Import Libraries:

In [1]:

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

In [17]:

```
import torch
import torchvision
import torch.nn as nn
from torch.utils.data import DataLoader
import torch.optim as optim
from torchvision import datasets, transforms
from matplotlib.pyplot import imshow, imsave
import matplotlib.pyplot as plt
import numpy as np
```

Model:

In [18]:

```
class ConvAE(nn.Module):
  def __init__(self):
    super(ConvAE, self).__init__()

    #Convolutional Encoder Layer structure based on:  http://richzhang.github.io/colorization/

                # note that there are 3 grayscale channels going into the AE, 3 color out
                # remember that stride 2 helps with image processing and removes need for pooling layer
    self.encoder = nn.Sequential(
                                                # total size: divide by 2 for each due to stride and kernel size
        nn.Conv2d(3, 64, 4, stride=2, padding=1, bias=False), #  64*256*256 dimensions (channels, height, width)
        nn.BatchNorm2d(64),
        nn.LeakyReLU(0.2),

        nn.Conv2d(64, 128, 4, stride=2, padding=1, bias=False), # 128*128*128 dimensions (channels, height, width)
        nn.BatchNorm2d(128),
        nn.LeakyReLU(0.2),

        nn.Conv2d(128, 256, 4, stride=2, padding=1, bias=False), # 256*64*64 dimensions (channels, height, width)
        nn.BatchNorm2d(256),
        nn.LeakyReLU(0.2),

        nn.Conv2d(256, 512, 3, stride=1, padding=1, bias=False), # 512*64*64 dimensions (channels, height, width)
        nn.BatchNorm2d(512),
        nn.LeakyReLU(0.2),

        nn.Conv2d(512, 512, 4, stride=2, padding=1, bias=False), # 512*32*32 dimensions (channels, height, width)
        nn.BatchNorm2d(512),
        nn.LeakyReLU(0.2),

    )
```

```
    self.decoder = nn.Sequential(

        nn.ConvTranspose2d(512, 512, 4, stride=2, padding=1, bias=False),
        nn.BatchNorm2d(512),
        nn.LeakyReLU(0.2),

        nn.ConvTranspose2d(512, 512, 4, stride=2, padding=1, bias=False),
        nn.BatchNorm2d(512),
        nn.LeakyReLU(0.2),

        nn.ConvTranspose2d(512, 256, 4, stride=2, padding=1, bias=False),
        nn.BatchNorm2d(256),
        nn.LeakyReLU(0.2),

        nn.ConvTranspose2d(256, 3, 4, stride=2, padding=1, bias=False),
        nn.BatchNorm2d(3),
    )

    # feeding shortcut through seems to reduce reconstruction cost for weight updates
    self.shortcut = nn.Sequential(nn.BatchNorm2d(3),)
    self.out = nn.Sequential(nn.Sigmoid()) # output is a sigmoid to produce a logistic sp
read of img data

  def forward(self, x):
    #encoded = self.encoder(x)
    #decoded = self.decoder(encoded)
    #out = self.out(decoded + self.shortcut(x))
    return self.out(self.decoder(self.encoder(x)) + self.shortcut(x))
```

Functions for Calling:

In [19]:

```
def transform(train_dir,test_dir):
  train_trans = transforms.Compose([
                                    transforms.ToTensor(),
#using gaussian blur with large kernel to keep it from leaning lines (and face features)
as much as color blurs to overlay. The residual part of the network should help with line
weights and the encoder will just focus on color weights
                                    transforms.RandomRotation(30),
                                    transforms.RandomHorizontalFlip(),
                                    transforms.GaussianBlur(kernel_size=7)
                                    ])

  test_trans = transforms.Compose([transforms.ToTensor()])

  train_data = datasets.ImageFolder(train_dir, transform=train_trans)
  test_data = datasets.ImageFolder(test_dir, transform=test_trans)
  return train_data,test_data

def fit_model(train_loader, test_loader, network, optimizer, criterion):
  network.train()
  for epoch in range(epochs):
    train_loss = 0
    test_loss = 0
    for data, target in train_loader:
      data, target = data.to(device), target.to(device)
      #gray = transforms.Grayscale(3)(data)
      logit = network(transforms.Grayscale(3)(data)) # grayscale input into network
      loss = criterion(logit, data) ## input gray training data and loss is against color
training data. This should update the weights in favor of coloring the grayscale images
      optimizer.zero_grad()
      loss.backward()
      optimizer.step()

      train_loss += loss.data

    scheduler.step()

    test_loss = 0
    network.eval()
```

```
    with torch.no_grad():
      for data, target in test_loader:
          data = data.to(device)
          #gray = transforms.Grayscale(3)(data)
          outputs = network(transforms.Grayscale(3)(data))
          loss = criterion(outputs, data) ## test loss needs to compare color and graysc
ale
          test_loss += loss.data

    #saves & prints intermitten images and values through training
    if (epoch == 0) or ((epoch+1) % 10 == 0):
        print(f"\ntrain epoch: {epoch+1}\ntrain loss: {train_loss/len(train_loader)}")
        print(f"test loss: {test_loss/len(test_loader)}")
        plot_image_reconstruction(network, img_loader, 1, {[0,epoch+1]})

def plot_image_reconstruction(network, imgs, img_num, idx):

     network.eval()
     for batch in imgs:

        img, _ = batch
        img = img.to(device)
        gray = transforms.Grayscale(3)(img)
        output = network(gray)

        output = output.view(output.size(0), 3, 512, 512).cpu().data
        plt.figure()
        f, axarr = plt.subplots(1,3)
        axarr[0].imshow(img.permute(0, 2, 3, 1).cpu()[img_num])
        axarr[1].imshow(gray.permute(0, 2, 3, 1).cpu()[img_num])
        axarr[2].imshow(output.permute(0, 2, 3, 1)[img_num])
        if idx[0] == 0: plt.title(f'Epoch number {idx[1]}')
        if idx[0] == 1: plt.title(f'Image Number {idx[1]}')
        break
```

Settings for Network:

In [20]:

```
train_dir = 'drive/MyDrive/face-HQ/train'
test_dir = 'drive/MyDrive/face-HQ/test'

## sample size 3000, train=2700, test=300
device = torch.device('cuda') ## not sure I need to use CPU at all but good to know ('cud
a' if torch.cuda.is_available() else 'cpu')
## small batch size due to only 1 input, 1 output and 3000 samples
batch_size = 1
learning_rate = 0.0001
epochs = 100

print_imgs =  16 ##sets up the print with images from test_loader data set (reloaded as i
mg_loader)

network = ConvAE().to(device)
optimizer = optim.Adam(network.parameters(),lr=learning_rate)
criterion = nn.MSELoss().to(device)    ## using MSE due to image reconstruction be about
finding regression, not classifying
# note: gamma is set to 0.5 to prevent too large of change in the learning rate
scheduler = torch.optim.lr_scheduler.MultiStepLR(optimizer, milestones=np.linspace(20,10
0, 8), gamma=0.5)


train_data,test_data = transform(train_dir, test_dir)
train_loader = torch.utils.data.DataLoader(train_data, batch_size = batch_size,shuffle=T
rue)
test_loader = torch.utils.data.DataLoader(test_data, batch_size = batch_size)
img_loader = torch.utils.data.DataLoader(test_data, batch_size = print_imgs)
```

Load: Note that model, functions and settings have to be activated before loading weights

In [21]:

```
network.load_state_dict(torch.load( 'drive/MyDrive/face-HQ/model_save/Colorize_ConvAE2'))
```

Out[21]:

```
<All keys matched successfully>
```

Save Model Weights

In [ ]:

```
torch.save(network.state_dict(), 'drive/MyDrive/face-HQ/model_save/Colorize_ConvAE2')
```

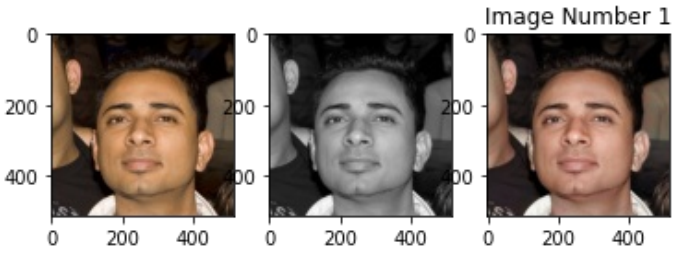
Print Test Images:

In [23]:

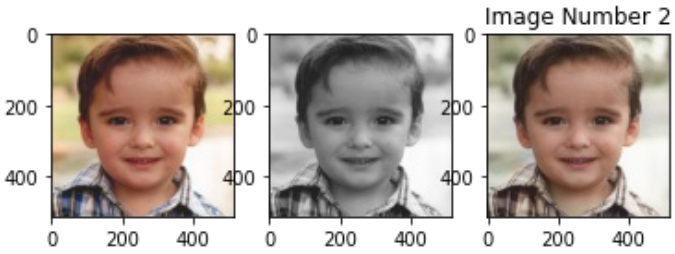
```
# note that the total photo limit is based on img_print size in 'settings'
for ii in range(print_imgs):
  plot_image_reconstruction(network, img_loader, img_num=ii, idx=[1,ii+1])
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:61: RuntimeWarning: More tha
n 20 figures have been opened. Figures created through the pyplot interface (`matplotlib.
pyplot.figure`) are retained until explicitly closed and may consume too much memory. (To
control this warning, see the rcParam `figure.max_open_warning`).
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:62: RuntimeWarning: More tha
n 20 figures have been opened. Figures created through the pyplot interface (`matplotlib.
pyplot.figure`) are retained until explicitly closed and may consume too much memory. (To
control this warning, see the rcParam `figure.max_open_warning`).
```

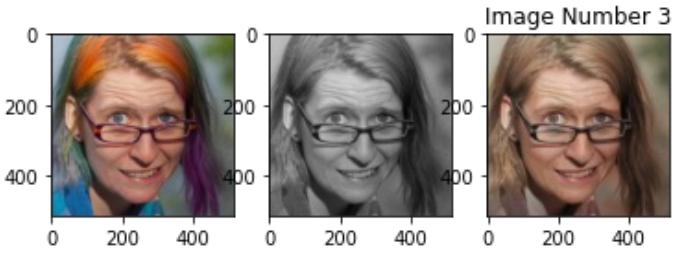
```
<Figure size 432x288 with 0 Axes>
```



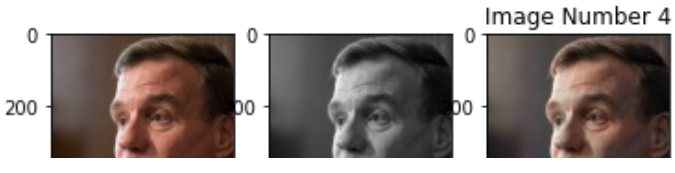

```
<Figure size 432x288 with 0 Axes>
```



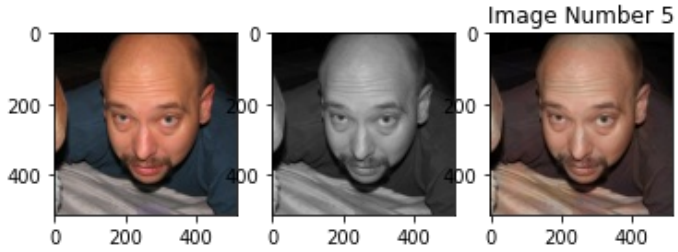

```
<Figure size 432x288 with 0 Axes>
```



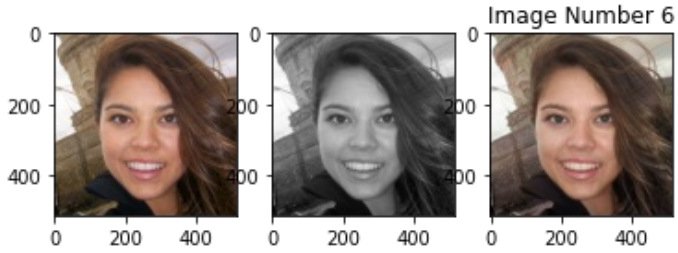

```
<Figure size 432x288 with 0 Axes>
```



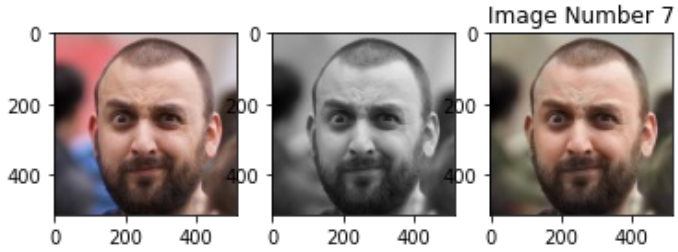
```
<Figure size 432x288 with 0 Axes>
```



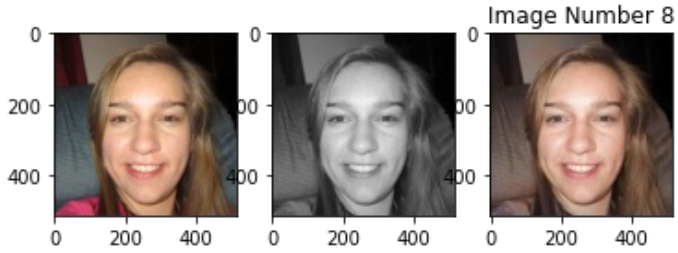

```
<Figure size 432x288 with 0 Axes>
```



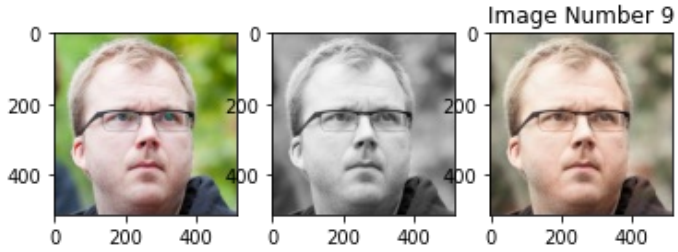

```
<Figure size 432x288 with 0 Axes>
```



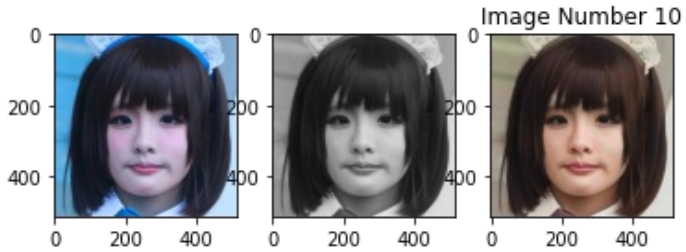

```
<Figure size 432x288 with 0 Axes>
```



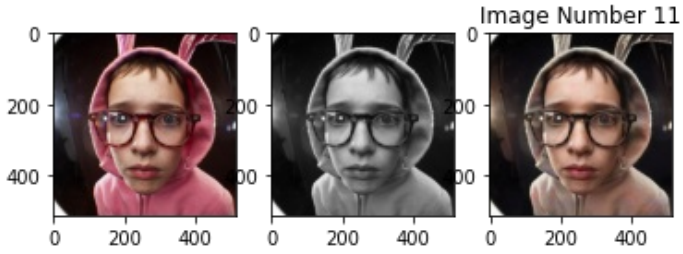

```
<Figure size 432x288 with 0 Axes>
```



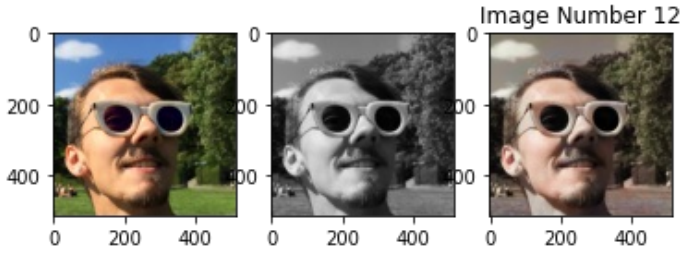

```
<Figure size 432x288 with 0 Axes>
```



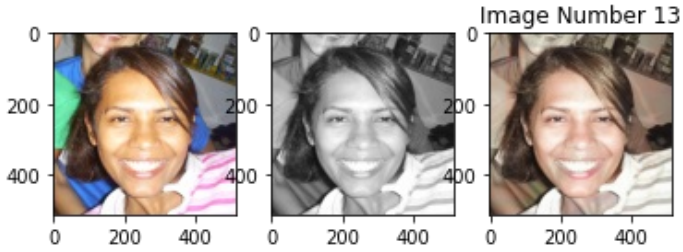

```
<Figure size 432x288 with 0 Axes>
```



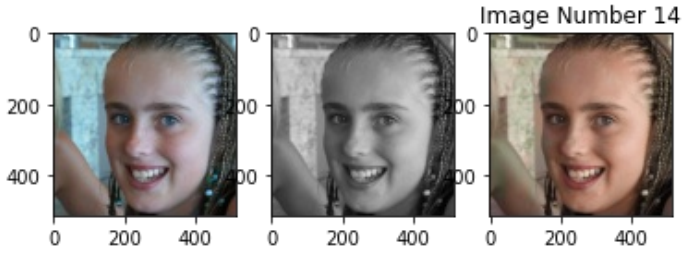

```
<Figure size 432x288 with 0 Axes>
```



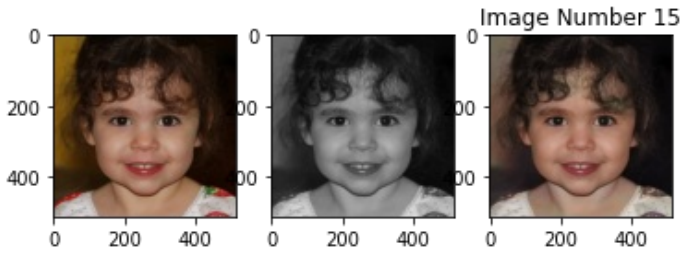

```
<Figure size 432x288 with 0 Axes>
```



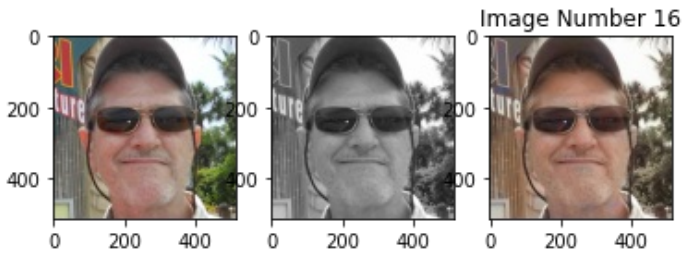

```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```



Train Model: Only run if making modifications. If modified, make sure to save for later use

In [ ]:

```
print(f"PRINT SETTINGS\nBATCH SIZE: {batch_size} \nLR: {learning_rate} \nCRITERION: {crit
```

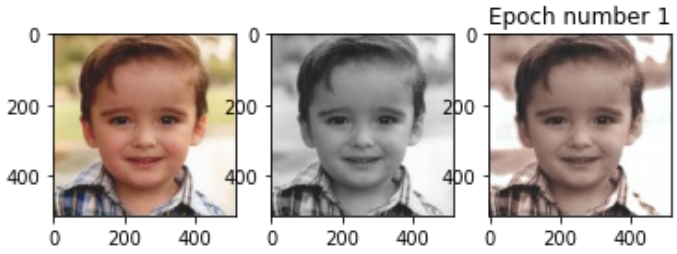
```
erion} \nOPTIMIZER: {optimizer} \nNETWORK: {network} ")
fit_model(train_loader, test_loader, network, optimizer, criterion)
```

```
PRINT SETTINGS
BATCH SIZE: 1
LR: 0.0001
CRITERION: MSELoss()
OPTIMIZER: Adam (
Parameter Group 0
    amsgrad: False
    betas: (0.9, 0.999)
    capturable: False
    eps: 1e-08
    foreach: None
    initial_lr: 0.0001
    lr: 0.0001
    maximize: False
    weight_decay: 0
)
NETWORK: ConvAE(
  (encoder): Sequential(
    (0): Conv2d(3, 64, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bias=False)
    (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): LeakyReLU(negative_slope=0.2)
    (3): Conv2d(64, 128, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bias=False)
    (4): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): LeakyReLU(negative_slope=0.2)
    (6): Conv2d(128, 256, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bias=False)
    (7): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (8): LeakyReLU(negative_slope=0.2)
    (9): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (10): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
)
    (11): LeakyReLU(negative_slope=0.2)
    (12): Conv2d(512, 512, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bias=False)
    (13): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
)
    (14): LeakyReLU(negative_slope=0.2)
  )
  (decoder): Sequential(
    (0): ConvTranspose2d(512, 512, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bia
s=False)
    (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): LeakyReLU(negative_slope=0.2)
    (3): ConvTranspose2d(512, 512, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bia
s=False)
    (4): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): LeakyReLU(negative_slope=0.2)
    (6): ConvTranspose2d(512, 256, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bia
s=False)
    (7): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (8): LeakyReLU(negative_slope=0.2)
    (9): ConvTranspose2d(256, 3, kernel_size=(4, 4), stride=(2, 2), padding=(1, 1), bias=
False)
    (10): BatchNorm2d(3, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  )
  (shortcut): Sequential(
    (0): BatchNorm2d(3, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  )
  (out): Sequential(
    (0): Sigmoid()
  )
)

train epoch: 1
train loss: 0.019855298101902008
test loss: 0.00868641585111618

train epoch: 12
train loss: 0.004712800495326519
test loss: 0.005733709782361984
```

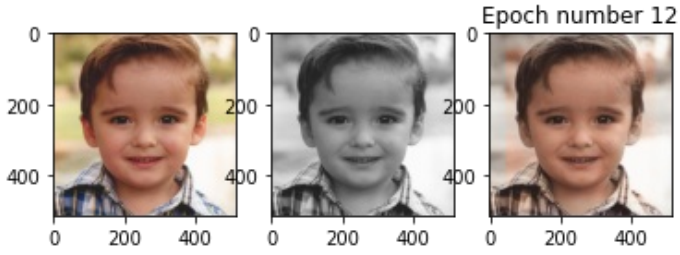
```
train epoch: 23
train loss: 0.0044458359479904175
test loss: 0.005444302689284086

train epoch: 34
train loss: 0.00438192393630743
test loss: 0.005383222829550505

train epoch: 45
train loss: 0.004330949392169714
test loss: 0.005324590485543013

train epoch: 56
train loss: 0.004271974321454763
test loss: 0.005320656578987837

train epoch: 67
train loss: 0.004273016005754471
test loss: 0.005329795181751251

---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
<ipython-input-69-9ba31f0ac46b> in <module>()
      1 print(f"PRINT SETTINGS\nBATCH SIZE: {batch_size} \nLR: {learning_rate} \nCRITERION: {criterion} \nOPTIMIZER: {optimizer} \nNETWORK: {network} ")
----> 2 fit_model(train_loader, test_loader, network, optimizer, criterion)

<ipython-input-67-0b648b46b091> in fit_model(train_loader, test_loader, network, optimizer, criterion)
     34     network.eval()
     35     with torch.no_grad():
---> 36       for data, target in test_loader:
     37           data = data.to(device)
     38           #gray = transforms.Grayscale(3)(data)

/usr/local/lib/python3.7/dist-packages/torch/utils/data/dataloader.py in __next__(self)
    650                 # TODO(https://github.com/pytorch/pytorch/issues/76750)
    651                 self._reset()  # type: ignore[call-arg]
--> 652             data = self._next_data()
    653             self._num_yielded += 1
    654             if self._dataset_kind == _DatasetKind.Iterable and \

/usr/local/lib/python3.7/dist-packages/torch/utils/data/dataloader.py in _next_data(self)
    690     def _next_data(self):
    691         index = self._next_index()  # may raise StopIteration
--> 692         data = self._dataset_fetcher.fetch(index)  # may raise StopIteration
    693         if self._pin_memory:
    694             data = _utils.pin_memory.pin_memory(data, self._pin_memory_device)

/usr/local/lib/python3.7/dist-packages/torch/utils/data/_utils/fetch.py in fetch(self, possibly_batched_index)
     47     def fetch(self, possibly_batched_index):
     48         if self.auto_collation:
---> 49             data = [self.dataset[idx] for idx in possibly_batched_index]
     50         else:
     51             data = self.dataset[possibly_batched_index]

/usr/local/lib/python3.7/dist-packages/torch/utils/data/_utils/fetch.py in <listcomp>(.0)
     47     def fetch(self, possibly_batched_index):
     48         if self.auto_collation:
---> 49             data = [self.dataset[idx] for idx in possibly_batched_index]
     50         else:
     51             data = self.dataset[possibly_batched_index]

/usr/local/lib/python3.7/dist-packages/torchvision/datasets/folder.py in __getitem__(self, index)
    228         """
    229         path, target = self.samples[index]
--> 230         sample = self.loader(path)
    231         if self.transform is not None:
    232             sample = self.transform(sample)

/usr/local/lib/python3.7/dist-packages/torchvision/datasets/folder.py in default_loader(p
```

```
/usr/local/lib/python3.7/dist-packages/torchvision/datasets/folder.py in default_loader(p
ath)
    267         return accimage_loader(path)
    268     else:
--> 269         return pil_loader(path)
    270
    271

/usr/local/lib/python3.7/dist-packages/torchvision/datasets/folder.py in pil_loader(path)
    247     with open(path, "rb") as f:
    248         img = Image.open(f)
--> 249         return img.convert("RGB")
    250
    251

/usr/local/lib/python3.7/dist-packages/PIL/Image.py in convert(self, mode, matrix, dither
, palette, colors)
    899         """
    900
--> 901         self.load()
    902
    903         if not mode and self.mode == "P":

/usr/local/lib/python3.7/dist-packages/PIL/ImageFile.py in load(self)
    249
    250                             b = b + s
--> 251                             n, err_code = decoder.decode(b)
    252                             if n < 0:
    253                                 break

KeyboardInterrupt:
```

```
<Figure size 432x288 with 0 Axes>
```




```
<Figure size 432x288 with 0 Axes>
```

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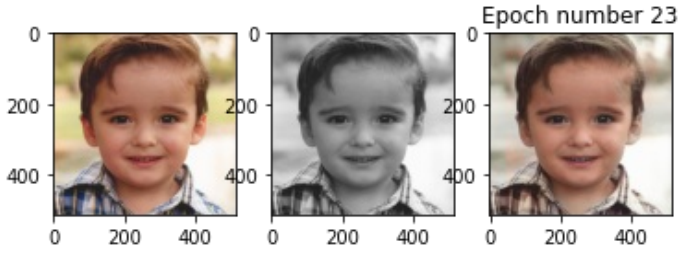


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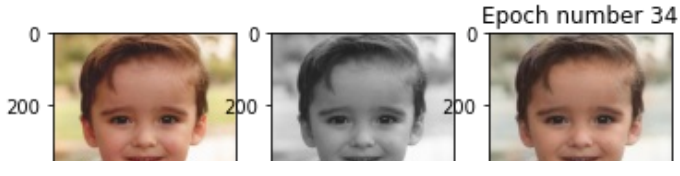

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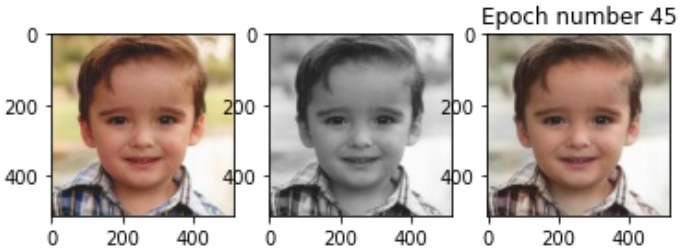


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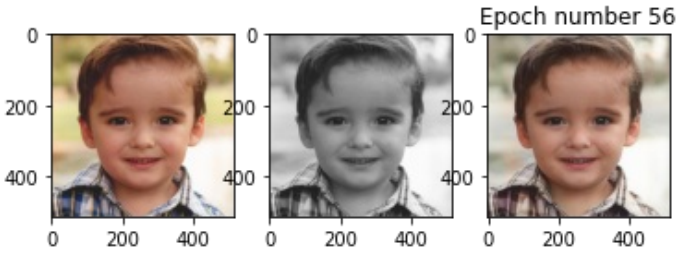


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