In [1]:

```
import pandas as pd

df=pd.read_csv('mnist.csv')
```

In [2]:

```
df.shape
```

Out[2]:

```
(60000, 785)
```

In [3]:

```
df.head()
```

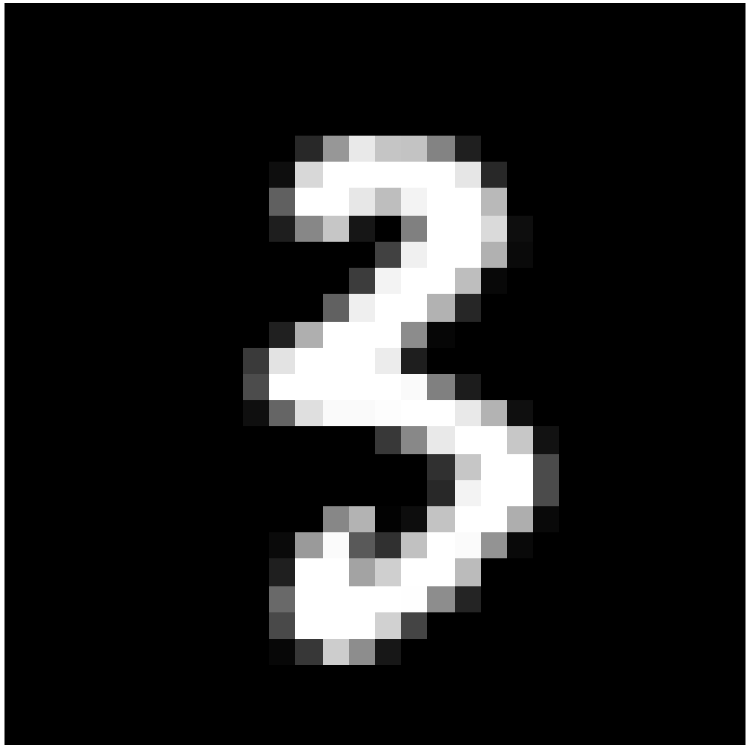
Out[3]:

	label	1x1	1x2	1x3	1x4	1x5	1x6	1x7	1x8	1x9	...	28x19	28x20	28x21	28x22	28x23	28x24	28x25	28x26	28x27	28x28
0	5	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
2	4	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
3	1	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
4	9	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0

5 rows × 785 columns

In [6]:

```
import matplotlib.pyplot as plt
img=df.iloc[45000,1:]

plt.imshow(img.values.reshape(28,28))
plt.gray()
plt.axis("off")
plt.show()
```

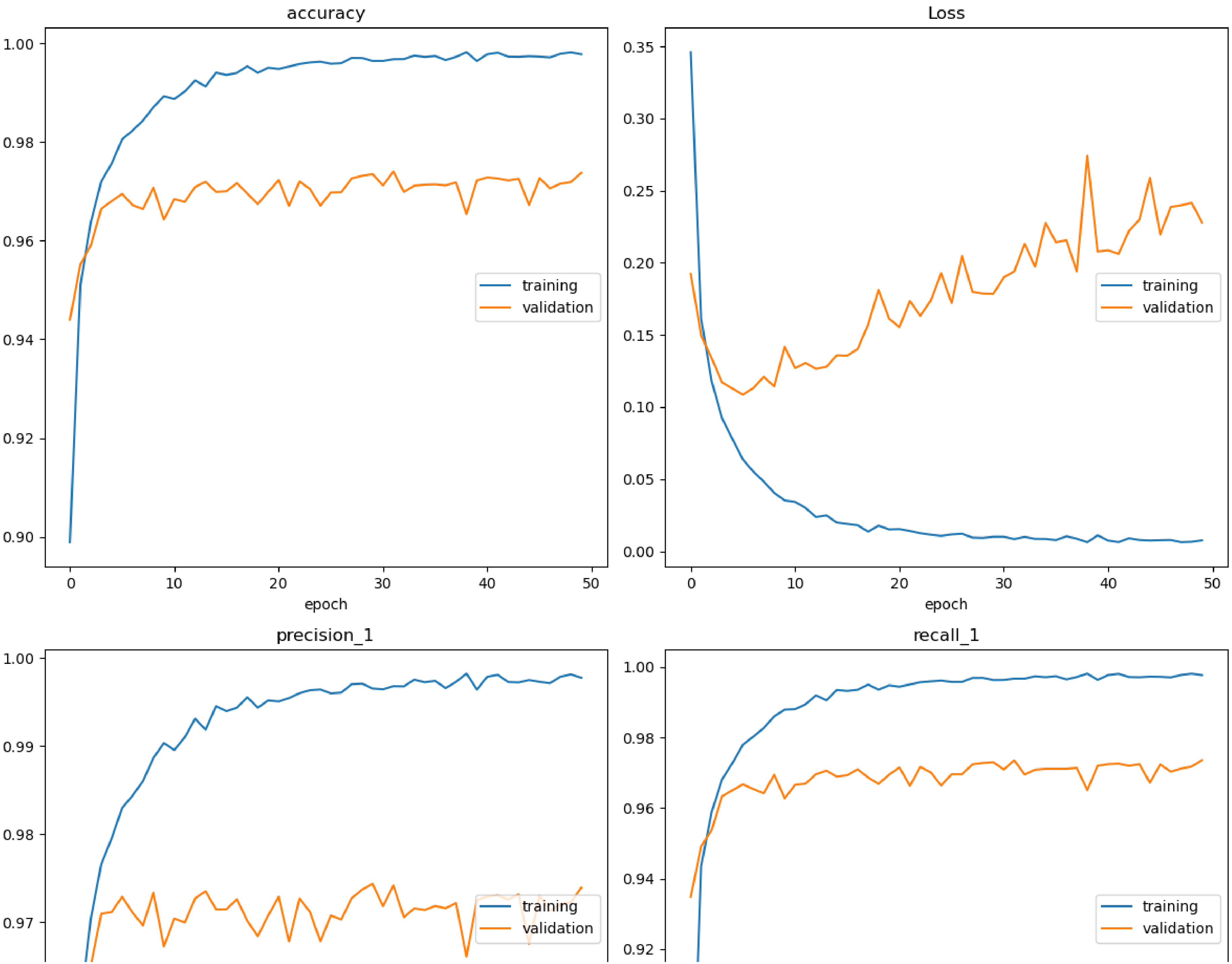


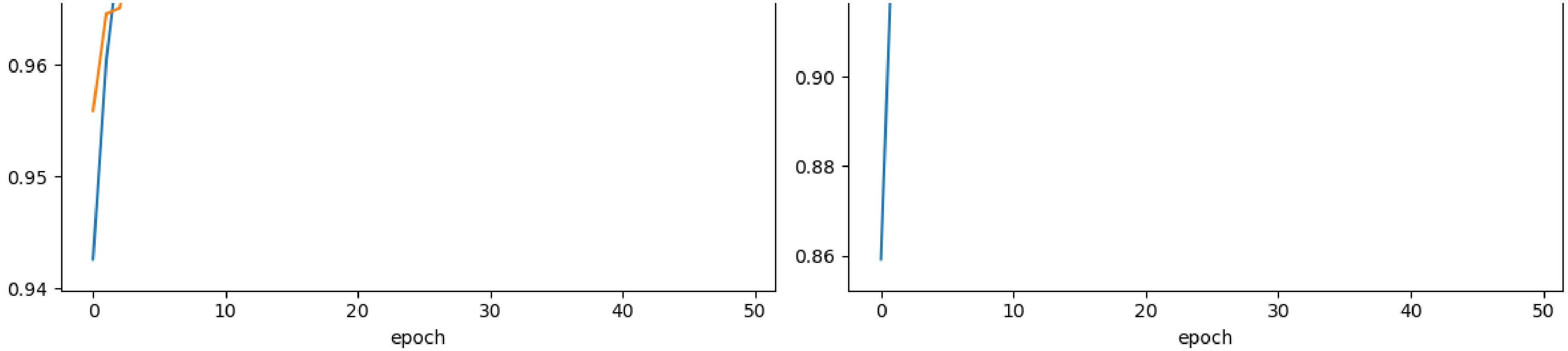
In [7]:
```
x=df.iloc[:,1:]
y=df.label

#scale inputs
x=x/255
#one hot encoding for outcome variable
y_encoded=pd.get_dummies(y)
```

In [8]:
```
from sklearn.model_selection import train_test_split
x_train,x_test,y_train,y_test=train_test_split(x,y_encoded,random_state=0)

from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense
import livelossplot
from livelossplot import PlotLossesKerasTF
from tensorflow.keras.metrics import Precision,Recall
```

In [11]:

```
model=Sequential()
model.add(Dense(50,activation="relu"))#hl1
model.add(Dense(50,activation="relu"))#hl2
model.add(Dense(10,activation="softmax"))#output
model.compile(loss="categorical_crossentropy",optimizer="adam",metrics=["accuracy",Precision(),Recall()])

model.fit(x_train,y_train,epochs=50,callbacks=[PlotLossesKerasTF()],validation_data=(x_test,y_test))
```


accuracy
Loss
precision_1
recall_1
epoch
epoch
training
validation
training
validation
training
validation
training
validation
1.00
0.98
0.96
0.94
0.92
0.90
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1.00
0.99
0.98
0.97
1.00
0.98
0.96
0.94
0.92
0
10
20
30
40
50



```
accuracy
	training             	 (min:    0.899, max:    0.998, cur:    0.998)
	validation           	 (min:    0.944, max:    0.974, cur:    0.974)
Loss
	training             	 (min:    0.006, max:    0.346, cur:    0.008)
	validation           	 (min:    0.109, max:    0.274, cur:    0.228)
precision_1
	training             	 (min:    0.943, max:    0.998, cur:    0.998)
	validation           	 (min:    0.956, max:    0.974, cur:    0.974)
recall_1
	training             	 (min:    0.859, max:    0.998, cur:    0.998)
	validation           	 (min:    0.935, max:    0.974, cur:    0.974)
1407/1407 [==============================] - 17s 12ms/step - loss: 0.0076 - accuracy: 0.9978 - precision_1: 0.9978 - recall_1:
0.9977 - val_loss: 0.2279 - val_accuracy: 0.9737 - val_precision_1: 0.9739 - val_recall_1: 0.9736
```

Out[11]:

```
<keras.callbacks.History at 0x1436c5a8c40>
```

In [12]:

```python
#prdict outcomes on test data
test_pred=model.predict(x_test)
```

```
469/469 [==============================] - 3s 5ms/step
```

In [13]:

```python
test_pred
```

Out[13]:

```
array([[8.1487950e-37, 3.9310974e-24, 8.9901713e-24, ..., 4.1011154e-22,
        9.4307998e-14, 4.5504377e-17],
       [2.3996783e-32, 0.0000000e+00, 9.3986878e-30, ..., 0.0000000e+00,
        1.5959676e-29, 4.4825691e-34],
       [3.7147523e-17, 6.4678052e-22, 1.0443475e-11, ..., 3.4092986e-20,
        4.7948455e-18, 2.6770554e-13],
       ...,
       [3.8704437e-20, 2.7454067e-18, 1.7706930e-21, ..., 2.1682658e-06,
        6.1712907e-10, 9.9999726e-01],
       [1.7688588e-09, 7.2452879e-21, 2.0752639e-13, ..., 1.0000000e+00,
        1.5331161e-17, 4.8252038e-14],
       [4.6927367e-24, 2.3818789e-37, 1.0000000e+00, ..., 1.6316394e-16,
        6.1963291e-27, 3.7005590e-36]], dtype=float32)
```

In [14]:

```
y_test_pred=test_pred.argmax(axis=1)
```

In [15]:

```
pd.crosstab(y_test.idxmax(axis=1),y_test_pred)
```

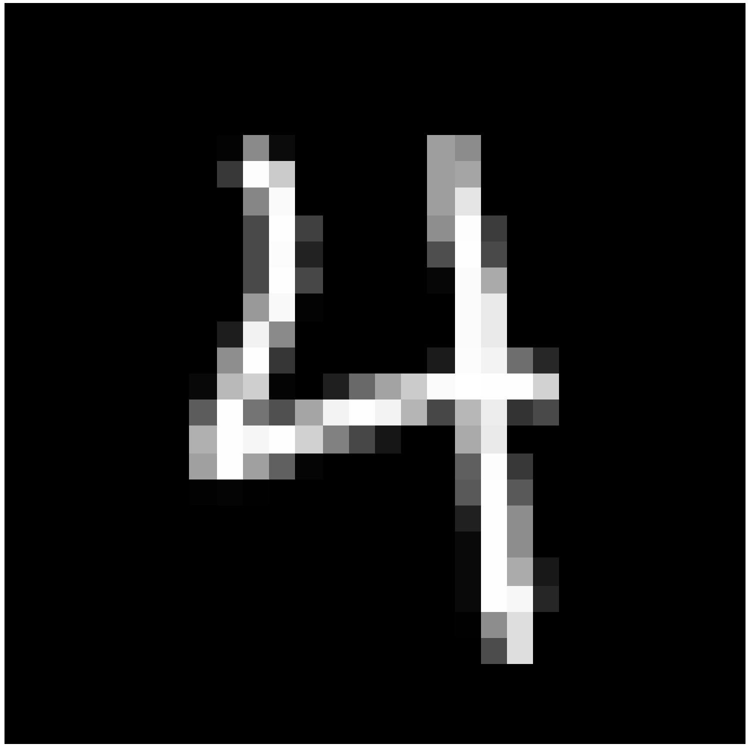
Out[15]:

col_0	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
row_0										
0	1492	0	3	0	4	1	3	2	3	2
1	0	1704	8	4	2	0	4	4	1	1
2	3	1	1422	2	6	2	3	8	8	3
3	0	0	17	1487	0	16	1	8	15	4
4	1	1	3	0	1402	0	1	4	2	20
5	8	0	4	12	3	1281	9	3	11	11
6	5	1	5	0	6	3	1445	0	3	0
7	0	2	17	3	5	1	1	1496	3	7
8	5	6	8	3	1	9	6	0	1442	4
9	2	0	0	6	16	6	0	22	6	1435

In [16]:

```
ind=700
img=x_test.values[ind,:]
```

```
plt.imshow(img.reshape(28,28))
plt.gray()
plt.axis("off")
plt.show()
print("Actual Label: ",y_test.values.argmax(axis=1)[ind])
print("Predicted Label: ",y_test_pred[ind])
```



```
Actual Label:  4
Predicted Label:  4
```

In [17]:

```
y_test.shape
```

Out[17]:

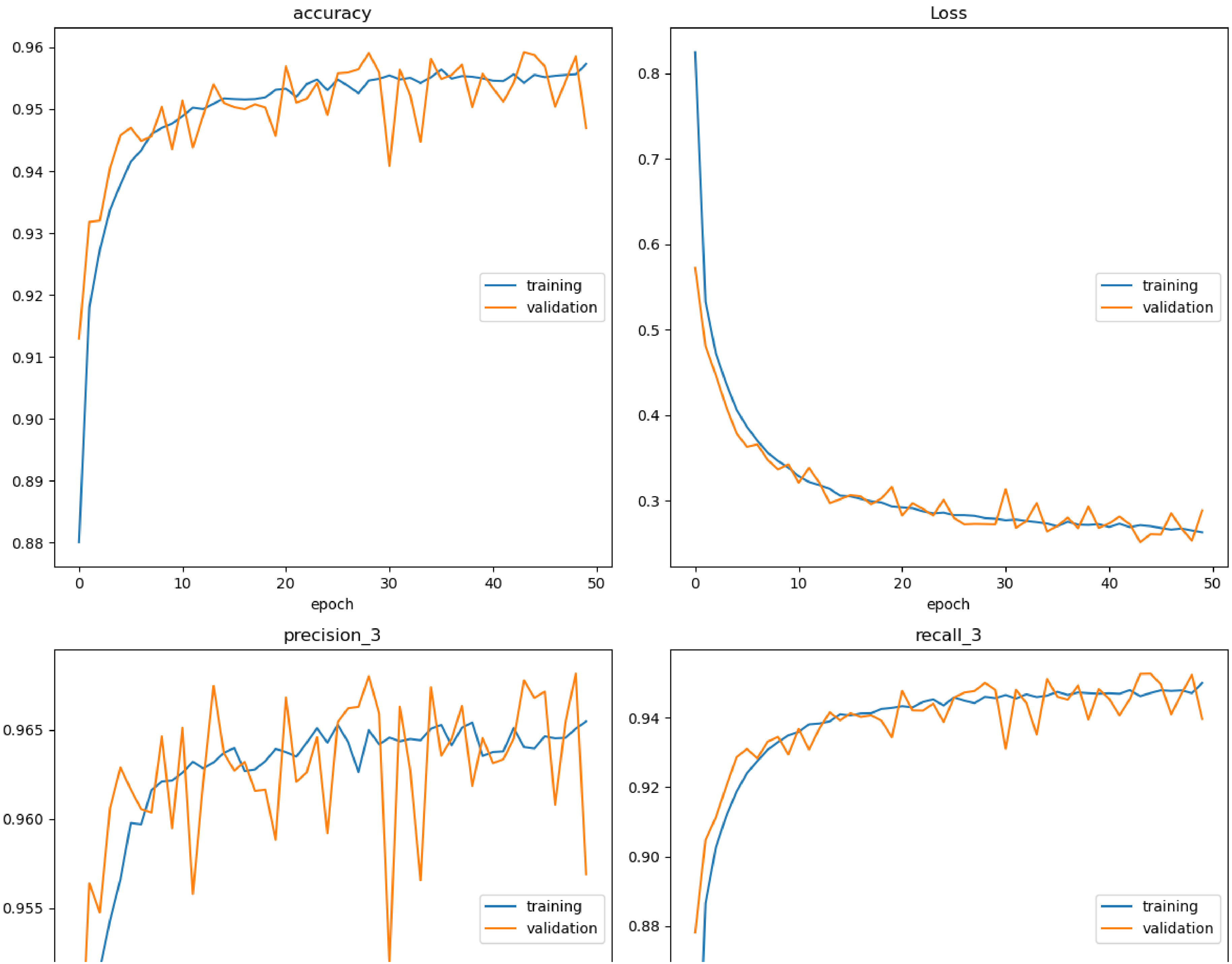
```
(15000, 10)
```

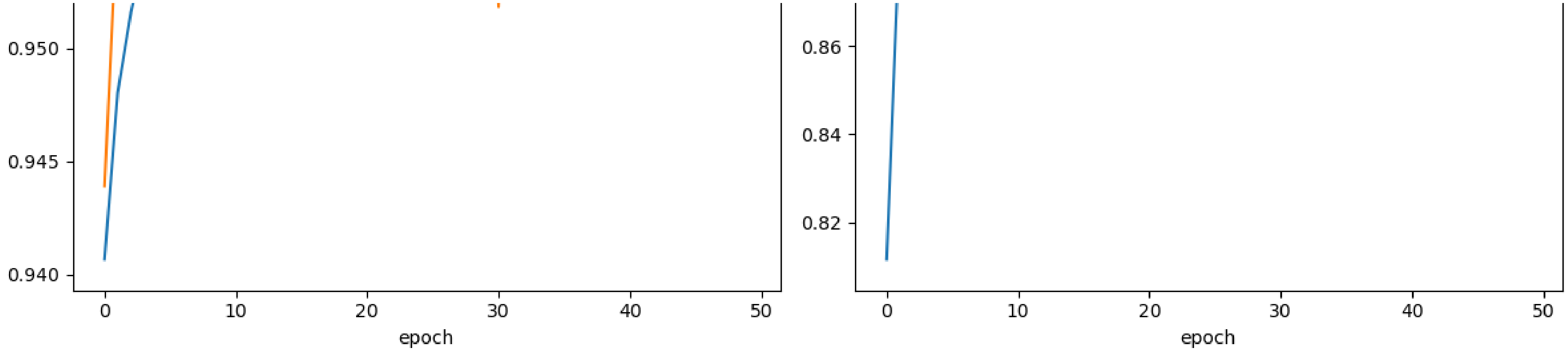
In [18]:

```
#l2  regularizer
from tensorflow.keras.regularizers import L2
```

In [20]:

```
model=Sequential()
model.add(Dense(50,activation="relu",kernel_regularizer=L2(l2=0.01)))#h1
model.add(Dense(50,activation="relu",kernel_regularizer=L2(l2=0.01)))#h2
model.add(Dense(10,activation="softmax"))#output
model.compile(loss="categorical_crossentropy",optimizer="adam",metrics=["accuracy",Precision(),Recall()])

model.fit(x_train,y_train,epochs=50,callbacks=[PlotLossesKerasTF()],validation_data=(x_test,y_test))
```


accuracy
0.96
0.95
0.94
0.93
0.92
0.91
0.90
0.89
0.88
0
10
20
30
40
50
epoch
training
validation
Loss
0.8
0.7
0.6
0.5
0.4
0.3
0
10
20
30
40
50
epoch
training
validation
precision_3
0.965
0.960
0.955
training
validation
recall_3
0.94
0.92
0.90
0.88
training
validation



```
accuracy
	training         	 (min:    0.880, max:    0.957, cur:    0.957)
	validation       	 (min:    0.913, max:    0.959, cur:    0.947)
Loss
	training         	 (min:    0.263, max:    0.825, cur:    0.263)
	validation       	 (min:    0.251, max:    0.572, cur:    0.288)
precision_3
	training         	 (min:    0.941, max:    0.965, cur:    0.965)
	validation       	 (min:    0.944, max:    0.968, cur:    0.957)
recall_3
	training         	 (min:    0.812, max:    0.950, cur:    0.950)
	validation       	 (min:    0.878, max:    0.953, cur:    0.940)
1407/1407 [==============================] - 19s 14ms/step - loss: 0.2629 - accuracy: 0.9573 - precision_3: 0.9655 - recall_3:
0.9500 - val_loss: 0.2884 - val_accuracy: 0.9469 - val_precision_3: 0.9569 - val_recall_3: 0.9396
```

Out[20]:

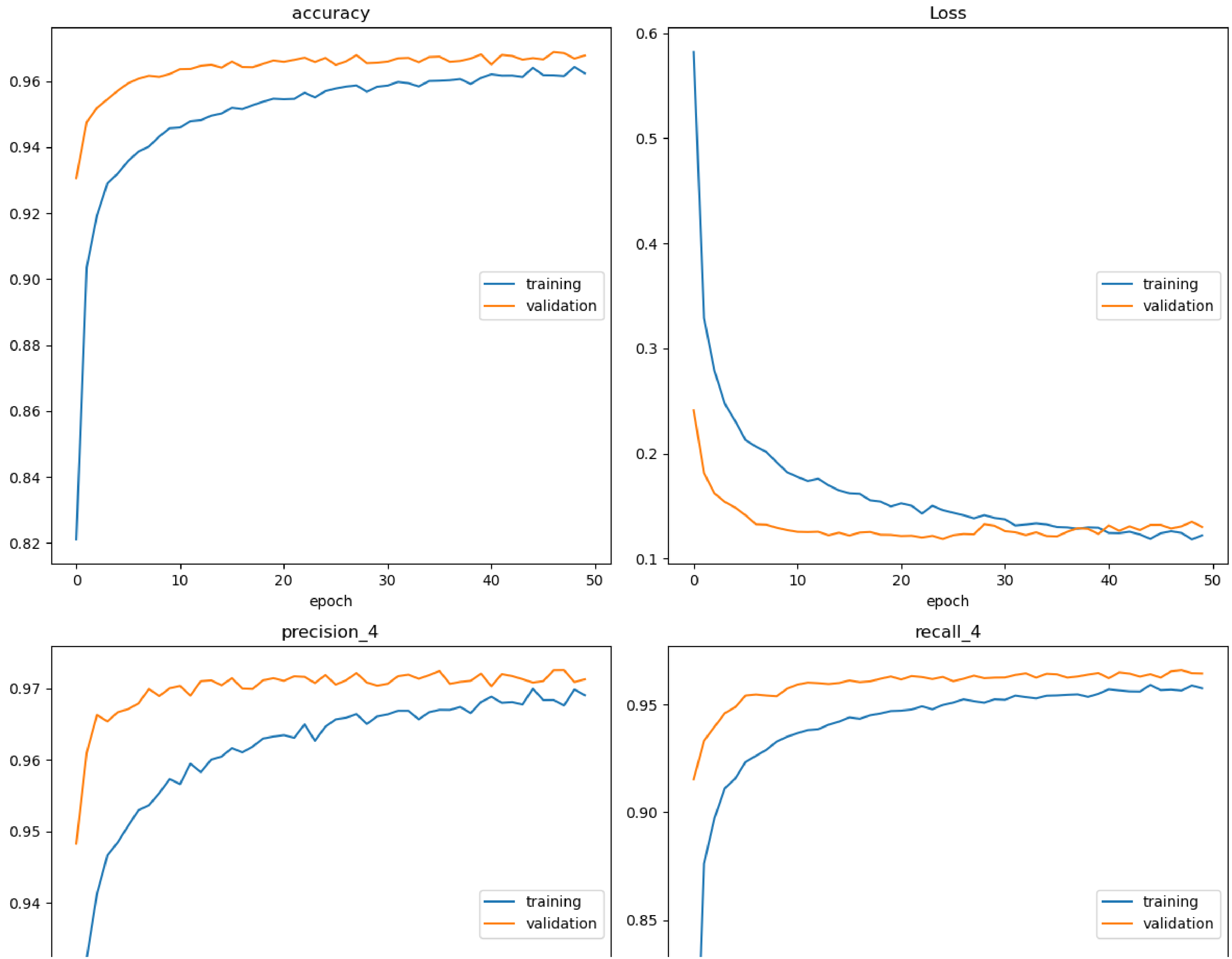
```
<keras.callbacks.History at 0x1430c9b9940>
```

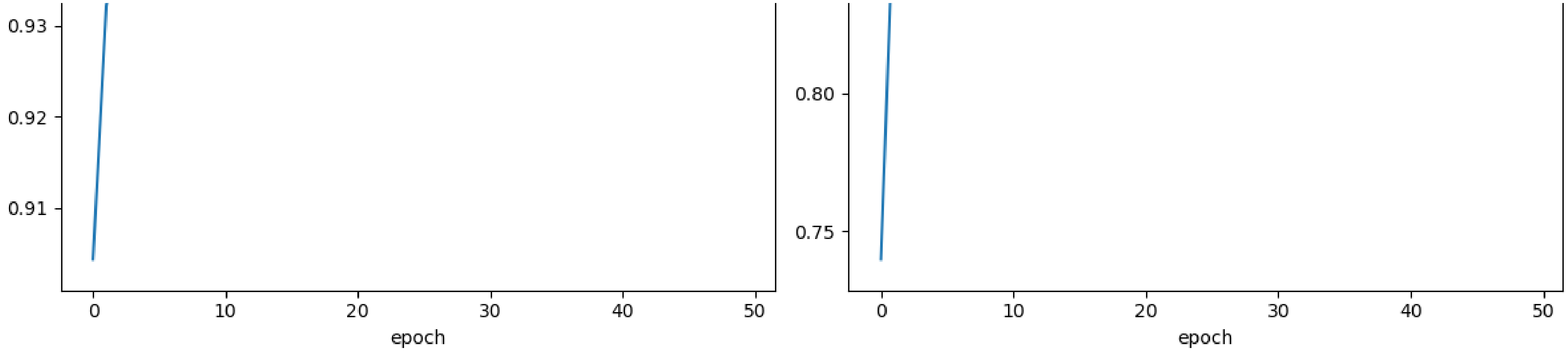
In [21]:

```python
from tensorflow.keras.layers import Dropout
```

In [22]:

```python
model=Sequential()
model.add(Dense(50,activation="relu"))#h1
model.add(Dropout(0.3)) # dropout layer
model.add(Dense(50,activation="relu"))#h2
model.add(Dropout(0.3)) # dropout layer
model.add(Dense(10,activation="softmax"))#output
model.compile(loss="categorical_crossentropy",
                  optimizer="adam",
                  metrics=["accuracy",Precision(),Recall()])

model.fit(x_train,y_train,epochs=50,callbacks=[PlotLossesKerasTF()],validation_data=(x_test,y_test))
```


accuracy
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0
10
20
30
40
50
epoch
training
validation
Loss
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
epoch
training
validation
precision_4
0.97
0.96
0.95
0.94
training
validation
recall_4
0.95
0.90
0.85
training
validation



```
accuracy
	 training         	 (min:    0.821, max:    0.964, cur:    0.962)
	 validation       	 (min:    0.931, max:    0.969, cur:    0.968)
Loss
	 training         	 (min:    0.118, max:    0.582, cur:    0.122)
	 validation       	 (min:    0.119, max:    0.241, cur:    0.130)
precision_4
	 training         	 (min:    0.904, max:    0.970, cur:    0.969)
	 validation       	 (min:    0.948, max:    0.973, cur:    0.971)
recall_4
	 training         	 (min:    0.740, max:    0.959, cur:    0.958)
	 validation       	 (min:    0.915, max:    0.966, cur:    0.964)
1407/1407 [==============================] - 22s 16ms/step - loss: 0.1220 - accuracy: 0.9624 - precision_4: 0.9690 - recall_4:
0.9575 - val_loss: 0.1301 - val_accuracy: 0.9677 - val_precision_4: 0.9713 - val_recall_4: 0.9644
```

Out[22]:

```
<keras.callbacks.History at 0x1430f1545b0>
```

In [ ]: