In [1]:
```
# imports
from keras.applications.resnet50 import ResNet50
from keras.preprocessing import image
from keras.applications.resnet50 import preprocess_input
from keras.models import load_model
from matplotlib import pyplot as plt
import numpy as np
import pickle
```

```
Using TensorFlow backend.
```

In [2]:
```
# load the neural network model
model = load_model('weights_v2/version_v2_23.h5')

#load the cnn model
cnn_model = ResNet50(weights='imagenet',include_top=False)

# load the index file
with open('search_index.pickle', 'rb') as f:
    indexes = pickle.load(f)
```

In [3]:
```
print(len(model.layers))
```

```
8
```

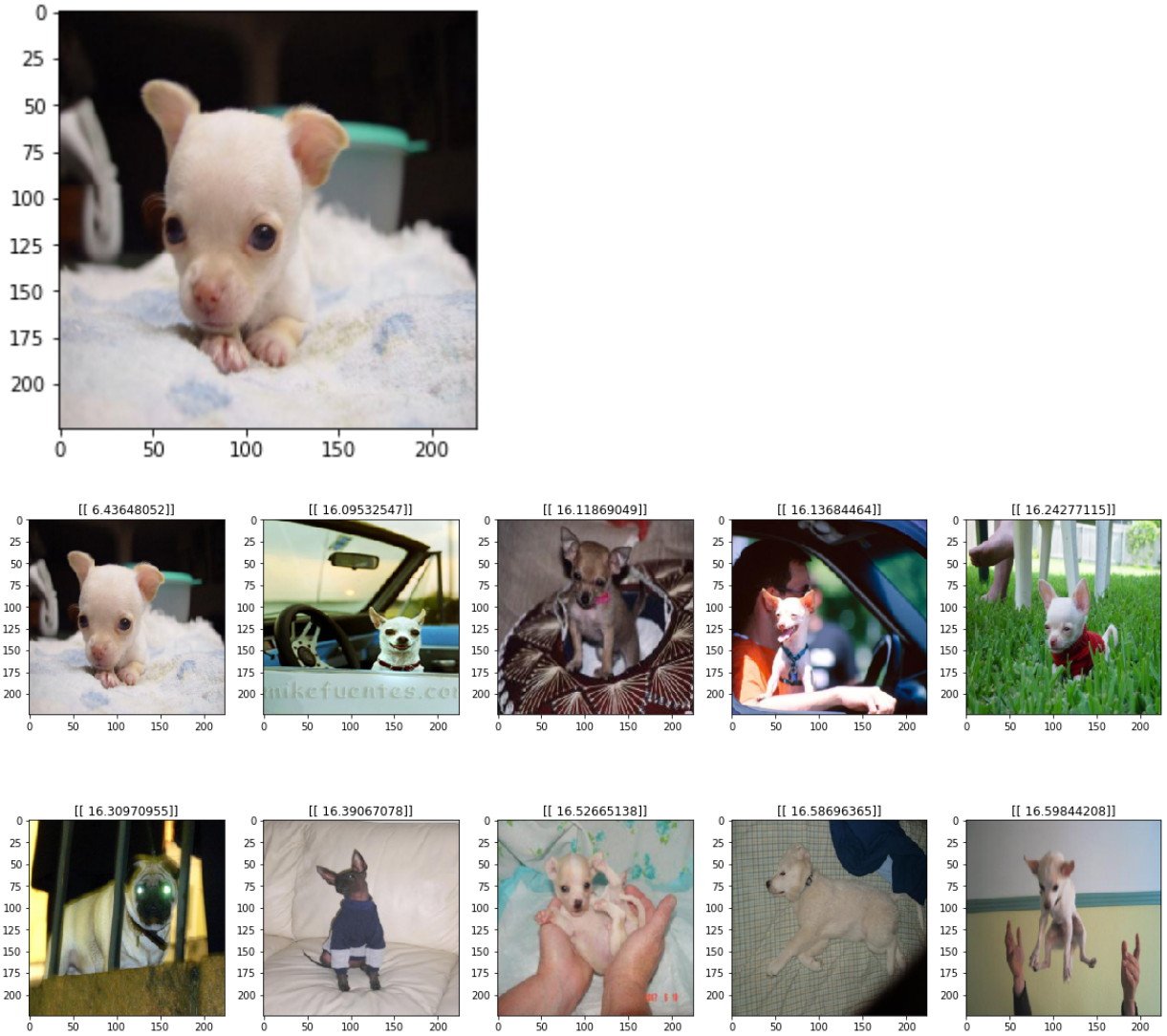
In [4]:
```
# helper funvtion to index the query image
# inputs - the image path and the cnn-model loaded above
# outputs - the flattened feature map of the query image extracted by the cnn-mod

def index_query(image_path, cnn_model):

    img = image.load_img(image_path, target_size=(224, 224))
    x = image.img_to_array(img)
    x = np.expand_dims(x, axis=0)
    x = preprocess_input(x)
    query = cnn_model.predict(x)
    query = query.flatten()

    imgplot = plt.imshow(img)
    plt.show()

    return query
```

In [35]:
```
# helper function to do the retreival
# inputs - the query index computed from the cnn_model,
#          the indexes list
#          and the number of results to retreive (topn)
# outputs - a list of tuples containing the retrieved image paths and their respe

def find_query(query_index, indexes, topn):

    retrieved = []

    for indx in indexes:
        search_image = indx[0]
        search_indx = indx[1]
        diff = query_index - search_indx
        diff = diff**2
        diff = np.reshape(diff,(1,2048))
        match_score = model.predict(diff)
        retrieved.append((search_image, match_score))

    sorted_retreival = sorted(retrieved, key=lambda x: x[1])

    selected = sorted_retreival[:topn]
    return selected


# for the purpose of comparison, I use the Euclidean Distance between the feature

def find_query_l2(query_index, indexes, topn):

    retrieved = []

    for indx in indexes:
        search_image = indx[0]
        search_indx = indx[1]
        diff = query_index - search_indx
        diff = diff**2
        match_score = sum(diff)
        retrieved.append((search_image, match_score))

    sorted_retreival = sorted(retrieved, key=lambda x: x[1])

    selected = sorted_retreival[:topn]
    return selected


# helper function to plot the topn results retrieved
def plot_results(selected_images, highlight = None):

    n = len(selected_images)

    fig = plt.figure(figsize=(20,10))

    for i in range(n):
        x = round(n / 5)
        a = fig.add_subplot(x,5,i+1)
        image_path = selected_images[i][0]
```

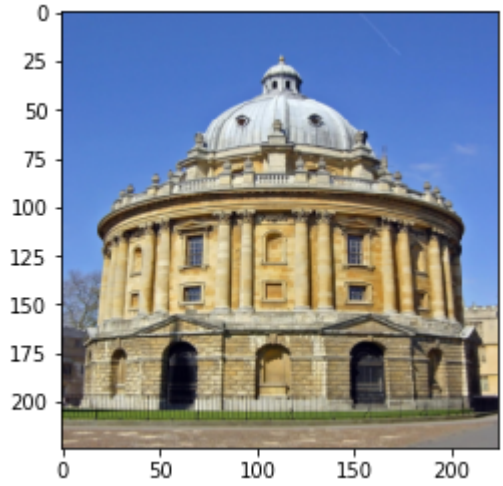
```
        img = image.load_img(image_path, target_size=(224, 224))
        plt.imshow(img)
        if i == highlight:
            a.set_title("RELEVANT")
        else:
            a.set_title(str(selected_images[i][1]))

    plt.show()
```

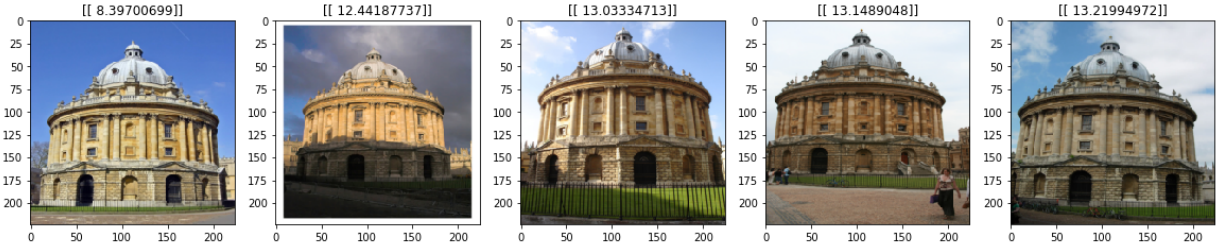
Test with trained images

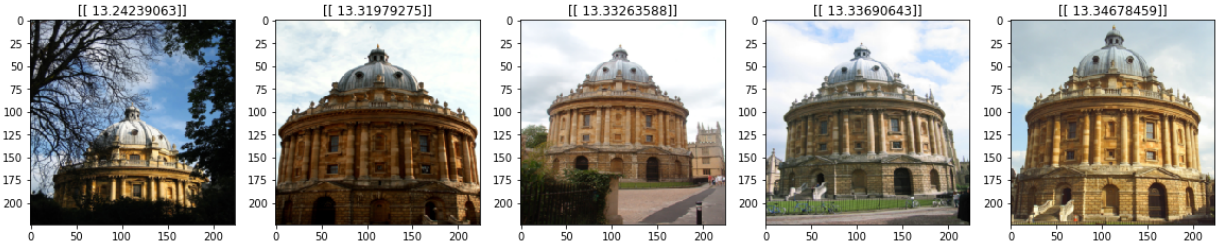
In [8]:
```
query_index = index_query('Dogs/n02085620-Chihuahua/n02085620_712.jpg', cnn_model
results = find_query(query_index, indexes, 10)
plot_results(results)
```



