In [1]:
```
pip install tensorflow
```

```
Requirement already satisfied: tensorflow in c:\programdata\anaconda3\lib\sit
e-packages (2.9.1)
Requirement already satisfied: h5py>=2.9.0 in c:\programdata\anaconda3\lib\si
te-packages (from tensorflow) (3.6.0)
Requirement already satisfied: keras<2.10.0,>=2.9.0rc0 in c:\programdata\anac
onda3\lib\site-packages (from tensorflow) (2.9.0)
Requirement already satisfied: six>=1.12.0 in c:\programdata\anaconda3\lib\si
te-packages (from tensorflow) (1.16.0)
Requirement already satisfied: absl-py>=1.0.0 in c:\programdata\anaconda3\lib
\site-packages (from tensorflow) (1.1.0)
Requirement already satisfied: google-pasta>=0.1.1 in c:\programdata\anaconda
3\lib\site-packages (from tensorflow) (0.2.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in c:\programdata\anaconda
3\lib\site-packages (from tensorflow) (1.42.0)
Requirement already satisfied: wrapt>=1.11.0 in c:\programdata\anaconda3\lib
\site-packages (from tensorflow) (1.12.1)
Requirement already satisfied: keras-preprocessing>=1.1.1 in c:\programdata\a
naconda3\lib\site-packages (from tensorflow) (1.1.2)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in c:\pro
gramdata\anaconda3\lib\site-packages (from tensorflow) (0.26.0)
Requirement already satisfied: packaging in c:\programdata\anaconda3\lib\site
-packages (from tensorflow) (21.3)
Requirement already satisfied: numpy>=1.20 in c:\programdata\anaconda3\lib\si
te-packages (from tensorflow) (1.21.5)
Requirement already satisfied: tensorboard<2.10,>=2.9 in c:\programdata\anaco
nda3\lib\site-packages (from tensorflow) (2.9.1)
Requirement already satisfied: setuptools in c:\programdata\anaconda3\lib\sit
e-packages (from tensorflow) (61.2.0)
Requirement already satisfied: flatbuffers<2,>=1.12 in c:\programdata\anacond
a3\lib\site-packages (from tensorflow) (1.12)
Requirement already satisfied: tensorflow-estimator<2.10.0,>=2.9.0rc0 in c:\p
rogramdata\anaconda3\lib\site-packages (from tensorflow) (2.9.0)
Requirement already satisfied: gast<=0.4.0,>=0.2.1 in c:\programdata\anaconda
3\lib\site-packages (from tensorflow) (0.4.0)
Requirement already satisfied: opt-einsum>=2.3.2 in c:\programdata\anaconda3
\lib\site-packages (from tensorflow) (3.3.0)
Requirement already satisfied: astunparse>=1.6.0 in c:\programdata\anaconda3
\lib\site-packages (from tensorflow) (1.6.3)
Requirement already satisfied: libclang>=13.0.0 in c:\programdata\anaconda3\l
ib\site-packages (from tensorflow) (14.0.1)
Requirement already satisfied: termcolor>=1.1.0 in c:\programdata\anaconda3\l
ib\site-packages (from tensorflow) (1.1.0)
Requirement already satisfied: protobuf<3.20,>=3.9.2 in c:\programdata\anacon
da3\lib\site-packages (from tensorflow) (3.19.1)
Requirement already satisfied: typing-extensions>=3.6.6 in c:\programdata\ana
conda3\lib\site-packages (from tensorflow) (4.1.1)
Requirement already satisfied: wheel<1.0,>=0.23.0 in c:\programdata\anaconda3
\lib\site-packages (from astunparse>=1.6.0->tensorflow) (0.37.1)
Requirement already satisfied: google-auth<3,>=1.6.3 in c:\programdata\anacon
da3\lib\site-packages (from tensorboard<2.10,>=2.9->tensorflow) (1.33.0)
Requirement already satisfied: markdown>=2.6.8 in c:\programdata\anaconda3\li
b\site-packages (from tensorboard<2.10,>=2.9->tensorflow) (3.3.4)
Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in c:\program
data\anaconda3\lib\site-packages (from tensorboard<2.10,>=2.9->tensorflow)
(0.4.6)
```

```
Requirement already satisfied: werkzeug>=1.0.1 in c:\programdata\anaconda3\li
b\site-packages (from tensorboard<2.10,>=2.9->tensorflow) (2.0.3)
Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in c:\programdat
a\anaconda3\lib\site-packages (from tensorboard<2.10,>=2.9->tensorflow) (1.8.
1)
Requirement already satisfied: requests<3,>=2.21.0 in c:\programdata\anaconda
3\lib\site-packages (from tensorboard<2.10,>=2.9->tensorflow) (2.27.1)
Requirement already satisfied: tensorboard-data-server<0.7.0,>=0.6.0 in c:\pr
ogramdata\anaconda3\lib\site-packages (from tensorboard<2.10,>=2.9->tensorflo
w) (0.6.1)
Requirement already satisfied: pyasn1-modules>=0.2.1 in c:\programdata\anacon
da3\lib\site-packages (from google-auth<3,>=1.6.3->tensorboard<2.10,>=2.9->te
nsorflow) (0.2.8)
Requirement already satisfied: rsa<5,>=3.1.4 in c:\programdata\anaconda3\lib
\site-packages (from google-auth<3,>=1.6.3->tensorboard<2.10,>=2.9->tensorflo
w) (4.7.2)
Requirement already satisfied: cachetools<5.0,>=2.0.0 in c:\programdata\anaco
nda3\lib\site-packages (from google-auth<3,>=1.6.3->tensorboard<2.10,>=2.9->t
ensorflow) (4.2.2)
Requirement already satisfied: requests-oauthlib>=0.7.0 in c:\programdata\ana
conda3\lib\site-packages (from google-auth-oauthlib<0.5,>=0.4.1->tensorboard<
2.10,>=2.9->tensorflow) (1.3.1)
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in c:\programdata\anacond
a3\lib\site-packages (from pyasn1-modules>=0.2.1->google-auth<3,>=1.6.3->tens
orboard<2.10,>=2.9->tensorflow) (0.4.8)
Requirement already satisfied: charset-normalizer~=2.0.0 in c:\programdata\an
aconda3\lib\site-packages (from requests<3,>=2.21.0->tensorboard<2.10,>=2.9->
tensorflow) (2.0.4)
Requirement already satisfied: idna<4,>=2.5 in c:\programdata\anaconda3\lib\s
ite-packages (from requests<3,>=2.21.0->tensorboard<2.10,>=2.9->tensorflow)
(3.3)
Requirement already satisfied: urllib3<1.27,>=1.21.1 in c:\programdata\anacon
da3\lib\site-packages (from requests<3,>=2.21.0->tensorboard<2.10,>=2.9->tens
orflow) (1.26.9)
Requirement already satisfied: certifi>=2017.4.17 in c:\programdata\anaconda3
\lib\site-packages (from requests<3,>=2.21.0->tensorboard<2.10,>=2.9->tensorf
low) (2021.10.8)
Requirement already satisfied: oauthlib>=3.0.0 in c:\programdata\anaconda3\li
b\site-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib<0.5,>=0.
4.1->tensorboard<2.10,>=2.9->tensorflow) (3.2.0)
Requirement already satisfied: pyparsing!=3.0.5,>=2.0.2 in c:\programdata\ana
conda3\lib\site-packages (from packaging->tensorflow) (3.0.4)
Note: you may need to restart the kernel to use updated packages.
```

In [2]:
```
pip install sklearn
```

```
Requirement already satisfied: sklearn in c:\programdata\anaconda3\lib\site-pac
kages (0.0)
Requirement already satisfied: scikit-learn in c:\programdata\anaconda3\lib\sit
e-packages (from sklearn) (1.0.2)
Note: you may need to restart the kernel to use updated packages.
Requirement already satisfied: threadpoolctl>=2.0.0 in c:\programdata\anaconda3
\lib\site-packages (from scikit-learn->sklearn) (2.2.0)
Requirement already satisfied: joblib>=0.11 in c:\programdata\anaconda3\lib\sit
e-packages (from scikit-learn->sklearn) (1.1.0)
Requirement already satisfied: numpy>=1.14.6 in c:\programdata\anaconda3\lib\si
te-packages (from scikit-learn->sklearn) (1.21.5)
Requirement already satisfied: scipy>=1.1.0 in c:\programdata\anaconda3\lib\sit
e-packages (from scikit-learn->sklearn) (1.7.3)
```

In [3]:
```
pip install matplotlib
```

```
Requirement already satisfied: matplotlib in c:\programdata\anaconda3\lib\site-
packages (3.5.1)
Requirement already satisfied: cycler>=0.10 in c:\programdata\anaconda3\lib\sit
e-packages (from matplotlib) (0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in c:\programdata\anaconda3\li
b\site-packages (from matplotlib) (4.25.0)
Requirement already satisfied: pyparsing>=2.2.1 in c:\programdata\anaconda3\lib
\site-packages (from matplotlib) (3.0.4)
Requirement already satisfied: python-dateutil>=2.7 in c:\programdata\anaconda3
\lib\site-packages (from matplotlib) (2.8.2)
Requirement already satisfied: packaging>=20.0 in c:\programdata\anaconda3\lib
\site-packages (from matplotlib) (21.3)
Requirement already satisfied: numpy>=1.17 in c:\programdata\anaconda3\lib\site
-packages (from matplotlib) (1.21.5)
Requirement already satisfied: pillow>=6.2.0 in c:\programdata\anaconda3\lib\si
te-packages (from matplotlib) (9.0.1)
Requirement already satisfied: kiwisolver>=1.0.1 in c:\programdata\anaconda3\li
b\site-packages (from matplotlib) (1.3.2)
Requirement already satisfied: six>=1.5 in c:\programdata\anaconda3\lib\site-pa
ckages (from python-dateutil>=2.7->matplotlib) (1.16.0)
Note: you may need to restart the kernel to use updated packages.
```

In [4]:
```
pip install keras
```

```
Requirement already satisfied: keras in c:\programdata\anaconda3\lib\site-packa
ges (2.9.0)
Note: you may need to restart the kernel to use updated packages.
```

In [5]:
```
pip install seaborn
```

```
Requirement already satisfied: seaborn in c:\programdata\anaconda3\lib\site-pac
kages (0.11.2)
Requirement already satisfied: matplotlib>=2.2 in c:\programdata\anaconda3\lib
\site-packages (from seaborn) (3.5.1)
Requirement already satisfied: scipy>=1.0 in c:\programdata\anaconda3\lib\site-
packages (from seaborn) (1.7.3)
Requirement already satisfied: pandas>=0.23 in c:\programdata\anaconda3\lib\sit
e-packages (from seaborn) (1.4.2)
Requirement already satisfied: numpy>=1.15 in c:\programdata\anaconda3\lib\site
-packages (from seaborn) (1.21.5)
Requirement already satisfied: kiwisolver>=1.0.1 in c:\programdata\anaconda3\li
b\site-packages (from matplotlib>=2.2->seaborn) (1.3.2)
Requirement already satisfied: cycler>=0.10 in c:\programdata\anaconda3\lib\sit
e-packages (from matplotlib>=2.2->seaborn) (0.11.0)
Requirement already satisfied: packaging>=20.0 in c:\programdata\anaconda3\lib
\site-packages (from matplotlib>=2.2->seaborn) (21.3)
Requirement already satisfied: pyparsing>=2.2.1 in c:\programdata\anaconda3\lib
\site-packages (from matplotlib>=2.2->seaborn) (3.0.4)
Requirement already satisfied: pillow>=6.2.0 in c:\programdata\anaconda3\lib\si
te-packages (from matplotlib>=2.2->seaborn) (9.0.1)
Requirement already satisfied: python-dateutil>=2.7 in c:\programdata\anaconda3
\lib\site-packages (from matplotlib>=2.2->seaborn) (2.8.2)
Requirement already satisfied: fonttools>=4.22.0 in c:\programdata\anaconda3\li
b\site-packages (from matplotlib>=2.2->seaborn) (4.25.0)
Requirement already satisfied: pytz>=2020.1 in c:\programdata\anaconda3\lib\sit
e-packages (from pandas>=0.23->seaborn) (2021.3)
Requirement already satisfied: six>=1.5 in c:\programdata\anaconda3\lib\site-pa
ckages (from python-dateutil>=2.7->matplotlib>=2.2->seaborn) (1.16.0)
Note: you may need to restart the kernel to use updated packages.
```

In [6]:
```
pip install pydotplus
```

```
Requirement already satisfied: pydotplus in c:\programdata\anaconda3\lib\site-p
ackages (2.0.2)
Requirement already satisfied: pyparsing>=2.0.1 in c:\programdata\anaconda3\lib
\site-packages (from pydotplus) (3.0.4)
Note: you may need to restart the kernel to use updated packages.
```

In [7]:

```
import matplotlib.pyplot as plt
from PIL import Image
import seaborn as sns
import numpy as np
import pandas as pd
import os
from tensorflow.keras.utils import to_categorical
from glob import glob


from sklearn.model_selection import train_test_split
import keras
from keras.models import Sequential
from keras.layers import Dense, Dropout
import tensorflow as tf
from sklearn.preprocessing import StandardScaler
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score, confusion_matrix, classification_repo
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import ReduceLROnPlateau
from tensorflow.keras import layers
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten

from sklearn.metrics import confusion_matrix
import itertools
import matplotlib.pyplot as plt

import warnings
warnings.filterwarnings("ignore")
```

In [8]:

```
df = pd.read_csv('skinCancer/abstract_metadata.csv')
df.head(10)
```

Out[8]:

	lesion_id	image_id	dx	dx_type	age	sex	localization
0	HAM_0000673	ISIC_0029659	akiec	histo	70	female	face
1	HAM_0005282	ISIC_0025178	akiec	histo	65	male	lower extremity
2	HAM_0006002	ISIC_0029915	akiec	histo	50	female	face
3	HAM_0000549	ISIC_0029360	akiec	histo	70	male	upper extremity
4	HAM_0000549	ISIC_0026152	akiec	histo	70	male	upper extremity
5	HAM_0006875	ISIC_0026575	akiec	histo	80	male	face
6	HAM_0006875	ISIC_0030586	akiec	histo	80	male	face
7	HAM_0002644	ISIC_0029417	akiec	histo	80	female	neck
8	HAM_0005282	ISIC_0028730	akiec	histo	65	male	lower extremity
9	HAM_0006898	ISIC_0029041	akiec	histo	80	male	scalp

In [9]:

```
df.isnull().sum()
```

Out[9]:

```
lesion_id       0
image_id        0
dx              0
dx_type         0
age             0
sex             0
localization    0
dtype: int64
```

In [10]:

```
df.count()
```

Out[10]:

```
lesion_id       700
image_id        700
dx              700
dx_type         700
age             700
sex             700
localization    700
dtype: int64
```

In [11]:

```
df['age'].fillna(int(df['age'].mean()),inplace=True)
df.isnull().sum()
```

Out[11]:

```
lesion_id       0
image_id        0
dx              0
dx_type         0
age             0
sex             0
localization    0
dtype: int64
```

In [12]:

```
lesion_type_dict = {
    'nv': 'Melanocytic nevi',
    'mel': 'Melanoma',
    'bkl': 'Benign keratosis-like lesions ',
    'bcc': 'Basal cell carcinoma',
    'akiec': 'Actinic keratoses',
    'vasc': 'Vascular lesions',
    'df': 'Dermatofibroma'
}
base_skin_dir = 'skinCancer'

imageid_path_dict = {os.path.splitext(os.path.basename(x))[0]: x
                     for x in glob(os.path.join(base_skin_dir, '*', '*.jpg'))}
```

In [13]:
```
df['path'] = df['image_id'].map(imageid_path_dict.get)
df['cell_type'] = df['dx'].map(lesion_type_dict.get)
df['cell_type_idx'] = pd.Categorical(df['cell_type']).codes
df.head()
```

Out[13]:

	lesion_id	image_id	dx	dx_type	age	sex	localization	
0	HAM_0000673	ISIC_0029659	akiec	histo	70	female	face	skinCancer\HAM10000_imag
1	HAM_0005282	ISIC_0025178	akiec	histo	65	male	lower extremity	skinCancer\HAM10000_imag
2	HAM_0006002	ISIC_0029915	akiec	histo	50	female	face	skinCancer\HAM10000_imag
3	HAM_0000549	ISIC_0029360	akiec	histo	70	male	upper extremity	skinCancer\HAM10000_imag
4	HAM_0000549	ISIC_0026152	akiec	histo	70	male	upper extremity	skinCancer\HAM10000_imag

In [14]:
```
df['image'] = df['path'].map(lambda x: np.asarray(Image.open(x).resize((125,100))
```

In [15]:

```
plt.figure(figsize=(20,10))
plt.subplots_adjust(left=0.125, bottom=1, right=0.9, top=2, hspace=0.2)
plt.subplot(2,4,1)
plt.title("AGE",fontsize=15)
plt.ylabel("Count")
df['age'].value_counts().plot.bar()

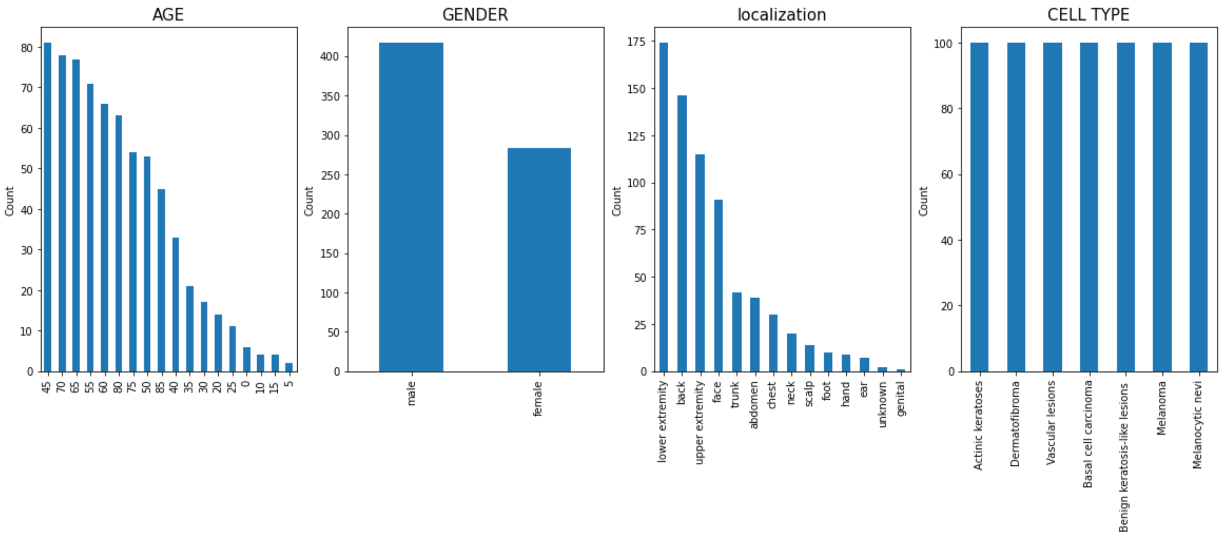
plt.subplot(2,4,2)
plt.title("GENDER",fontsize=15)
plt.ylabel("Count")
df['sex'].value_counts().plot.bar()

plt.subplot(2,4,3)
plt.title("localization",fontsize=15)
plt.ylabel("Count")
plt.xticks(rotation=45)
df['localization'].value_counts().plot.bar()

plt.subplot(2,4,4)
plt.title("CELL TYPE",fontsize=15)
plt.ylabel("Count")
df['cell_type'].value_counts().plot.bar()
```

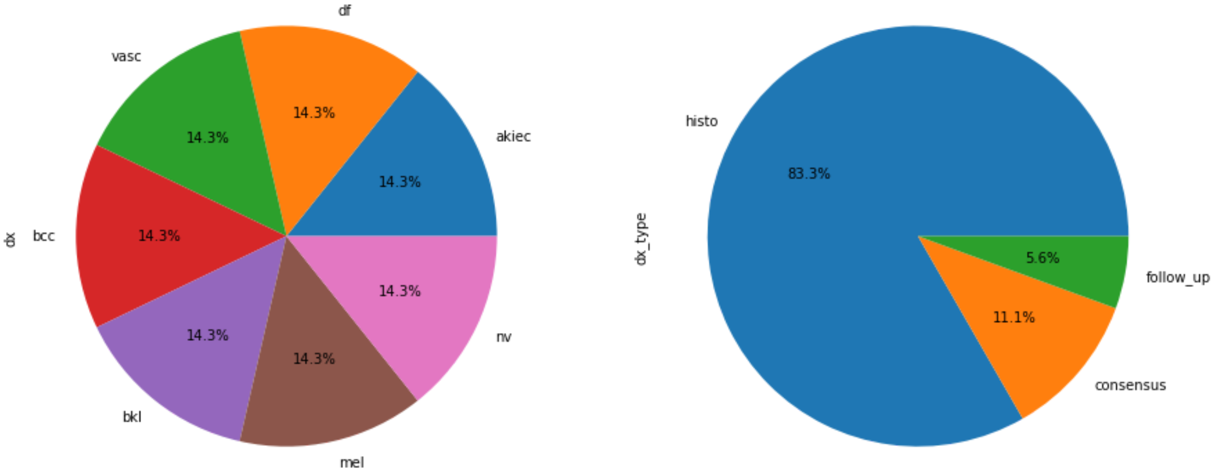
Out[15]:

```
<AxesSubplot:title={'center':'CELL TYPE'}, ylabel='Count'>
```



In [16]:

```
plt.figure(figsize=(15,10))
plt.subplot(1,2,1)
df['dx'].value_counts().plot.pie(autopct="%1.1f%%")
plt.subplot(1,2,2)
df['dx_type'].value_counts().plot.pie(autopct="%1.1f%%")
plt.show()
```



In [17]:

```
features=df.drop(columns=['cell_type_idx','image_id'],axis=1)
target=df['cell_type_idx']
features.head()
```

Out[17]:

	lesion_id	dx	dx_type	age	sex	localization	
0	HAM_0000673	akiec	histo	70	female	face	skinCancer\HAM10000_images_part_2\ISIC_
1	HAM_0005282	akiec	histo	65	male	lower extremity	skinCancer\HAM10000_images_part_1\ISIC_
2	HAM_0006002	akiec	histo	50	female	face	skinCancer\HAM10000_images_part_2\ISIC_
3	HAM_0000549	akiec	histo	70	male	upper extremity	skinCancer\HAM10000_images_part_2\ISIC_
4	HAM_0000549	akiec	histo	70	male	upper extremity	skinCancer\HAM10000_images_part_1\ISIC_

In [18]:
```
x_train_o, x_test_o, y_train_o, y_test_o = train_test_split(features, target, tes
tf.unique(x_train_o.cell_type.values)
```

Out[18]:
```
Unique(y=<tf.Tensor: shape=(7,), dtype=string, numpy=
array([b'Melanoma', b'Benign keratosis-like lesions ',
       b'Melanocytic nevi', b'Actinic keratoses', b'Dermatofibroma',
       b'Basal cell carcinoma', b'Vascular lesions'], dtype=object)>, idx=<tf.T
ensor: shape=(525,), dtype=int32, numpy=
array([0, 1, 0, 0, 0, 2, 3, 4, 0, 0, 1, 0, 3, 1, 2, 3, 5, 3, 2, 1, 4, 3,
       3, 1, 6, 0, 1, 4, 4, 0, 2, 6, 6, 0, 3, 5, 4, 2, 4, 6, 6, 2, 6, 3,
       1, 6, 2, 4, 3, 2, 5, 4, 1, 5, 1, 6, 2, 5, 3, 2, 5, 0, 0, 0, 4, 6,
       4, 4, 1, 4, 0, 2, 0, 0, 3, 5, 6, 6, 3, 5, 3, 3, 0, 0, 1, 1, 1, 6,
       5, 2, 3, 5, 3, 1, 4, 3, 0, 1, 5, 5, 0, 0, 6, 5, 3, 4, 0, 4, 4, 6,
       6, 4, 3, 4, 0, 5, 6, 1, 2, 5, 2, 3, 5, 4, 5, 0, 0, 2, 2, 3, 0, 6,
       4, 2, 3, 2, 5, 2, 1, 1, 6, 3, 0, 5, 0, 5, 2, 6, 6, 2, 6, 2, 2, 6,
       6, 1, 0, 2, 4, 2, 6, 1, 6, 4, 6, 2, 5, 1, 3, 2, 3, 3, 1, 5, 3, 3,
       4, 0, 2, 3, 5, 5, 1, 3, 3, 5, 4, 6, 0, 6, 3, 5, 6, 4, 0, 2, 2, 1,
       2, 6, 2, 4, 3, 1, 1, 5, 2, 0, 5, 6, 3, 4, 0, 5, 5, 3, 5, 2, 1, 3,
       6, 6, 2, 1, 6, 0, 1, 1, 4, 2, 6, 0, 6, 4, 1, 1, 5, 6, 6, 1, 0, 0,
       6, 4, 4, 4, 2, 1, 2, 2, 1, 6, 4, 0, 4, 3, 0, 1, 6, 5, 2, 5, 6, 0,
       1, 5, 6, 4, 3, 6, 6, 1, 2, 6, 5, 0, 4, 0, 2, 3, 3, 4, 6, 4, 6, 3,
       0, 4, 1, 0, 5, 0, 2, 5, 5, 2, 4, 2, 5, 2, 0, 6, 2, 0, 5, 1, 2, 5,
       1, 6, 2, 0, 3, 1, 4, 1, 2, 0, 4, 0, 6, 5, 6, 1, 1, 2, 0, 0, 5, 0,
       2, 3, 2, 1, 2, 0, 1, 2, 4, 5, 1, 4, 1, 2, 5, 2, 0, 4, 2, 2, 5, 4,
       5, 1, 4, 2, 1, 4, 1, 3, 0, 5, 6, 3, 4, 4, 6, 3, 3, 3, 4, 1, 4, 2,
       5, 5, 0, 6, 6, 0, 6, 4, 4, 2, 5, 1, 1, 4, 0, 5, 4, 3, 1, 1, 3, 5,
       6, 3, 6, 1, 0, 4, 5, 5, 2, 3, 3, 6, 0, 5, 2, 4, 6, 0, 1, 5, 3, 2,
       0, 2, 5, 0, 3, 1, 5, 4, 4, 6, 0, 3, 0, 6, 5, 1, 1, 5, 0, 3, 2, 5,
       0, 6, 0, 6, 6, 1, 5, 1, 1, 5, 4, 0, 5, 1, 0, 0, 5, 4, 3, 2, 6, 5,
       6, 4, 3, 3, 6, 5, 2, 4, 3, 3, 0, 4, 2, 3, 3, 2, 3, 5, 3, 0, 4, 2,
       6, 3, 6, 0, 3, 1, 2, 2, 4, 5, 2, 0, 6, 5, 3, 4, 4, 1, 2, 6, 4, 3,
       4, 6, 4, 6, 3, 1, 3, 1, 0, 4, 3, 0, 6, 3, 1, 1, 3, 1, 6])>)
```

In [19]:
```
x_train = np.asarray(x_train_o['image'].tolist())
x_test = np.asarray(x_test_o['image'].tolist())

x_train_mean = np.mean(x_train)
x_train_std = np.std(x_train)


x_test_mean = np.mean(x_test)
x_test_std = np.std(x_test)

x_train = (x_train - x_train_mean)/x_train_std
x_test = (x_test - x_test_mean)/x_test_std
```

In [20]:
```
# Perform one-hot encoding on the labels
y_train = to_categorical(y_train_o, num_classes = 7)
y_test = to_categorical(y_test_o, num_classes = 7)
y_test
```

Out[20]:
```
array([[0., 1., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 1.],
       [1., 0., 0., ..., 0., 0., 0.],
       ...,
       [0., 0., 0., ..., 1., 0., 0.],
       [0., 0., 0., ..., 0., 0., 1.],
       [0., 0., 0., ..., 0., 0., 1.]], dtype=float32)
```

In [21]:
```
y_test[1]
```

Out[21]:
```
array([0., 0., 0., 0., 0., 0., 1.], dtype=float32)
```

In [22]:
```
y_train
```

Out[22]:
```
array([[0., 0., 0., ..., 0., 1., 0.],
       [0., 0., 1., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 1., 0.],
       ...,
       [1., 0., 0., ..., 0., 0., 0.],
       [0., 0., 1., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 1.]], dtype=float32)
```

In [23]:
```
y_test_o.value_counts()
```

Out[23]:
```
1    28
2    27
3    27
0    25
4    24
6    23
5    21
Name: cell_type_idx, dtype: int64
```

In [24]:
```
# x_train, x_validate, y_train, y_validate = train_test_split(x_train, y_train, t


# Reshape image in 3 dimensions (height = 100, width = 125 , canal = 3)
x_train = x_train.reshape(x_train_o.shape[0], *(100, 125, 3))
x_test = x_test.reshape(x_test_o.shape[0], *(100, 125, 3))

```

In [25]:
```
x_train = x_train.reshape(x_train.shape[0],125*100*3)
x_test = x_test.reshape(x_test.shape[0],125*100*3)
print(x_train.shape)
print(x_test.shape)
```

```
(525, 37500)
(175, 37500)
```

In [26]:

```
print(x_train)
```

```
[[-0.09140732 -0.49162806 -0.46808566 ...  0.23818623 -0.02078013
   0.12047425]
 [ 0.07338946 -0.79767921 -0.09140732 ...  0.04984706 -0.44454326
   0.16755904]
 [-0.11494971 -0.44454326 -0.2091193  ...  0.02630467 -0.42100087
  -0.1855769 ]
 ...
 [ 1.22696689  0.23818623  0.70903416 ...  1.58010283 -0.1855769
   0.54423739]
 [-0.13849211 -0.70350962 -0.65642483 ... -0.32683128 -0.72705202
  -0.75059442]
 [ 1.60364523  0.61486458  0.70903416 ...  1.55656044  0.77966135
   0.77966135]]
```

Decision Tree

In [27]:
```
depth = range(1,51,5)
testing_accuracy = []
training_accuracy = []
score = 0

for i in depth:
    tree = DecisionTreeClassifier(max_depth = i, criterion = 'entropy')
    tree.fit(x_train, y_train)

    y_predict_train = tree.predict(x_train)
    training_accuracy.append(accuracy_score(y_train, y_predict_train))

    y_predict_test = tree.predict(x_test)
    acc_score = accuracy_score(y_test,y_predict_test)
    testing_accuracy.append(acc_score)

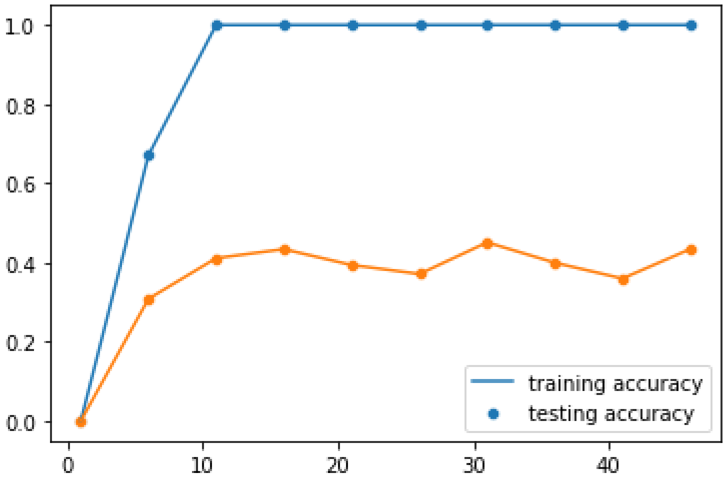
    print(i)

    if score < acc_score:
        score = acc_score
        best_depth = i

sns.lineplot(depth, training_accuracy)
sns.scatterplot(depth, training_accuracy)
sns.lineplot(depth, testing_accuracy)
sns.scatterplot(depth, testing_accuracy)
plt.legend(['training accuracy', 'testing accuracy'])
```

```
1
6
11
16
21
26
31
36
41
46
```

Out[27]:
```
<matplotlib.legend.Legend at 0x176832bef40>
```



In [28]:
```
print('This is the best depth for Decision Tree Classifier: ', best_depth, '\nAcc
result = confusion_matrix(y_test.argmax(axis=1), y_predict_test.argmax(axis=1),)
print("Confusion Matrix:","\n", result)
report = classification_report(y_test.argmax(axis=1), y_predict_test.argmax(axis=
print("Classification Report:" , "\n", report)
```

```
This is the best depth for Decision Tree Classifier:  31
Accuracy score is:  0.4514285714285714
Confusion Matrix:
 [[15  3  0  1  2  2  2]
 [ 4  9  1  7  2  3  2]
 [ 0  1 14  3  1  5  3]
 [ 6  4  2 10  2  1  2]
 [ 3  6  1  2  7  2  3]
 [ 1  2  3  2  2 11  0]
 [ 1  2  3  2  2  3 10]]
Classification Report:
               precision    recall  f1-score   support

           0       0.50      0.60      0.55        25
           1       0.33      0.32      0.33        28
           2       0.58      0.52      0.55        27
           3       0.37      0.37      0.37        27
           4       0.39      0.29      0.33        24
           5       0.41      0.52      0.46        21
           6       0.45      0.43      0.44        23

    accuracy                           0.43       175
   macro avg       0.43      0.44      0.43       175
weighted avg       0.43      0.43      0.43       175
```

Random Forest

In [29]:
```
#random Forest
depth = range(5,51,5)
testing_accuracy = []
training_accuracy = []
score = 0

for i in depth:
    tree = RandomForestClassifier(max_depth = i, criterion = 'gini', random_state
    tree.fit(x_train, y_train)

    y_predict_train = tree.predict(x_train)
    training_accuracy.append(accuracy_score(y_train, y_predict_train))

    y_predict_test = tree.predict(x_test)
    acc_score = accuracy_score(y_test,y_predict_test)
    testing_accuracy.append(acc_score)

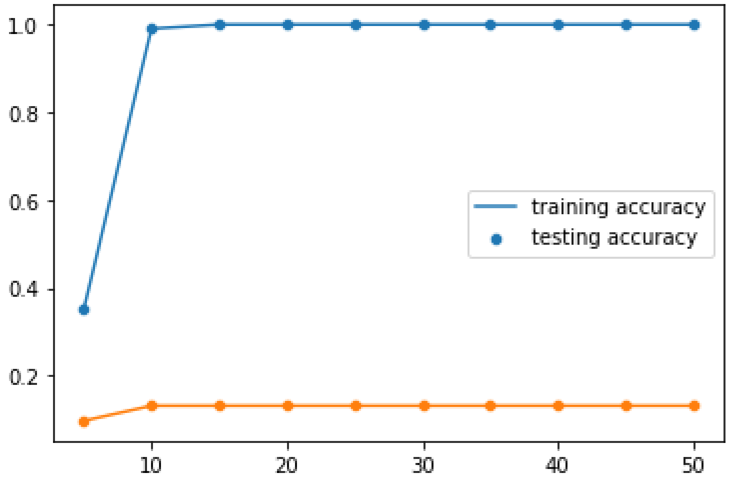
    print(i)

    if score < acc_score:
        score = acc_score
        best_depth = i

sns.lineplot(depth, training_accuracy)
sns.scatterplot(depth, training_accuracy)
sns.lineplot(depth, testing_accuracy)
sns.scatterplot(depth, testing_accuracy)
plt.legend(['training accuracy', 'testing accuracy'])
```

```
5
10
15
20
25
30
35
40
45
50
```

Out[29]:
```
<matplotlib.legend.Legend at 0x1768335cc10>
```



```
In [30]: print('This is the best depth for Decision Tree Classifier: ', best_depth, '\nAcc
         result = confusion_matrix(y_test.argmax(axis=1), y_predict_test.argmax(axis=1),)
         print("Confusion Matrix:","\n", result)
         report = classification_report(y_test.argmax(axis=1), y_predict_test.argmax(axis=
         print("Classification Report:" , "\n", report)
```

```
This is the best depth for Decision Tree Classifier:  10
Accuracy score is:  0.13142857142857142
Confusion Matrix:
 [[25  0  0  0  0  0  0]
 [25  2  0  0  1  0  0]
 [15  0  6  0  0  6  0]
 [26  0  0  1  0  0  0]
 [19  0  0  0  5  0  0]
 [15  0  2  0  0  4  0]
 [19  0  0  0  0  0  4]]
Classification Report:
               precision    recall  f1-score   support

           0       0.17      1.00      0.30        25
           1       1.00      0.07      0.13        28
           2       0.75      0.22      0.34        27
           3       1.00      0.04      0.07        27
           4       0.83      0.21      0.33        24
           5       0.40      0.19      0.26        21
           6       1.00      0.17      0.30        23

    accuracy                           0.27       175
   macro avg       0.74      0.27      0.25       175
weighted avg       0.75      0.27      0.24       175
```

KNN

In [31]:

```
k = range(1,500,2)
testing_accuracy = []
training_accuracy = []
score = 0

for i in k:
    knn = KNeighborsClassifier(n_neighbors = i)
    knn.fit(x_train, y_train)

    y_predict_train = knn.predict(x_train)
    training_accuracy.append(accuracy_score(y_train, y_predict_train))

    y_predict_test = knn.predict(x_test)
    acc_score = accuracy_score(y_test,y_predict_test)
    testing_accuracy.append(acc_score)

    print(i)

    if score < acc_score:
        score = acc_score
        best_k = i


sns.lineplot(k, training_accuracy)
sns.scatterplot(k, training_accuracy)
sns.lineplot(k, testing_accuracy)
sns.scatterplot(k, testing_accuracy)
plt.legend(['training accuracy', 'testing accuracy'])
```

```
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```

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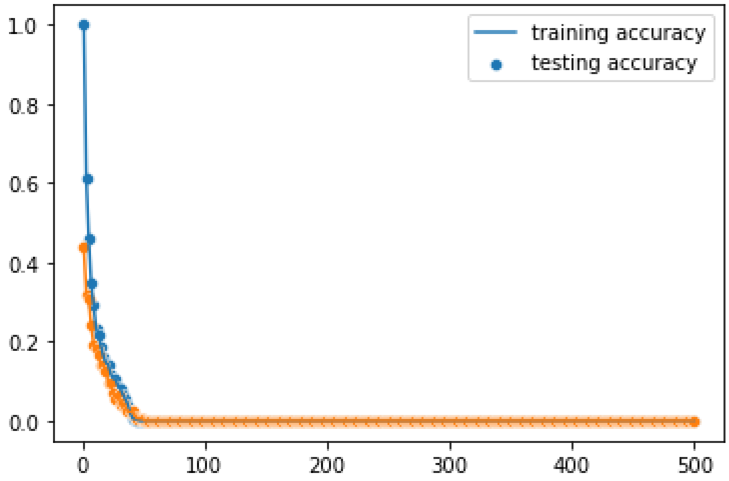
```

```
Out[31]: <matplotlib.legend.Legend at 0x176834059a0>
```



In [32]:
```
'''print('This is the best depth for Decision Tree Classifier: ', best_depth, '\n
result = confusion_matrix(y_test.argmax(axis=1), y_predict_test.argmax(axis=1),)
print("Confusion Matrix:","\n", result)
report = classification_report(y_test.argmax(axis=1), y_predict_test.argmax(axis=
print("Classification Report:" , "\n", report)
```

```
Confusion Matrix:
 [[25  0  0  0  0  0  0]
 [28  0  0  0  0  0  0]
 [27  0  0  0  0  0  0]
 [27  0  0  0  0  0  0]
 [24  0  0  0  0  0  0]
 [21  0  0  0  0  0  0]
 [23  0  0  0  0  0  0]]
Classification Report:
               precision    recall  f1-score   support

           0       0.14      1.00      0.25        25
           1       0.00      0.00      0.00        28
           2       0.00      0.00      0.00        27
           3       0.00      0.00      0.00        27
           4       0.00      0.00      0.00        24
           5       0.00      0.00      0.00        21
           6       0.00      0.00      0.00        23

    accuracy                           0.14       175
   macro avg       0.02      0.14      0.04       175
weighted avg       0.02      0.14      0.04       175
```

In [33]:
```
x_train = x_train.reshape(x_train_o.shape[0], *(100, 125, 3))
x_test = x_test.reshape(x_test_o.shape[0], *(100, 125, 3))
x_train.shape
```

Out[33]:
```
(525, 100, 125, 3)
```

MLP

In [36]:
```
x_train = x_train.reshape(x_train.shape[0],125*100*3)
x_test = x_test.reshape(x_test.shape[0],125*100*3)

# define the keras model
model = Sequential()

model.add(Dense(units= 128, kernel_initializer = 'uniform', activation = 'relu',
model.add(Dense(units= 256, kernel_initializer = 'uniform', activation = 'relu'))
model.add(Dense(units= 512, kernel_initializer = 'uniform', activation = 'relu'))
model.add(Dense(units= 64, kernel_initializer = 'uniform', activation = 'relu'))
model.add(Dense(units = 7, kernel_initializer = 'uniform', activation = 'softmax'
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_5 (Dense)             (None, 128)               4800128

 dense_6 (Dense)             (None, 256)               33024

 dense_7 (Dense)             (None, 512)               131584

 dense_8 (Dense)             (None, 64)                32832

 dense_9 (Dense)             (None, 7)                 455

=================================================================
Total params: 4,998,023
Trainable params: 4,998,023
Non-trainable params: 0
_________________________________________________________________
```

In [37]:
```
# compile the keras model
model.compile(optimizer = "Adam", loss = 'categorical_crossentropy', metrics = ['

# fit the keras model on the dataset
history = model.fit(x_train, y_train, batch_size = 500, epochs = 25)
```

```
Epoch 1/25
2/2 [==============================] - 1s 29ms/step - loss: 1.9491 - accuracy:
0.1257
Epoch 2/25
2/2 [==============================] - 0s 13ms/step - loss: 1.8978 - accuracy:
0.1905
Epoch 3/25
2/2 [==============================] - 0s 13ms/step - loss: 1.7399 - accuracy:
0.3390
Epoch 4/25
2/2 [==============================] - 0s 13ms/step - loss: 1.6039 - accuracy:
0.3562
Epoch 5/25
2/2 [==============================] - 0s 12ms/step - loss: 1.4988 - accuracy:
0.3524
Epoch 6/25
2/2 [==============================] - 0s 15ms/step - loss: 1.4950 - accuracy:
0.3657
Epoch 7/25
2/2 [==============================] - 0s 13ms/step - loss: 1.3831 - accuracy:
0.4000
Epoch 8/25
2/2 [==============================] - 0s 12ms/step - loss: 1.3151 - accuracy:
0.4495
Epoch 9/25
2/2 [==============================] - 0s 14ms/step - loss: 1.3002 - accuracy:
0.4705
Epoch 10/25
2/2 [==============================] - 0s 14ms/step - loss: 1.2552 - accuracy:
0.4933
Epoch 11/25
2/2 [==============================] - 0s 13ms/step - loss: 1.3706 - accuracy:
0.4324
Epoch 12/25
2/2 [==============================] - 0s 14ms/step - loss: 1.2265 - accuracy:
0.4990
Epoch 13/25
2/2 [==============================] - 0s 13ms/step - loss: 1.1778 - accuracy:
0.5029
Epoch 14/25
2/2 [==============================] - 0s 14ms/step - loss: 1.1279 - accuracy:
0.5467
Epoch 15/25
2/2 [==============================] - 0s 14ms/step - loss: 1.1085 - accuracy:
0.5410
Epoch 16/25
2/2 [==============================] - 0s 13ms/step - loss: 1.0667 - accuracy:
0.5581
Epoch 17/25
2/2 [==============================] - 0s 14ms/step - loss: 1.0408 - accuracy:
0.5733
```

```
Epoch 18/25
2/2 [==============================] - 0s 13ms/step - loss: 1.0052 - accuracy:
0.5676
Epoch 19/25
2/2 [==============================] - 0s 13ms/step - loss: 0.9885 - accuracy:
0.5981
Epoch 20/25
2/2 [==============================] - 0s 13ms/step - loss: 0.9567 - accuracy:
0.5943
Epoch 21/25
2/2 [==============================] - 0s 13ms/step - loss: 0.9513 - accuracy:
0.6210
Epoch 22/25
2/2 [==============================] - 0s 13ms/step - loss: 0.9449 - accuracy:
0.6000
Epoch 23/25
2/2 [==============================] - 0s 14ms/step - loss: 1.0138 - accuracy:
0.5733
Epoch 24/25
2/2 [==============================] - 0s 13ms/step - loss: 0.9050 - accuracy:
0.6190
Epoch 25/25
2/2 [==============================] - 0s 13ms/step - loss: 0.8578 - accuracy:
0.6533
```

In [38]:

```
accuracy = model.evaluate(x_test, y_test, verbose=1)[1]
print("Test: accuracy = ",accuracy*100,"%")
```

```
6/6 [==============================] - 0s 5ms/step - loss: 1.7181 - accuracy:
0.3543
Test: accuracy =  35.428571701049805 %
```

CNN

In [39]:

```
x_train = x_train.reshape(x_train.shape[0], 125,100,3)
x_test = x_test.reshape(x_test.shape[0], 125, 100, 3)
print(x_train.shape)
print(x_test.shape)
```

```
(525, 125, 100, 3)
(175, 125, 100, 3)
```

In [40]:
```
input_shape = (125, 100, 3)
num_classes = 7

model = Sequential()
model.add(Conv2D(64, kernel_size=(3, 3),activation='relu',padding = 'Same',input_
model.add(Conv2D(64,kernel_size=(3, 3), activation='relu',padding = 'Same'))
model.add(MaxPooling2D(pool_size = (2, 2)))
model.add(Dropout(0.16))

model.add(Conv2D(128, (3, 3), activation='relu',padding = 'same'))
model.add(Conv2D(128, (3, 3), activation='relu',padding = 'Same'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.20))

model.add(Flatten())
model.add(Dense(512, activation='relu'))
model.add(Dense(256, activation='relu'))
model.add(Dropout(0.3))
model.add(Dense(num_classes, activation='softmax'))
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 125, 100, 64)      1792

 conv2d_1 (Conv2D)           (None, 125, 100, 64)      36928

 max_pooling2d (MaxPooling2D  (None, 62, 50, 64)       0
 )

 dropout (Dropout)           (None, 62, 50, 64)        0

 conv2d_2 (Conv2D)           (None, 62, 50, 128)       73856

 conv2d_3 (Conv2D)           (None, 62, 50, 128)       147584

 max_pooling2d_1 (MaxPooling  (None, 31, 25, 128)      0
 2D)

 dropout_1 (Dropout)         (None, 31, 25, 128)       0

 flatten (Flatten)           (None, 99200)             0

 dense_10 (Dense)            (None, 512)               50790912

 dense_11 (Dense)            (None, 256)               131328

 dropout_2 (Dropout)         (None, 256)               0

 dense_12 (Dense)            (None, 7)                 1799

=================================================================
Total params: 51,184,199
Trainable params: 51,184,199
```

```
Non-trainable params: 0
_________________________________________________________________
```

In [41]:

```
model.compile(optimizer= "Adam",
            loss='categorical_crossentropy',
            metrics=['accuracy'])

learning_rate_reduction = ReduceLROnPlateau(monitor='val_accuracy',
                                            patience=4,
                                            verbose=1,
                                            factor=0.5,
                                            min_lr=0.00001)
```

In [42]:

```
#x_train, x_validate, y_train, y_validate = train_test_split(x_train, y_train, te


# Reshape image in 3 dimensions (height = 100, width = 125 , canal = 3)
x_train = x_train.reshape(x_train.shape[0], *(125, 100, 3))
x_test = x_test.reshape(x_test.shape[0], *(125, 100, 3))
#x_validate = x_validate.reshape(x_validate.shape[0], *(100, 125, 3))

tf.config.run_functions_eagerly(True)


model.fit(x_train, y_train, batch_size = 500, epochs = 10)
```

```
Epoch 1/10
2/2 [==============================] - 23s 1s/step - loss: 2.8459 - accuracy:
0.1181
Epoch 2/10
2/2 [==============================] - 22s 1s/step - loss: 4.6677 - accuracy:
0.1619
Epoch 3/10
2/2 [==============================] - 22s 1s/step - loss: 2.0321 - accuracy:
0.2095
Epoch 4/10
2/2 [==============================] - 22s 1s/step - loss: 1.9045 - accuracy:
0.2305
Epoch 5/10
2/2 [==============================] - 22s 1s/step - loss: 1.9055 - accuracy:
0.2305
Epoch 6/10
2/2 [==============================] - 22s 1s/step - loss: 1.8571 - accuracy:
0.2438
Epoch 7/10
2/2 [==============================] - 22s 1s/step - loss: 1.8045 - accuracy:
0.2629
Epoch 8/10
2/2 [==============================] - 22s 1s/step - loss: 1.7417 - accuracy:
0.2705
Epoch 9/10
2/2 [==============================] - 22s 1s/step - loss: 1.7266 - accuracy:
0.2743
Epoch 10/10
2/2 [==============================] - 22s 1s/step - loss: 1.7334 - accuracy:
0.2514
```

Out[42]:

```
<keras.callbacks.History at 0x1768e234790>
```

In [43]:

```
test_loss, test_acc = model.evaluate(x_test, y_test)
print("Test Accuracy: ",test_acc*100,"%")
```

```
6/6 [==============================] - 2s 301ms/step - loss: 1.7346 - accuracy:
0.3029
Test Accuracy:  30.28571307659149 %
```

In [ ]:

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