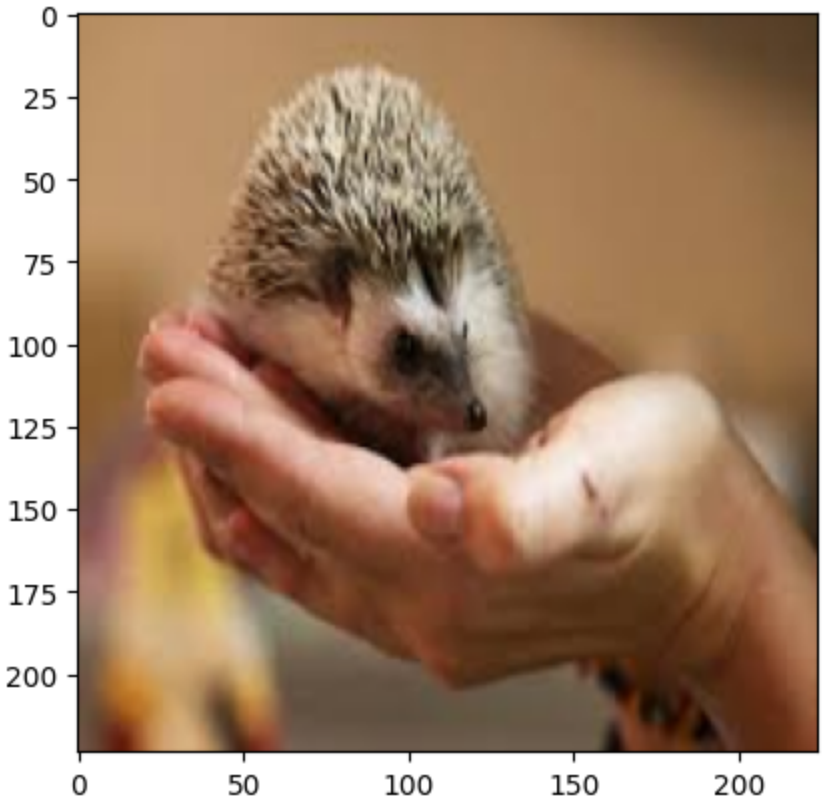

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```



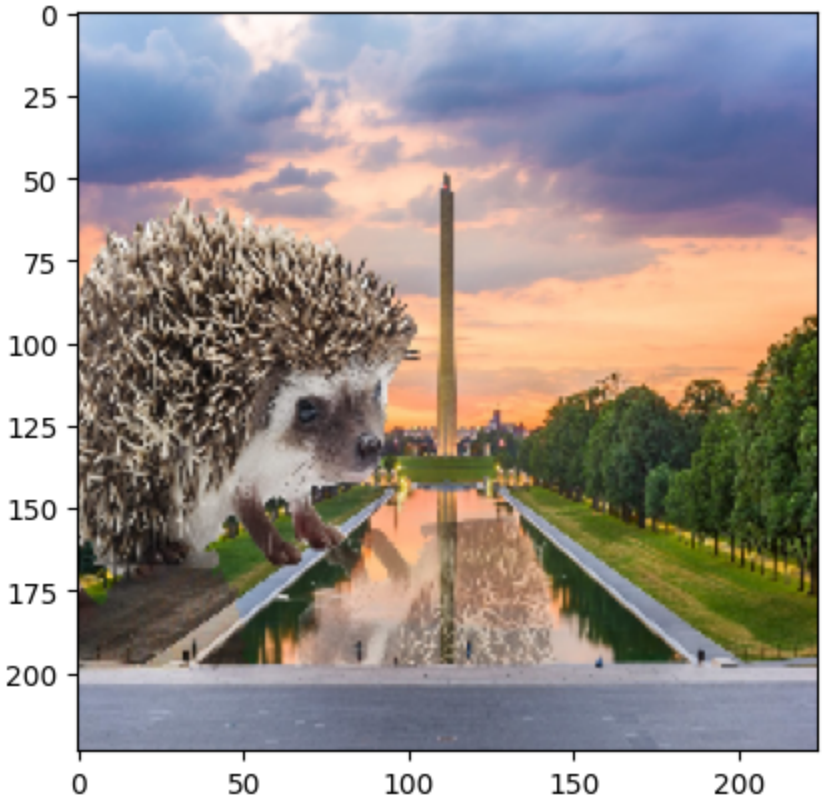

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



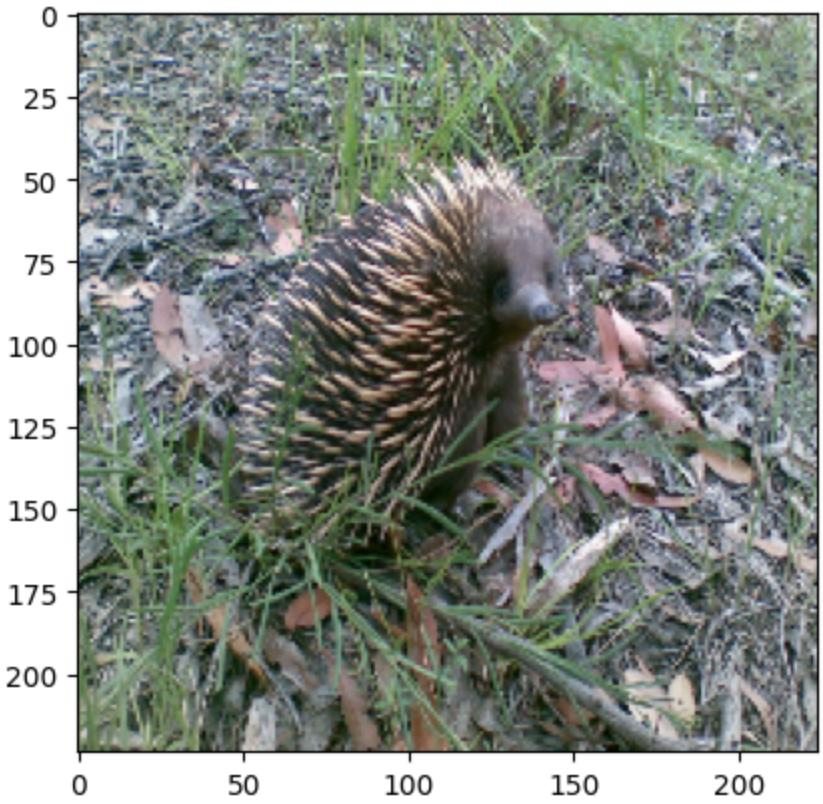

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



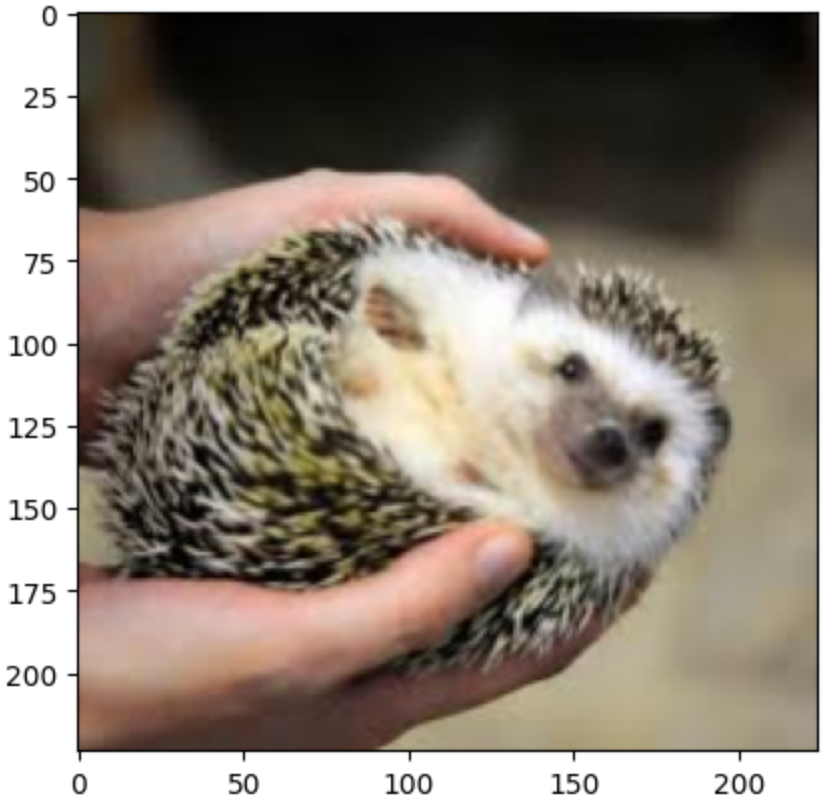

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 29ms/step
```



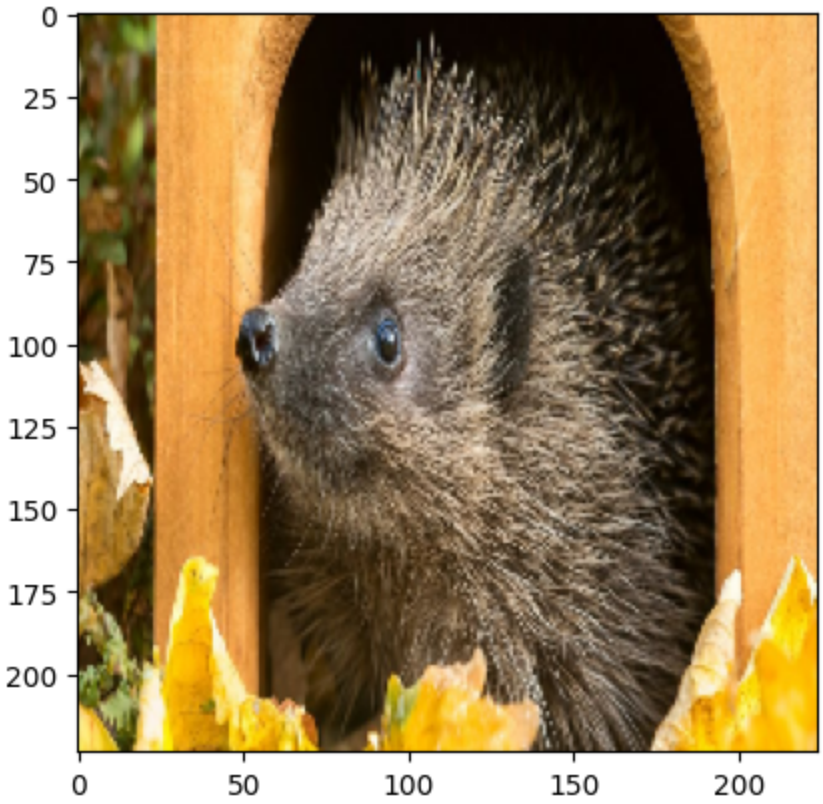

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```



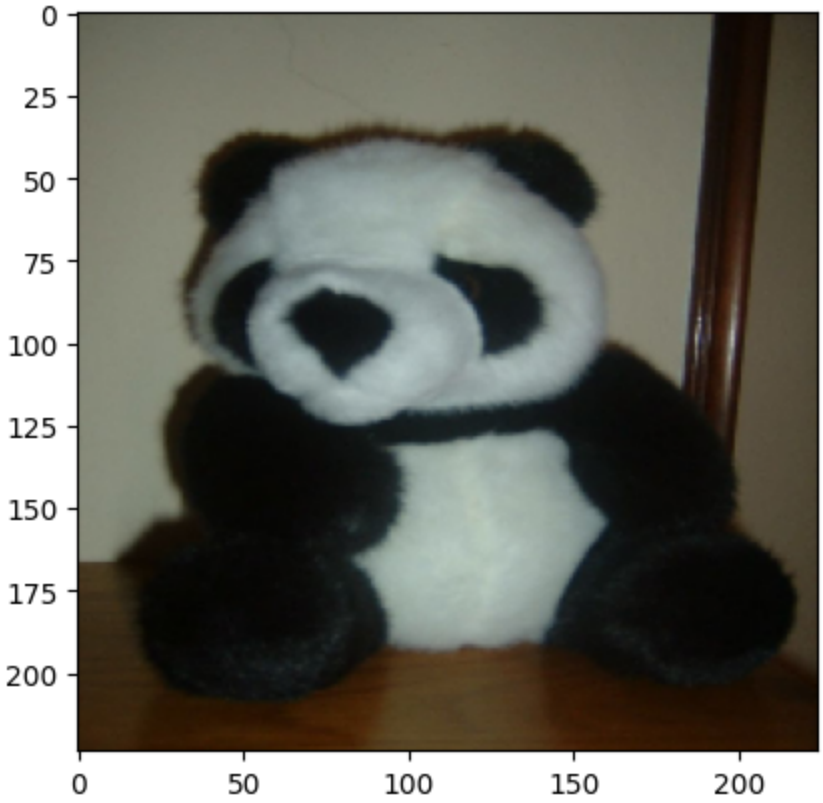

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



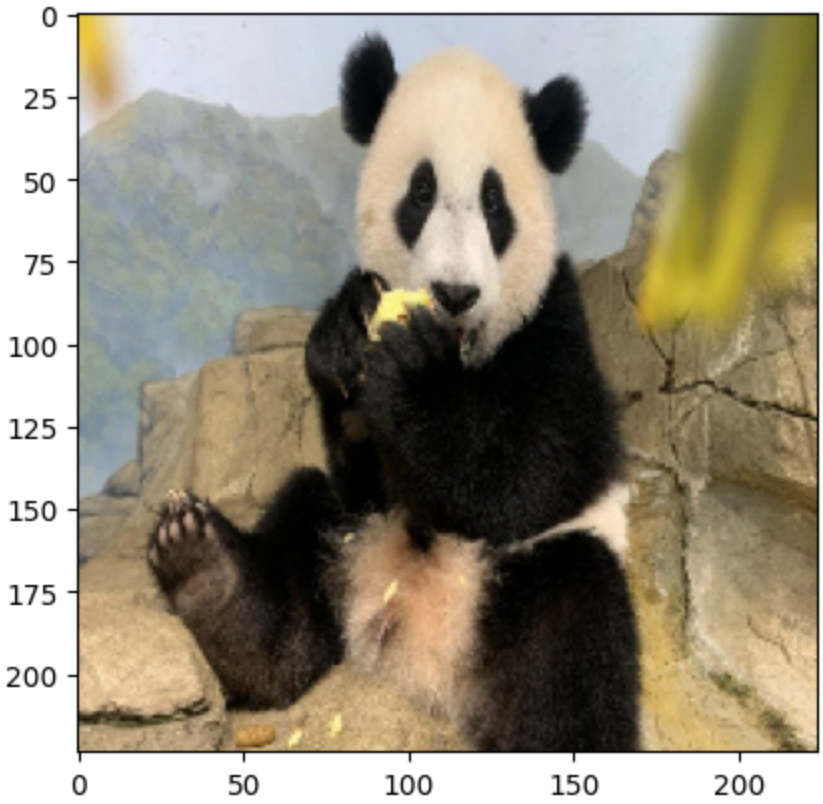

```
predict = hedgehog
goed
2
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



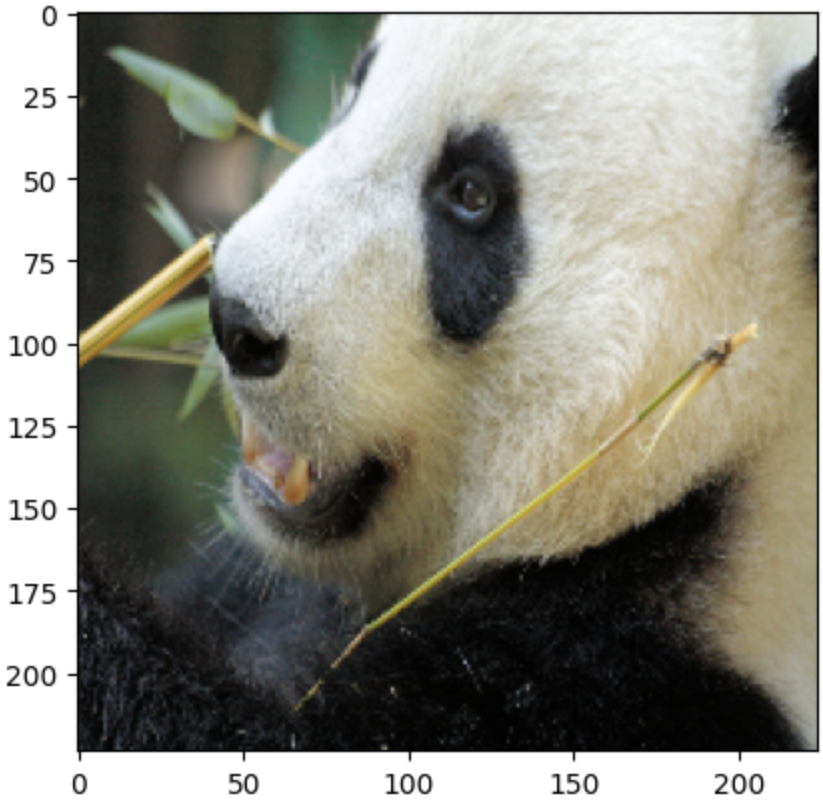

```
predict = hedgehog
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



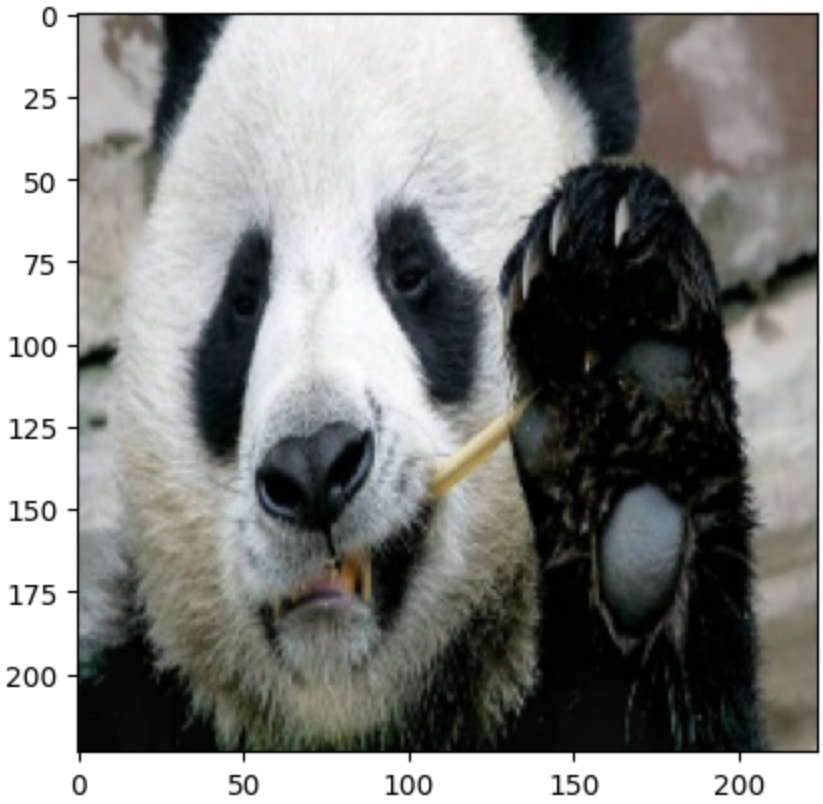

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



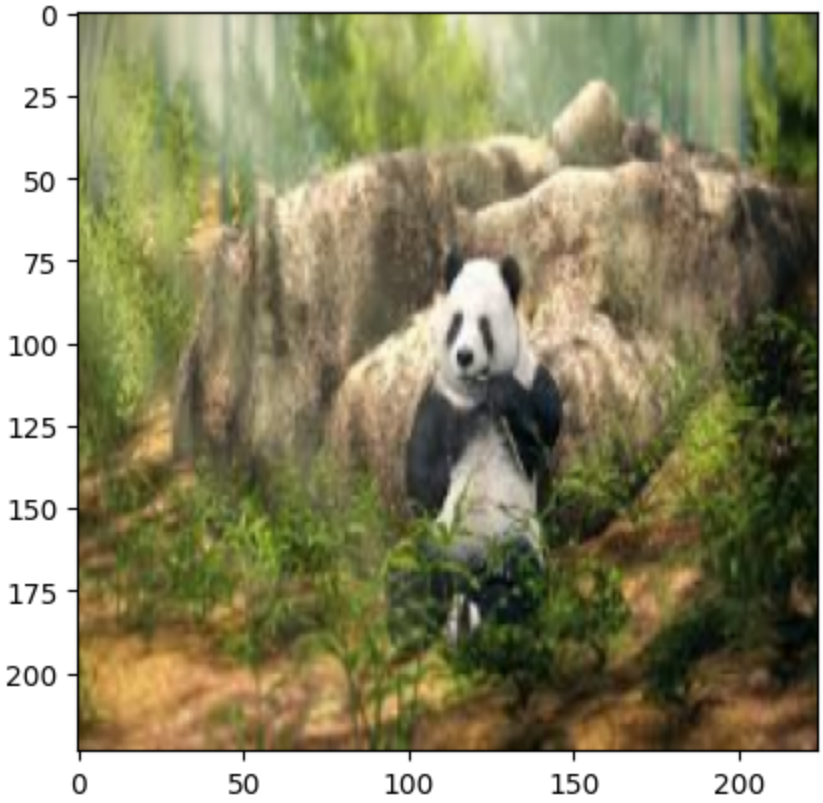

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



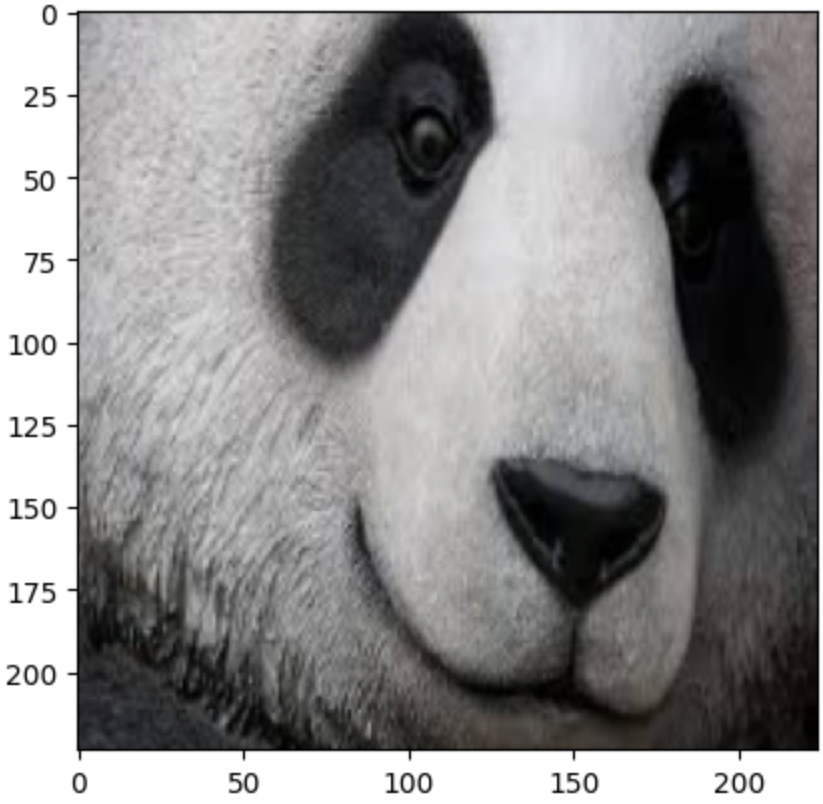

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 21ms/step
```



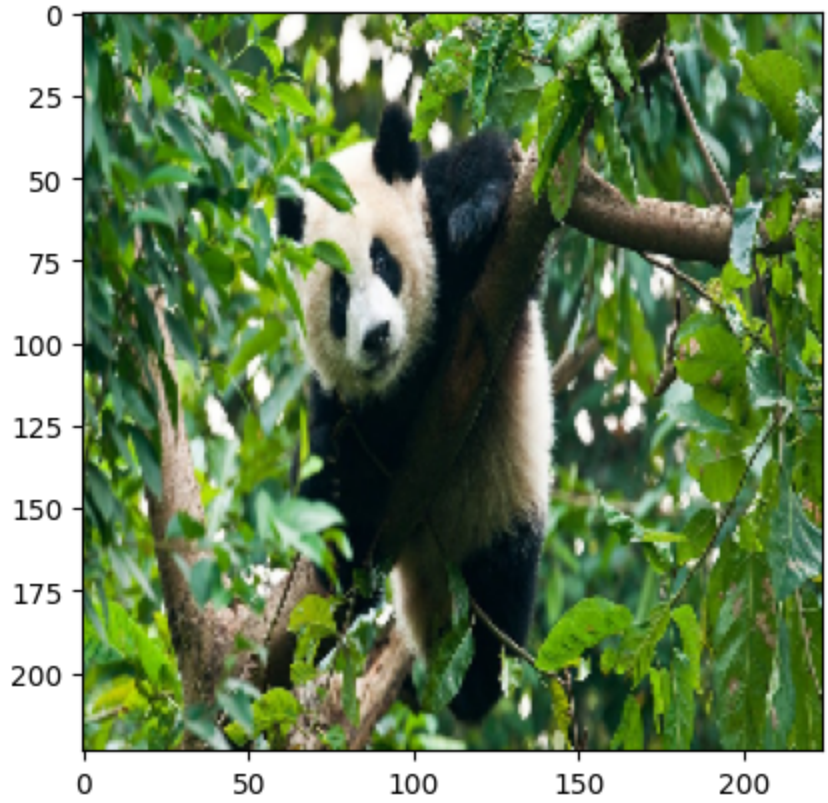

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```



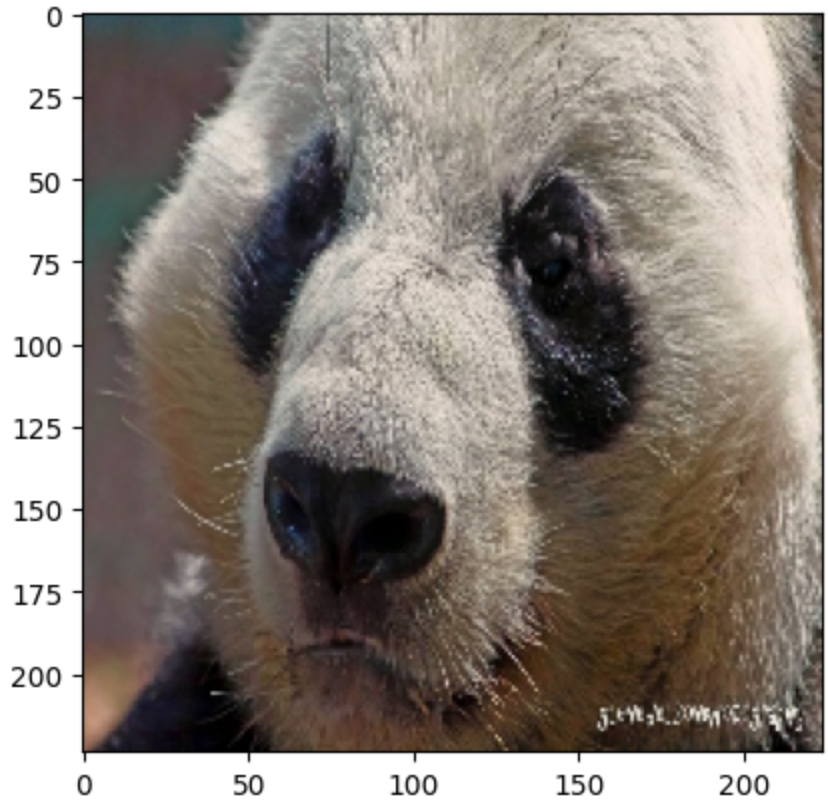

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



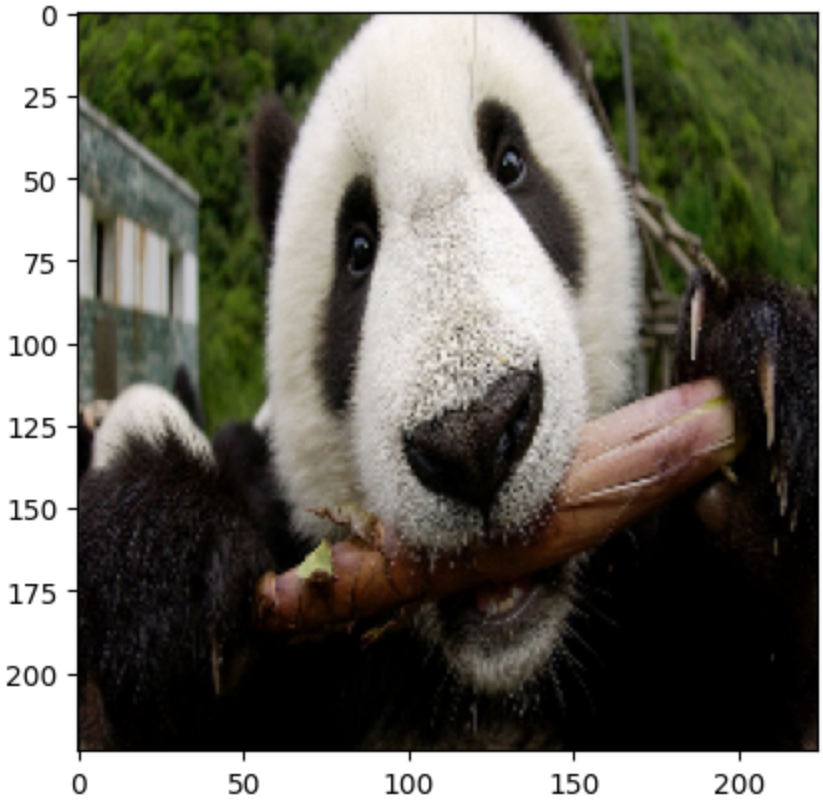

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



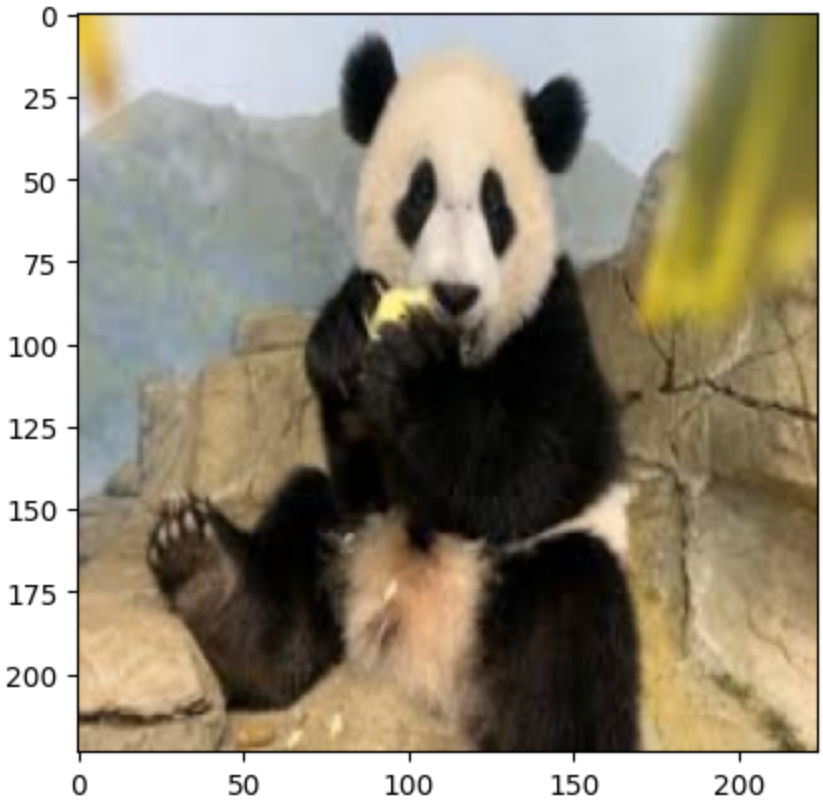

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



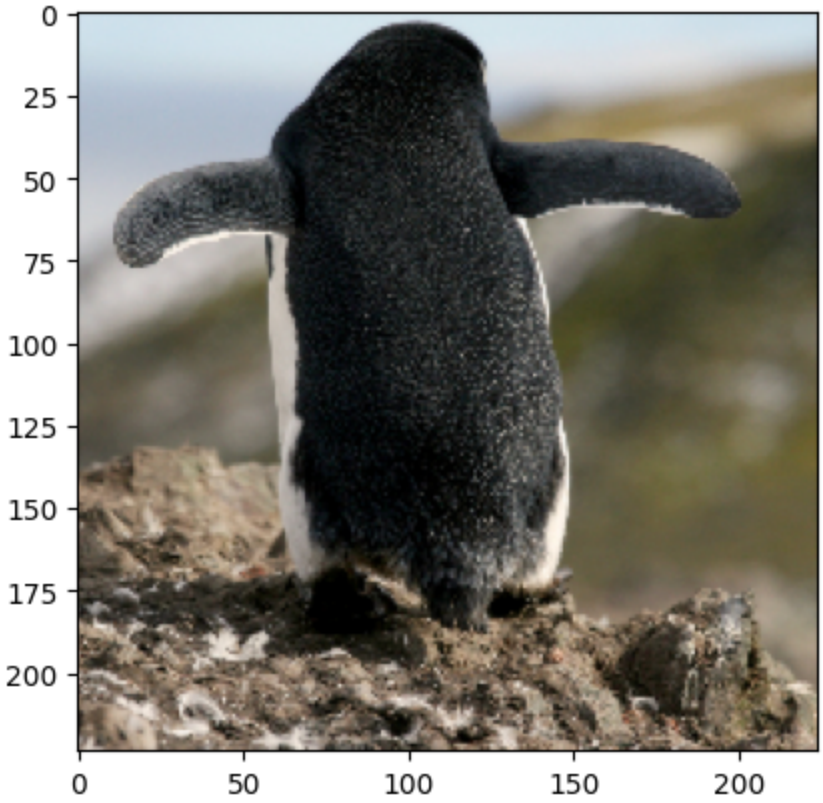

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



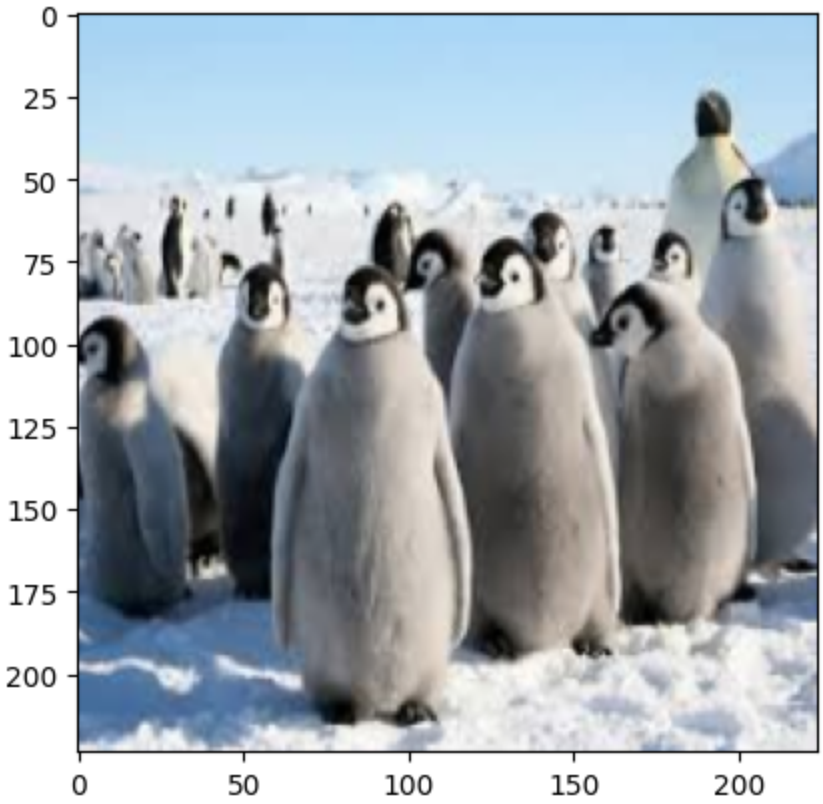

```
predict = panda
goed
3
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```



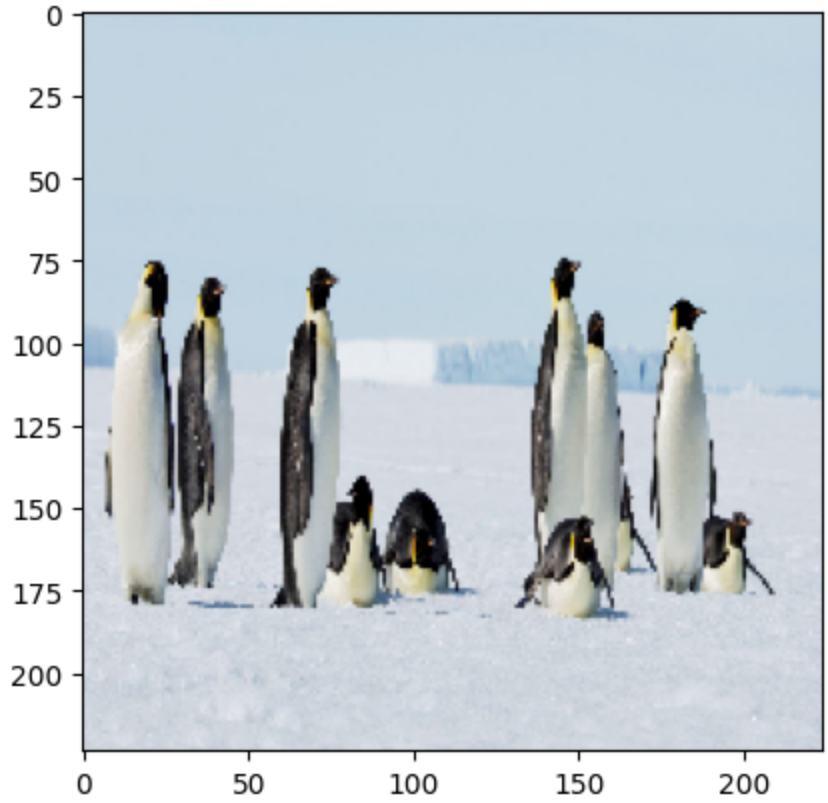

```
predict = panda
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



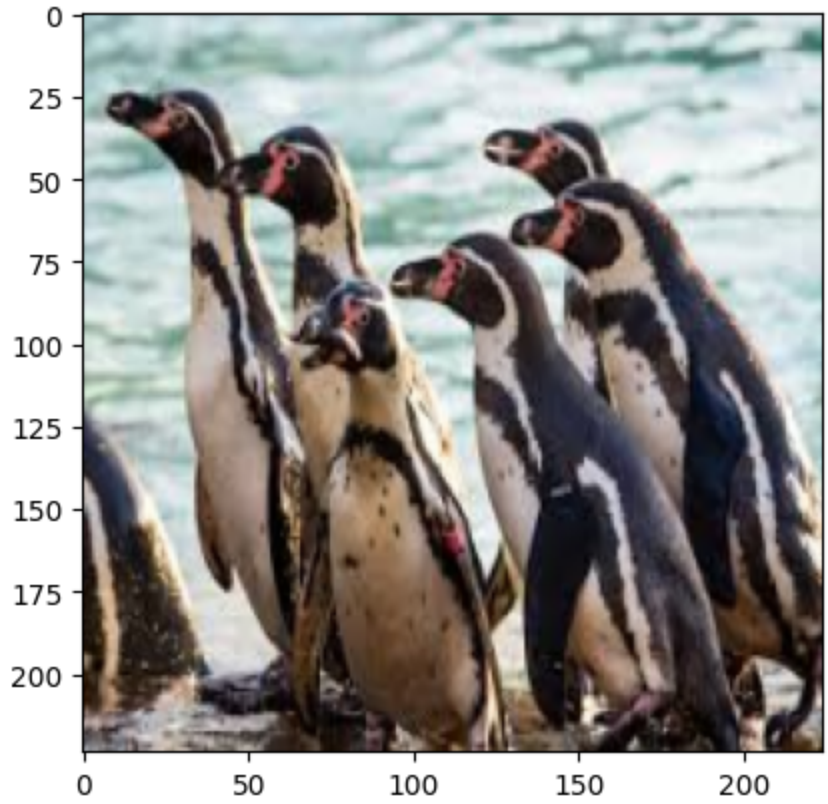

```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 24ms/step
```



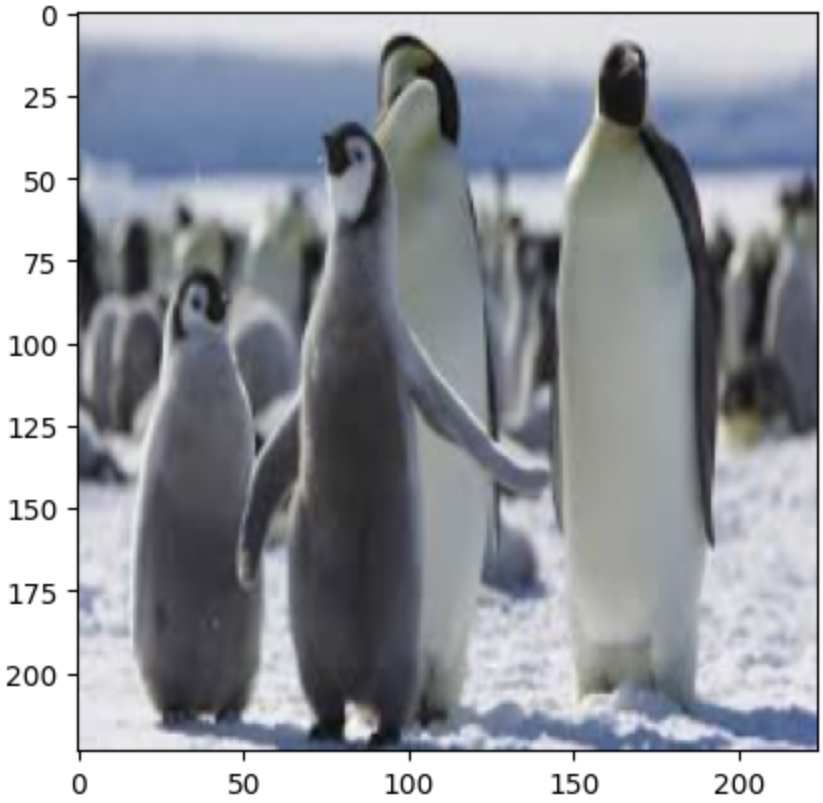

```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



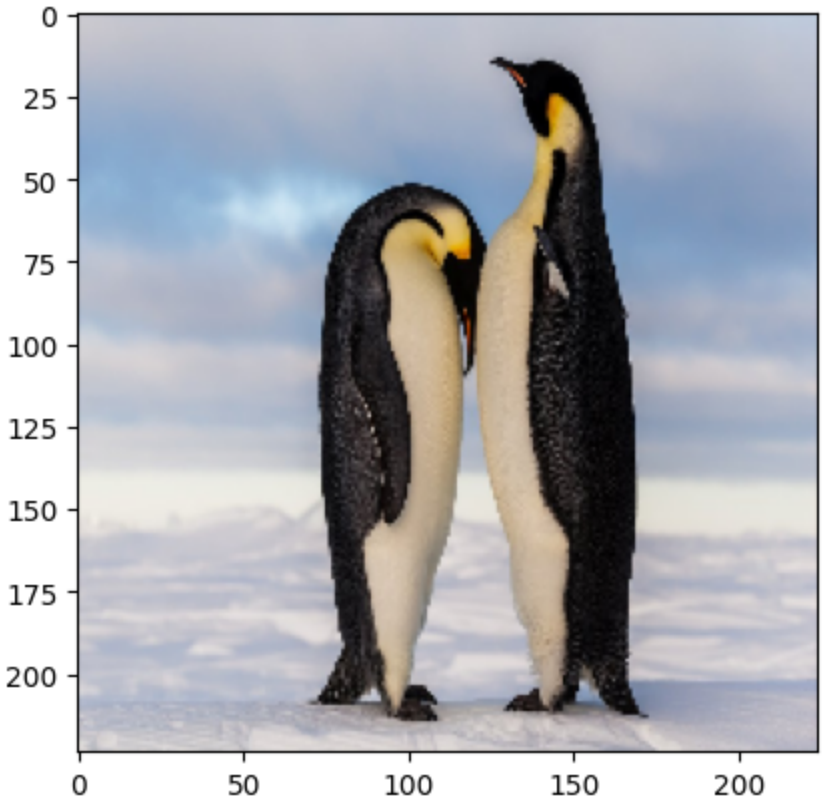

```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```



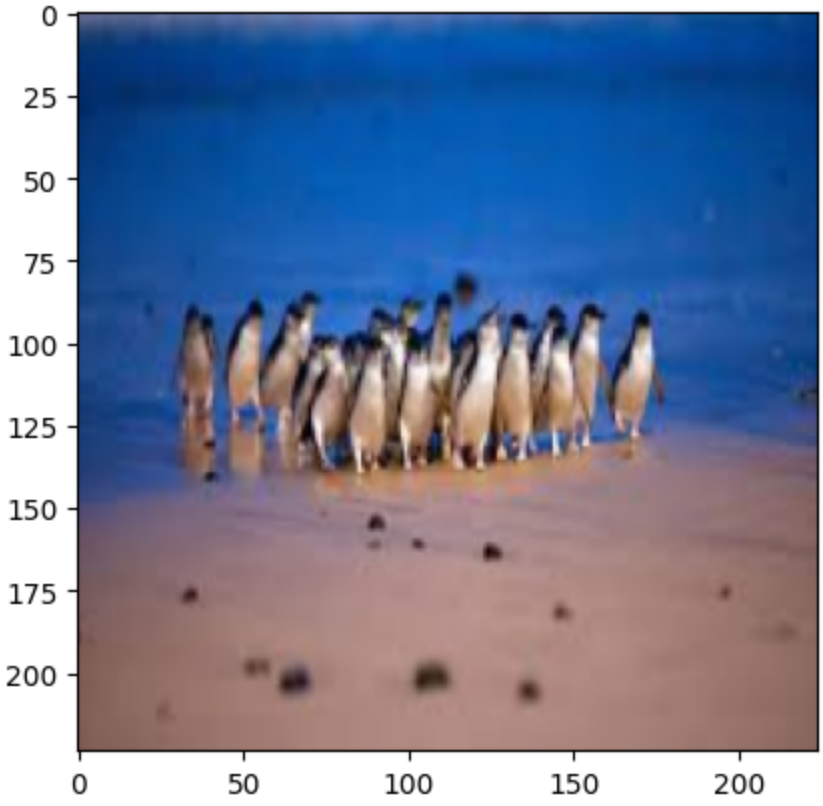

```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```



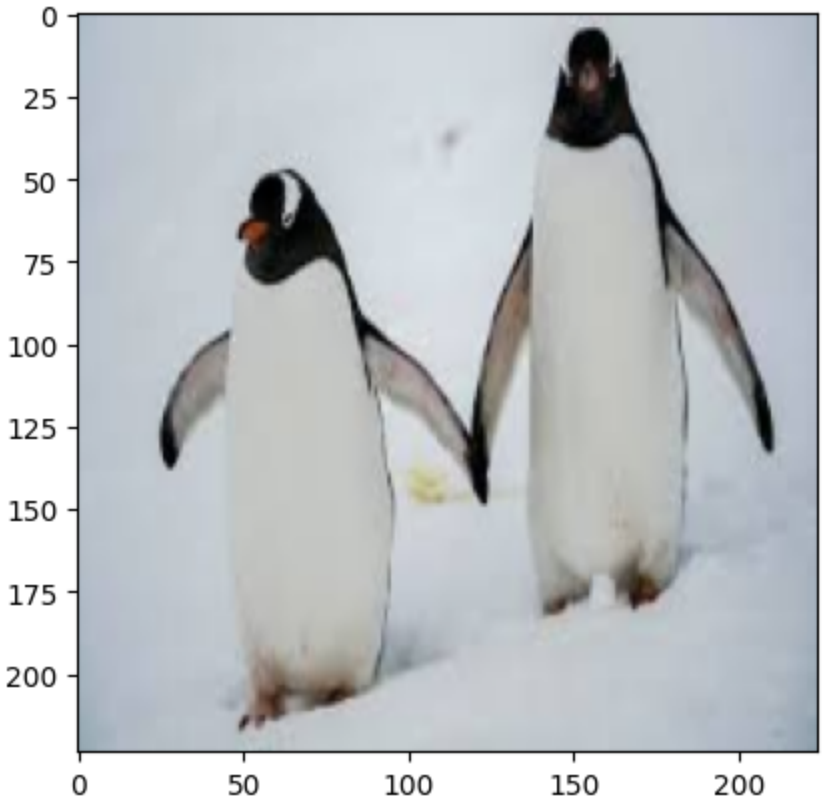

```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 21ms/step
```



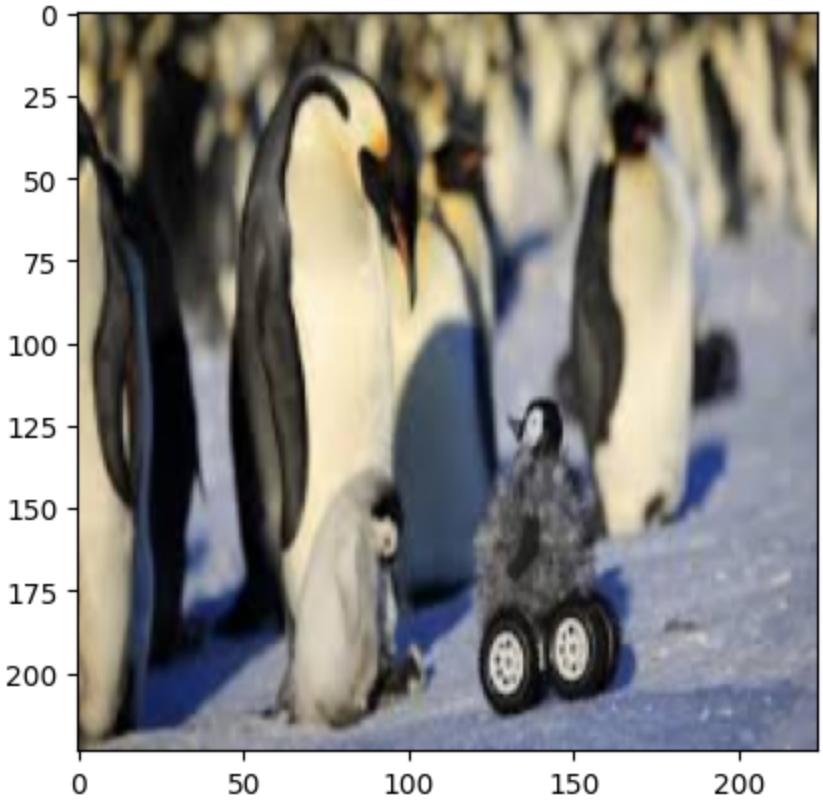

```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



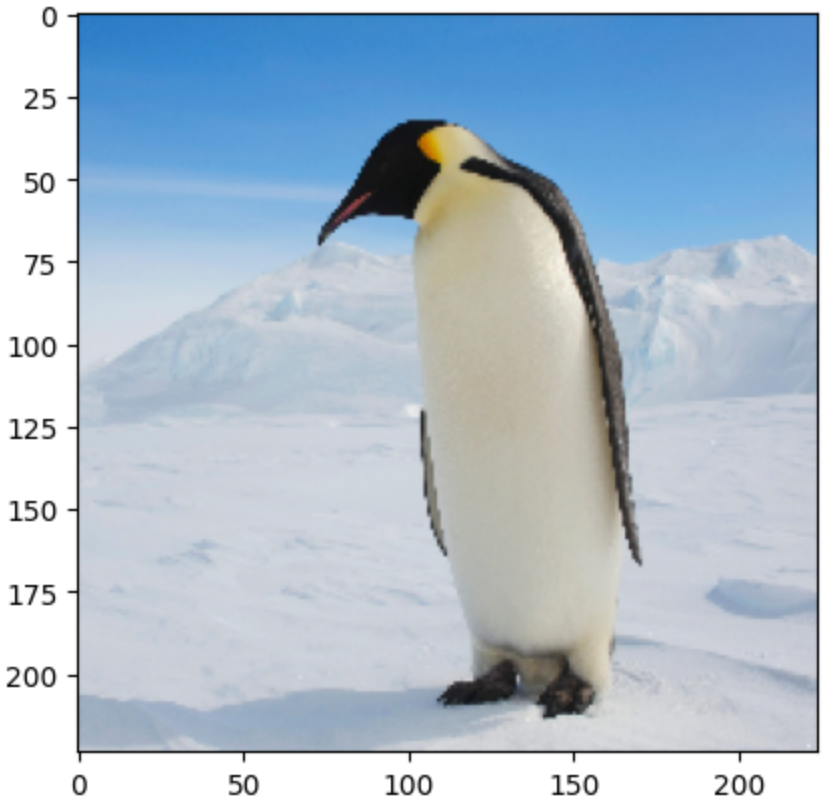

```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```




```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```

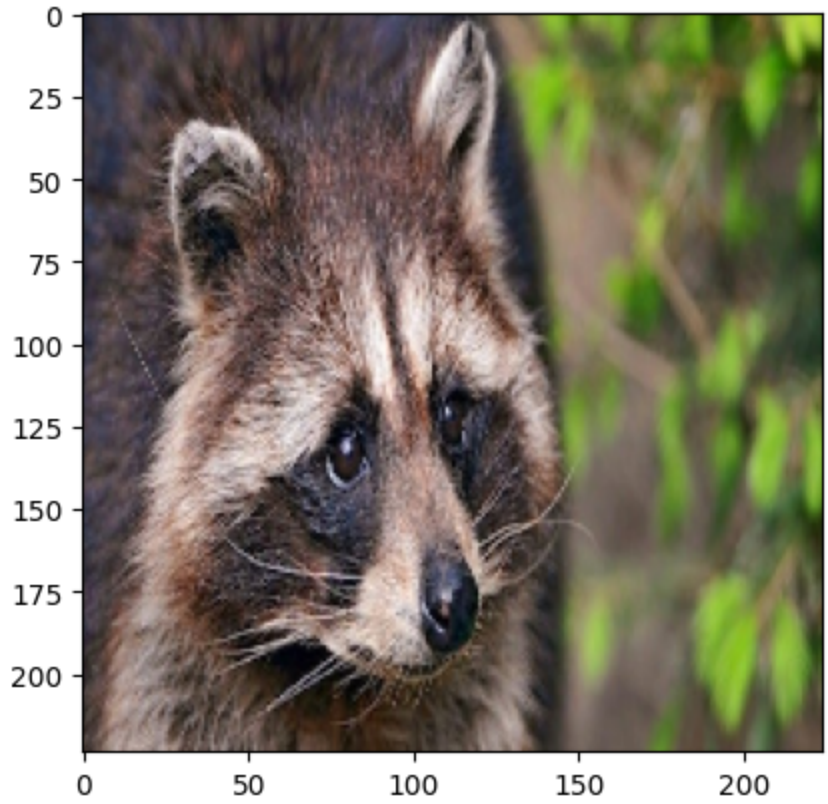



```
predict = penguin
goed
4
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```

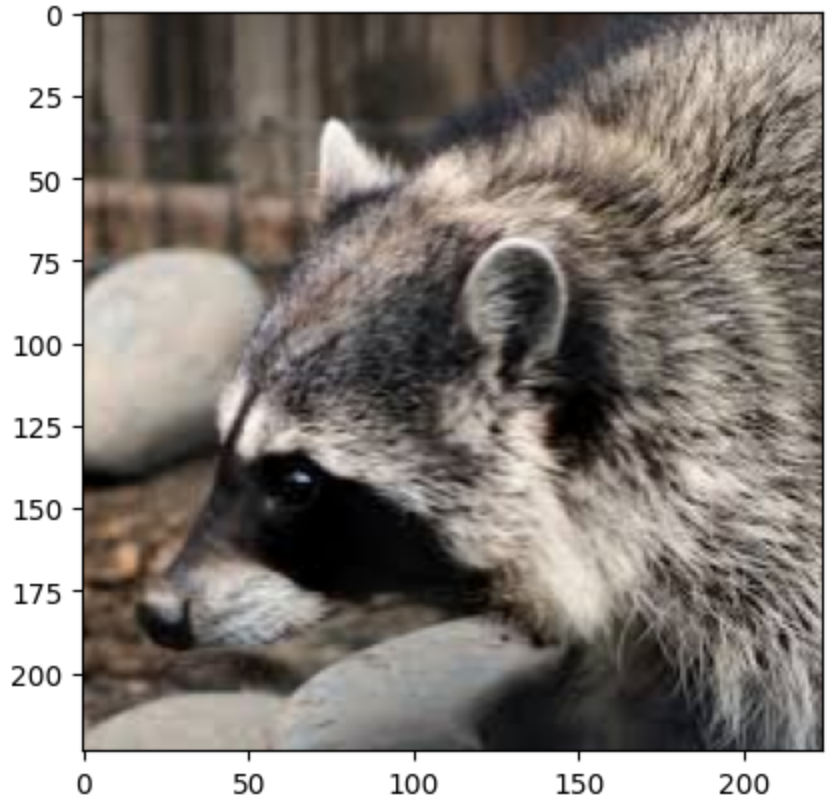



```
predict = penguin
goed
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```

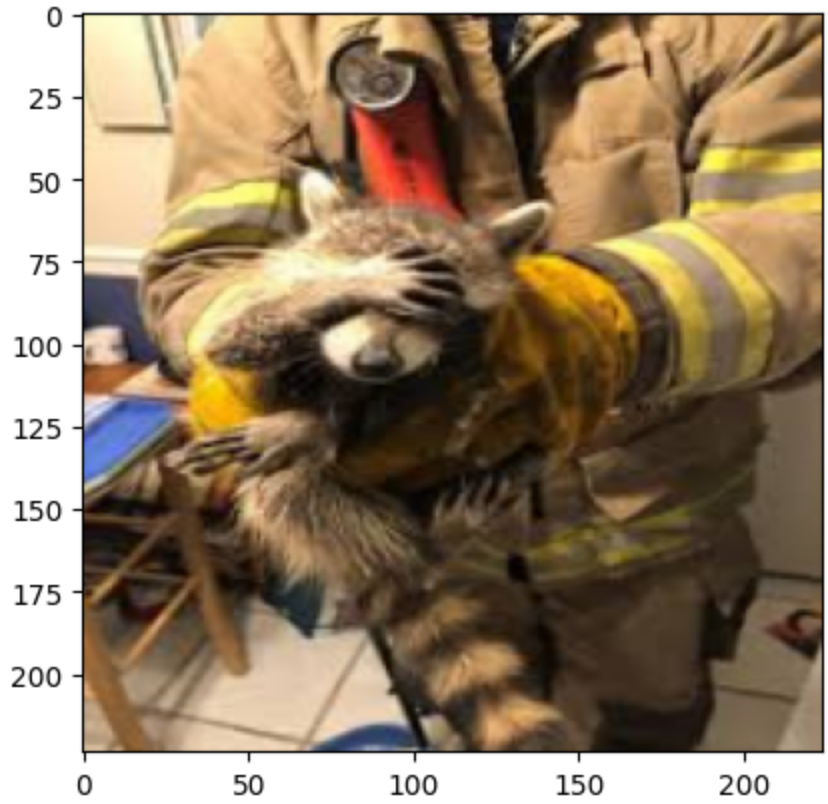

```
predict = hedgehog
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



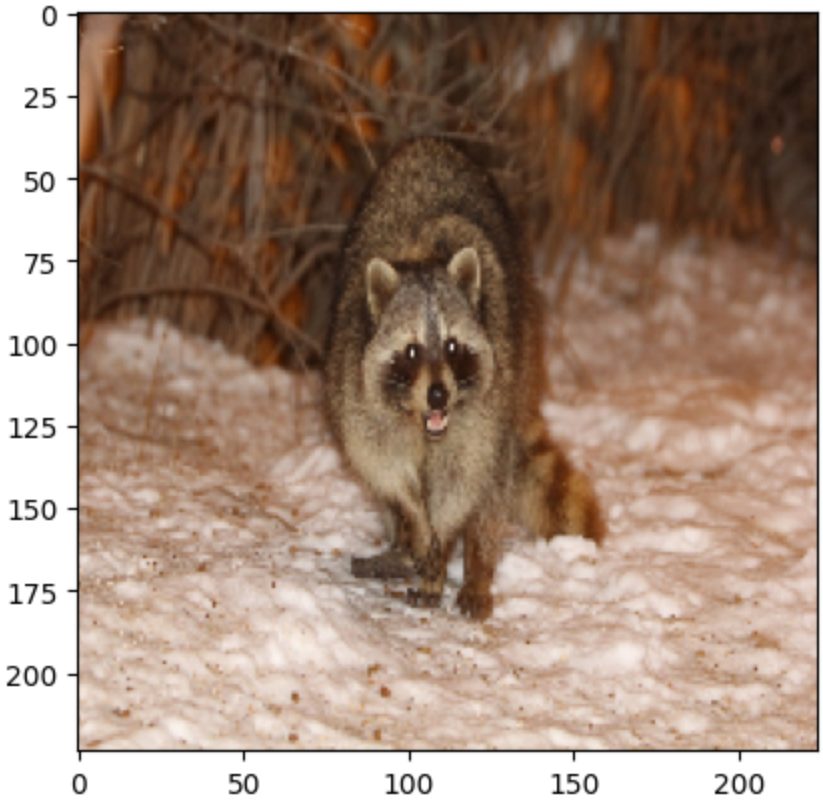

```
predict = hedgehog
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```



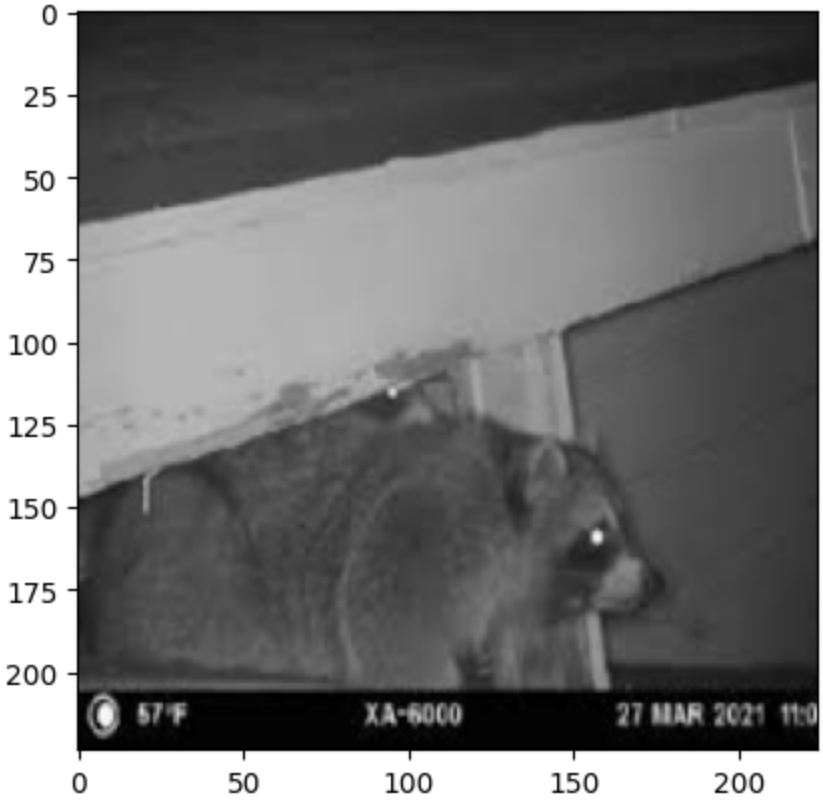

```
predict = hedgehog
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 21ms/step
```



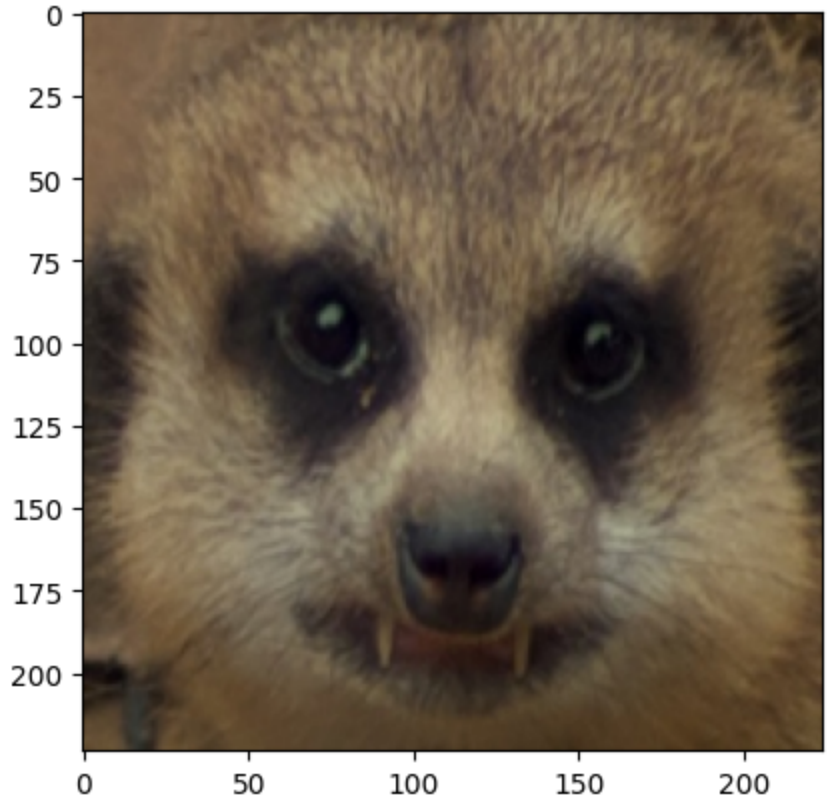

```
predict = crab
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



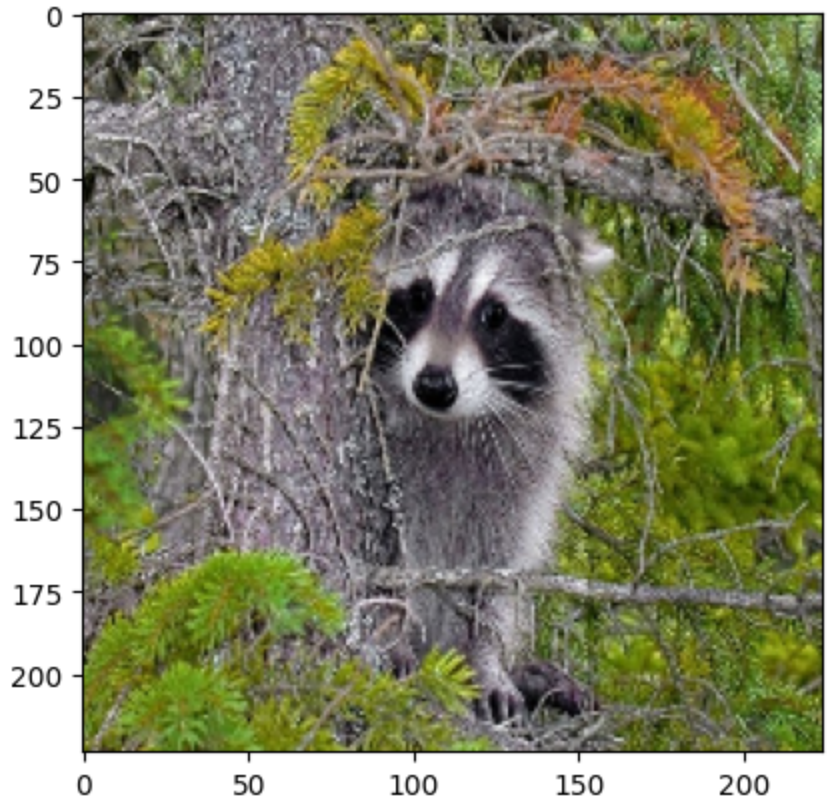

```
predict = panda
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



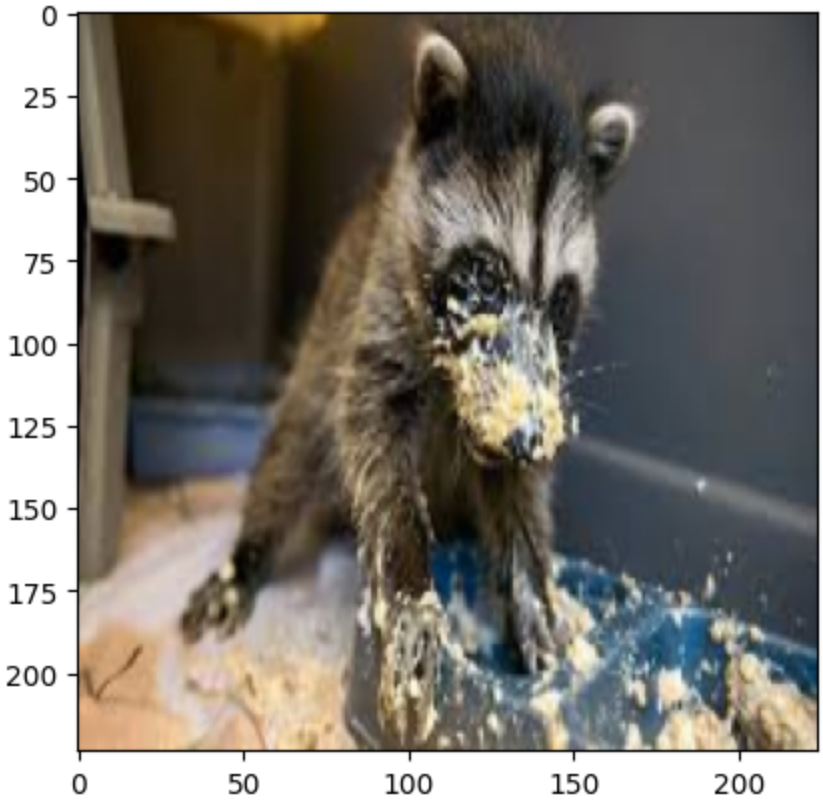

```
predict = duck
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 22ms/step
```



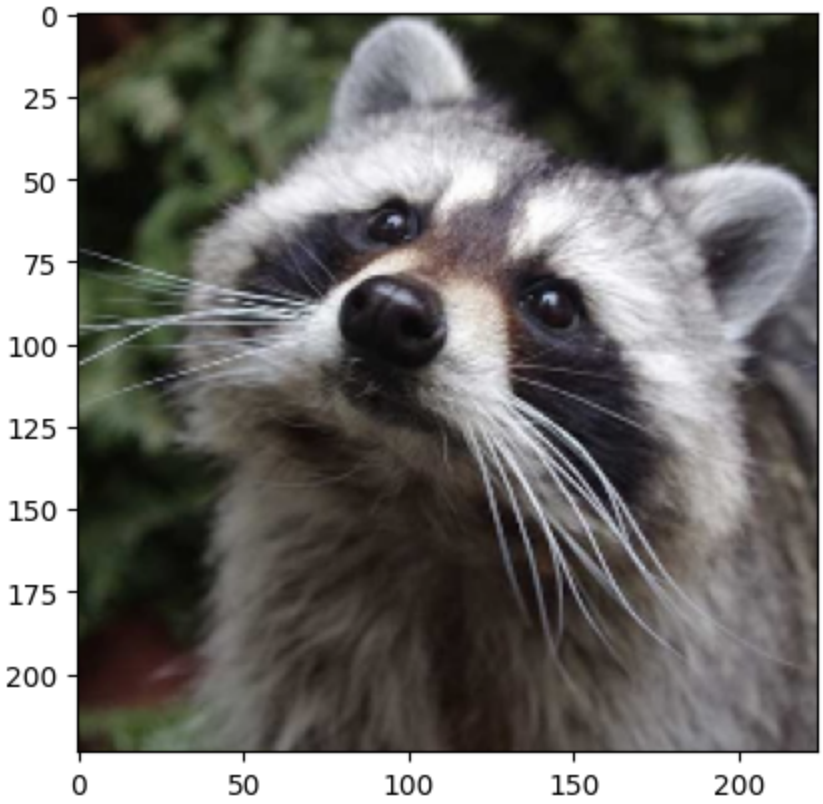

```
predict = hedgehog
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 25ms/step
```




```
predict = hedgehog
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 26ms/step
```




```
predict = hedgehog
fout
5
(1, 224, 224, 3)
1/1 [==============================] - 0s 23ms/step
```




```
predict = hedgehog
fout
totaal = 60
acc = 81.66666666666667 %
```

In this cell we iterate trough all the pictures and run them trough the model seperately. We also check if the guess was correct and calculated the accuracy of the model.

Additional Questions

1. Explain what your input object represents and how the result should be classified
2. Explain the pre-processing steps of the object training image(s) before you can feed it to the network.
3. What features do you think are extracted (relevant)?
4. Show (in report and video) how accurate your predicted model is, how does your detection behave in other unseen situations? Also explain in what situation and why it does (not) perform well. Supported your statements by measurement data!
5. Explain the parameters that you used for re-training this network?
6. This example uses a custom (but pre-trained) network architecture, explain how it works and why it is build up this way?

1.the imputs objects are animals wich should be classified in the correct species 2.the images are converted from BGR to RGB, resized to 224*224, processed to fit in an array of [*...1]. wich is then converted to a numpy array. this array then gets the same shape as the vgg16 model input by adding or removing columns. 3.colour and shape 4.our accuracy is 81.7%. mainly the raccoon and the hedgehog are similar 5.the vgg16 model is used as feature regignition, the added parameters will serve as image classification. it consists of 2 fully connected layers 6.the model consists of convolution layers followed by a pooling layer wich simplifies the output. this is done 5 times in the vgg16 model.

Finetuning

Finetuning by retraining all weights in the network as described in the workflow is Optional, but this will lead to a better accuracy of your final model,

the accyracy is already decently high, retraining the entire model will not result in significantly higher accuracy. therefore it will be a waste of tima and recources