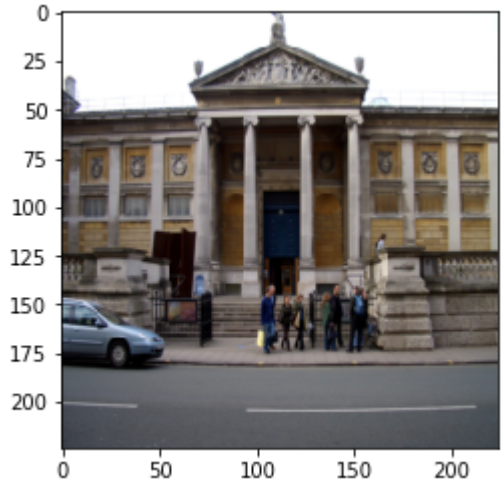
In [17]:
```
query_index = index_query('oxford_selected/radcliffe_cam/radcliffe_camera_000027.
results = find_query(query_index, indexes, 10)
plot_results(results)
```

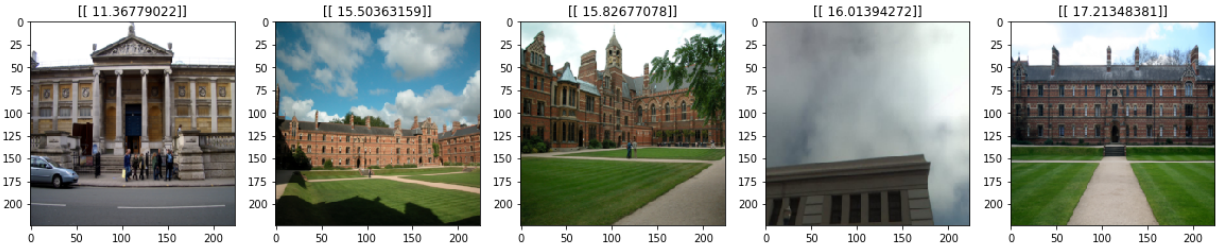


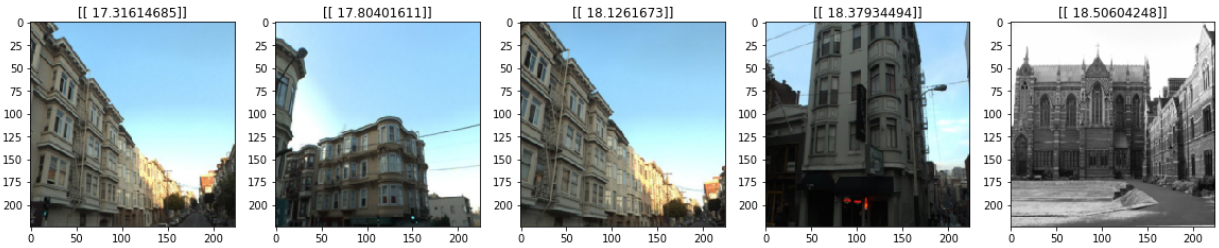




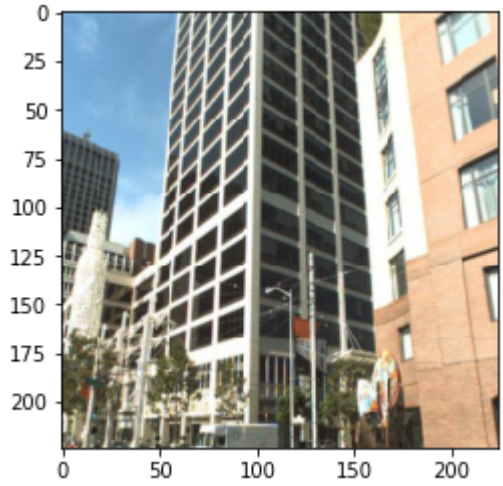
In [23]:
```
query_index = index_query('oxford_selected/ashmolean/ashmolean_000000.jpg', cnn_m
results = find_query(query_index, indexes, 10)
plot_results(results)
```

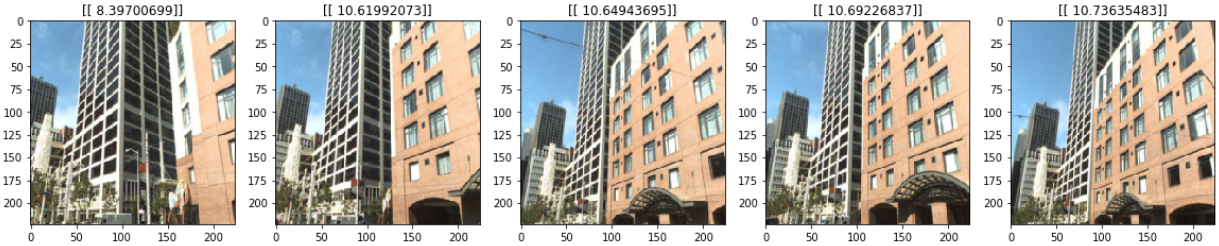


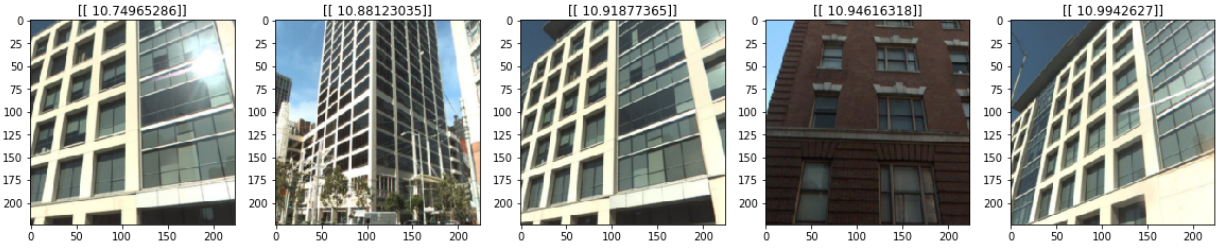




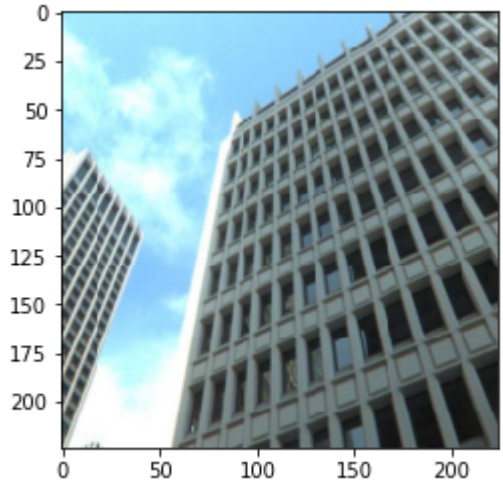
In [19]:
```
query_index = index_query('san_fran_selected/18/PCI_sp_12357_37.793396_-122.39295
results = find_query(query_index, indexes, 10)
plot_results(results)
```

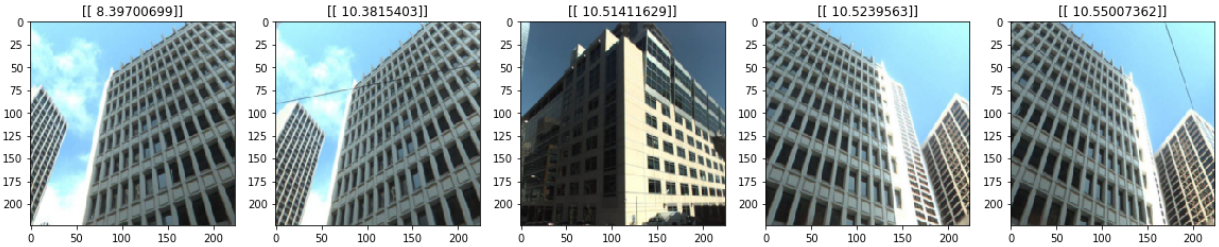


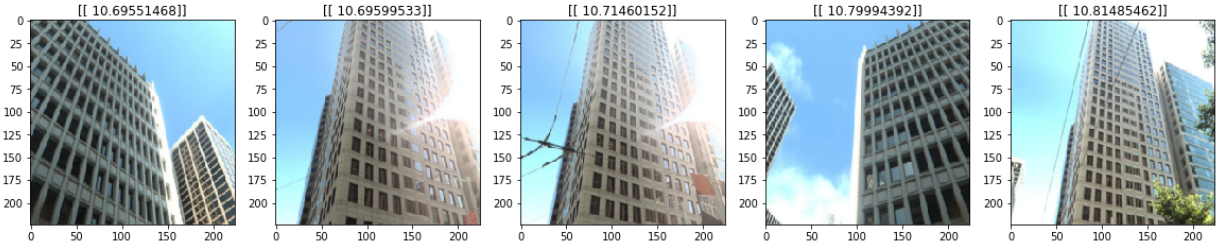




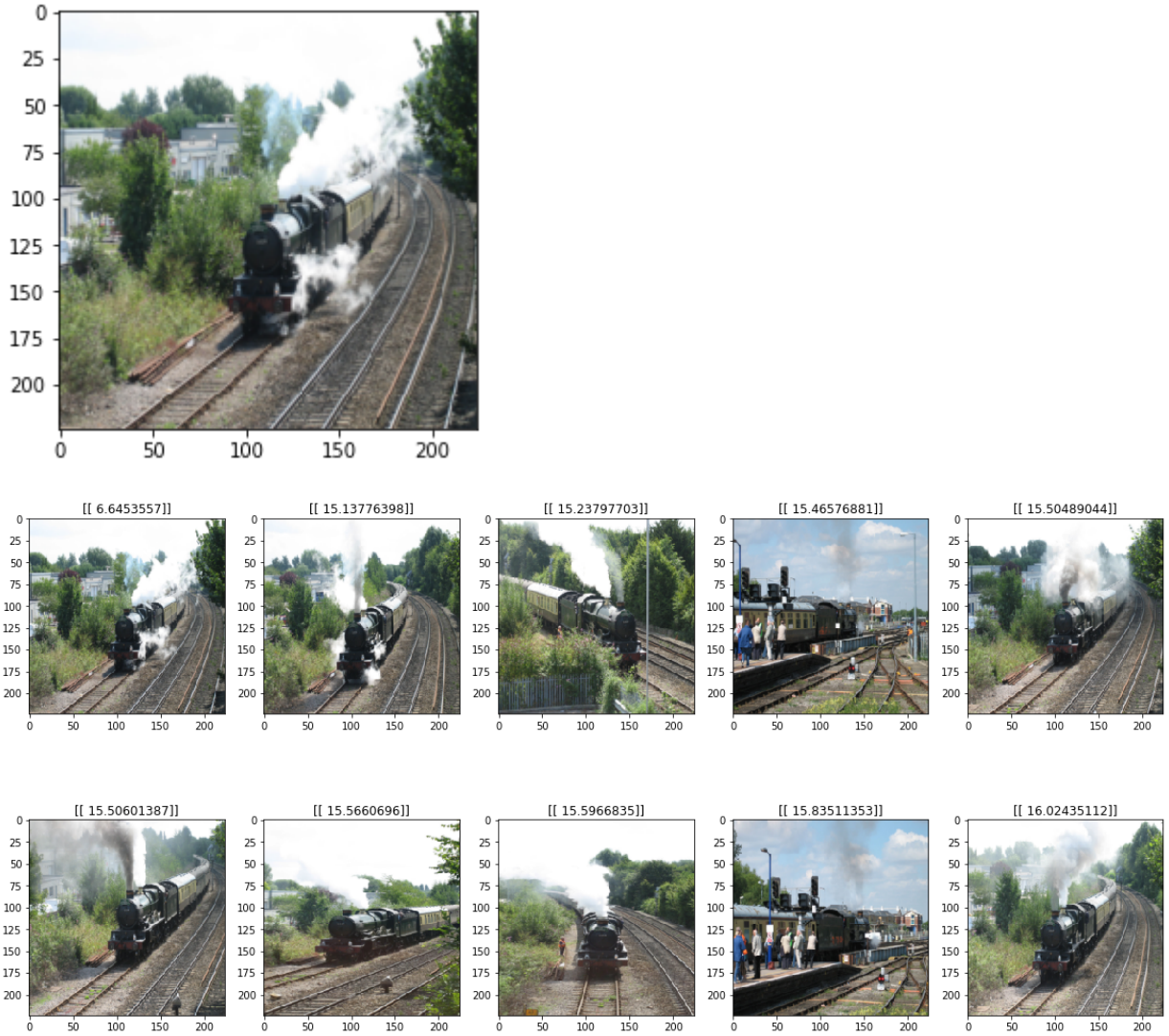
In [20]:
```
query_index = index_query('san_fran_selected/16/PCI_sp_12318_37.792333_-122.39429
results = find_query(query_index, indexes, 10)
plot_results(results)
```







In [45]:
```
query_index = index_query('oxford_selected/railway/worcester_000131.jpg', cnn_mod
results = find_query(query_index, indexes, 10)
plot_results(results)
```



test with freshly indexed images

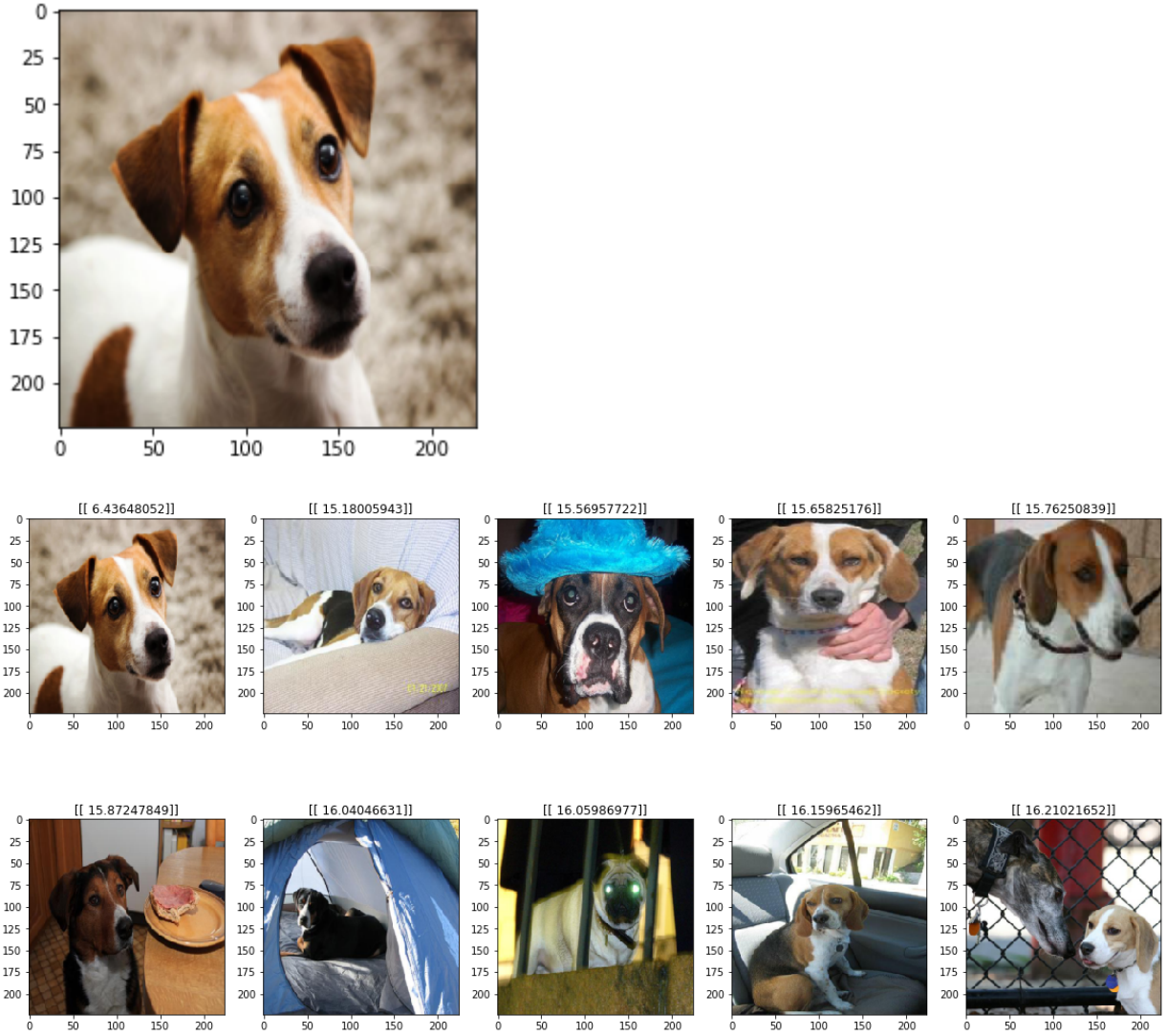
In [30]:
```
# read the test indexes
with open('test_index.pickle', 'rb') as f:
    test_indexes = pickle.load(f)
```

In [31]:
```
a = indexes
a = a + test_indexes
print (len(a))
print (len(indexes))
```

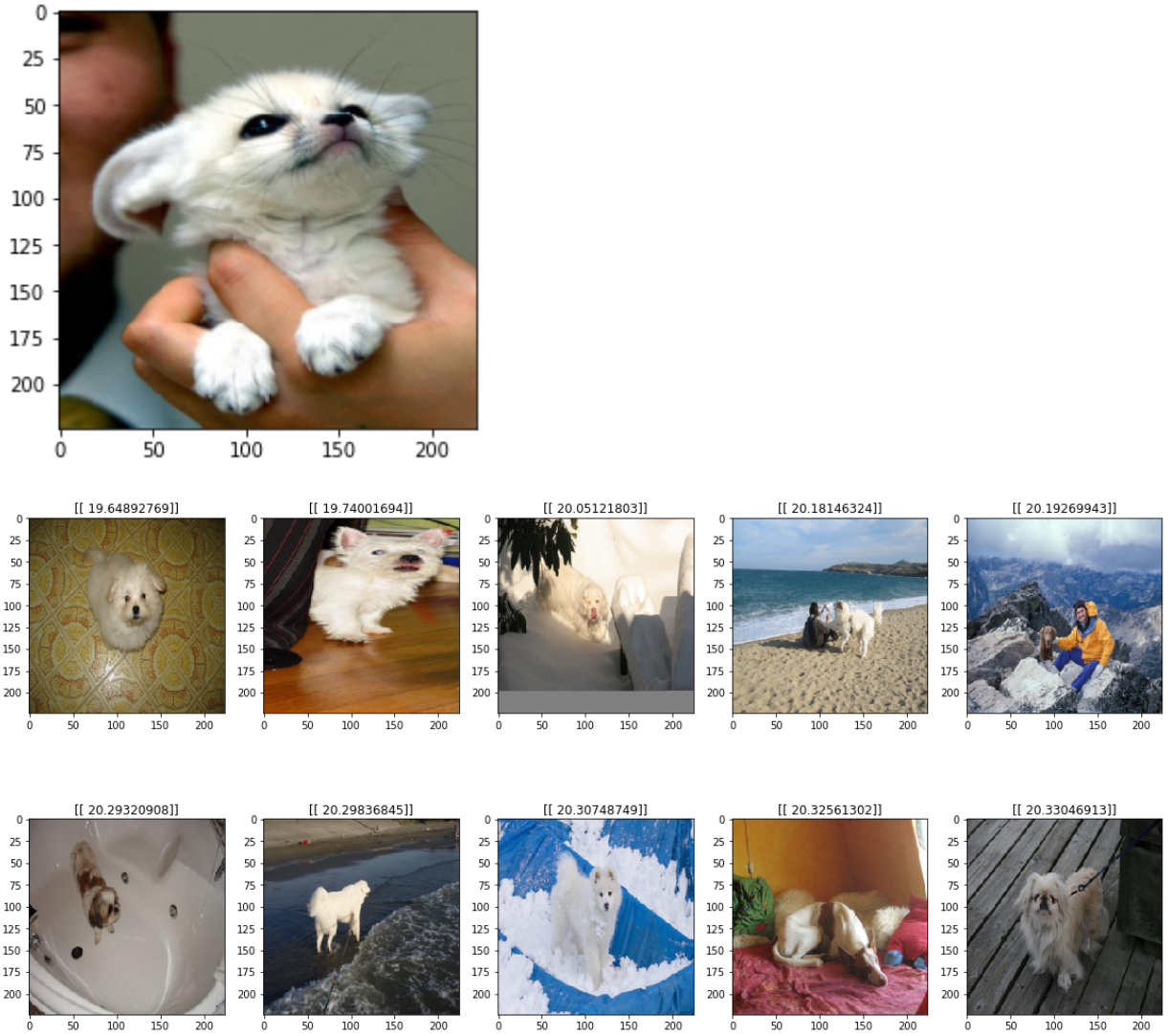
```
23936
23925
```

In [32]:
```
indexes = a
```

In [33]:
```
#image doesnt exist in indexes that were trained on
#retrieving from freshly appended indexes
query_index = index_query('test_images/kukkur.jpg', cnn_model)
results = find_query(query_index, indexes, 10)
plot_results(results)
```



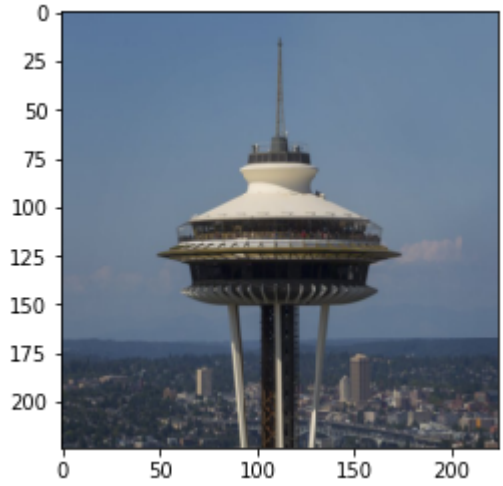
In [97]:
```
#image doesnt exist in indexes that were trained on
#retrieving from freshly appended indexes
# exact image did not exist in the database ... image taken from the internet...
query_index = index_query('test_images/kutta.jpg', cnn_model)
results = find_query(query_index, indexes, 10)
plot_results(results)
```

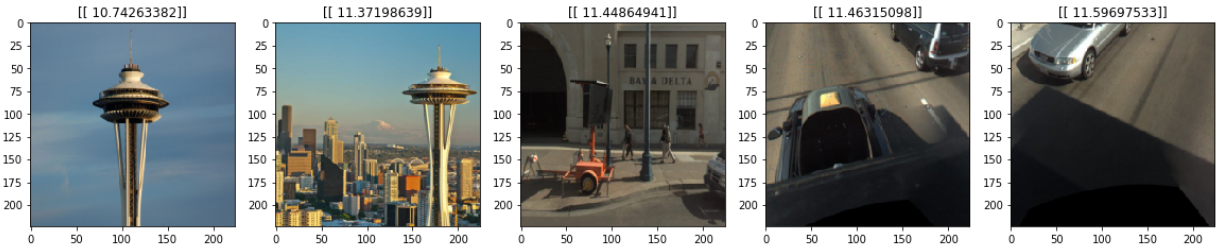


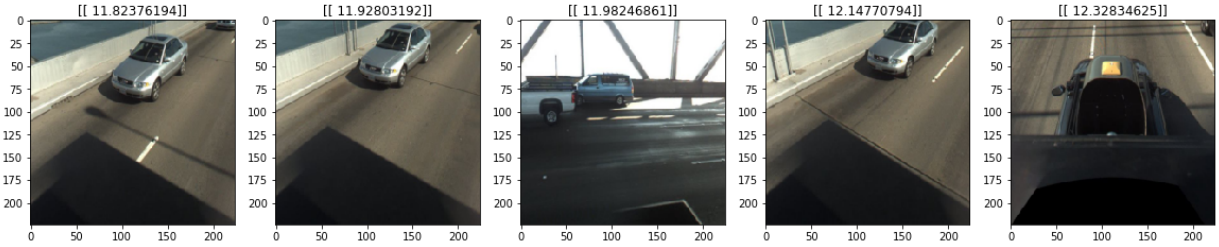
This result is from an intermediate version of the model

The final version results differ as shown during comparison below

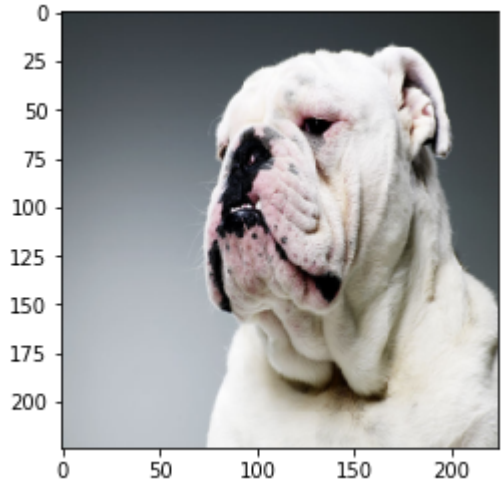
In [27]:
```
# EXACT image doesnt exist in indexes that were trained on
#retrieving from freshly appended indexes
# 2 out of 3 retrieved in top 10
query_index = index_query('test_images/space_needle_1.jpg', cnn_model)
results = find_query(query_index, indexes, 10)
plot_results(results)
```



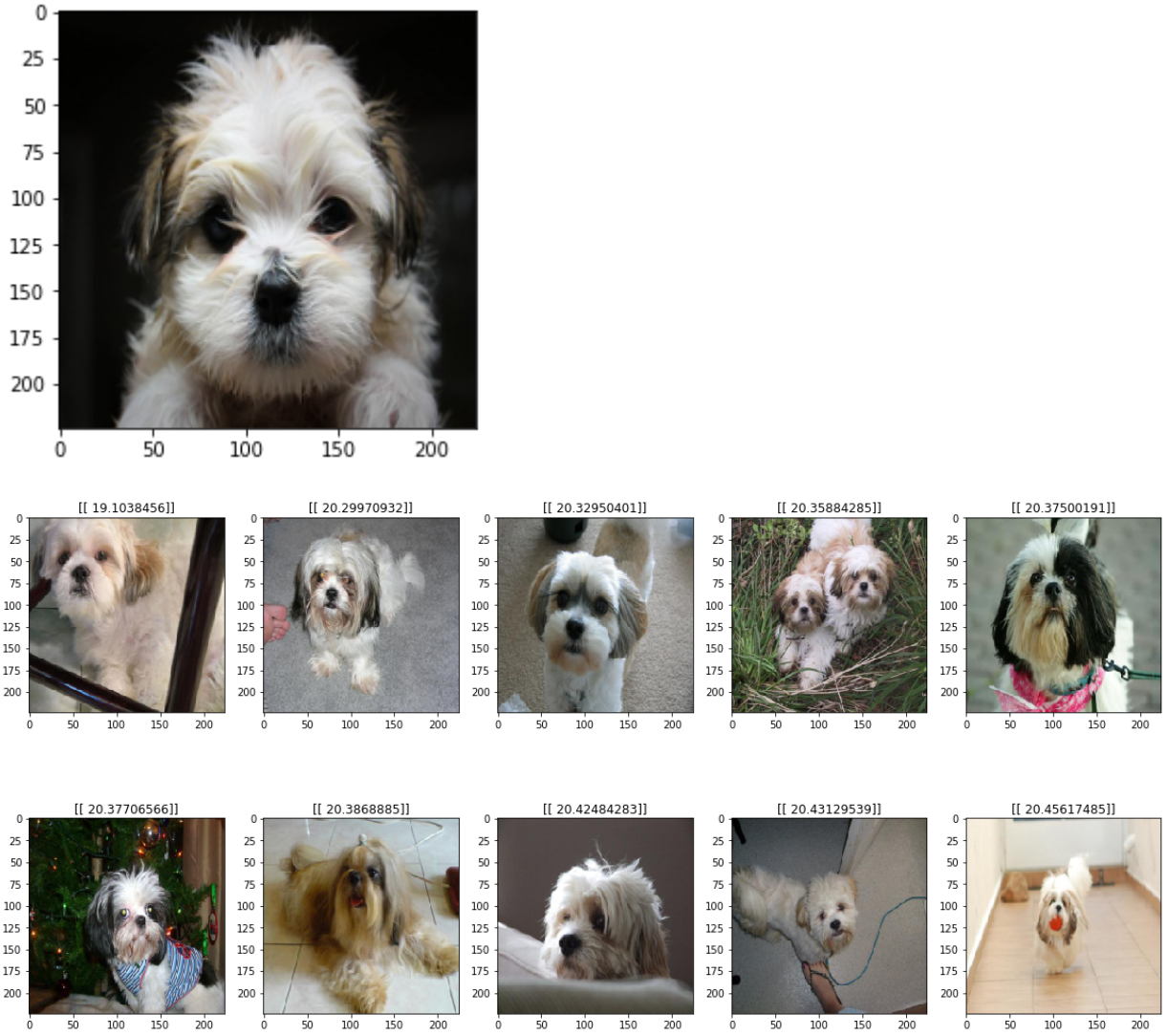




In [29]:
```
# image downloaded from internet
# EXACT image doesnt exist in indexes that were trained on
query_index = index_query('test_images/6-face.jpg', cnn_model)
results = find_query(query_index, indexes, 20)
plot_results(results)
```



In [103]:
```
# image downloaded from internet
# EXACT image doesnt exist in indexes that were trained on
query_index = index_query('test_images/puppy_photo_on_flickr.jpg', cnn_model)
results = find_query(query_index, indexes, 10)
plot_results(results)
```



Augmentation test

In [40]:
```
# image downloaded from quora
# what explains the match?!
# windows in oxford are vertical but the san-fransisco windows are horizontal

query_index = index_query('test_rotated', cnn_model)
results = find_query(query_index, indexes, 10)
plot_results(results)
```

Evaluation against Euclidean Distance

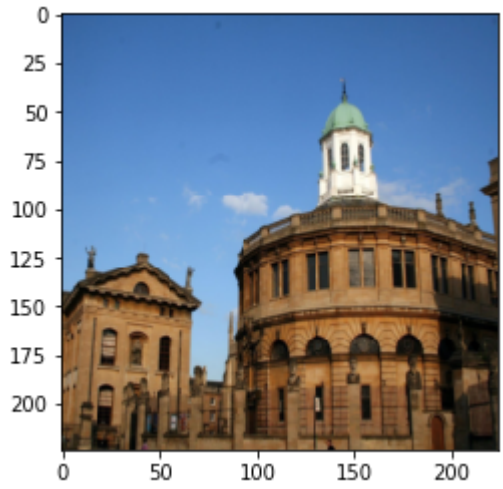
Relevant Results are defined by visually inspecting the results of each search and appending the same artefact as in the query manually into the relevant list

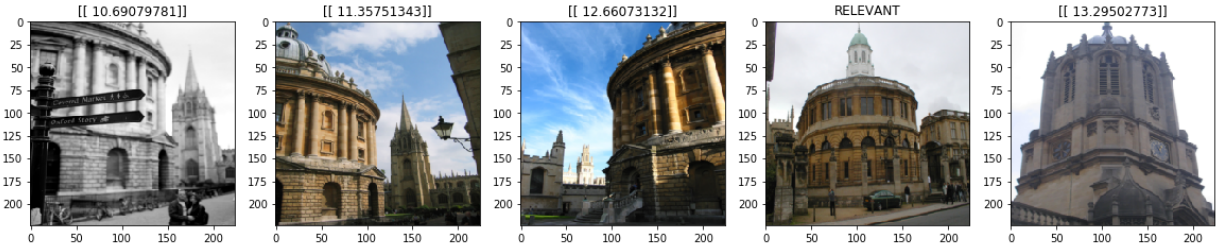
First 10 results are from the Neural Net Model and the next 10 are from Euclidean Distance

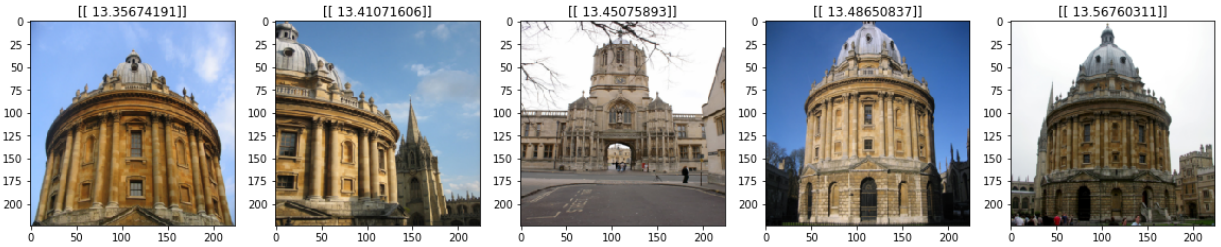
Search

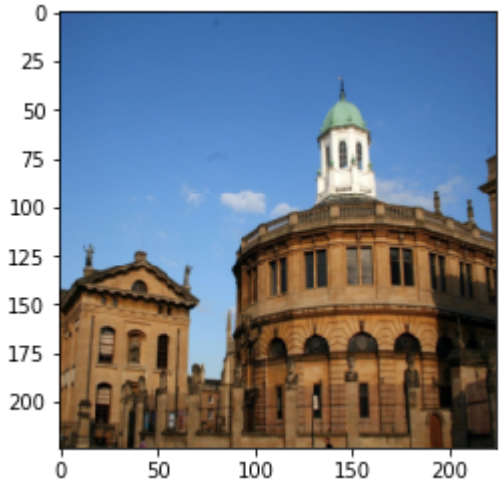
The relevant image with this case is being retrieved by the Neural Network Model, BUT NOT THE EUCLIDEAN DISTANCE SEARCH

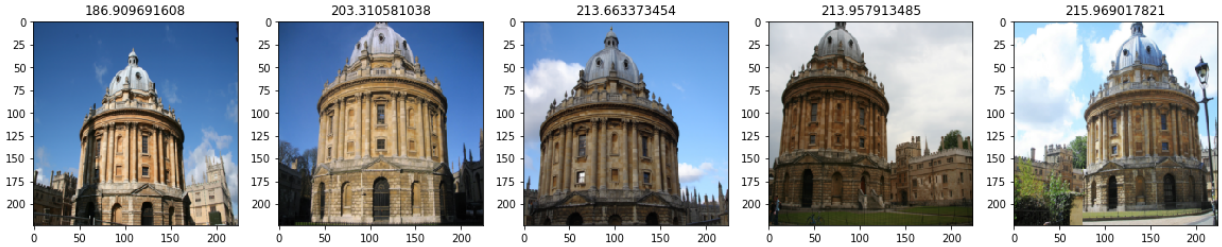
In [44]:
```
# EXACT TEST IMAGE DOES NOT EXIST IN THE DATABASE

# RELEVANT IMAGE IS MARKED AS "RELEVANT", USING 'highlight' INSTEAD OF SCORE

query_index = index_query('main-qimg-a2233912a89872a2076e6799392a7f44-c', cnn_mod
results = find_query(query_index, indexes, 10)
plot_results(results, highlight = 3)

query_index = index_query('main-qimg-a2233912a89872a2076e6799392a7f44-c', cnn_mod
results_l2 = find_query_l2(query_index, indexes, 10)
plot_results(results_l2)
```

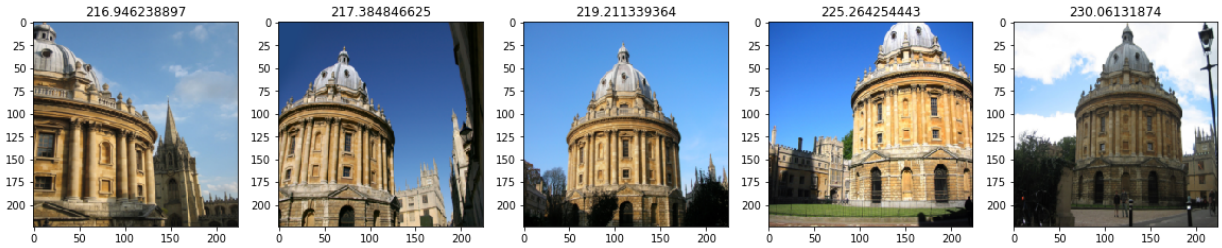




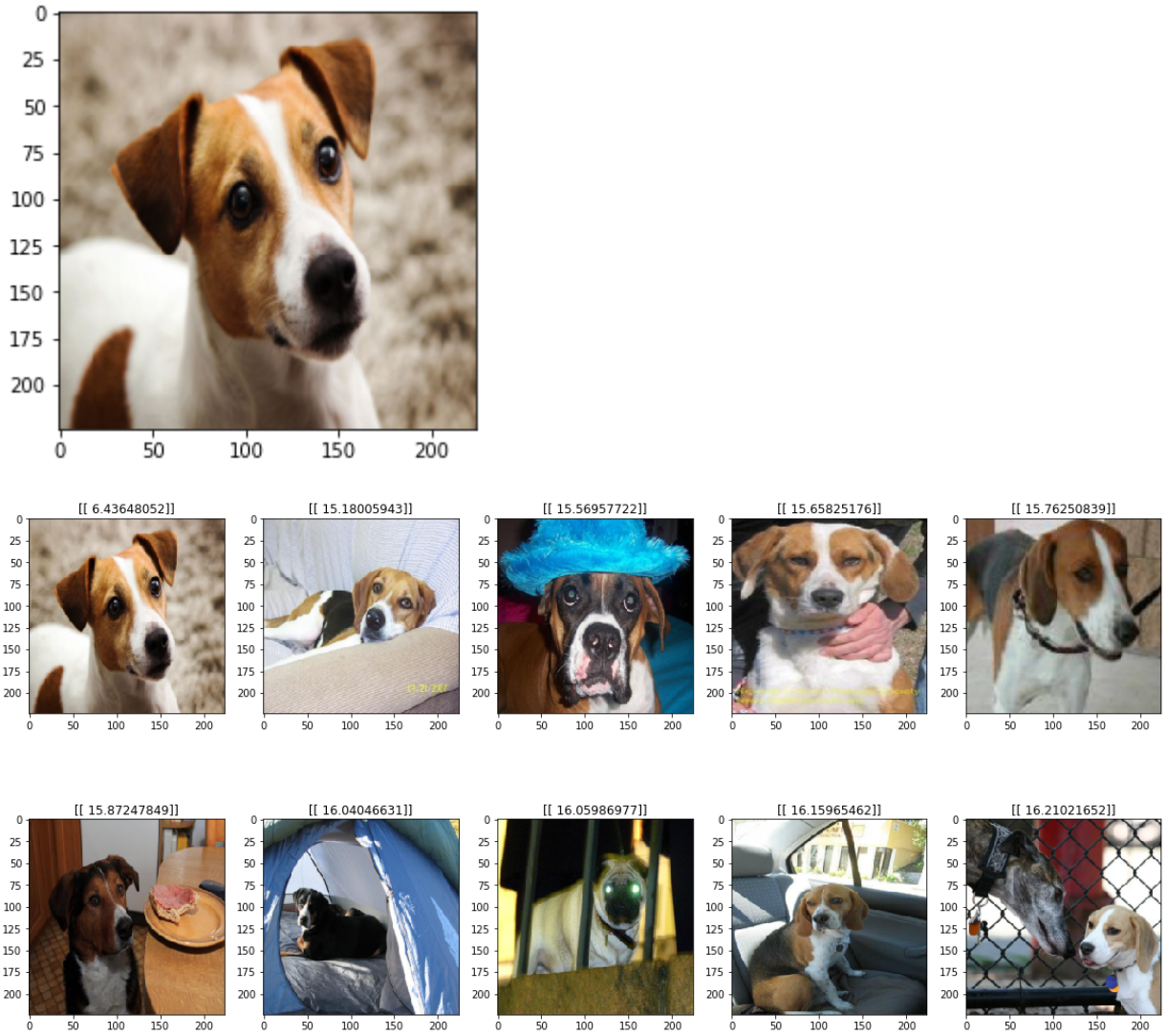


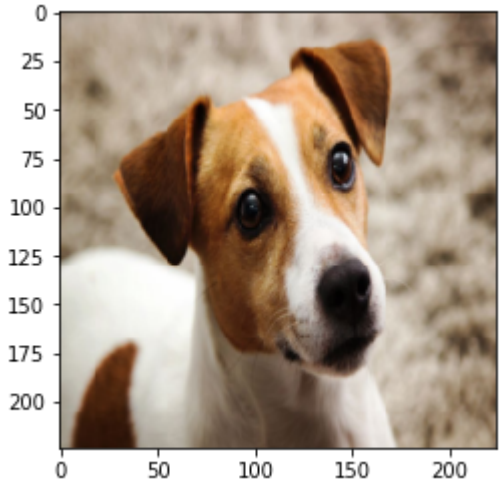


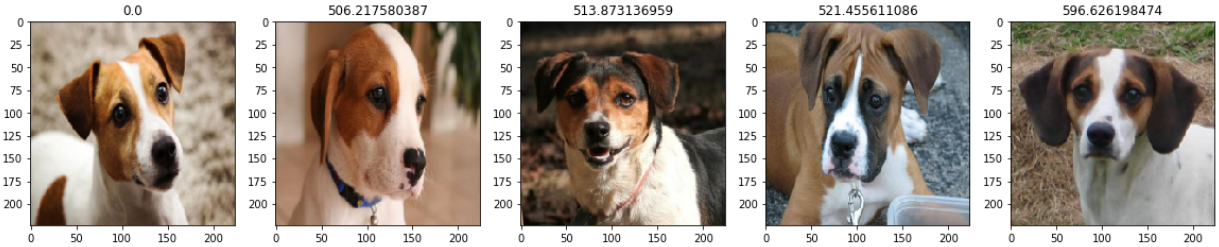

186.909691608
203.310581038
213.663373454
213.957913485
215.969017821

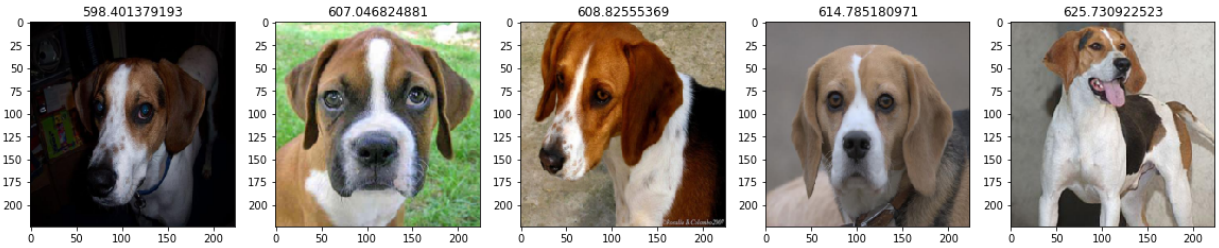

216.946238897
217.384846625
219.211339364
225.264254443
230.06131874

In [41]:
```
#image doesnt exist in indexes that were trained on
#retrieving from freshly appended indexes

query_index = index_query('test_images/kukkur.jpg', cnn_model)
results = find_query(query_index, indexes, 10)
plot_results(results)

query_index = index_query('test_images/kukkur.jpg', cnn_model)
results_l2 = find_query_l2(query_index, indexes, 10)
plot_results(results_l2)
```

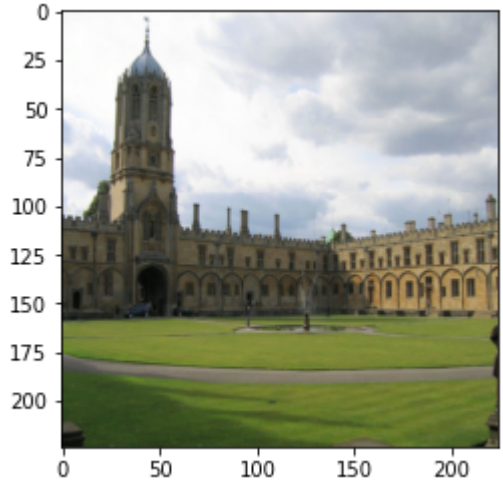


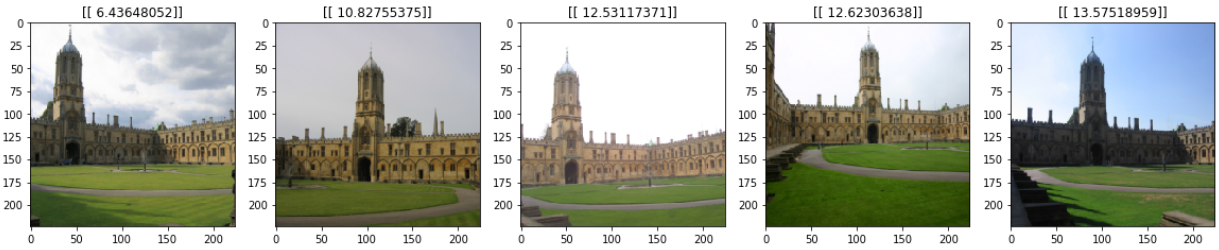


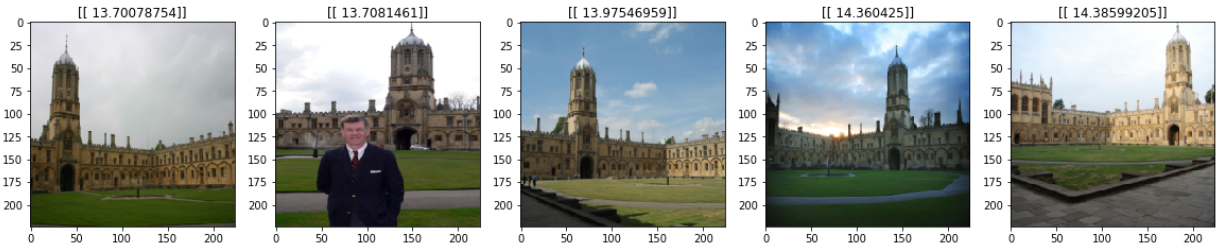

0.0
506.217580387
513.873136959
521.455611086
596.626198474

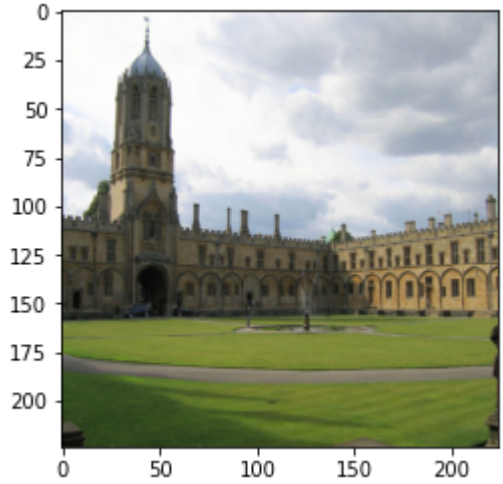

598.401379193
607.046824881
608.82555369
614.785180971
625.730922523

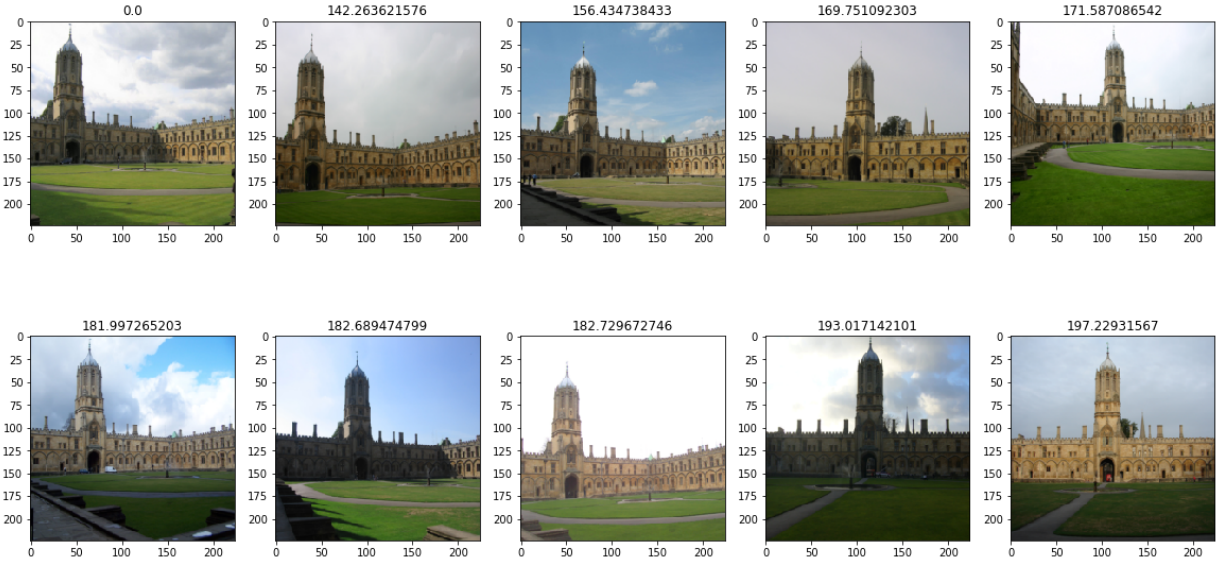
In [43]:
```
query_index = index_query('oxford_selected/Christ_Church/christ_church_000435.jpg
results = find_query(query_index, indexes, 10)
plot_results(results)

query_index = index_query('oxford_selected/Christ_Church/christ_church_000435.jpg
results_l2 = find_query_l2(query_index, indexes, 10)
plot_results(results_l2)
```









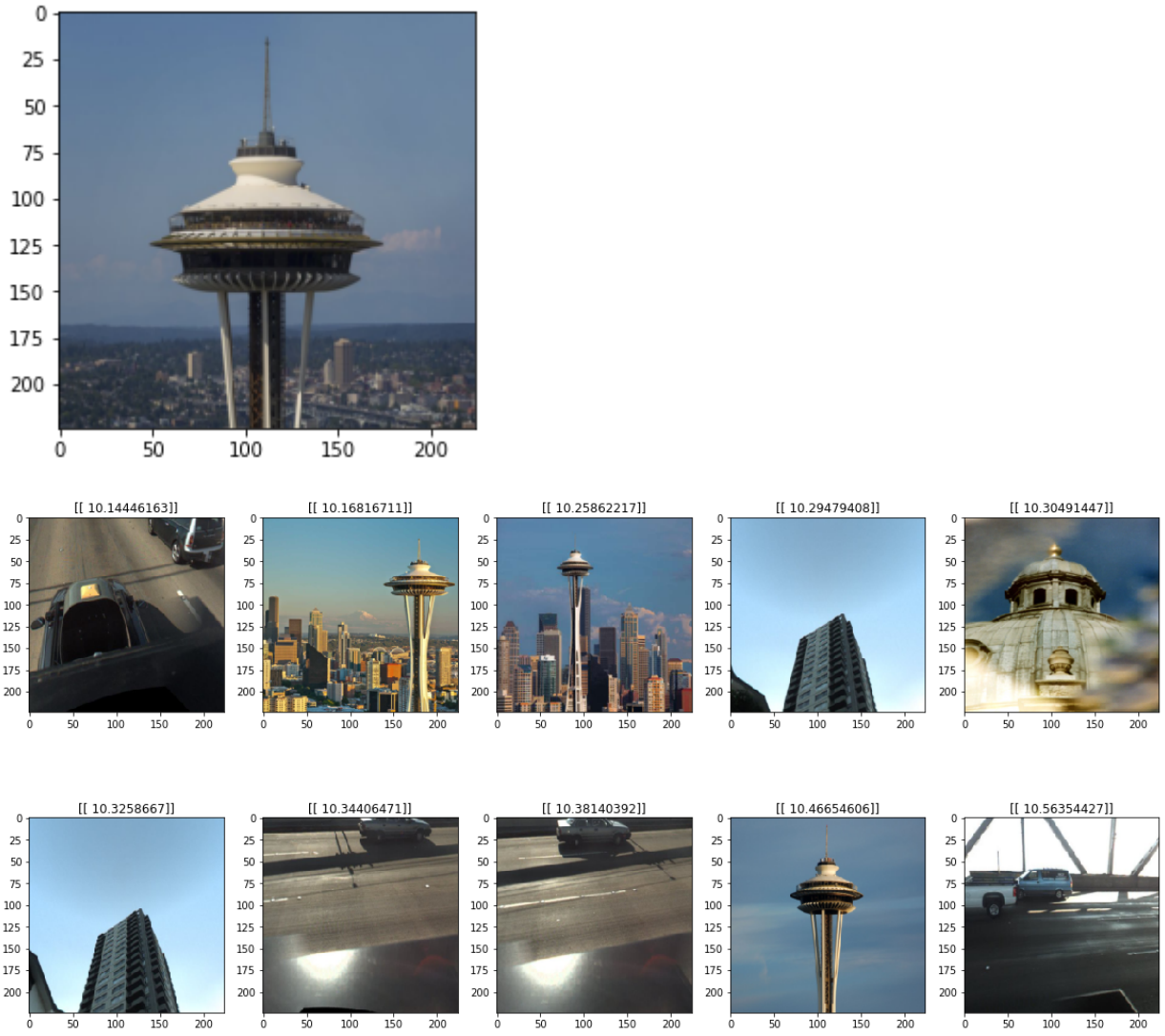


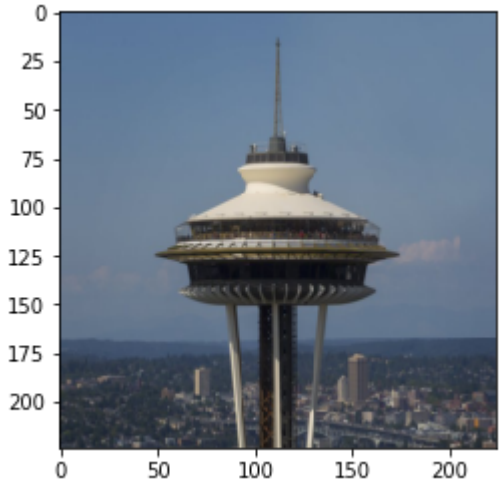
ALL THREE SPACE NEEDLE IMAGES ARE NOW BEING RETRIEVED BY THE NEURAL NETWORK MODEL

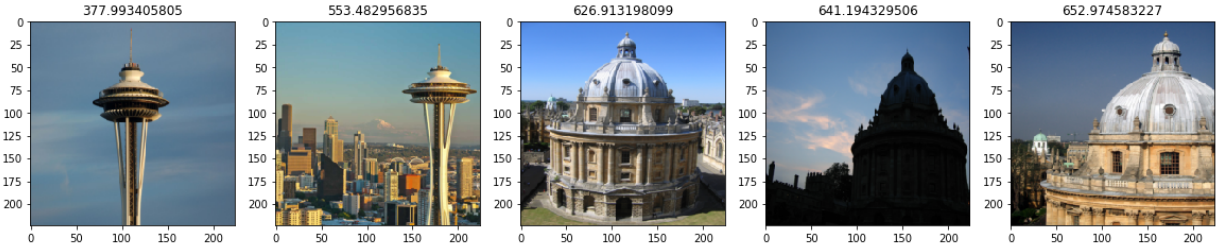
NOT TRUE FOR EUCLIDEAN SEARCH

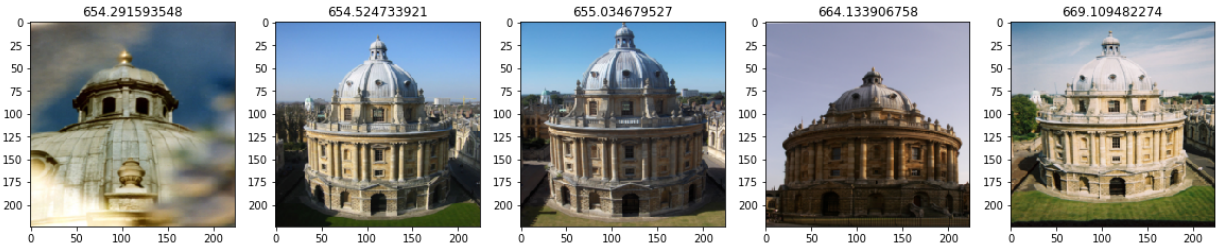
Also a similar search result as Euclidean here has also been retrieved by an earlier version of NEURAL NETWORK as demonstrated in one of the tests above

In [49]:
```
# EXACT image doesnt exist in indexes that were trained on
#retrieving from freshly appended indexes
# 3 out of 3 retrieved in top 10
query_index = index_query('test_images/space_needle_1.jpg', cnn_model)
results = find_query(query_index, indexes, 10)
plot_results(results)

query_index = index_query('test_images/space_needle_1.jpg', cnn_model)
results_l2 = find_query_l2(query_index, indexes, 10)
plot_results(results_l2)
```

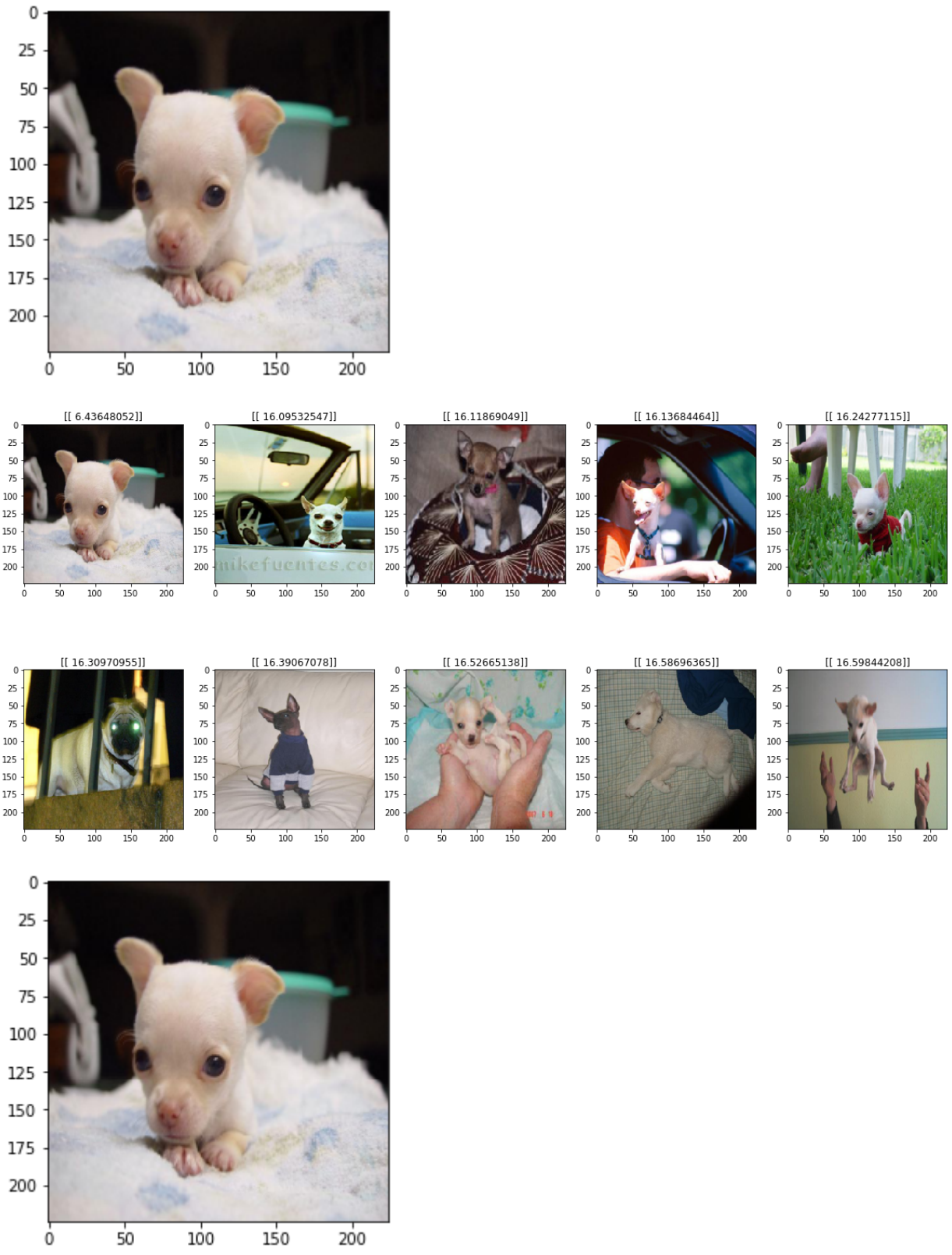


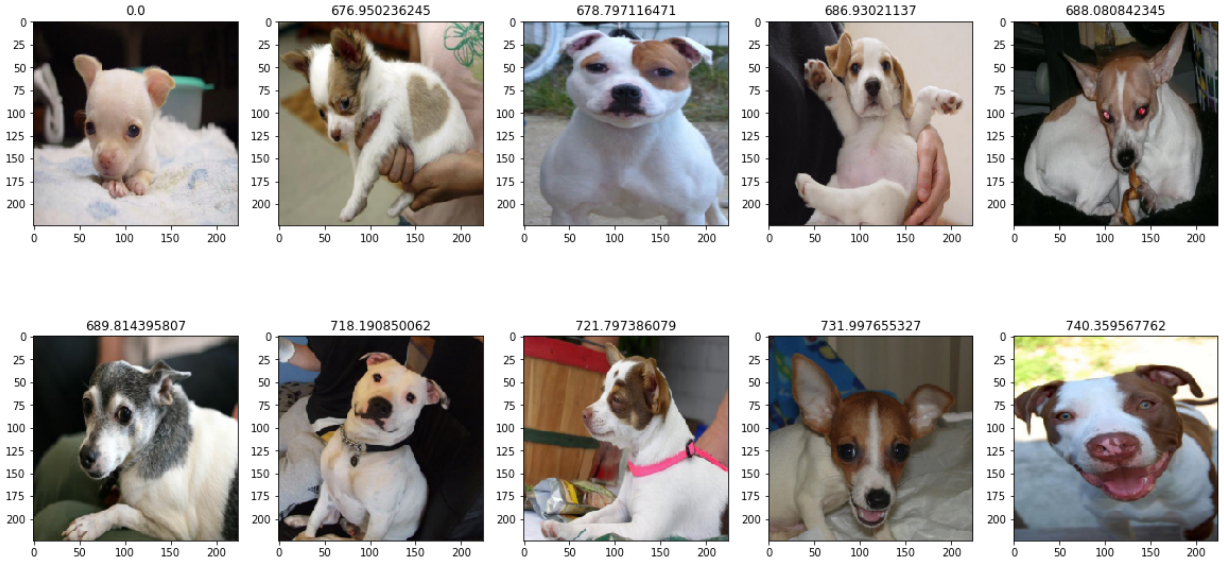



377.993405805
553.482956835
626.913198099
641.194329506
652.974583227


654.291593548
654.524733921
655.034679527
664.133906758
669.109482274

In [50]:
```
query_index = index_query('Dogs/n02085620-Chihuahua/n02085620_712.jpg', cnn_model
results = find_query(query_index, indexes, 10)
plot_results(results)

query_index = index_query('Dogs/n02085620-Chihuahua/n02085620_712.jpg', cnn_model
results_l2 = find_query_l2(query_index, indexes, 10)
plot_results(results_l2)
```





to interpret the above results I have printed the results below in text

NOTICE HOW ALL OF THE FIRST 5 IMAGES RETRIEVED FROM THE NEURAL NETWORK BELONG TO THE SAME CLASS "Chihuahua" AS THE QUERY IMAGE

THE NEURAL NETWORK RETRIEVES 7 IMAGES FROM THE SAME CLASS

EUCLIDEAN ONLY RETRIEVES 4

WITH A CLASS BASED EVALUATION SCHEME NEURAL NETWORK OUTPERFORMS EUCLIDEAN HERE TOO.

In [54]:
```
for res in results:
    print (res)
```

```
('Dogs/n02085620-Chihuahua/n02085620_712.jpg', array([[ 6.43648052]], dtype=flo
at32))
('Dogs/n02085620-Chihuahua/n02085620_12334.jpg', array([[ 16.09532547]], dtype=
float32))
('Dogs/n02085620-Chihuahua/n02085620_7292.jpg', array([[ 16.11869049]], dtype=f
loat32))
('Dogs/n02085620-Chihuahua/n02085620_4572.jpg', array([[ 16.13684464]], dtype=f
loat32))
('Dogs/n02085620-Chihuahua/n02085620_431.jpg', array([[ 16.24277115]], dtype=fl
oat32))
('Dogs/n02110958-pug/n02110958_6274.jpg', array([[ 16.30970955]], dtype=float3
2))
('Dogs/n02113978-Mexican_hairless/n02113978_143.jpg', array([[ 16.39067078]], d
type=float32))
('Dogs/n02085620-Chihuahua/n02085620_11337.jpg', array([[ 16.52665138]], dtype=
float32))
('Dogs/n02111500-Great_Pyrenees/n02111500_409.jpg', array([[ 16.58696365]], dty
pe=float32))
('Dogs/n02085620-Chihuahua/n02085620_10621.jpg', array([[ 16.59844208]], dtype=
float32))
```

In [52]:
```
for res in results_l2:
    print (res)
```

```
('Dogs/n02085620-Chihuahua/n02085620_712.jpg', 0.0)
('Dogs/n02085620-Chihuahua/n02085620_1346.jpg', 676.95023624452733)
('Dogs/n02093256-Staffordshire_bullterrier/n02093256_14608.jpg', 678.7971164712
1781)
('Dogs/n02088364-beagle/n02088364_17314.jpg', 686.93021137002393)
('Dogs/n02085620-Chihuahua/n02085620_1620.jpg', 688.08084234482544)
('Dogs/n02087046-toy_terrier/n02087046_3462.jpg', 689.81439580714493)
('Dogs/n02093256-Staffordshire_bullterrier/n02093256_2737.jpg', 718.19085006189
073)
('Dogs/n02085620-Chihuahua/n02085620_5312.jpg', 721.79738607890465)
('Dogs/n02087046-toy_terrier/n02087046_5386.jpg', 731.9976553271149)
('Dogs/n02093428-American_Staffordshire_terrier/n02093428_2199.jpg', 740.359567
7623772)
```

In [ ]:
```

```

END OF TESTS

FINAL NOTE: TO UPDATE THE NEURAL NETWORK I ALSO CHANGED THE GROUND TRUTHS OF THE TRAINING DATASET ....

.... TO A DIFFERENT SET OF PRIME NUMBERS IN THE FOLLOWING ORDER : 7, 11, 17, 37 AND 71

In [ ]: