Heart Disease Data EDA and Prediction with Machine Learning Models

Import libraries

In [2]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
import os
import yellowbrick
import pickle

from matplotlib.collections import PathCollection
from statsmodels.graphics.gofplots import qqplot
from sklearn.preprocessing import MinMaxScaler
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.neighbors import KNeighborsClassifier
from sklearn.svm import SVC
from sklearn.naive_bayes import GaussianNB
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier, AdaBoostClassifier, ExtraTreesClassifi
from sklearn.metrics import classification_report, accuracy_score
from xgboost import XGBClassifier
from yellowbrick.classifier import PrecisionRecallCurve, ROCAUC, ConfusionMatrix
from yellowbrick.style import set_palette
from yellowbrick.model_selection import LearningCurve, FeatureImportances
from yellowbrick.contrib.wrapper import wrap

# --- Libraries Settings ---
warnings.filterwarnings('ignore')
sns.set_style('whitegrid')
plt.rcParams['figure.dpi']=100
set_palette('dark')
```

Color Palettes

This section will create some color palettes that will be used in this notebook.

In [3]:
```
# --- Create List of Color Palletes ---
red_grad = ['#FF0000', '#BF0000', '#800000', '#400000', '#000000']
pink_grad = ['#8A0030', '#BA1141', '#FF5C8A', '#FF99B9', '#FFDEEB']
purple_grad = ['#4C0028', '#7F0043', '#8E004C', '#A80059', '#C10067']
color_mix = ['#F38BB2', '#FFB9CF', '#FFD7D7', '#F17881', '#E7525B']
black_grad = ['#100C07', '#3E3B39', '#6D6A6A', '#9B9A9C', '#CAC9CD']

# --- Plot Color Palletes --
sns.palplot(red_grad)
sns.palplot(pink_grad)
sns.palplot(purple_grad)
sns.palplot(color_mix)
sns.palplot(black_grad)
```

Read data

In [4]:
```
df = pd.read_csv("/input/heart-disease-dataset/heart.csv")

df.head().style.background_gradient(cmap='Reds').set_properties(**{'font-family': 'Segoe UI'}).hide_index()
```

Out[4]:

age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slope	ca	thal	target
52	1	0	125	212	0	1	168	0	1.000000	2	2	3	0
53	1	0	140	203	1	0	155	1	3.100000	0	0	3	0
70	1	0	145	174	0	1	125	1	2.600000	0	0	3	0
61	1	0	148	203	0	1	161	0	0.000000	2	1	3	0
62	0	0	138	294	1	1	106	0	1.900000	1	3	2	0

In [5]:
```
# --- Print Dataset Info ---
print('\033[1m'+'.: Dataset Info :.'+'\033[0m')
print('*' * 30)
print('Total Rows:'+'\033[1m', df.shape[0])
print('\033[0m'+'Total Columns:'+'\033[1m', df.shape[1])
print('\033[0m'+'*' * 30)
print('\n')

# --- Print Dataset Detail ---
print('\033[1m'+'.: Dataset Details :.'+'\033[0m')
print('*' * 30)
df.info(memory_usage = False)
```

```
.: Dataset Info :.
******************************
Total Rows: 1025
Total Columns: 14
******************************


.: Dataset Details :.
******************************
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1025 entries, 0 to 1024
Data columns (total 14 columns):
 #   Column    Non-Null Count  Dtype
---  ------    --------------  -----
 0   age       1025 non-null   int64
 1   sex       1025 non-null   int64
 2   cp        1025 non-null   int64
 3   trestbps  1025 non-null   int64
 4   chol      1025 non-null   int64
 5   fbs       1025 non-null   int64
 6   restecg   1025 non-null   int64
 7   thalach   1025 non-null   int64
 8   exang     1025 non-null   int64
 9   oldpeak   1025 non-null   float64
 10  slope     1025 non-null   int64
 11  ca        1025 non-null   int64
 12  thal      1025 non-null   int64
 13  target    1025 non-null   int64
dtypes: float64(1), int64(13)
```

It is evident that the dataset has been successfully imported. The dataset comprises 14 columns with 303 observations, and there are no null values present. Above, the details of each variable can also be observed.

However, it appears that the data types for some columns do not match. The following steps will address fixing the data types for those columns before performing any analysis.

In [6]:
```
# --- Fix Data Types ---
lst=['sex', 'cp', 'fbs', 'restecg', 'exang', 'slope', 'ca', 'thal']
df[lst] = df[lst].astype(object)
```

Data exploration

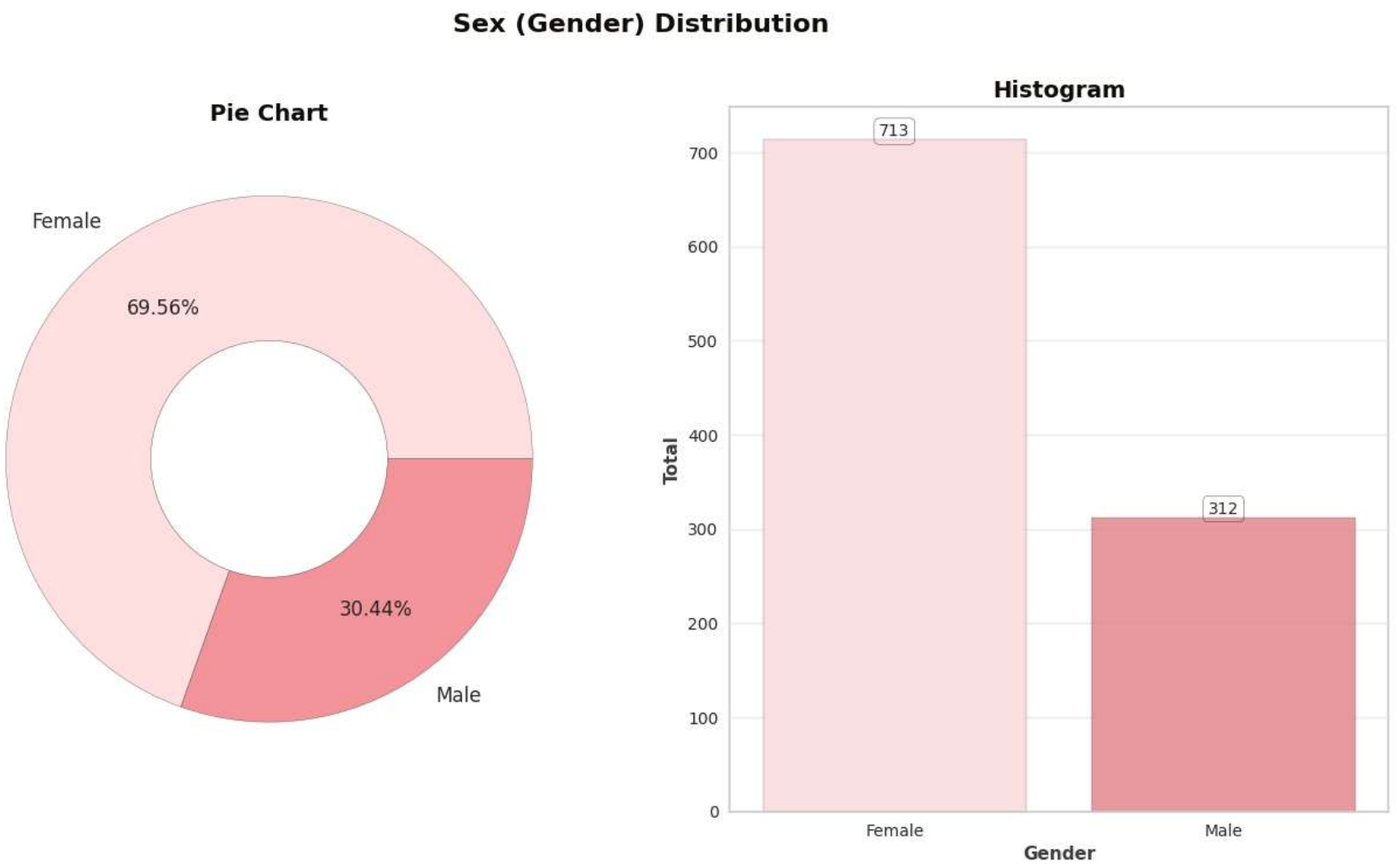
Sex (Gender)

In [7]:
```
# --- Setting Colors, Labels, Order ---
colors=color_mix[2:4]
labels=['Female', 'Male']
order=df['sex'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16, 8))
plt.suptitle('Sex (Gender) Distribution', fontweight='heavy',
             fontsize='16', fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1, 2, 1)
plt.title('Pie Chart', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[0])
plt.pie(df['sex'].value_counts(), labels=labels, colors=colors, pctdistance=0.7,
        autopct='%.2f%%', wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]),
        textprops={'fontsize':12})
centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)
```

```
# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[0])
ax = sns.countplot(x='sex', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0],
                       linewidth=0.25, boxstyle='round'))

plt.xlabel('Gender', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.xticks([0, 1], labels)
plt.grid(axis='y', alpha=0.4)
countplt
# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 25)
print('\033[1m'+'.: Sex (Gender) Total :.'+'\033[0m')
print('*' * 25)
df.sex.value_counts(dropna=False)
```

```
*************************
.: Sex (Gender) Total :.
*************************
1    713
0    312
Name: sex, dtype: int64
```

Out[7]:



cp (Chest Pain Type)

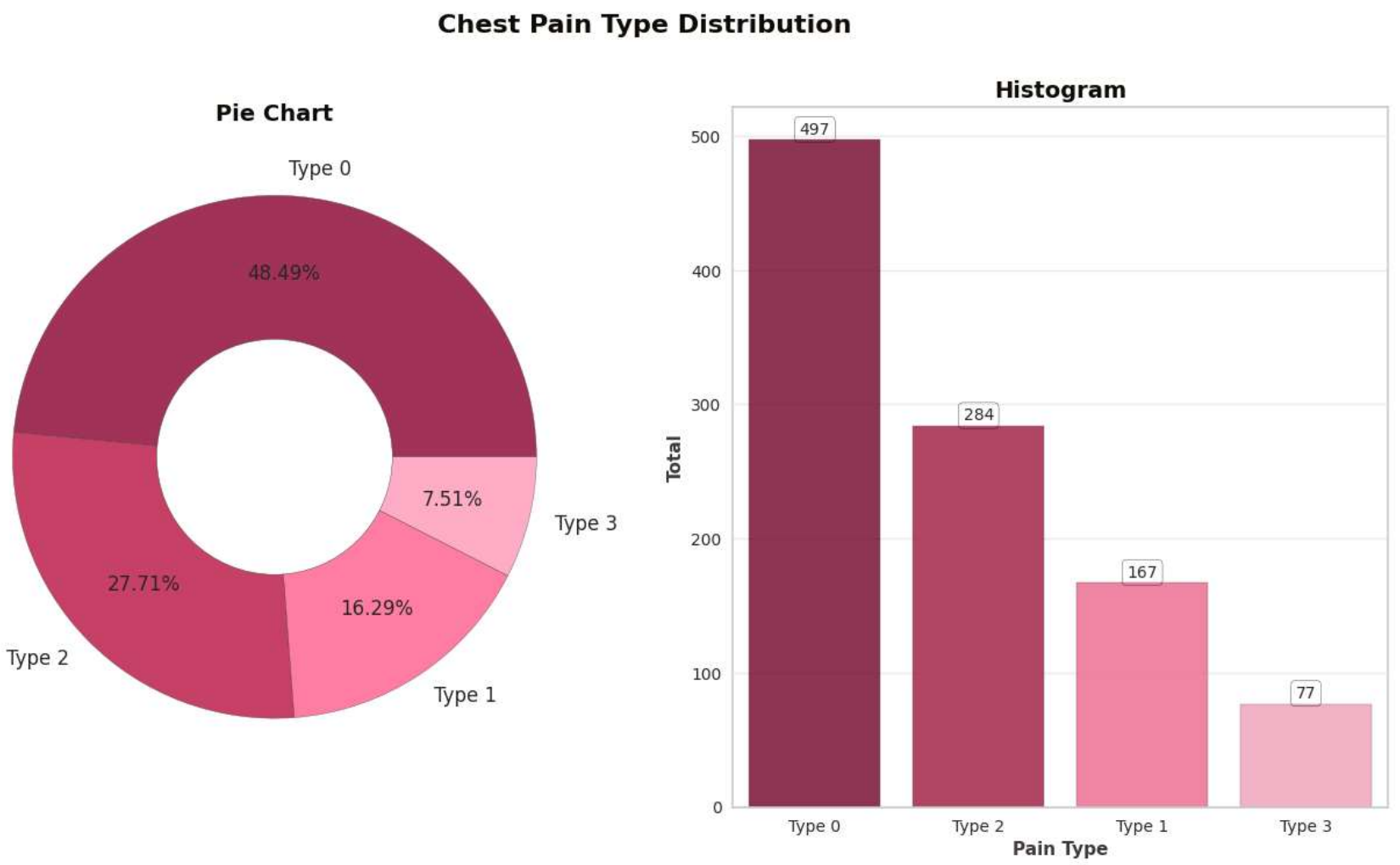
In [8]:

```
# --- Setting Colors, Labels, Order ---
colors=pink_grad[0:4]
labels=['Type 0', 'Type 2', 'Type 1', 'Type 3']
order=df['cp'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16, 8))
plt.suptitle('Chest Pain Type Distribution', fontweight='heavy', fontsize=16,
             fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1, 2, 1)
plt.title('Pie Chart', fontweight='bold', fontsize=14,fontfamily='sans-serif',
          color=black_grad[0])
plt.pie(df['cp'].value_counts(), labels=labels, colors=colors, pctdistance=0.7,
        autopct='%.2f%%', textprops={'fontsize':12},
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]))
centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)

# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='cp', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
```

```
            rect.get_height()+4.25,rect.get_height(),
            horizontalalignment='center', fontsize=10,
            bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                      boxstyle='round'))

plt.xlabel('Pain Type', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.xticks([0, 1, 2, 3], labels)
plt.grid(axis='y', alpha=0.4)
countplt

# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 30)
print('\033[1m'+'.: Chest Pain Type Total :.'+'\033[0m')
print('*' * 30)
df.cp.value_counts(dropna=False)
```

```
******************************
.: Chest Pain Type Total :.
******************************
```

Out[8]:
```
0    497
2    284
1    167
3     77
Name: cp, dtype: int64
```



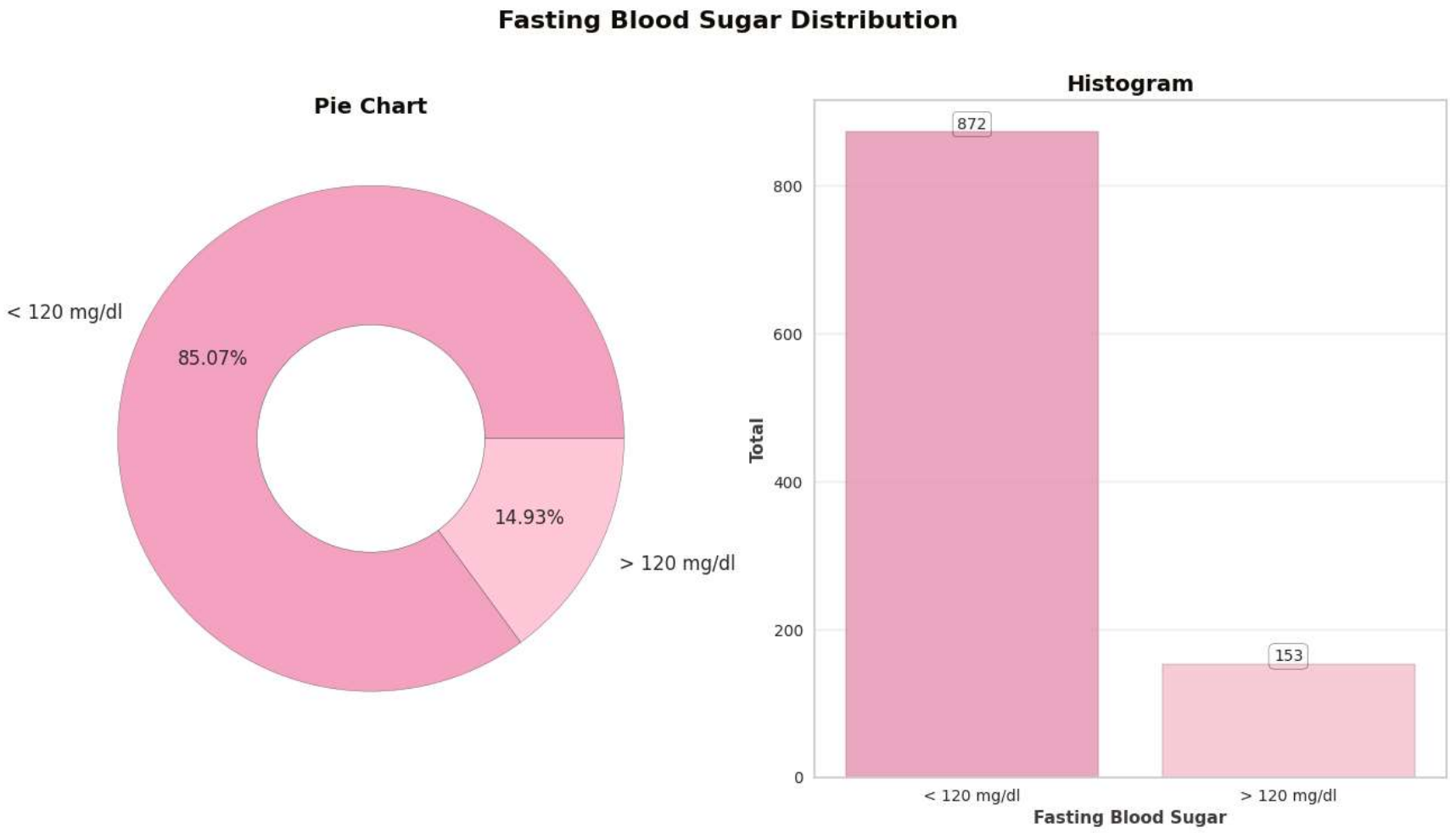
fbs (Fasting Blood Sugar)

In [9]:
```
# --- Setting Colors, Labels, Order ---
colors=color_mix[0:2]
labels=['< 120 mg/dl', '> 120 mg/dl']
order=df['fbs'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16, 8))
plt.suptitle('Fasting Blood Sugar Distribution', fontweight='heavy',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1, 2, 1)
plt.title('Pie Chart', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
plt.pie(df['fbs'].value_counts(), labels=labels, colors=colors,
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]), autopct='%.2f%%',
        pctdistance=0.7, textprops={'fontsize':12})
centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)

# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='fbs', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                       boxstyle='round'))

plt.xlabel('Fasting Blood Sugar', fontweight='bold', fontsize=11,
```

```
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.xticks([0, 1], labels)
plt.grid(axis='y', alpha=0.4)
countplt


# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 32)
print('\033[1m'+'.: Fasting Blood Sugar Total :.'+'\033[0m')
print('*' * 32)
df.fbs.value_counts(dropna=False)
```

```
********************************
.: Fasting Blood Sugar Total :.
********************************
0    872
1    153
Name: fbs, dtype: int64
```

Out[9]:



restecg (Resting Electrocardiographic Results)

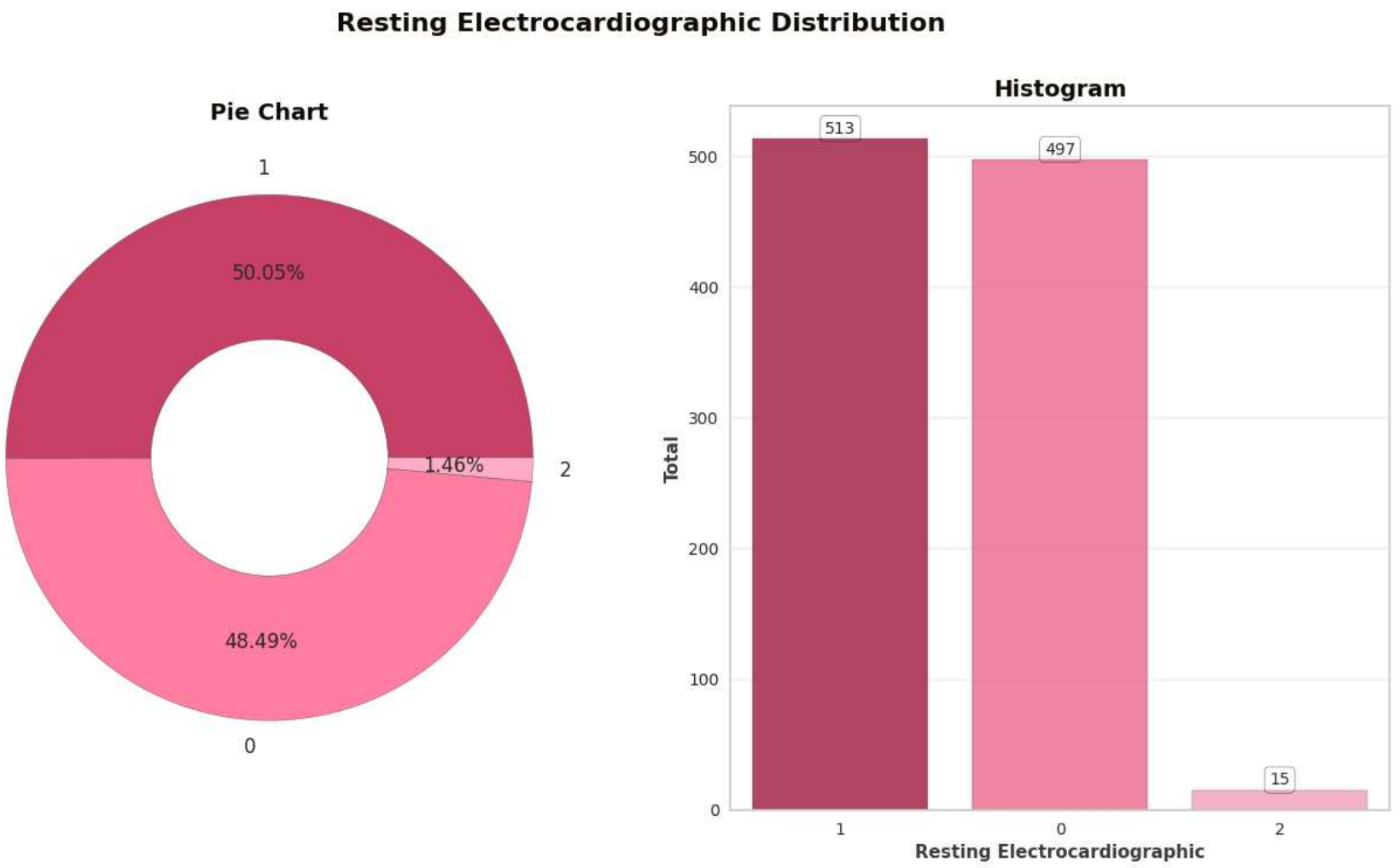
In [10]:

```
# --- Setting Colors, Labels, Order ---
colors=pink_grad[1:4]
labels=['1', '0', '2']
order=df['restecg'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16, 8))
plt.suptitle('Resting Electrocardiographic Distribution', fontweight='heavy',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1,2,1)
plt.title('Pie Chart', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
plt.pie(df['restecg'].value_counts(), labels=labels, colors=colors,
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]), autopct='%.2f%%',
        pctdistance=0.7, textprops={'fontsize':12})
centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)

# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='restecg', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                       boxstyle='round'))

plt.xlabel('Resting Electrocardiographic', fontweight='bold', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.grid(axis='y', alpha=0.4)
countplt

# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 50)
```

```
print('\033[1m'+'.: Resting Electrocardiographic Results Total :.'+'\033[0m')
print('*' * 50)
df.restecg.value_counts(dropna=False)
```

```
**************************************************
.: Resting Electrocardiographic Results Total :.
**************************************************
```

Out[10]:
```
1    513
0    497
2     15
Name: restecg, dtype: int64
```

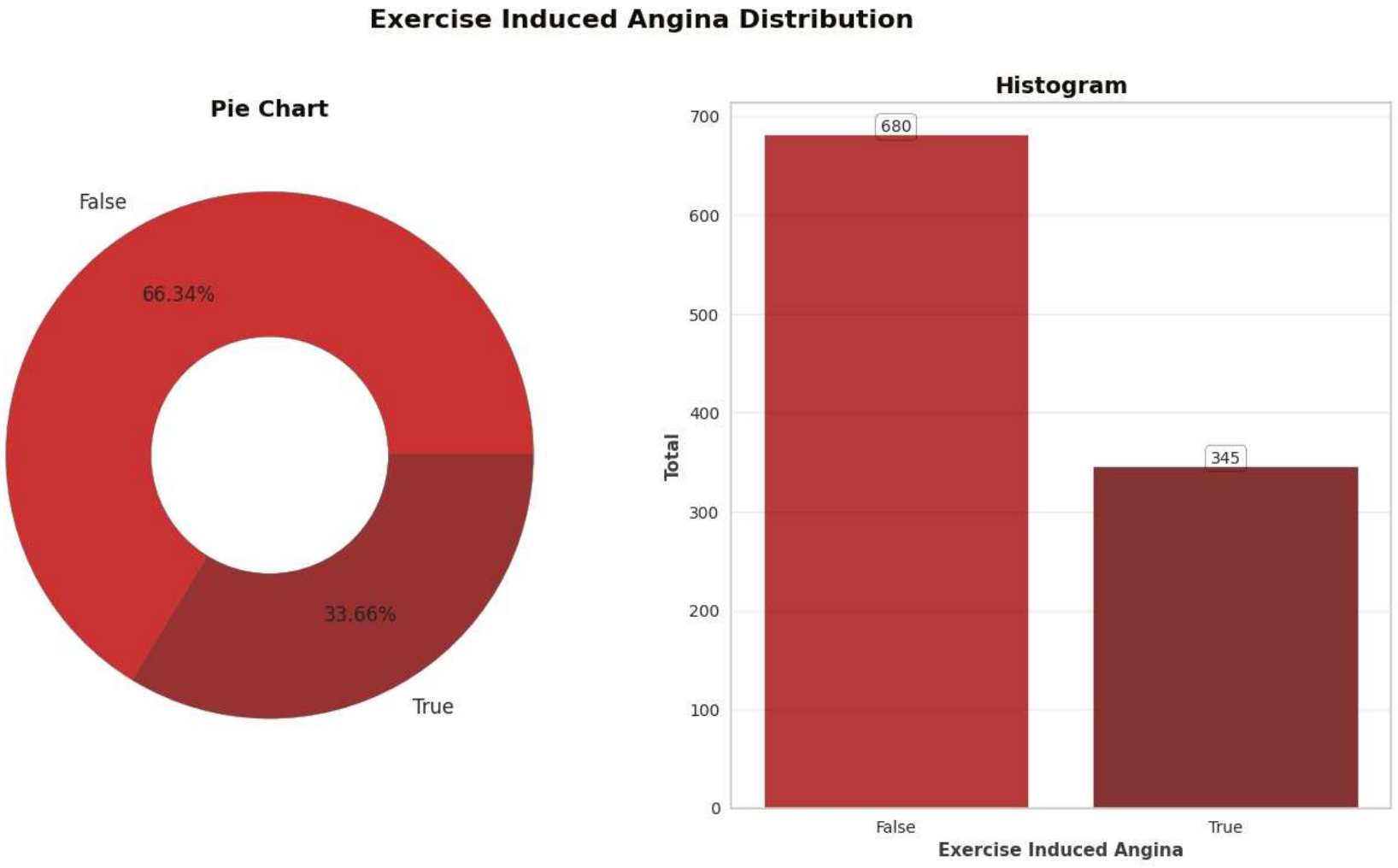


exang (Exercise Induced Angina)

In [11]:
```
# --- Setting Colors, Labels, Order ---
colors=red_grad[1:3]
labels=['False', 'True']
order=df['exang'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16, 8))
plt.suptitle('Exercise Induced Angina Distribution', fontweight='heavy',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1,2,1)
plt.title('Pie Chart', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
plt.pie(df['exang'].value_counts(), labels=labels, colors=colors,
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]), autopct='%.2f%%',
        pctdistance=0.7, textprops={'fontsize':12})
centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)

# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='exang', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                       boxstyle='round'))

plt.xlabel('Exercise Induced Angina', fontweight='bold', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.xticks([0, 1], labels)
plt.grid(axis='y', alpha=0.4)
countplt

# --- Count Categorical Labels w/out Dropping Null Walues ---
print('*' * 35)
print('\033[1m'+'.: Exercise Induced Angina Total :.'+'\033[0m')
print('*' * 35)
df.exang.value_counts(dropna=False)
```

```
***********************************
.: Exercise Induced Angina Total :.
***********************************
```

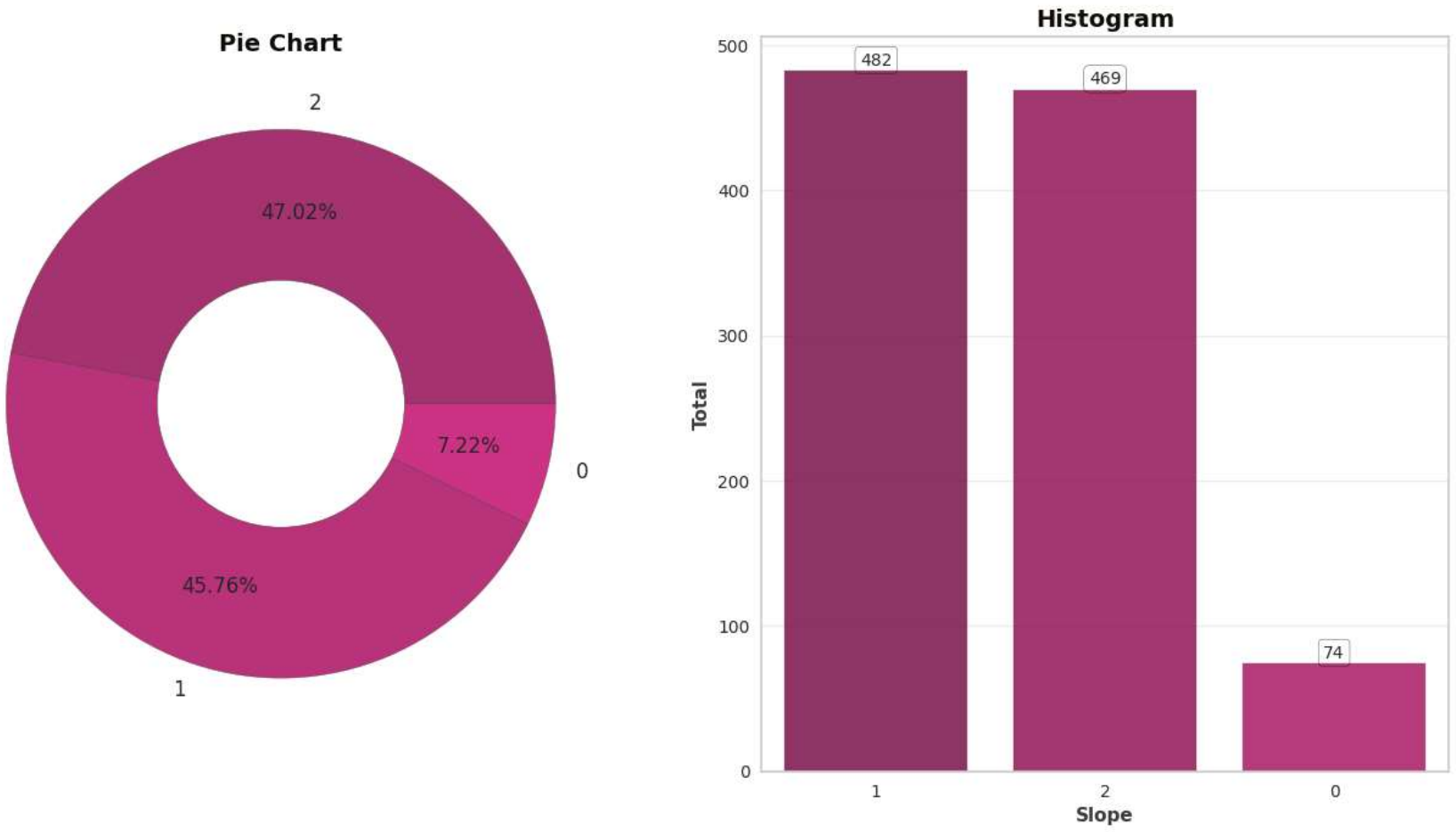
Out[11]:
```
0    680
1    345
Name: exang, dtype: int64
```



slope (Slope of the Peak Exercise)

In [12]:
```
# --- Setting Colors, Labels, Order ---
colors=purple_grad[2:5]
labels=['2', '1', '0']
order=df['slope'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16, 8))
plt.suptitle('Slope of the Peak Exercise Distribution', fontweight='heavy',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1, 2, 1)
plt.title('Pie Chart', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[0])
plt.pie(df['slope'].value_counts(), labels=labels, colors=colors,
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]), autopct='%.2f%%',
        pctdistance=0.7, textprops={'fontsize':12})
centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)


# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='slope', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                       boxstyle='round'))

plt.xlabel('Slope', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.grid(axis='y', alpha=0.4)
countplt
# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 20)
print('\033[1m'+'.: Slope Total :.'+'\033[0m')
print('*' * 20)
df.slope.value_counts(dropna=False)
```

Out[12]:
```
********************
.: Slope Total :.
********************
1    482
2    469
0     74
Name: slope, dtype: int64
```

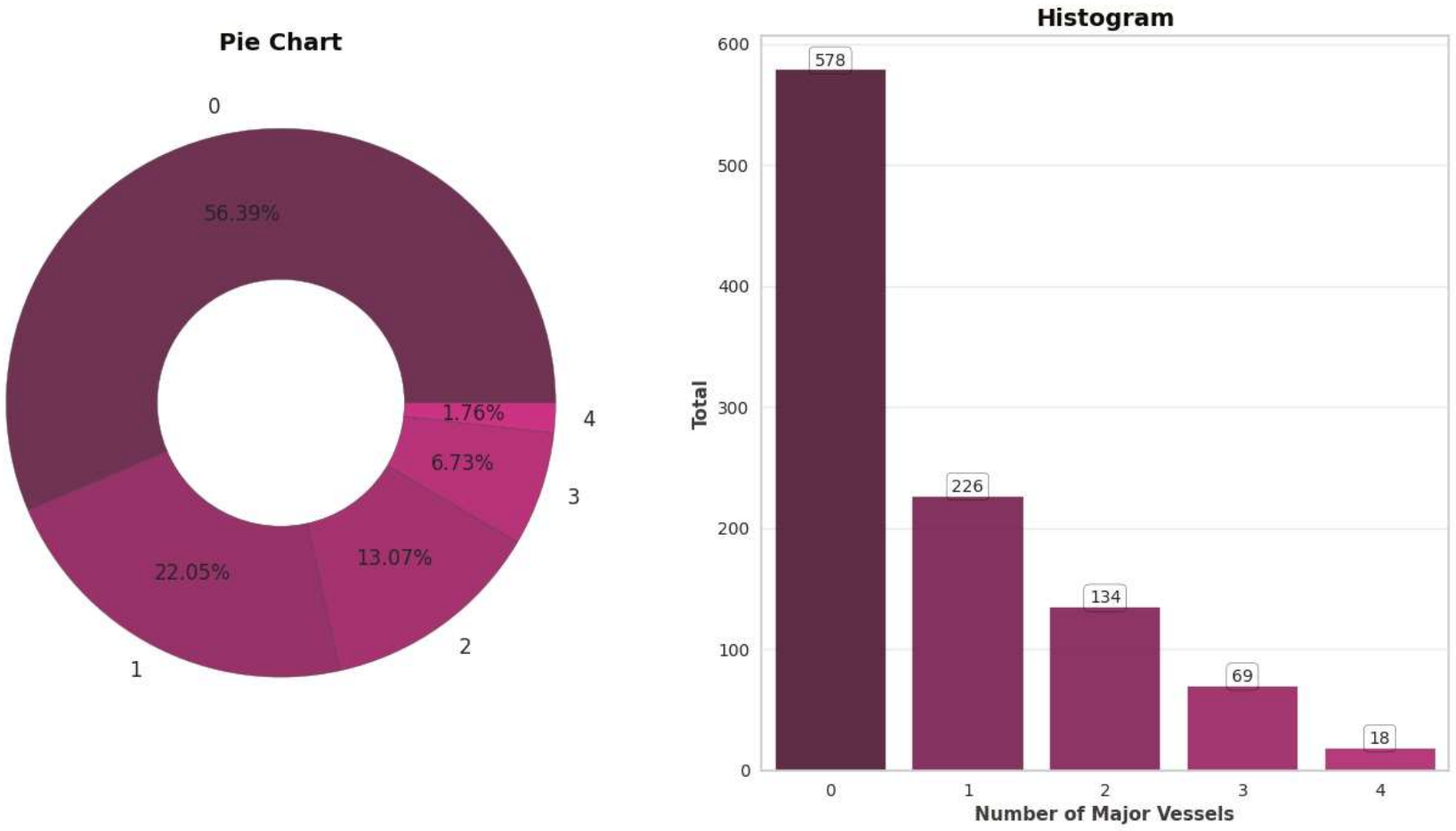


ca (Number of Major Vessels)

In [13]:
```
# --- Setting Colors, Labels, Order ---
colors=purple_grad
labels=['0', '1', '2', '3', '4']
order=df['ca'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16, 8))
plt.suptitle('Number of Major Vessels Distribution', fontweight='heavy',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1,2,1)
plt.title('Pie Chart', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
plt.pie(df['ca'].value_counts(), labels=labels, colors=colors,
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]),
        autopct='%.2f%%', pctdistance=0.7, textprops={'fontsize':12})

centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)

# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='ca', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                       boxstyle='round'))

plt.xlabel('Number of Major Vessels', fontweight='bold', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.grid(axis='y', alpha=0.4)
countplt

# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 40)
print('\033[1m'+'.: Number of Major Vessels Total :.'+'\033[0m')
print('*' * 40)
df.ca.value_counts(dropna=False)
```

```
****************************************
.: Number of Major Vessels Total :.
****************************************
```

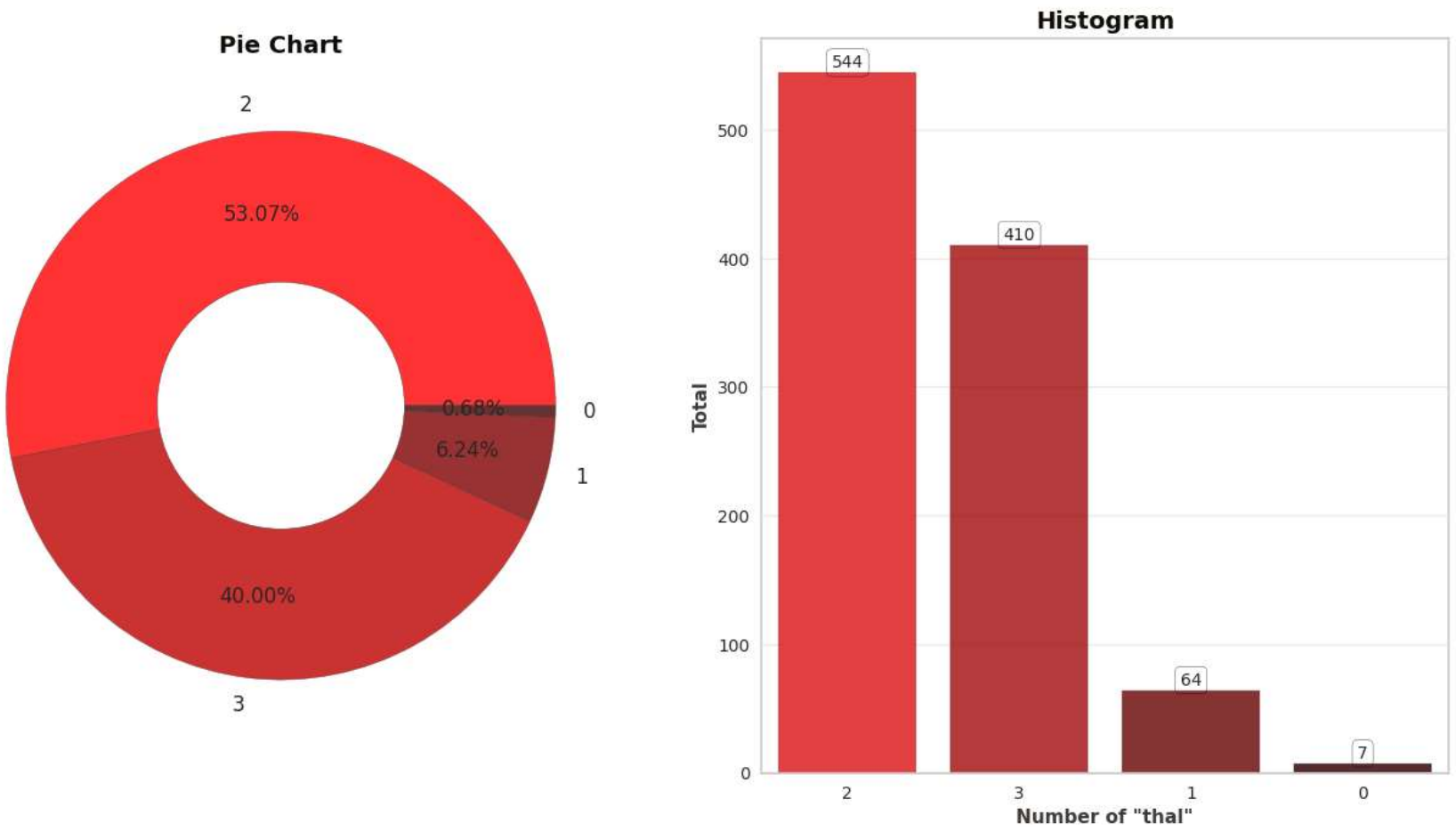
Out[13]:
```
0    578
1    226
2    134
3     69
4     18
Name: ca, dtype: int64
```



thal

In [14]:
```
# --- Setting Colors, Labels, Order ---
colors=red_grad[0:4]
labels=['2', '3', '1', '0']
order=df['thal'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16,8))
plt.suptitle('"thal" Distribution', fontweight='heavy', fontsize=16,
             fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1,2,1)
plt.title('Pie Chart', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
plt.pie(df['thal'].value_counts(), labels=labels, colors=colors,
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]),
        autopct='%.2f%%', pctdistance=0.7, textprops={'fontsize':12})

centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)

# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='thal', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                       boxstyle='round'))

plt.xlabel('Number of "thal"', fontweight='bold', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.grid(axis='y', alpha=0.4)
countplt

# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 20)
print('\033[1m'+'.: "thal" Total :.'+'\033[0m')
print('*' * 20)
df.thal.value_counts(dropna=False)
```

Out[14]:
```
********************
.: "thal" Total :.
********************
2    544
3    410
1     64
0      7
Name: thal, dtype: int64
```

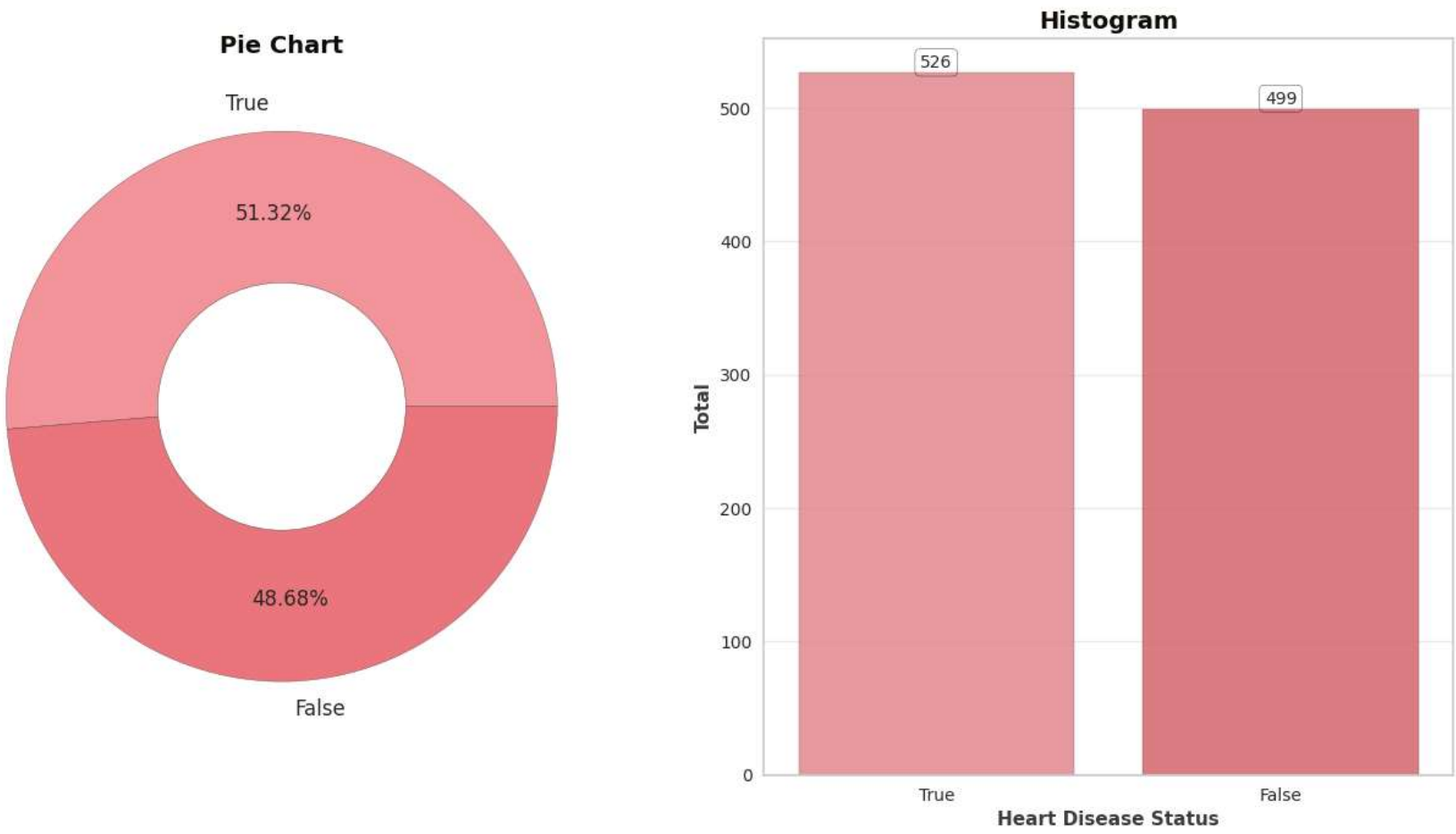


target (Heart Diseases Status)

In [15]:
```
# --- Setting Colors, Labels, Order ---
colors=color_mix[3:5]
labels=['True', 'False']
order=df['target'].value_counts().index

# --- Size for Both Figures ---
plt.figure(figsize=(16,8))
plt.suptitle('Heart Diseases Distribution', fontweight='heavy',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])

# --- Pie Chart ---
plt.subplot(1, 2, 1)
plt.title('Pie Chart', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
plt.pie(df['target'].value_counts(), labels=labels, colors=colors,
        wedgeprops=dict(alpha=0.8, edgecolor=black_grad[1]), autopct='%.2f%%',
        pctdistance=0.7, textprops={'fontsize':12})
centre=plt.Circle((0, 0), 0.45, fc='white', edgecolor=black_grad[1])
plt.gcf().gca().add_artist(centre)

# --- Histogram ---
countplt = plt.subplot(1, 2, 2)
plt.title('Histogram', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[0])
ax = sns.countplot(x='target', data=df, palette=colors, order=order,
                   edgecolor=black_grad[2], alpha=0.85)
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+4.25,rect.get_height(),
             horizontalalignment='center', fontsize=10,
             bbox=dict(facecolor='none', edgecolor=black_grad[0], linewidth=0.25,
                       boxstyle='round'))

plt.xlabel('Heart Disease Status', fontweight='bold', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Total', fontweight='bold', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])
plt.xticks([0, 1], labels)
plt.grid(axis='y', alpha=0.4)
countplt

# --- Count Categorical Labels w/out Dropping Null Values ---
print('*' * 45)
print('\033[1m'+'.: Heart Diseases Status (target) Total :.'+'\033[0m')
print('*' * 45)
df.target.value_counts(dropna=False)
```

```
*********************************************
.: Heart Diseases Status (target) Total :.
*********************************************
```

Out[15]:
```
1    526
0    499
Name: target, dtype: int64
```



Numerical Variable

The second variable that will be explored is numerical variable

Descriptive Statistics

In [16]:
```
# --- Descriptive Statistics ---
df.select_dtypes(exclude='object').describe().T.style.background_gradient(cmap='PuRd').set_properties(**{'font-family':
```

Out[16]:

	count	mean	std	min	25%	50%	75%	max
age	1025.000000	54.434146	9.072290	29.000000	48.000000	56.000000	61.000000	77.000000
trestbps	1025.000000	131.611707	17.516718	94.000000	120.000000	130.000000	140.000000	200.000000
chol	1025.000000	246.000000	51.592510	126.000000	211.000000	240.000000	275.000000	564.000000
thalach	1025.000000	149.114146	23.005724	71.000000	132.000000	152.000000	166.000000	202.000000
oldpeak	1025.000000	1.071512	1.175053	0.000000	0.000000	0.800000	1.800000	6.200000
target	1025.000000	0.513171	0.500070	0.000000	0.000000	1.000000	1.000000	1.000000

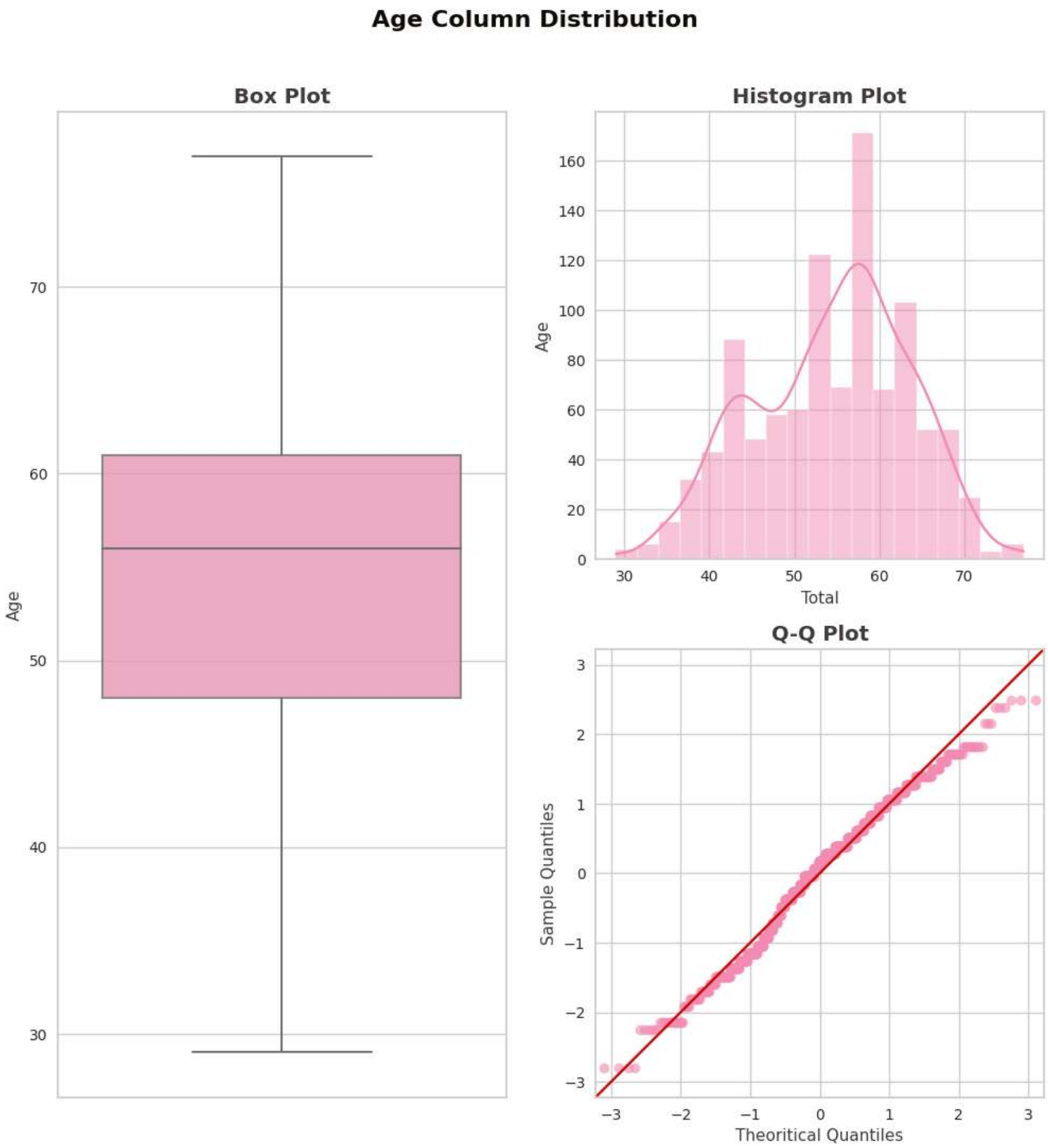
Continuous Column Distribution

This section will show the distribution of numerical variables in histograms, boxplots, Q-Q Plots, skewness and kurtosis values.

In [17]:
```
# --- Variable, Color & Plot Size ---
var = 'age'
color = color_mix[0]
fig=plt.figure(figsize=(12, 12))

# --- Skewness & Kurtosis ---
print('\033[1m'+'.: Age Column Skewness & Kurtosis :.'+'\033[0m')
print('*' * 40)
print('Skewness:'+'\033[1m {:.3f}'.format(df[var].skew(axis = 0, skipna = True)))
print('\033[0m'+'Kurtosis:'+'\033[1m {:.3f}'.format(df[var].kurt(axis = 0, skipna = True)))
print('\n')

# --- General Title ---
fig.suptitle('Age Column Distribution', fontweight='bold', fontsize=16,
             fontfamily='sans-serif', color=black_grad[0])
fig.subplots_adjust(top=0.9)

# --- Histogram ---
ax_1=fig.add_subplot(2, 2, 2)
plt.title('Histogram Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.histplot(data=df, x=var, kde=True, color=color)
plt.xlabel('Total', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Age', fontweight='regular', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])

# --- Q-Q Plot ---
ax_2=fig.add_subplot(2, 2, 4)
plt.title('Q-Q Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
qqplot(df[var], fit=True, line='45', ax=ax_2, markerfacecolor=color,
       markeredgecolor=color, alpha=0.6)
plt.xlabel('Theoritical Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Sample Quantiles', fontweight='regular', fontsize=11,
```

```
           fontfamily='sans-serif', color=black_grad[1])

# --- Box Plot ---
ax_3=fig.add_subplot(1, 2, 1)
plt.title('Box Plot', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[1])
sns.boxplot(data=df, y=var, color=color, boxprops=dict(alpha=0.8), linewidth=1.5)
plt.ylabel('Age', fontweight='regular', fontsize=11, fontfamily='sans-serif',
           color=black_grad[1])

plt.show()
```

```
.: Age Column Skewness & Kurtosis :.
**************************************
Skewness: -0.249
Kurtosis: -0.526
```

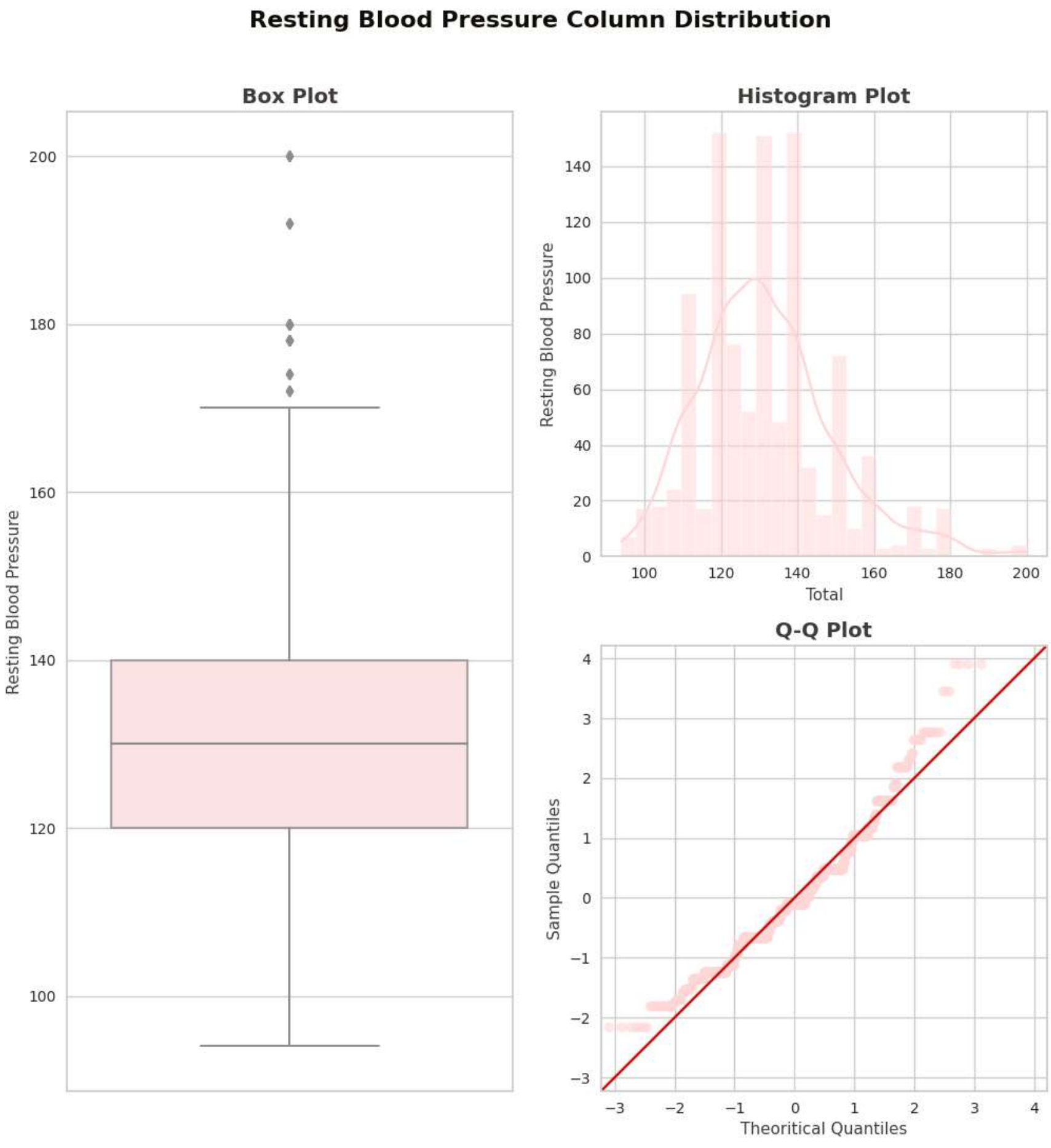


trestbps (Resting Blood Pressure in mm Hg)

In [18]:
```
# --- Variable, Color & Plot Size ---
var = 'trestbps'
color = color_mix[2]
fig=plt.figure(figsize=(12, 12))

# --- Skewness & Kurtosis ---
print('\033[1m'+'.: Resting Blood Pressure Column Skewness & Kurtosis :.'+'\033[0m')
print('*' * 55)
print('Skewness:'+'\033[1m {:.3f}'.format(df[var].skew(axis = 0, skipna = True)))
print('\033[0m'+'Kurtosis:'+'\033[1m {:.3f}'.format(df[var].kurt(axis = 0, skipna = True)))
print('\n')

# --- General Title ---
fig.suptitle('Resting Blood Pressure Column Distribution', fontweight='bold',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])
fig.subplots_adjust(top=0.9)
```

```python
# --- Histogram ---
ax_1=fig.add_subplot(2, 2, 2)
plt.title('Histogram Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.histplot(data=df, x=var, kde=True, color=color)
plt.xlabel('Total', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Resting Blood Pressure', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

# --- Q-Q Plot ---
ax_2=fig.add_subplot(2, 2, 4)
plt.title('Q-Q Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
qqplot(df[var], fit=True, line='45', ax=ax_2, markerfacecolor=color,
       markeredgecolor=color, alpha=0.6)
plt.xlabel('Theoritical Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Sample Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

# --- Box Plot ---
ax_3=fig.add_subplot(1, 2, 1)
plt.title('Box Plot', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[1])
sns.boxplot(data=df, y=var, color=color, boxprops=dict(alpha=0.8), linewidth=1.5)
plt.ylabel('Resting Blood Pressure', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

plt.show()
```

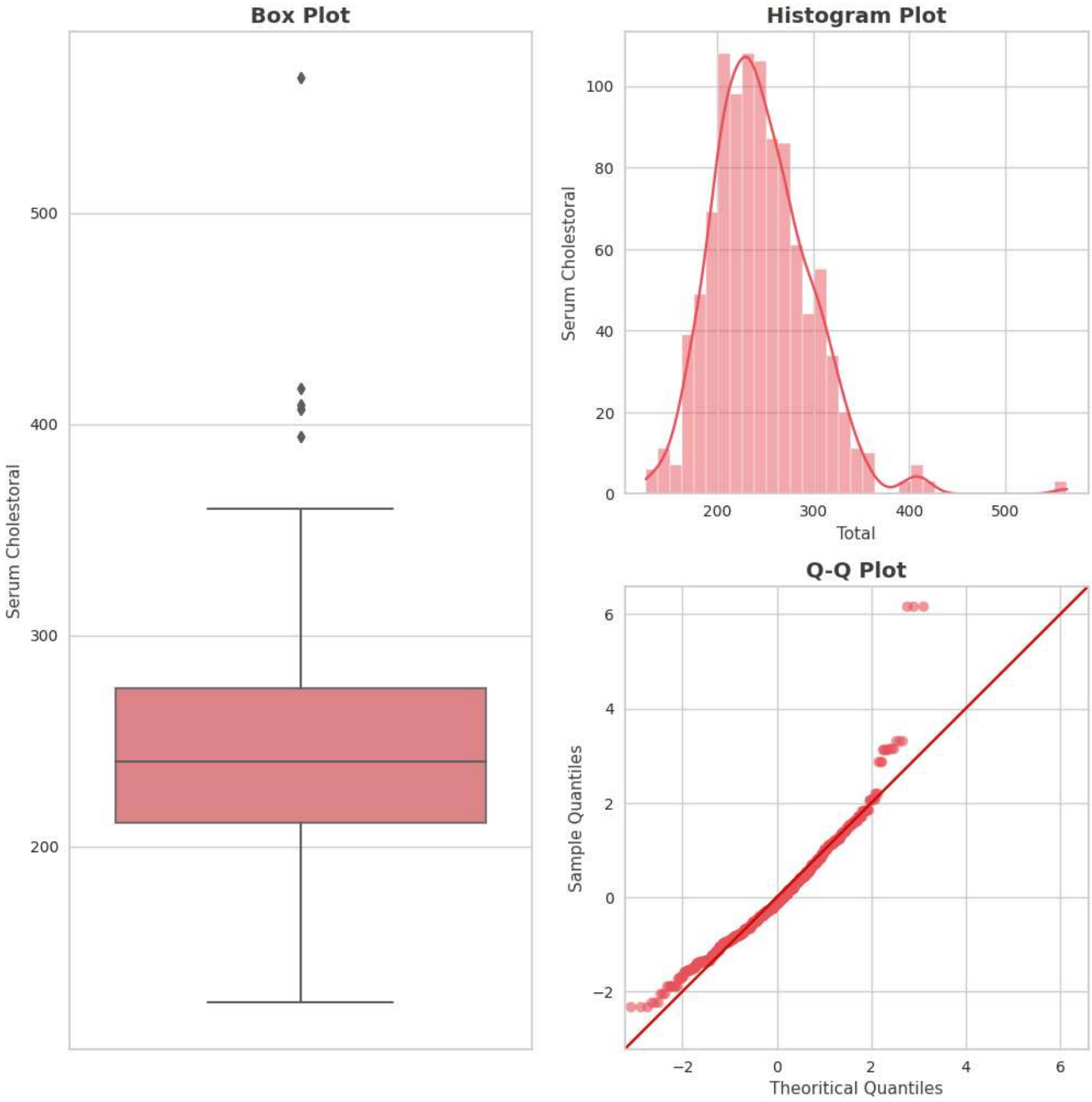
```
.: Resting Blood Pressure Column Skewness & Kurtosis :.
**************************************************
Skewness: 0.740
Kurtosis: 0.991
```



chol (Serum Cholestoral in mg/dl)

In [19]:
```
# --- Variable, Color & Plot Size ---
var = 'chol'
color = color_mix[4]
fig=plt.figure(figsize=(12, 12))

# --- Skewness & Kurtosis ---
print('\033[1m'+'.: Serum Cholestoral Column Skewness & Kurtosis :.'+'\033[0m')
print('*' * 45)
print('Skewness:'+'\033[1m {:.3f}'.format(df[var].skew(axis = 0, skipna = True)))
print('\033[0m'+'Kurtosis:'+'\033[1m {:.3f}'.format(df[var].kurt(axis = 0, skipna = True)))
print('\n')

# --- General Title ---
fig.suptitle('Serum Cholestoral Column Distribution', fontweight='bold',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])
fig.subplots_adjust(top=0.9)

# --- Histogram ---
ax_1=fig.add_subplot(2, 2, 2)
plt.title('Histogram Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.histplot(data=df, x=var, kde=True, color=color)
plt.xlabel('Total', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Serum Cholestoral', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
# --- Q-Q Plot ---
ax_2=fig.add_subplot(2, 2, 4)
plt.title('Q-Q Plot', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[1])
qqplot(df[var], fit=True, line='45', ax=ax_2, markerfacecolor=color,
       markeredgecolor=color, alpha=0.6)
plt.xlabel('Theoritical Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Sample Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

# --- Box Plot ---
ax_3=fig.add_subplot(1, 2, 1)
plt.title('Box Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.boxplot(data=df, y=var, color=color, boxprops=dict(alpha=0.8), linewidth=1.5)
plt.ylabel('Serum Cholestoral', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

plt.show()
```

```
.: Serum Cholestoral Column Skewness & Kurtosis :.
*********************************************
Skewness: 1.074
Kurtosis: 3.997
```

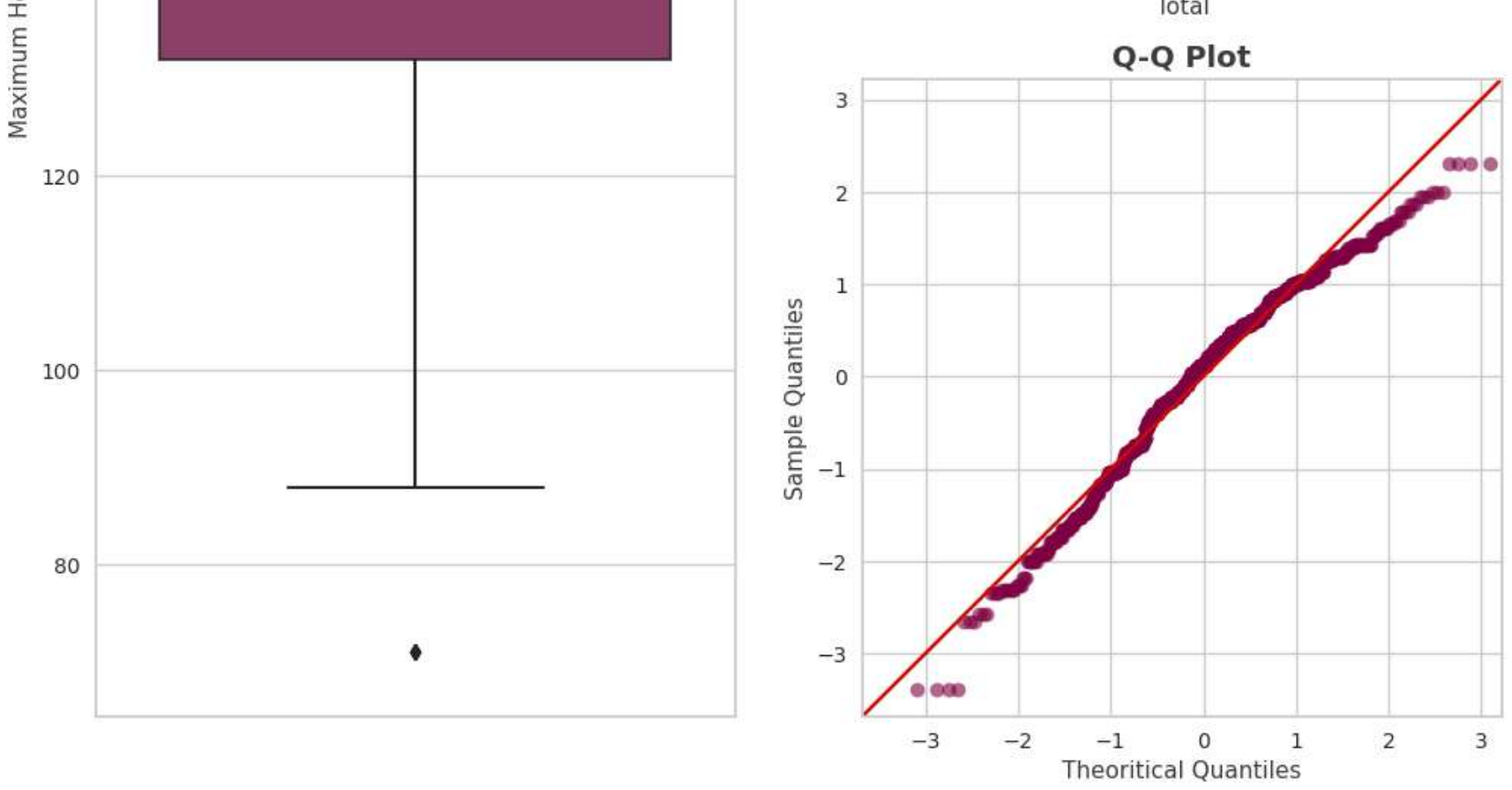


thalach (Maximum Heart Rate)

In [20]:
```
# --- Variable, Color & Plot Size ---
var = 'thalach'
color = purple_grad[1]
fig=plt.figure(figsize=(12, 12))

# --- Skewness & Kurtosis ---
print('\033[1m'+'.: Maximum Heart Rate Column Skewness & Kurtosis :.'+'\033[0m')
print('*' * 50)
print('Skewness:'+'\033[1m {:.3f}'.format(df[var].skew(axis = 0, skipna = True)))
print('\033[0m'+'Kurtosis:'+'\033[1m {:.3f}'.format(df[var].kurt(axis = 0, skipna = True)))
print('\n')

# --- General Title ---
fig.suptitle('Maximum Heart Rate Column Distribution', fontweight='bold',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])
fig.subplots_adjust(top=0.9)

# --- Histogram ---
ax_1=fig.add_subplot(2, 2, 2)
plt.title('Histogram Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.histplot(data=df, x=var, kde=True, color=color)
plt.xlabel('Total', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Maximum Heart Rate', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

# --- Q-Q Plot ---
ax_2=fig.add_subplot(2, 2, 4)
plt.title('Q-Q Plot', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[1])
qqplot(df[var], fit=True, line='45', ax=ax_2, markerfacecolor=color,
       markeredgecolor=color, alpha=0.6)
plt.xlabel('Theoritical Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
```

```
plt.ylabel('Sample Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

# --- Box Plot ---
ax_3=fig.add_subplot(1, 2, 1)
plt.title('Box Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.boxplot(data=df, y=var, color=color, boxprops=dict(alpha=0.8), linewidth=1.5)
plt.ylabel('Maximum Heart Rate', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

plt.show()
```

```
.: Maximum Heart Rate Column Skewness & Kurtosis :.
**************************************************
Skewness: -0.514
Kurtosis: -0.089
```



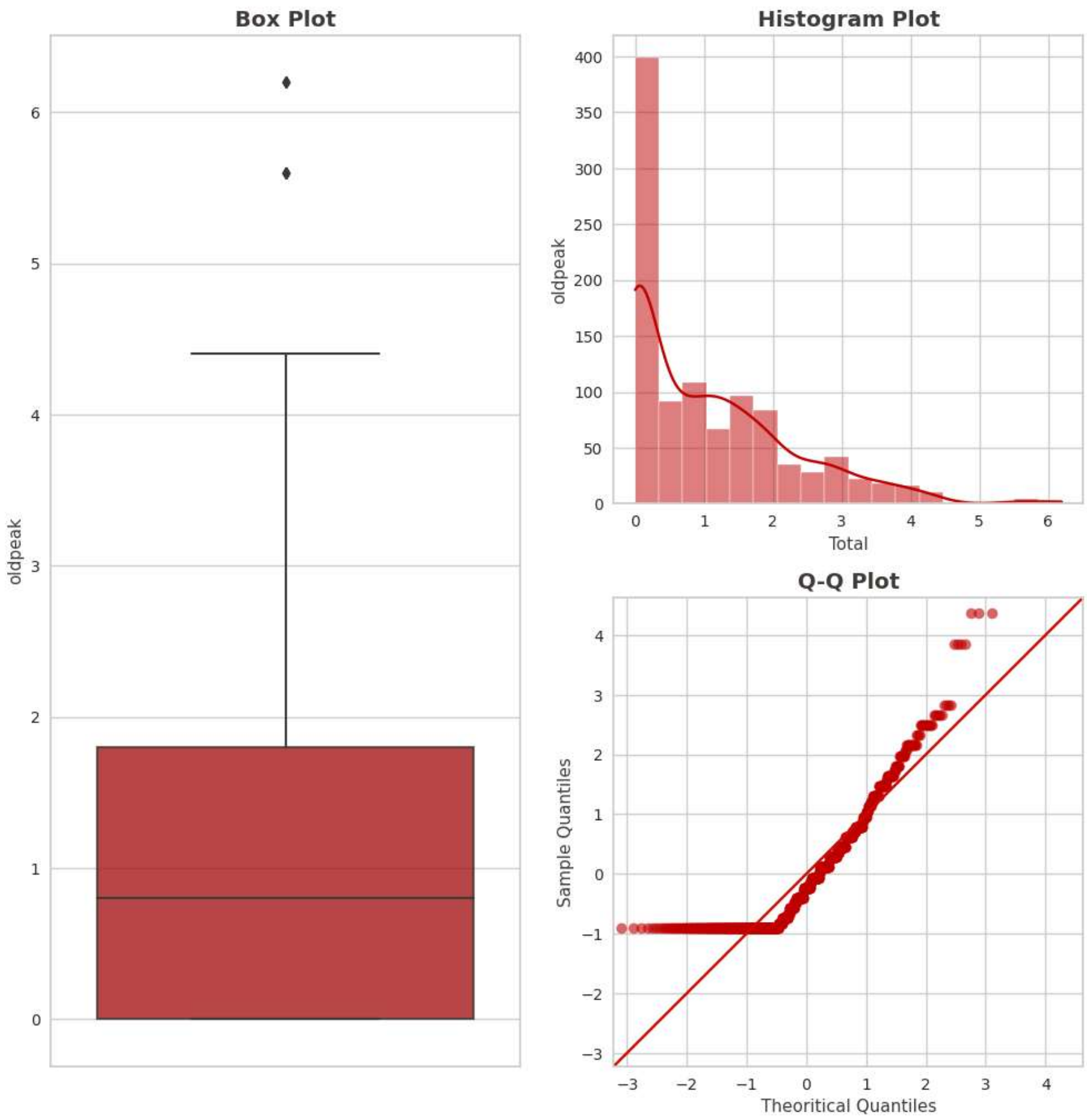
oldpeak

In [21]:

```
# --- Variable, Color & Plot Size ---
var = 'oldpeak'
color = red_grad[1]
fig=plt.figure(figsize=(12, 12))

# --- Skewness & Kurtosis ---
print('\033[1m'+'.: "oldpeak" Column Skewness & Kurtosis :.'+'\033[0m')
print('*' * 40)
print('Skewness:'+'\033[1m {:.3f}'.format(df[var].skew(axis = 0, skipna = True)))
print('\033[0m'+'Kurtosis:'+'\033[1m {:.3f}'.format(df[var].kurt(axis = 0, skipna = True)))
print('\n')

# --- General Title ---
fig.suptitle('"oldpeak" Column Distribution', fontweight='bold',
             fontsize=16, fontfamily='sans-serif', color=black_grad[0])
fig.subplots_adjust(top=0.9)
```

```
# --- Histogram ---
ax_1=fig.add_subplot(2, 2, 2)
plt.title('Histogram Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.histplot(data=df, x=var, kde=True, color=color)
plt.xlabel('Total', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('oldpeak', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

# --- Q-Q Plot ---
ax_2=fig.add_subplot(2, 2, 4)
plt.title('Q-Q Plot', fontweight='bold', fontsize=14, fontfamily='sans-serif',
          color=black_grad[1])
qqplot(df[var], fit=True, line='45', ax=ax_2, markerfacecolor=color,
       markeredgecolor=color, alpha=0.6)
plt.xlabel('Theoritical Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Sample Quantiles', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

# --- Box Plot ---
ax_3=fig.add_subplot(1, 2, 1)
plt.title('Box Plot', fontweight='bold', fontsize=14,
          fontfamily='sans-serif', color=black_grad[1])
sns.boxplot(data=df, y=var, color=color, boxprops=dict(alpha=0.8), linewidth=1.5)
plt.ylabel('oldpeak', fontweight='regular', fontsize=11,
           fontfamily='sans-serif', color=black_grad[1])

plt.show()
```

```
.: "oldpeak" Column Skewness & Kurtosis :.
**************************************
Skewness: 1.211
Kurtosis: 1.314
```

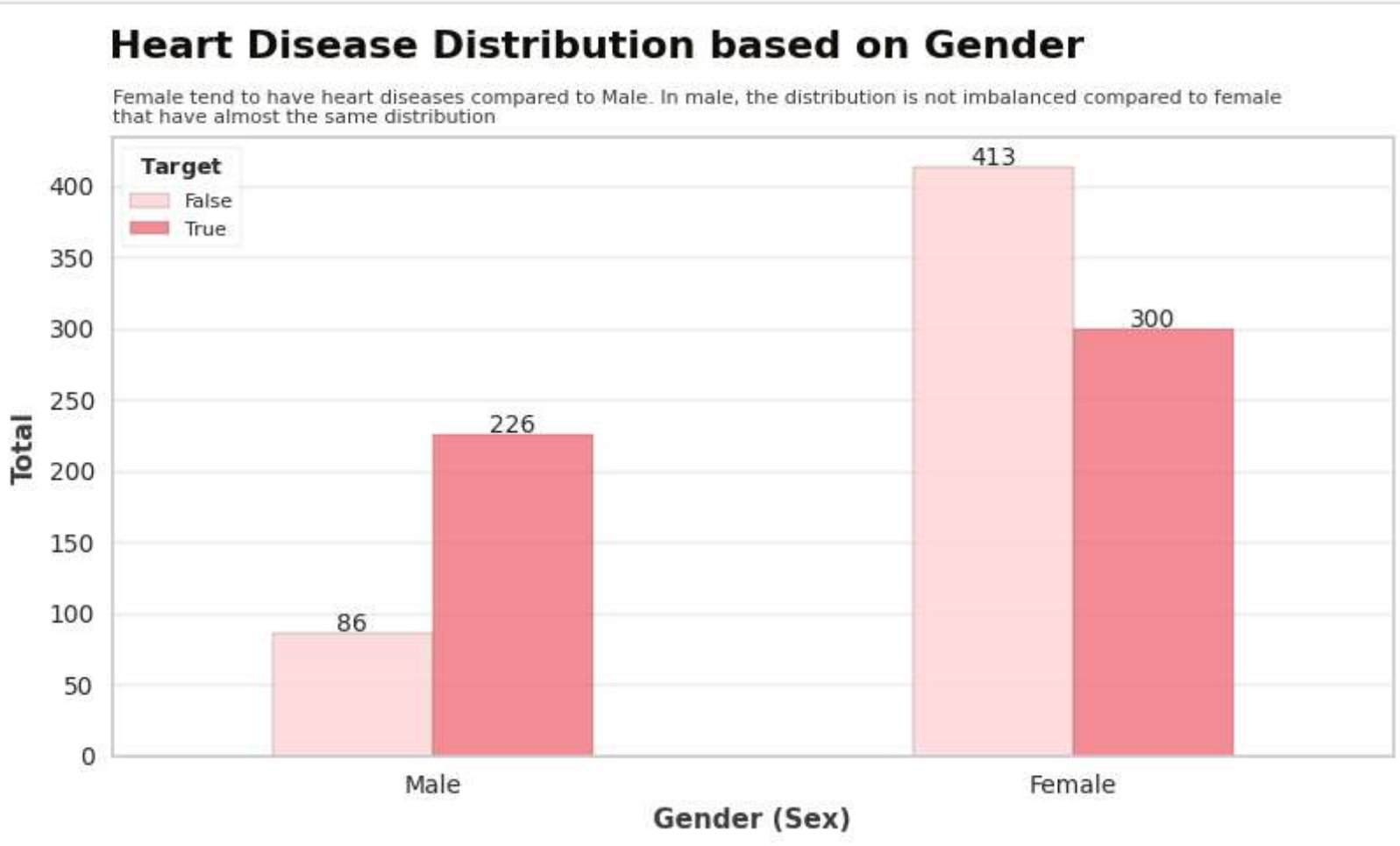


EDA

This section will perform some EDA to get more insights about dataset.

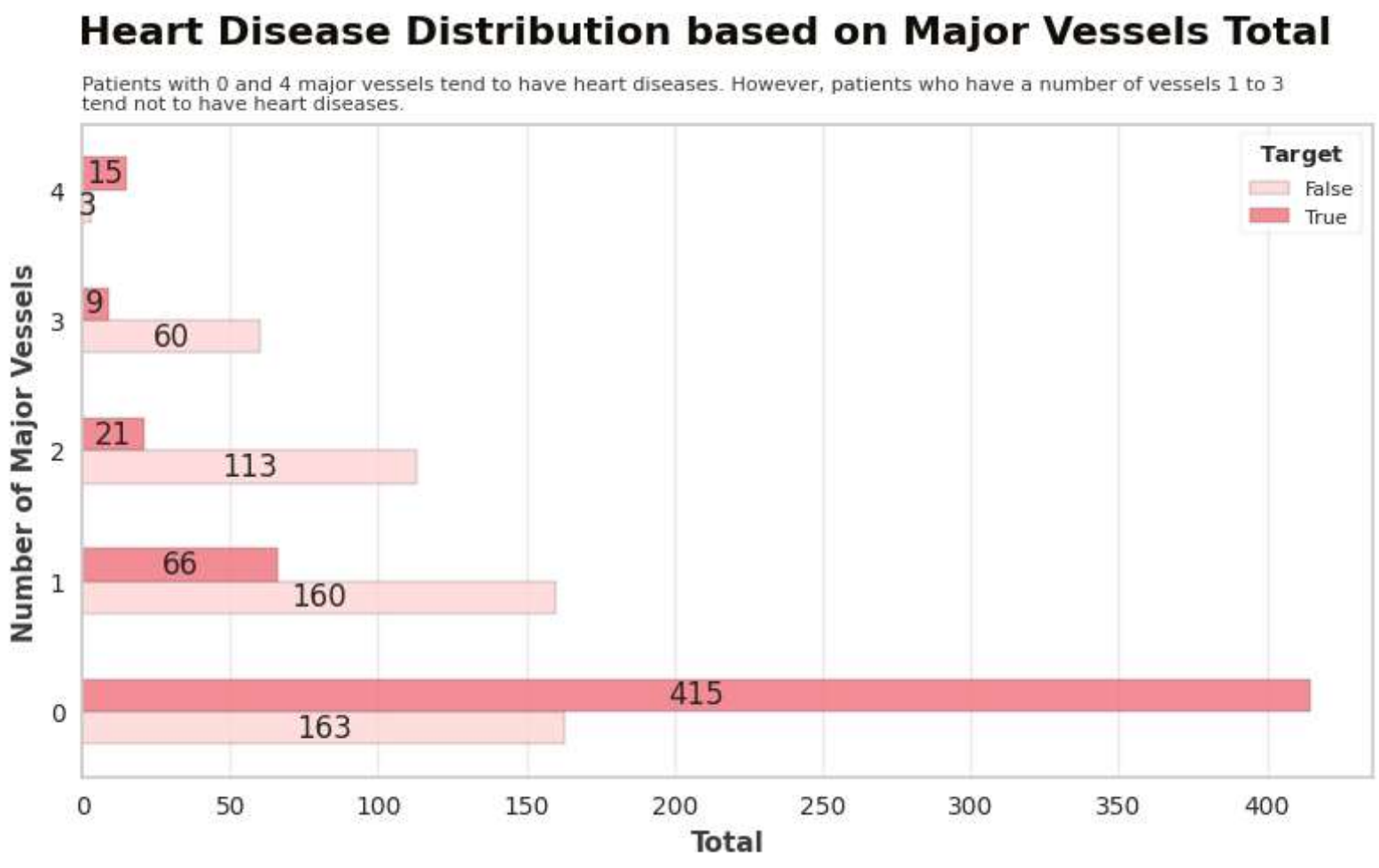
Heart Disease Distribution based on Gender

In [22]:
```
# --- Labels Settings ---
labels = ['False', 'True']
label_gender = np.array([0, 1])
label_gender2 = ['Male', 'Female']

# --- Creating Bar Chart ---
ax = pd.crosstab(df.sex, df.target).plot(kind='bar', figsize=(8, 5),
                                         color=color_mix[2:4],
                                         edgecolor=black_grad[2], alpha=0.85)
# --- Bar Chart Settings ---
for rect in ax.patches:
    ax.text (rect.get_x()+rect.get_width()/2,
             rect.get_height()+1.25,rect.get_height(),
             horizontalalignment='center', fontsize=10)

plt.suptitle('Heart Disease Distribution based on Gender', fontweight='heavy',
             x=0.065, y=0.98, ha='left', fontsize='16', fontfamily='sans-serif',
             color=black_grad[0])
plt.title('Female tend to have heart diseases compared to Male. In male, the distribution is not imbalanced compared to
          fontsize='8', fontfamily='sans-serif', loc='left', color=black_grad[1])
plt.tight_layout(rect=[0, 0.04, 1, 1.025])
plt.xlabel('Gender (Sex)', fontfamily='sans-serif', fontweight='bold',
           color=black_grad[1])
plt.ylabel('Total', fontfamily='sans-serif', fontweight='bold',
           color=black_grad[1])
plt.xticks(label_gender, label_gender2, rotation=0)
plt.grid(axis='y', alpha=0.4)
plt.grid(axis='x', alpha=0)
plt.legend(labels=labels, title='$\\bf{Target}$', fontsize='8',
           title_fontsize='9', loc='upper left', frameon=True);
```



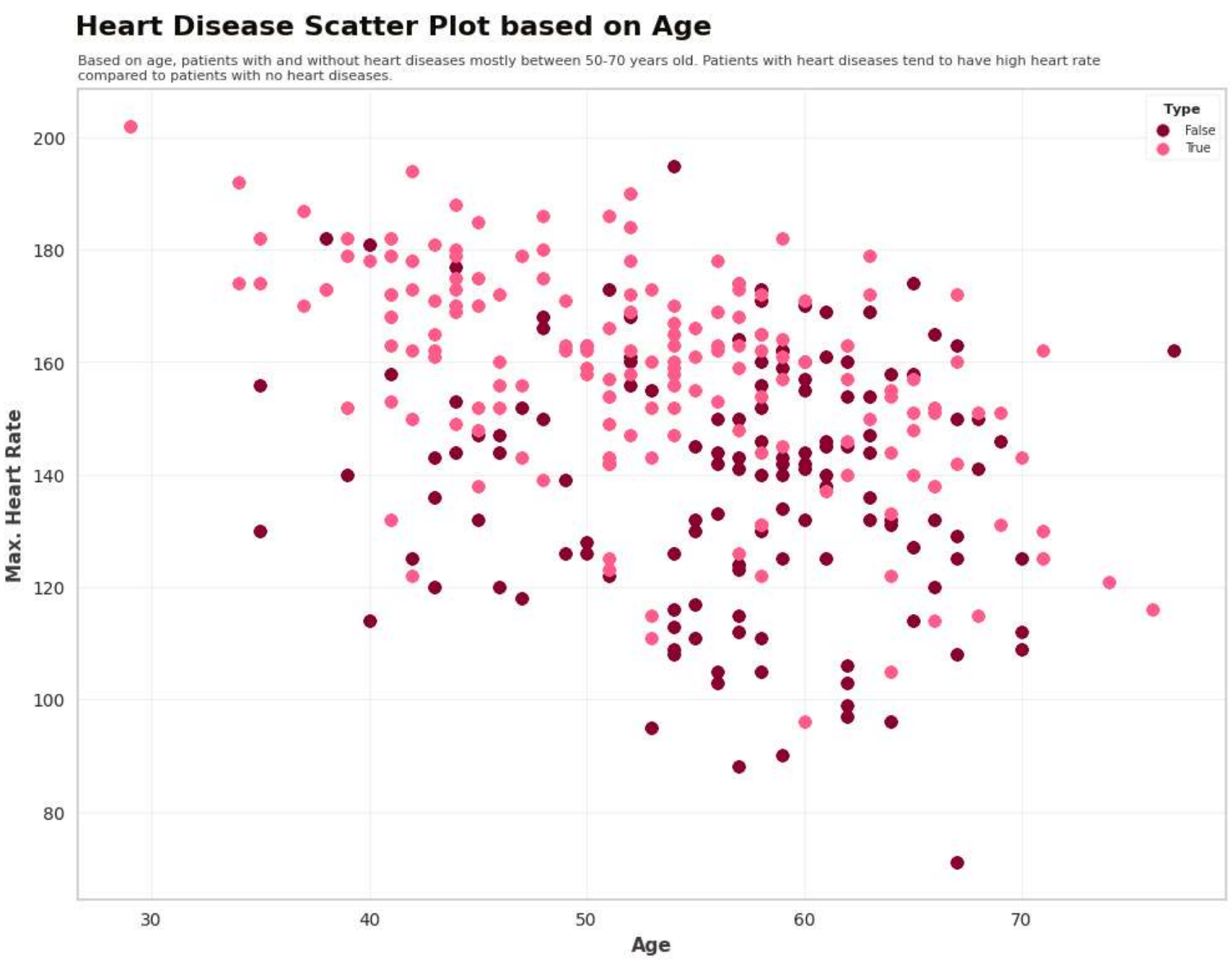
Heart Disease Distribution based on Major Vessels Total

```
In [23]: # --- Labels Settings ---
labels = ['False', 'True']

# --- Creating Horizontal Bar Chart ---
ax = pd.crosstab(df.ca, df.target).plot(kind='barh', figsize=(8, 5),
                                        color=color_mix[2:4],
                                        edgecolor=black_grad[2], alpha=0.85)
# --- Horizontal Bar Chart Settings ---
for rect in ax.patches:
    width, height = rect.get_width(), rect.get_height()
    x, y = rect.get_xy()
    ax.text (x+width/2, y+height/2, '{:.0f}'.format(width),
             horizontalalignment='center', verticalalignment='center')

plt.suptitle('Heart Disease Distribution based on Major Vessels Total',
             fontweight='heavy', x=0.069, y=0.98, ha='left', fontsize='16',
             fontfamily='sans-serif', color=black_grad[0])
plt.title('Patients with 0 and 4 major vessels tend to have heart diseases. However, patients who have a number of vesse
          fontsize='8', fontfamily='sans-serif', loc='left', color=black_grad[1])
plt.tight_layout(rect=[0, 0.04, 1, 1.025])
plt.xlabel('Total', fontfamily='sans-serif', fontweight='bold', color=black_grad[1])
plt.ylabel('Number of Major Vessels', fontfamily='sans-serif', fontweight='bold',
           color=black_grad[1])
plt.yticks(rotation=0)
plt.grid(axis='x', alpha=0.4)
plt.grid(axis='y', alpha=0)
plt.legend(labels=labels, title='$\\bf{Target}$', fontsize='8', frameon=True,
           title_fontsize='9', loc='upper right');
```



Heart Disease Scatter Plot based on Age

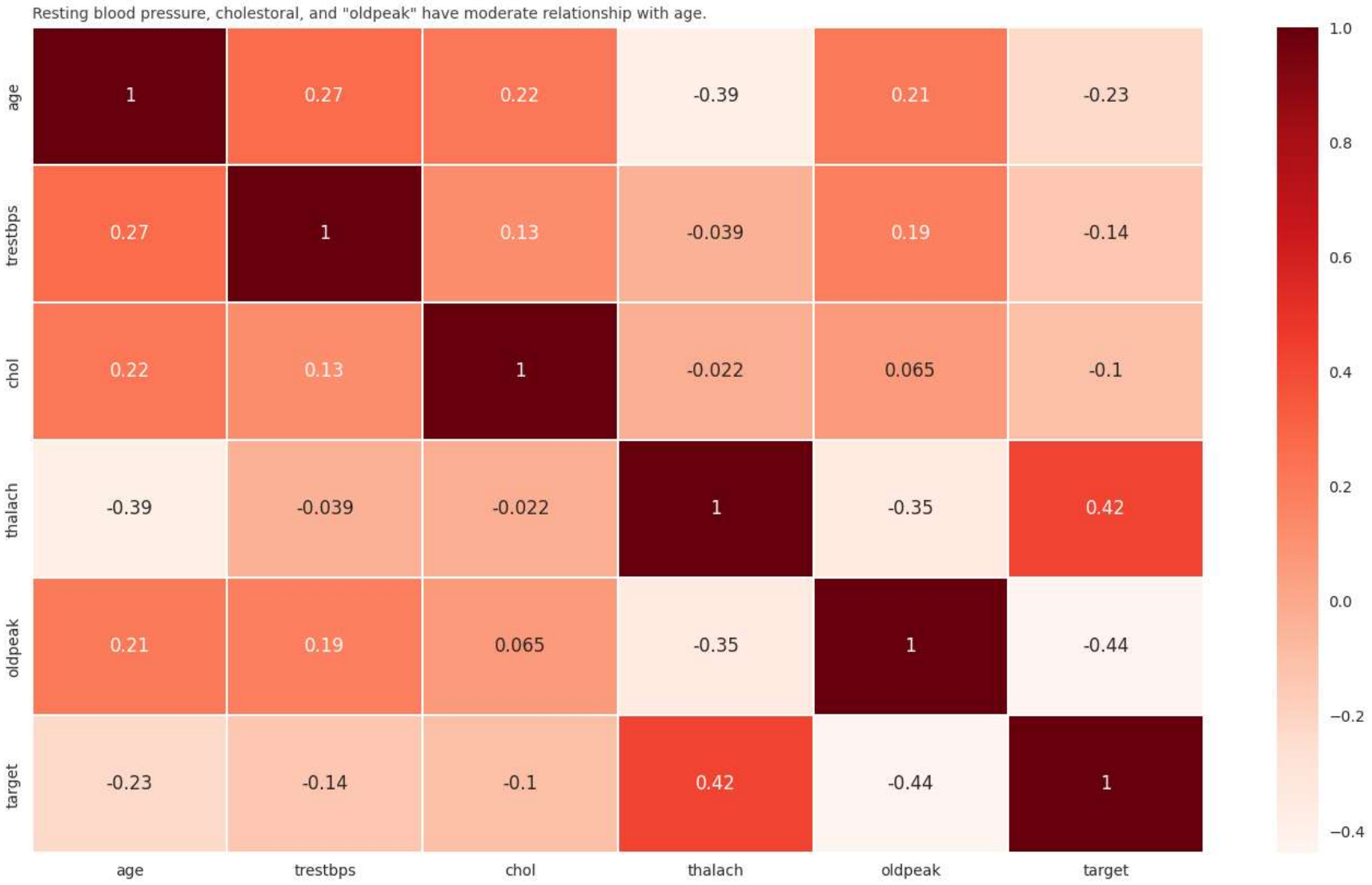
In [24]:
```
# -- Scatter Plot Size & Titles Settings ---
plt.figure(figsize=(10, 8))
plt.suptitle('Heart Disease Scatter Plot based on Age', fontweight='heavy',
             x=0.048, y=0.98, ha='left', fontsize='16', fontfamily='sans-serif',
             color=black_grad[0])
plt.title('Based on age, patients with and without heart diseases mostly between 50-70 years old. Patients with heart di
          fontsize='8', fontfamily='sans-serif', loc='left', color=black_grad[1])
plt.tight_layout(rect=[0, 0.04, 1, 1.01])

# --- Creating Scatter Plot ---
plt.scatter(x=df.age[df.target==0], y=df.thalach[(df.target==0)], c=pink_grad[0])
plt.scatter(x=df.age[df.target==1], y=df.thalach[(df.target==1)], c=pink_grad[2])

# --- Scatter Plot Legend & Labels Settings ---
plt.legend(['False', 'True'], title='$\\bf{Type}$', fontsize='7',
           title_fontsize='8', loc='upper right', frameon=True)
plt.xlabel('Age', fontweight='bold', fontsize='11',
           fontfamily='sans-serif', color=black_grad[1])
plt.ylabel('Max. Heart Rate', fontweight='bold', fontsize='11',
           fontfamily='sans-serif', color=black_grad[1])
plt.ticklabel_format(style='plain', axis='both')
plt.grid(axis='both', alpha=0.4, lw=0.5)
plt.show();
```



Heatmap

Below is correlation map/heatmap of numerical variables to show correlation level/values for each variables with others.

In [25]:
```
# --- Correlation Map (Heatmap) ---
plt.figure(figsize=(14, 9))
sns.heatmap(df.corr(), annot=True, cmap='Reds', linewidths=0.1)
plt.suptitle('Correlation Map of Numerical Variables', fontweight='heavy',
             x=0.03, y=0.98, ha='left', fontsize='16', fontfamily='sans-serif',
             color=black_grad[0])
plt.title('Resting blood pressure, cholestoral, and "oldpeak" have moderate relationship with age.',
          fontsize='10', fontfamily='sans-serif', loc='left', color=black_grad[1])
plt.tight_layout(rect=[0, 0.04, 1, 1.01])
```



Dataset Pre-processing

One-Hot Encoding

The data pre-processing will be transforming categorical variables using one-hot encoding technique.

In [26]:
```
# --- Creating Dummy Variables for cp, thal and slope ---
cp = pd.get_dummies(df['cp'], prefix='cp')
thal = pd.get_dummies(df['thal'], prefix='thal')
slope = pd.get_dummies(df['slope'], prefix='slope')

# --- Merge Dummy Variables to Main Data Frame ---
frames = [df, cp, thal, slope]
df = pd.concat(frames, axis = 1)
```

In [27]:
```
# --- Display New Data Frame ---
df.head().style.background_gradient(cmap='PuRd').hide_index().set_properties(**{'font-family': 'Segoe UI'})
```

Out[27]:

age	sex	cp	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	slope	ca	thal	target	cp_0	cp_1	cp_2	cp_3	thal_0	thal_1	thal_2
52	1	0	125	212	0	1	168	0	1.000000	2	2	3	0	1	0	0	0	0	0	0
53	1	0	140	203	1	0	155	1	3.100000	0	0	3	0	1	0	0	0	0	0	0
70	1	0	145	174	0	1	125	1	2.600000	0	0	3	0	1	0	0	0	0	0	0
61	1	0	148	203	0	1	161	0	0.000000	2	1	3	0	1	0	0	0	0	0	0
62	0	0	138	294	1	1	106	0	1.900000	1	3	2	0	1	0	0	0	0	0	1

Dropping Unnecessary Variables

In [28]:
```
# --- Drop Unnecessary Variables ---
df = df.drop(columns = ['cp', 'thal', 'slope'])
```

In [29]:
```
# --- Display New Data Frame ---
df.head().style.background_gradient(cmap='Reds').hide_index().set_properties(**{'font-family': 'Segoe UI'})
```

Out[29]:

age	sex	trestbps	chol	fbs	restecg	thalach	exang	oldpeak	ca	target	cp_0	cp_1	cp_2	cp_3	thal_0	thal_1	thal_2	thal_3	slope_0
52	1	125	212	0	1	168	0	1.000000	2	0	1	0	0	0	0	0	0	1	0
53	1	140	203	1	0	155	1	3.100000	0	0	1	0	0	0	0	0	0	1	1
70	1	145	174	0	1	125	1	2.600000	0	0	1	0	0	0	0	0	0	1	1
61	1	148	203	0	1	161	0	0.000000	1	0	1	0	0	0	0	0	0	1	0
62	0	138	294	1	1	106	0	1.900000	3	0	1	0	0	0	0	0	1	0	0

Features Separating

In this section, the 'target' (dependent) column will be seperated from independent columns.

In [30]:
```
# --- Seperating Dependent Features ---
x = df.drop(['target'], axis=1)
y = df['target']
```

Data Normalization

In this section, data normalization will be performed to normalize the range of independent variables or features of data.

Data normalization will use **min-max normalization.**

Min-max normalization is often known as feature scaling where the values of a numeric range of a feature of data, are reduced to a scale between 0 and 1.

In [31]:
```
# --- Data Normalization using Min-Max Method ---
x = MinMaxScaler().fit_transform(x)
```

Splitting the Dataset

The dataset will be splitted into 80:20 ratio (80% training and 20% testing).

In [32]:
```
# --- Splitting Dataset into 80:20 ---
x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.2, random_state=4)
```

Model Implementation

Logistic Regression

In [33]:
```
# --- Applying Logistic Regression ---
LRclassifier = LogisticRegression(max_iter=1000, random_state=1, solver='liblinear', penalty='l1')
LRclassifier.fit(x_train, y_train)

y_pred_LR = LRclassifier.predict(x_test)
```

Logistic Regression -84% acc

In [34]:
```
# --- LR Accuracy ---
LRAcc = accuracy_score(y_pred_LR, y_test)
print('.:. Logistic Regression Accuracy:'+'\033[1m {:.2f}%'.format(LRAcc*100)+' .:.')
```

```
.:. Logistic Regression Accuracy: 83.90% .:.
```

K-Nearest Neighbour (KNN)

In [35]:
```
# --- Applying KNN ---
KNNClassifier = KNeighborsClassifier(n_neighbors=3)
KNNClassifier.fit(x_train, y_train)

y_pred_KNN = KNNClassifier.predict(x_test)
```

KNearest Neighbors - 96% acc

In [36]:
```
# --- KNN Accuracy ---
KNNAcc = accuracy_score(y_pred_KNN, y_test)
print('.:. K-Nearest Neighbour Accuracy:'+'\033[1m {:.2f}%'.format(KNNAcc*100)+' .:.')
```

```
.:. K-Nearest Neighbour Accuracy: 95.61% .:.
```

Support Vector Machine (SVM)

In [37]:
```
# --- Applying SVM ---
SVMclassifier = SVC(kernel='linear', max_iter=1000, C=10, probability=True)
SVMclassifier.fit(x_train, y_train)

y_pred_SVM = SVMclassifier.predict(x_test)
```

SVM - 84% acc

In [38]:
```
# --- SVM Accuracy ---
SVMAcc = accuracy_score(y_pred_SVM, y_test)
print('.:. Support Vector Machine Accuracy:'+'\033[1m {:.2f}%'.format(SVMAcc*100)+' .:.')
```

```
.:. Support Vector Machine Accuracy: 83.90% .:.
```

Gaussian Naive Bayes

In [39]:
```
# --- Applying Gaussian NB ---
GNBclassifier = GaussianNB(var_smoothing=0.1)
GNBclassifier.fit(x_train, y_train)

y_pred_GNB = GNBclassifier.predict(x_test)
```

Gaussian Naive Bayes - 83% acc

In [40]:
```
# --- GNB Accuracy ---
GNBAcc = accuracy_score(y_pred_GNB, y_test)
print('.:. Gaussian Naive Bayes Accuracy:'+'\033[1m {:.2f}%'.format(GNBAcc*100)+' .:.')
```

```
.:. Gaussian Naive Bayes Accuracy: 82.44% .:.
```

Decision Tree

In [41]:
```
# --- Applying Decision Tree ---
DTCclassifier = DecisionTreeClassifier(max_depth=3, min_samples_leaf=5, criterion='entropy', min_samples_split=5,
```

```
                                        splitter='random', random_state=1)

DTCclassifier.fit(x_train, y_train)
y_pred_DTC = DTCclassifier.predict(x_test)
```

Decision Tree- 84% acc

In [42]:
```
# --- Decision Tree Accuracy ---
DTCAcc = accuracy_score(y_pred_DTC, y_test)
print('.:. Decision Tree Accuracy:'+'\033[1m {:.2f}%'.format(DTCAcc*100)+' .:.')
```

```
.:. Decision Tree Accuracy: 83.90% .:.
```

Random Forest

In [43]:
```
# --- Applying Random Forest ---
RFclassifier = RandomForestClassifier(n_estimators=1000, random_state=1, max_leaf_nodes=20, min_samples_split=15)

RFclassifier.fit(x_train, y_train)
y_pred_RF = RFclassifier.predict(x_test)
```

Random Forest - 89% acc

In [44]:
```
# --- Random Forest Accuracy ---
RFAcc = accuracy_score(y_pred_RF, y_test)
print('.:. Random Forest Accuracy:'+'\033[1m {:.2f}%'.format(RFAcc*100)+' .:.')
```

```
.:. Random Forest Accuracy: 88.78% .:.
```

Gradient Boosting

In [45]:
```
# --- Applying Gradient Boosting ---
GBclassifier = GradientBoostingClassifier(random_state=1, n_estimators=100, max_leaf_nodes=3, loss='exponential',
                                          min_samples_leaf=20)

GBclassifier.fit(x_train, y_train)
y_pred_GB = GBclassifier.predict(x_test)
```

Gradient Boosting - 88% acc

In [46]:
```
# --- Gradient Boosting Accuracy ---
GBAcc = accuracy_score(y_pred_GB, y_test)
print('.:. Gradient Boosting Accuracy:'+'\033[1m {:.2f}%'.format(GBAcc*100)+' .:.')
```

```
.:. Gradient Boosting Accuracy: 86.83% .:.
```

Machine Learning Models Comparison

In [47]:
```
# --- Create Accuracy Comparison Table ---
compare = pd.DataFrame({'Model': ['Logistic Regression', 'K-Nearest Neighbour', 'Support Vector Machine',
                                  'Gaussian Naive Bayes', 'Decision Tree', 'Random Forest', 'Gradient Boosting'
                                  ],
                        'Accuracy': [LRAcc*100, KNNAcc*100, SVMAcc*100, GNBAcc*100, DTCAcc*100, RFAcc*100, GBAcc*100,
                                     ]})

# --- Create Accuracy Comparison Table ---
compare.sort_values(by='Accuracy', ascending=False).style.background_gradient(cmap='PuRd').hide_index().set_properties(
```

Out[47]:

Model	Accuracy
K-Nearest Neighbour	95.609756
Random Forest	88.780488
Gradient Boosting	86.829268
Logistic Regression	83.902439
Support Vector Machine	83.902439
Decision Tree	83.902439
Gaussian Naive Bayes	82.439024