# Data Dictionary

`age` - Age of the patient

`sex` - Sex of the patient

`cp` - Chest pain type ~ 0 = Typical Angina, 1 = Atypical Angina, 2 = Non-anginal Pain, 3 = Asymptomatic

`trtbps` - Resting blood pressure (in mm Hg)

`chol` - Cholestoral in mg/dl fetched via BMI sensor

`fbs` - (fasting blood sugar > 120 mg/dl) ~ 1 = True, 0 = False

`restecg` - Resting electrocardiographic results ~ 0 = Normal, 1 = ST-T wave normality, 2 = Left ventricular hypertrophy

`thalachh` - Maximum heart rate achieved

`oldpeak` - Previous peak

`slp` - Slope

`caa` - Number of major vessels

`thall` - Thalium Stress Test result ~ (0,3)

`exng` - Exercise induced angina ~ 1 = Yes, 0 = No

`output` - Target variable

# 1.0 Packages import

In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
warnings.filterwarnings("ignore")
```

# 2. Heart disease Dataset

In [2]:
```
df = pd.read_csv("heart.csv")
```

In [3]:
```
print("The shape of the dataset is : ", df.shape)
```

```
The shape of the dataset is :  (303, 14)
```

# 2.1 Show the frist 5 cells

In [4]:
```
df.head()
```

Out[4]:

| | age | sex | cp | trtbps | chol | fbs | restecg | thalachh | exng | oldpeak | slp | caa | thall | output |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 63 | 1 | 3 | 145 | 233 | 1 | 0 | 150 | 0 | 2.3 | 0 | 0 | 1 | 1 |
| **1** | 37 | 1 | 2 | 130 | 250 | 0 | 1 | 187 | 0 | 3.5 | 0 | 0 | 2 | 1 |
| **2** | 41 | 0 | 1 | 130 | 204 | 0 | 0 | 172 | 0 | 1.4 | 2 | 0 | 2 | 1 |
| **3** | 56 | 1 | 1 | 120 | 236 | 0 | 1 | 178 | 0 | 0.8 | 2 | 0 | 2 | 1 |
| **4** | 57 | 0 | 0 | 120 | 354 | 0 | 1 | 163 | 1 | 0.6 | 2 | 0 | 2 | 1 |

# 2.2 Separating the columns in categorical and continuous

In [5]:
```
cat_cols = ['sex','exng','caa','cp','fbs','restecg','slp','thall']
con_cols = ["age","trtbps","chol","thalachh","oldpeak"]
target_col = ["output"]
print("The categorial cols are : ", cat_cols)
print("The continuous cols are : ", con_cols)
print("The target variable is : ", target_col)
```

```
The categorial cols are :  ['sex', 'exng', 'caa', 'cp', 'fbs', 'restecg', 'slp', 'thall']
The continuous cols are :  ['age', 'trtbps', 'chol', 'thalachh', 'oldpeak']
The target variable is :  ['output']
```

# Summary

In [6]:
```
df[con_cols].describe().transpose()
```

Out[6]:

| | count | mean | std | min | 25% | 50% | 75% | max |
|---|---|---|---|---|---|---|---|---|
| **age** | 303.0 | 54.366337 | 9.082101 | 29.0 | 47.5 | 55.0 | 61.0 | 77.0 |
| **trtbps** | 303.0 | 131.623762 | 17.538143 | 94.0 | 120.0 | 130.0 | 140.0 | 200.0 |
| **chol** | 303.0 | 246.264026 | 51.830751 | 126.0 | 211.0 | 240.0 | 274.5 | 564.0 |
| **thalachh** | 303.0 | 149.646865 | 22.905161 | 71.0 | 133.5 | 153.0 | 166.0 | 202.0 |
| **oldpeak** | 303.0 | 1.039604 | 1.161075 | 0.0 | 0.0 | 0.8 | 1.6 | 6.2 |

In [7]:
```
df[cat_cols].describe().transpose()
```

Out[7]:

| | count | mean | std | min | 25% | 50% | 75% | max |
|---|---|---|---|---|---|---|---|---|
| **sex** | 303.0 | 0.683168 | 0.466011 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 |
| **exng** | 303.0 | 0.326733 | 0.469794 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| **caa** | 303.0 | 0.729373 | 1.022606 | 0.0 | 0.0 | 0.0 | 1.0 | 4.0 |
| **cp** | 303.0 | 0.966997 | 1.032052 | 0.0 | 0.0 | 1.0 | 2.0 | 3.0 |
| **fbs** | 303.0 | 0.148515 | 0.356198 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| **restecg** | 303.0 | 0.528053 | 0.525860 | 0.0 | 0.0 | 1.0 | 1.0 | 2.0 |
| **slp** | 303.0 | 1.399340 | 0.616226 | 0.0 | 1.0 | 1.0 | 2.0 | 2.0 |
| **thall** | 303.0 | 2.313531 | 0.612277 | 0.0 | 2.0 | 2.0 | 3.0 | 3.0 |

## 2.3 Check Missing value

In [8]:
```
df.isnull().sum()
```

Out[8]:
```
age         0
sex         0
cp          0
trtbps      0
chol        0
fbs         0
restecg     0
thalachh    0
exng        0
oldpeak     0
slp         0
caa         0
thall       0
output      0
dtype: int64
```

# No Missing values

In [9]:
```
df[df.duplicated()]
```

Out[9]:

| | age | sex | cp | trtbps | chol | fbs | restecg | thalachh | exng | oldpeak | slp | caa | thall | output |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **164** | 38 | 1 | 2 | 138 | 175 | 0 | 1 | 173 | 0 | 0.0 | 2 | 4 | 2 | 1 |

In [10]:
```
df.drop_duplicates(keep='first',inplace=True)
```

In [11]:
```
df[df.duplicated()]
```

Out[11]:

| | age | sex | cp | trtbps | chol | fbs | restecg | thalachh | exng | oldpeak | slp | caa | thall | output |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

# 3. Exploratory Data Analysis

## 3.1 Univariate Analyis

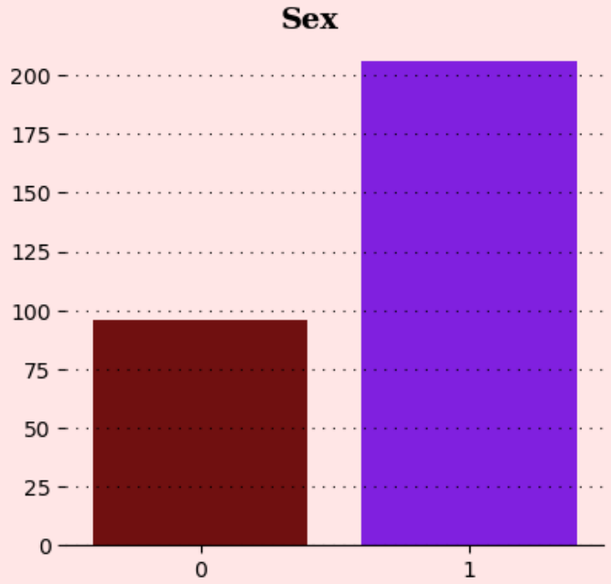
### 3.1.1 plot for cat_cols

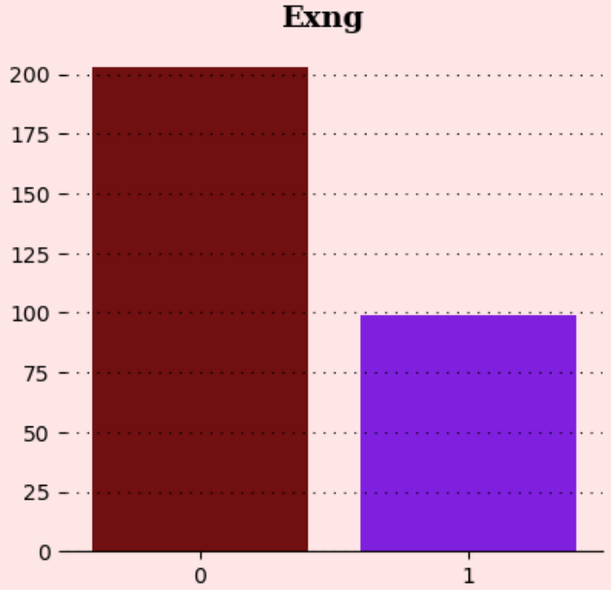
In [12]:
```
fig = plt.figure(figsize=(18,15))
gs = fig.add_gridspec(3,3)
gs.update(wspace=0.5, hspace=0.25)
ax0 = fig.add_subplot(gs[0,0])
```

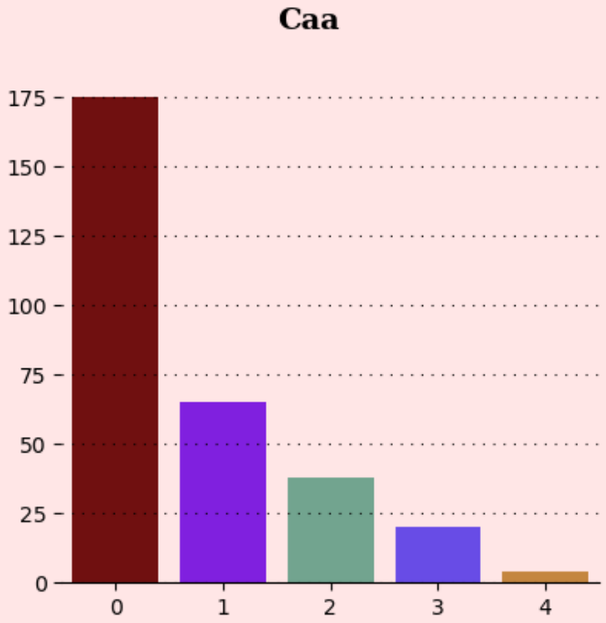
```
ax1 = fig.add_subplot(gs[0,1])
ax2 = fig.add_subplot(gs[0,2])
ax3 = fig.add_subplot(gs[1,0])
ax4 = fig.add_subplot(gs[1,1])
ax5 = fig.add_subplot(gs[1,2])
ax6 = fig.add_subplot(gs[2,0])
ax7 = fig.add_subplot(gs[2,1])
ax8 = fig.add_subplot(gs[2,2])
background_color = "#ffe6e6"
color_palette = ["#800000","#8000ff","#6aac90","#5833ff","#da8829"]
fig.patch.set_facecolor(background_color)
ax0.set_facecolor(background_color)
ax1.set_facecolor(background_color)
ax2.set_facecolor(background_color)
ax3.set_facecolor(background_color)
ax4.set_facecolor(background_color)
ax5.set_facecolor(background_color)
ax6.set_facecolor(background_color)
ax7.set_facecolor(background_color)
ax8.set_facecolor(background_color)
# Title of the plot
ax0.spines["bottom"].set_visible(False)
ax0.spines["left"].set_visible(False)
ax0.spines["top"].set_visible(False)
ax0.spines["right"].set_visible(False)
ax0.tick_params(left=False, bottom=False)
ax0.set_xticklabels([])
ax0.set_yticklabels([])
ax0.text(0.5,0.5,
 'Count plot for various\n categorical features\n_________________',
 horizontalalignment='center',
 verticalalignment='center',
 fontsize=18, fontweight='bold',
 fontfamily='serif',
 color="#000000")
# Sex count
ax1.text(0.3, 220, 'Sex', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax1.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.countplot(ax=ax1,data=df,x='sex',palette=color_palette)
ax1.set_xlabel("")
ax1.set_ylabel("")
# Exng count
ax2.text(0.3, 220, 'Exng', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax2.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.countplot(ax=ax2,data=df,x='exng',palette=color_palette)
ax2.set_xlabel("")
ax2.set_ylabel("")
# Caa count
ax3.text(1.5, 200, 'Caa', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax3.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
```

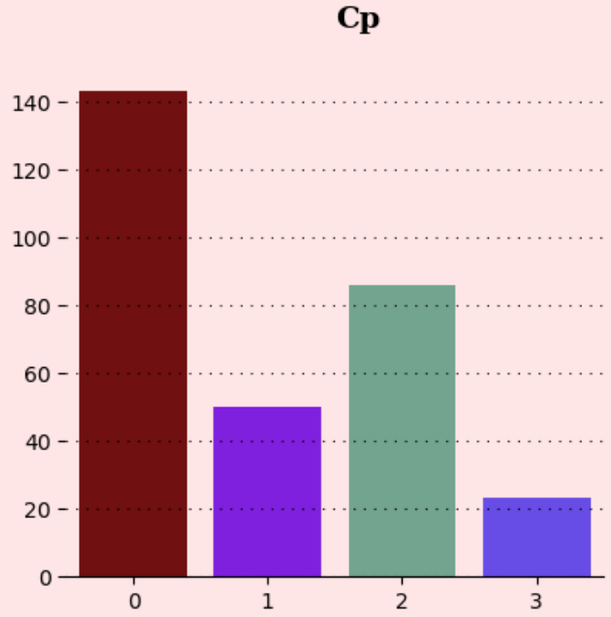
```
sns.countplot(ax=ax3,data=df,x='caa',palette=color_palette)
ax3.set_xlabel("")
ax3.set_ylabel("")
# Cp count
ax4.text(1.5, 162, 'Cp', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax4.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.countplot(ax=ax4,data=df,x='cp',palette=color_palette)
ax4.set_xlabel("")
ax4.set_ylabel("")
# Fbs count
ax5.text(0.5, 290, 'Fbs', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax5.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.countplot(ax=ax5,data=df,x='fbs',palette=color_palette)
ax5.set_xlabel("")
ax5.set_ylabel("")
# Restecg count
ax6.text(0.75, 165, 'Restecg', fontsize=14, fontweight='bold', fontfamily='serif', color="000000")
ax6.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.countplot(ax=ax6,data=df,x='restecg',palette=color_palette)
ax6.set_xlabel("")
ax6.set_ylabel("")
# Slp count
ax7.text(0.85, 155, 'Slp', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax7.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.countplot(ax=ax7,data=df,x='slp',palette=color_palette)
ax7.set_xlabel("")
ax7.set_ylabel("")
# Thall count
ax8.text(1.2, 180, 'Thall', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax8.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.countplot(ax=ax8,data=df,x='thall',palette=color_palette)
ax8.set_xlabel("")
ax8.set_ylabel("")
for s in ["top","right","left"]:
 ax1.spines[s].set_visible(False)
 ax2.spines[s].set_visible(False)
 ax3.spines[s].set_visible(False)
 ax4.spines[s].set_visible(False)
 ax5.spines[s].set_visible(False)
 ax6.spines[s].set_visible(False)
 ax7.spines[s].set_visible(False)
 ax8.spines[s].set_visible(False)
```

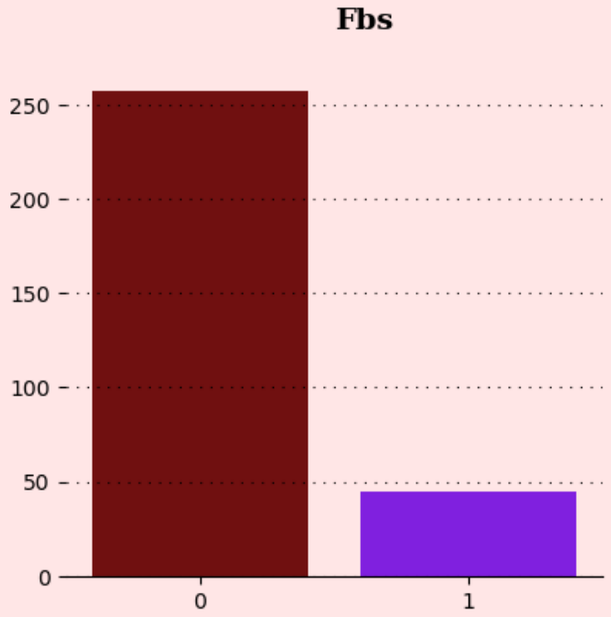
## Count plot for various categorical features



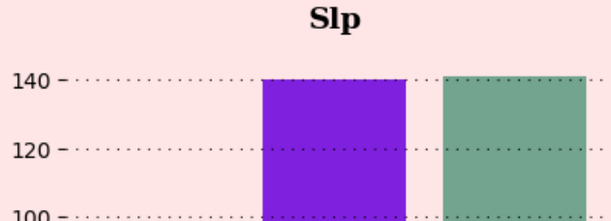



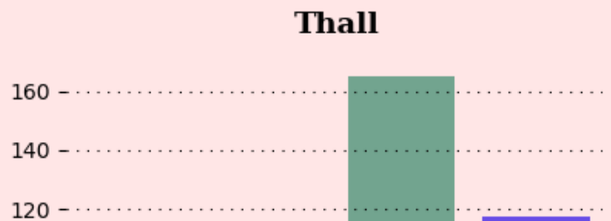



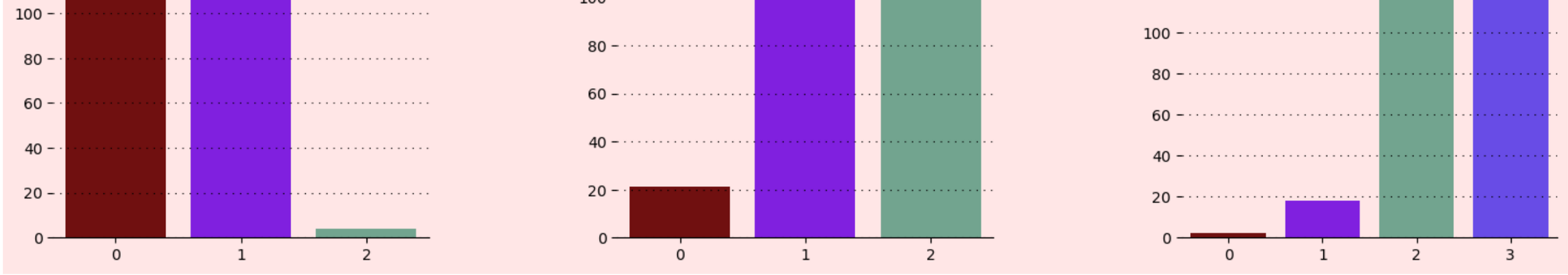









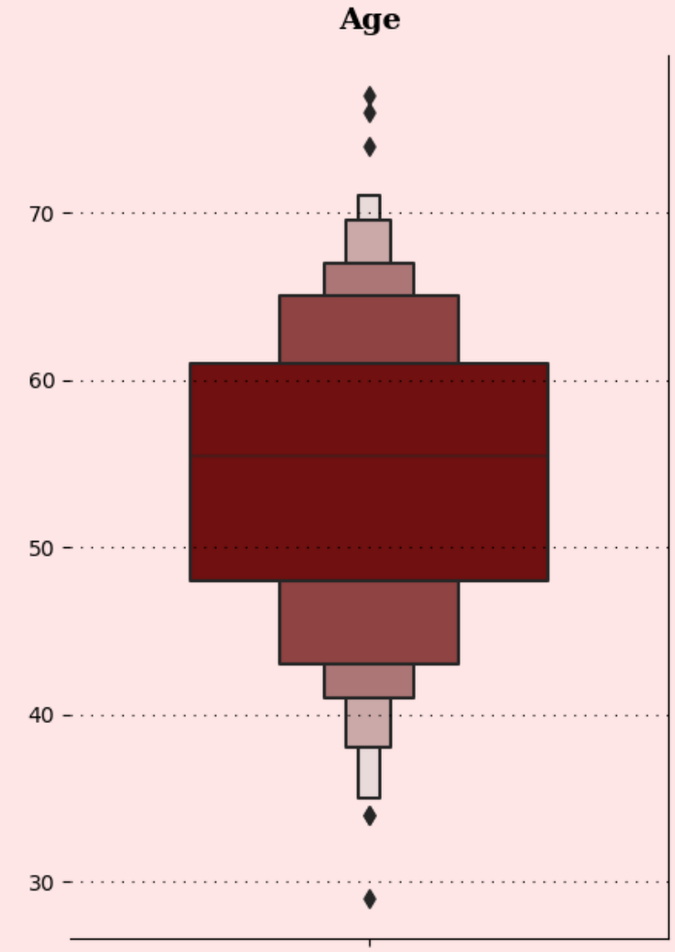

### 3.1.2 Boxen plot for con_cols

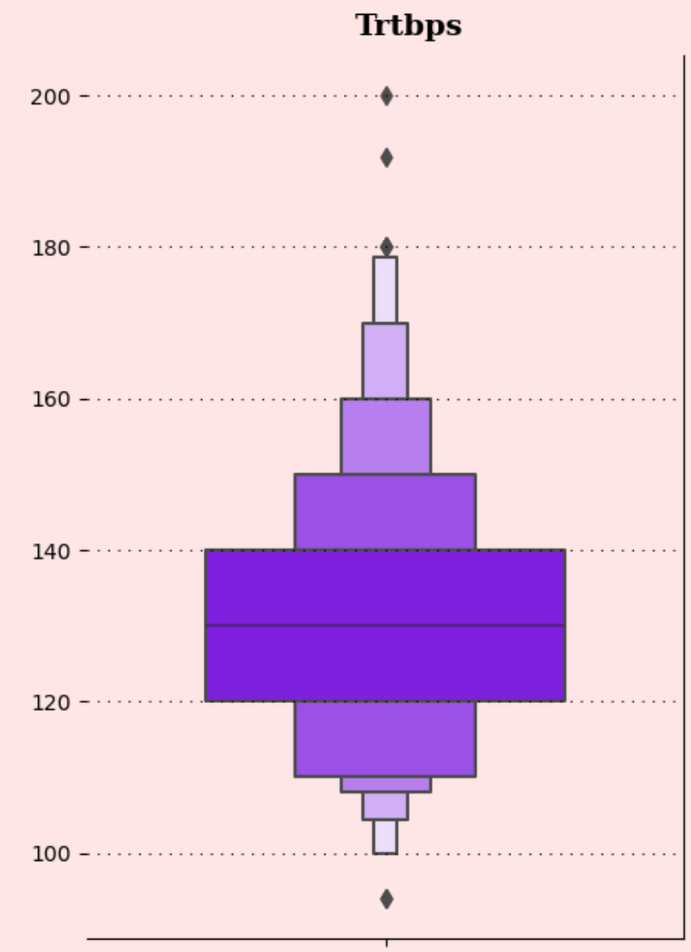
In [13]:

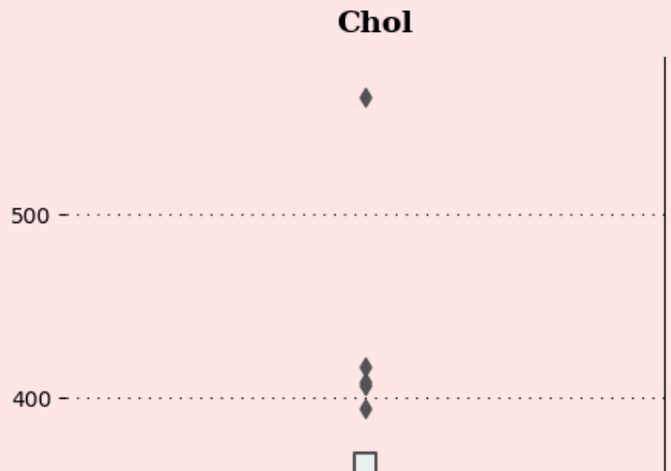
```
fig = plt.figure(figsize=(18,16))
gs = fig.add_gridspec(2,3)
gs.update(wspace=0.3, hspace=0.15)
ax0 = fig.add_subplot(gs[0,0])
ax1 = fig.add_subplot(gs[0,1])
ax2 = fig.add_subplot(gs[0,2])
ax3 = fig.add_subplot(gs[1,0])
ax4 = fig.add_subplot(gs[1,1])
ax5 = fig.add_subplot(gs[1,2])
background_color = "#ffe6e6"
color_palette = ["#800000","#8000ff","#6aac90","#5833ff","#da8829"]
fig.patch.set_facecolor(background_color)
ax0.set_facecolor(background_color)
ax1.set_facecolor(background_color)
ax2.set_facecolor(background_color)
ax3.set_facecolor(background_color)
ax4.set_facecolor(background_color)
ax5.set_facecolor(background_color)
# Title of the plot
ax0.spines["bottom"].set_visible(False)
ax0.spines["left"].set_visible(False)
ax0.spines["top"].set_visible(False)
ax0.spines["right"].set_visible(False)
ax0.tick_params(left=False, bottom=False)
ax0.set_xticklabels([])
ax0.set_yticklabels([])
ax0.text(0.5,0.5,
 'Boxen plot for various\n continuous features\n_________________',
 horizontalalignment='center',
 verticalalignment='center',
 fontsize=18, fontweight='bold',
 fontfamily='serif',
```

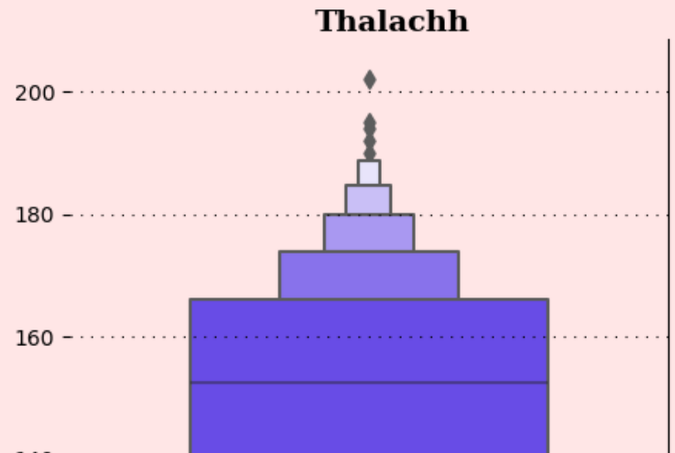
```
 color="#000000")
# Age
ax1.text(-0.05, 81, 'Age', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax1.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.boxenplot(ax=ax1,y=df['age'],palette=["#800000"],width=0.6)
ax1.set_xlabel("")
ax1.set_ylabel("")
# Trtbps
ax2.text(-0.05, 208, 'Trtbps', fontsize=14, fontweight='bold', fontfamily='serif', color="000000")
ax2.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.boxenplot(ax=ax2,y=df['trtbps'],palette=["#8000ff"],width=0.6)
ax2.set_xlabel("")
ax2.set_ylabel("")
# Chol
ax3.text(-0.05, 600, 'Chol', fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax3.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.boxenplot(ax=ax3,y=df['chol'],palette=["#6aac90"],width=0.6)
ax3.set_xlabel("")
ax3.set_ylabel("")
# Thalachh
ax4.text(-0.09, 210, 'Thalachh', fontsize=14, fontweight='bold', fontfamily='serif', color="000000")
ax4.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.boxenplot(ax=ax4,y=df['thalachh'],palette=["#5833ff"],width=0.6)
ax4.set_xlabel("")
ax4.set_ylabel("")
# oldpeak
ax5.text(-0.1, 6.6, 'Oldpeak', fontsize=14, fontweight='bold', fontfamily='serif', color="000000")
ax5.grid(color='#000000', linestyle=':', axis='y', zorder=0, dashes=(1,5))
sns.boxenplot(ax=ax5,y=df['oldpeak'],palette=["#da8829"],width=0.6)
ax5.set_xlabel("")
ax5.set_ylabel("")
for s in ["top","left"]:
 ax1.spines[s].set_visible(False)
 ax2.spines[s].set_visible(False)
 ax3.spines[s].set_visible(False)
 ax4.spines[s].set_visible(False)
 ax5.spines[s].set_visible(False)
```

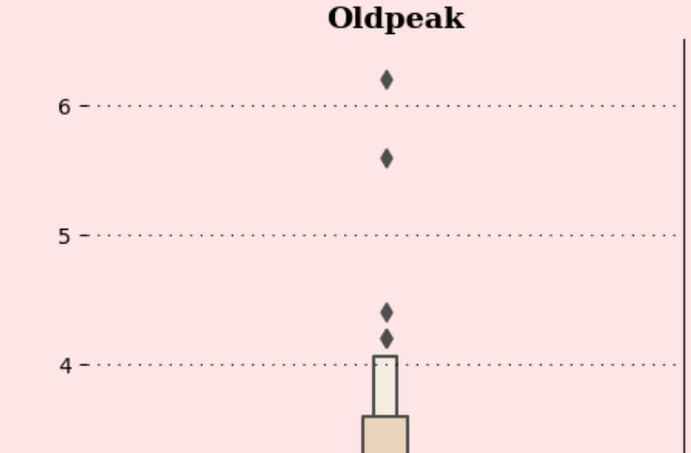
## Boxen plot for various continuous features

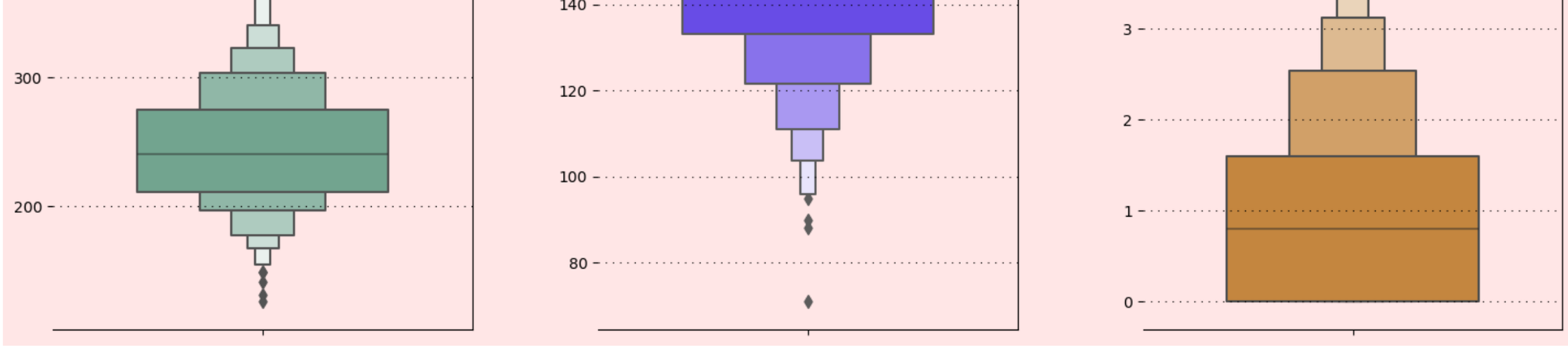


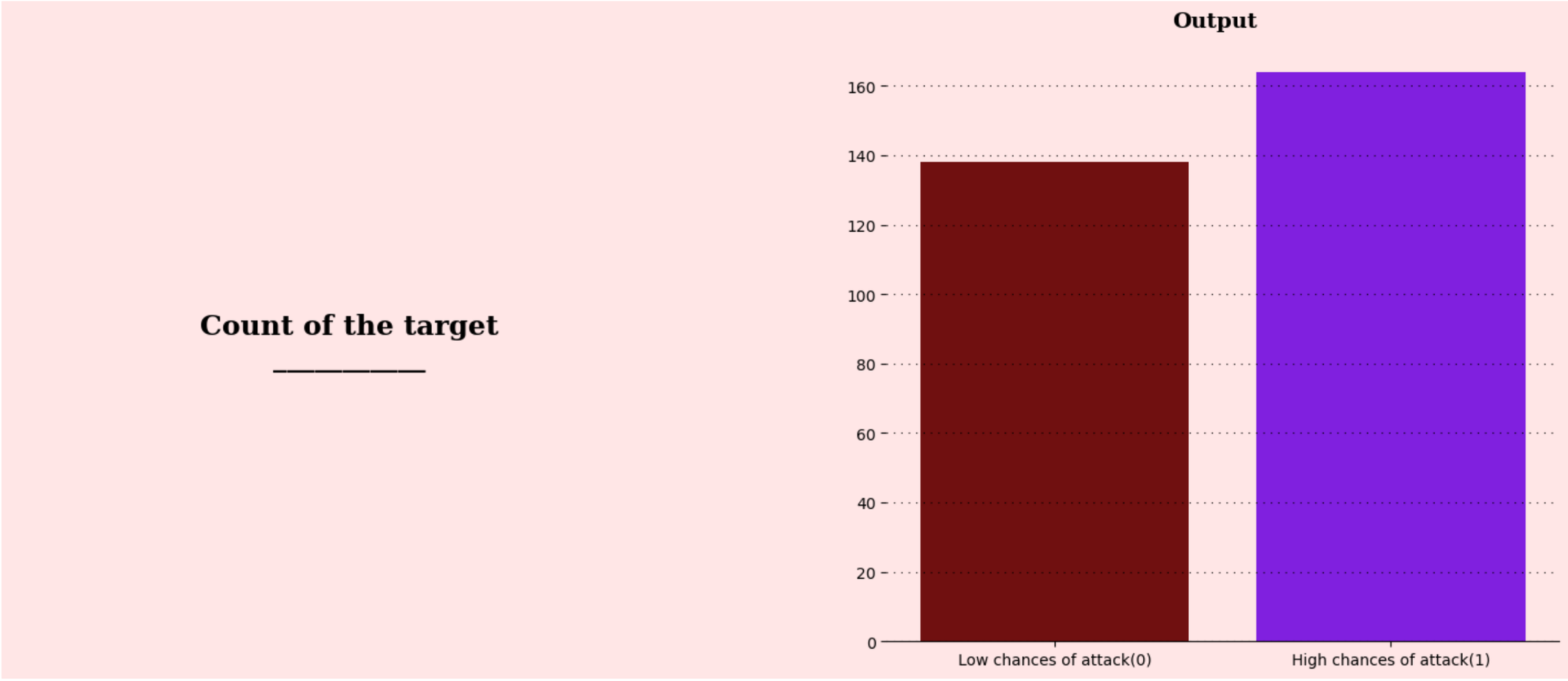






### 3.1.3 plot of target

In [14]:
```
fig = plt.figure(figsize=(18,7))
gs = fig.add_gridspec(1,2)
gs.update(wspace=0.3, hspace=0.15)
ax0 = fig.add_subplot(gs[0,0])
ax1 = fig.add_subplot(gs[0,1])

background_color = "#ffe6e6"
color_palette = ["#800000","#8000ff","#6aac90","#5833ff","#da8829"]
fig.patch.set_facecolor(background_color)
ax0.set_facecolor(background_color)
ax1.set_facecolor(background_color)

# Title of the plot
ax0.text(0.5,0.5,"Count of the target\n___________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')

ax0.set_xticklabels([])
ax0.set_yticklabels([])
ax0.tick_params(left=False, bottom=False)

# Target Count
ax1.text(0.35,177,"Output",fontsize=14, fontweight='bold', fontfamily='serif', color="#000000")
ax1.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.countplot(ax=ax1, data=df, x = 'output',palette = color_palette)
```

```
ax1.set_xlabel("")
ax1.set_ylabel("")
ax1.set_xticklabels(["Low chances of attack(0)","High chances of attack(1)"])

ax0.spines["top"].set_visible(False)
ax0.spines["left"].set_visible(False)
ax0.spines["bottom"].set_visible(False)
ax0.spines["right"].set_visible(False)
ax1.spines["top"].set_visible(False)
ax1.spines["left"].set_visible(False)
ax1.spines["right"].set_visible(False)
```




## 3.2 Bivariate Analysis

## 3.2.1 Correlation matrix of con_cols

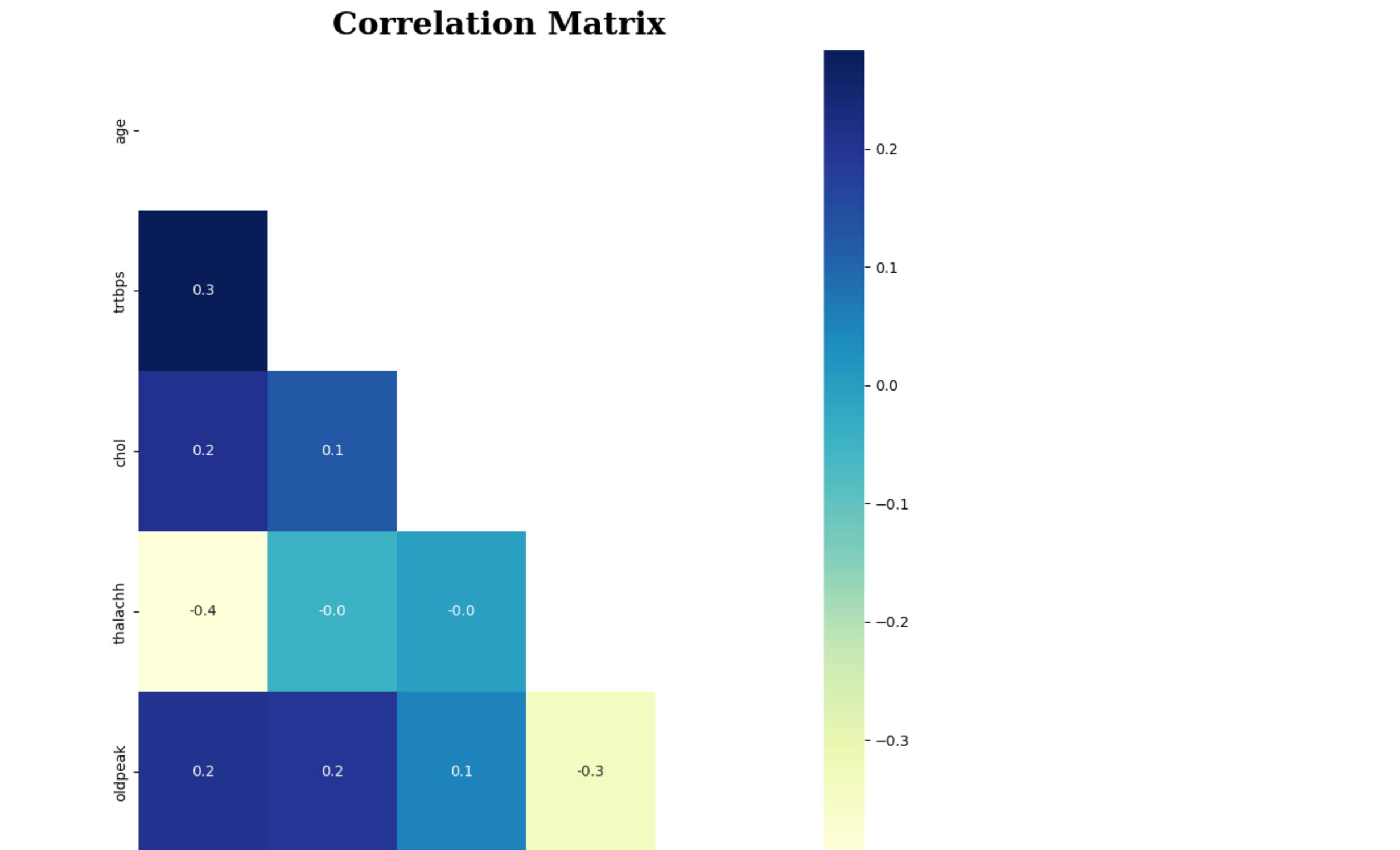
In [15]:
```
df_corr = df[con_cols].corr().transpose()
```

In [16]:
```
df_corr
```

Out[16]:

| | age | trtbps | chol | thalachh | oldpeak |
|---|---|---|---|---|---|
| **age** | 1.000000 | 0.283121 | 0.207216 | -0.395235 | 0.206040 |
| **trtbps** | 0.283121 | 1.000000 | 0.125256 | -0.048023 | 0.194600 |
| **chol** | 0.207216 | 0.125256 | 1.000000 | -0.005308 | 0.050086 |
| **thalachh** | -0.395235 | -0.048023 | -0.005308 | 1.000000 | -0.342201 |
| **oldpeak** | 0.206040 | 0.194600 | 0.050086 | -0.342201 | 1.000000 |

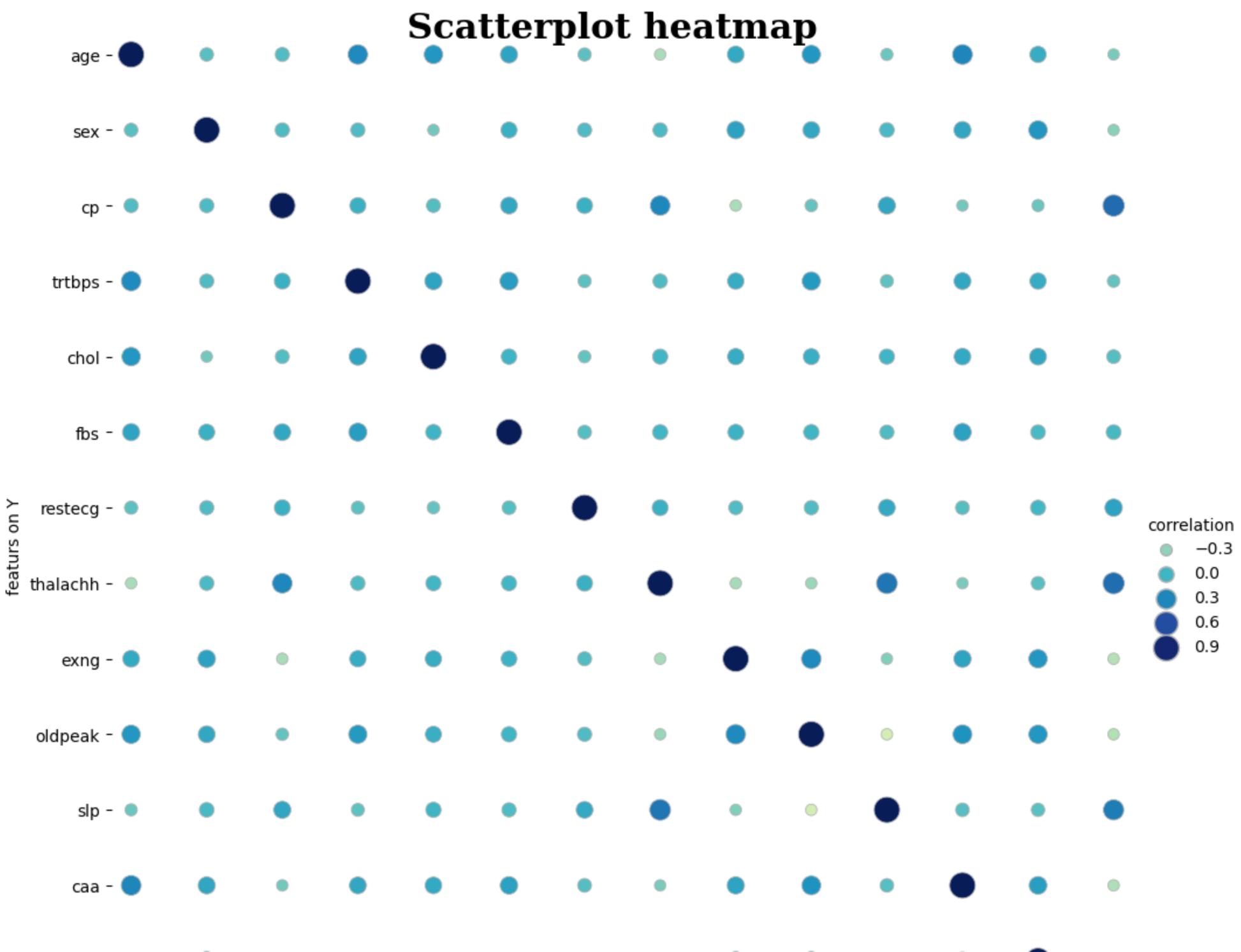
In [17]:
```
fig = plt.figure(figsize=(10,10))
gs = fig.add_gridspec(1,1)
gs.update(wspace=0.3, hspace=0.15)
ax0 = fig.add_subplot(gs[0,0])

color_palette = ["#5833ff","#da8829"]
mask = np.triu(np.ones_like(df_corr))
ax0.text(1.5,-0.1,"Correlation Matrix",fontsize=22, fontweight='bold', fontfamily='serif', color="#000000")
df_corr = df[con_cols].corr().transpose()
sns.heatmap(df_corr,mask=mask,fmt=".1f",annot=True,cmap='YlGnBu')
plt.show()
```

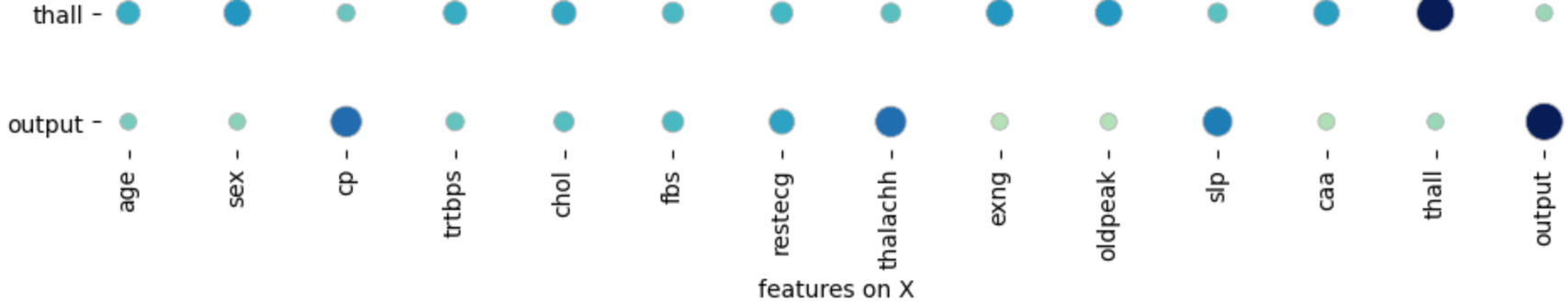

Correlation Matrix
age
trtbps
chol
thalachh
oldpeak
0.3
0.2
0.1
-0.4
-0.0
-0.0
0.2
0.2
0.1
-0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3


## 3.2.2 Scatterplot

In [18]:
```
fig = plt.figure(figsize=(12,12))
corr_mat = df.corr().stack().reset_index(name="correlation")
g = sns.relplot(
    data=corr_mat,
    x="level_0", y="level_1", hue="correlation", size="correlation",
    palette="YlGnBu", hue_norm=(-1, 1), edgecolor=".7",
    height=10, sizes=(50, 250), size_norm=(-.2, .8),
)
g.set(xlabel="features on X", ylabel="featurs on Y", aspect="equal")
g.fig.suptitle('Scatterplot heatmap',fontsize=22, fontweight='bold', fontfamily='serif', color="#000000")
g.despine(left=True, bottom=True)
g.ax.margins(.02)
for label in g.ax.get_xticklabels():
    label.set_rotation(90)
for artist in g.legend.legendHandles:
    artist.set_edgecolor(".7")
plt.show()
```

```
<Figure size 1200x1200 with 0 Axes>
```


Scatterplot heatmap
age
sex
cp
trtbps
chol
fbs
restecg
thalachh
exng
oldpeak
slp
caa
features on Y
correlation
−0.3
0.0
0.3
0.6
0.9




### 3.2.3 Distribution of continuous features according to target variable

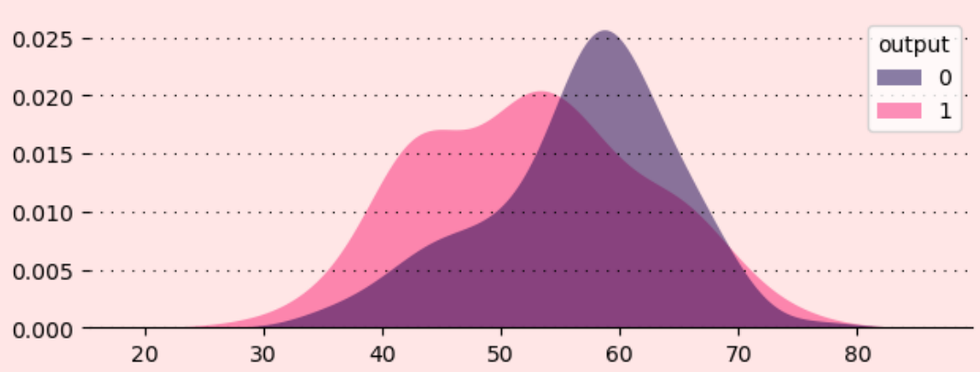
In [19]:
```
fig = plt.figure(figsize=(18,18))
gs = fig.add_gridspec(5,2)
gs.update(wspace=0.5, hspace=0.5)
ax0 = fig.add_subplot(gs[0,0])
ax1 = fig.add_subplot(gs[0,1])
ax2 = fig.add_subplot(gs[1,0])
ax3 = fig.add_subplot(gs[1,1])
ax4 = fig.add_subplot(gs[2,0])
ax5 = fig.add_subplot(gs[2,1])
ax6 = fig.add_subplot(gs[3,0])
ax7 = fig.add_subplot(gs[3,1])
ax8 = fig.add_subplot(gs[4,0])
ax9 = fig.add_subplot(gs[4,1])

background_color = "#ffe6e6"
color_palette = ["#800000","#8000ff","#6aac90","#150050","#FB2576"]
fig.patch.set_facecolor(background_color)
ax0.set_facecolor(background_color)
ax1.set_facecolor(background_color)
ax2.set_facecolor(background_color)
ax3.set_facecolor(background_color)
ax4.set_facecolor(background_color)
ax5.set_facecolor(background_color)
ax6.set_facecolor(background_color)
ax7.set_facecolor(background_color)
ax8.set_facecolor(background_color)
ax9.set_facecolor(background_color)

# Age title
ax0.text(0.5,0.5,"Distribution of age\naccording to\n target variable\n___________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
```

```
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax0.spines["bottom"].set_visible(False)
ax0.set_xticklabels([])
ax0.set_yticklabels([])
ax0.tick_params(left=False, bottom=False)

# Age
ax1.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax1, data=df, x='age',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax1.set_xlabel("")
ax1.set_ylabel("")

# TrTbps title
ax2.text(0.5,0.5,"Distribution of trtbps\naccording to\n target variable\n__________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax2.spines["bottom"].set_visible(False)
ax2.set_xticklabels([])
ax2.set_yticklabels([])
ax2.tick_params(left=False, bottom=False)

# TrTbps
ax3.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax3, data=df, x='trtbps',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax3.set_xlabel("")
ax3.set_ylabel("")

# Chol title
ax4.text(0.5,0.5,"Distribution of chol\naccording to\n target variable\n__________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax4.spines["bottom"].set_visible(False)
ax4.set_xticklabels([])
ax4.set_yticklabels([])
ax4.tick_params(left=False, bottom=False)

# Chol
ax5.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax5, data=df, x='chol',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax5.set_xlabel("")
```

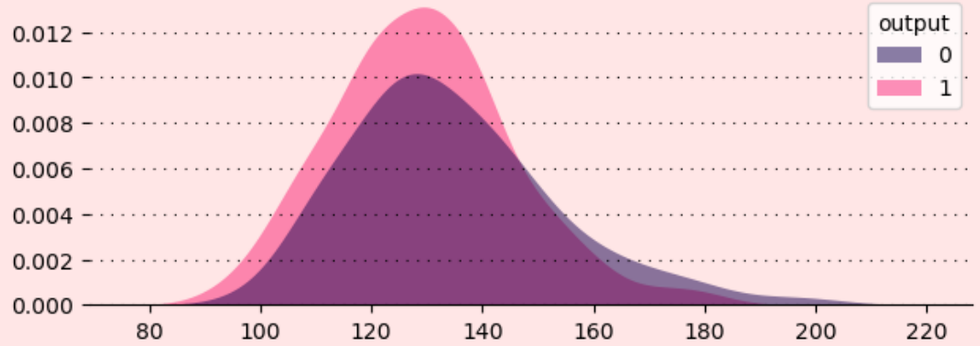
```
ax5.set_ylabel("")

# Thalachh title
ax6.text(0.5,0.5,"Distribution of thalachh\naccording to\n target variable\n__________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax6.spines["bottom"].set_visible(False)
ax6.set_xticklabels([])
ax6.set_yticklabels([])
ax6.tick_params(left=False, bottom=False)

# Thalachh
ax7.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax7, data=df, x='thalachh',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax7.set_xlabel("")
ax7.set_ylabel("")

# Oldpeak title
ax8.text(0.5,0.5,"Distribution of oldpeak\naccording to\n target variable\n__________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax8.spines["bottom"].set_visible(False)
ax8.set_xticklabels([])
ax8.set_yticklabels([])
ax8.tick_params(left=False, bottom=False)

# Oldpeak
ax9.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax9, data=df, x='oldpeak',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax9.set_xlabel("")
ax9.set_ylabel("")

for i in ["top","left","right"]:
    ax0.spines[i].set_visible(False)
    ax1.spines[i].set_visible(False)
    ax2.spines[i].set_visible(False)
    ax3.spines[i].set_visible(False)
    ax4.spines[i].set_visible(False)
    ax5.spines[i].set_visible(False)
    ax6.spines[i].set_visible(False)
    ax7.spines[i].set_visible(False)
```

```
    ax8.spines[i].set_visible(False)
    ax9.spines[i].set_visible(False)
```

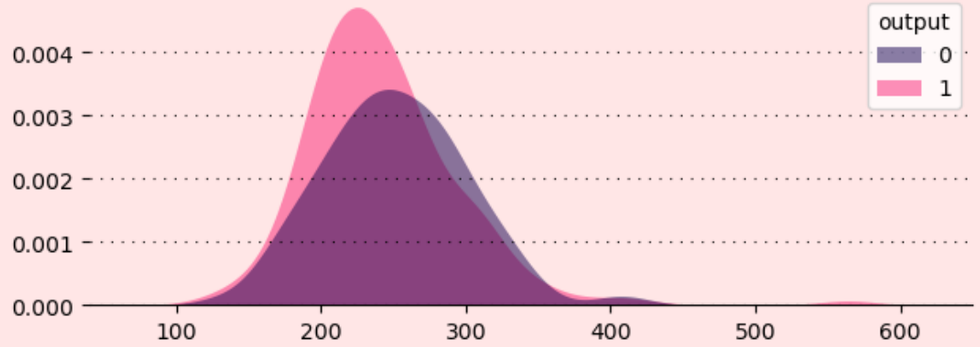
**Distribution of age according to target variable**



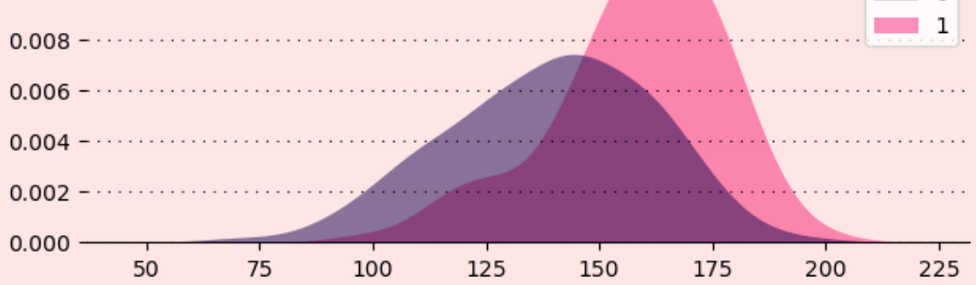

**Distribution of trtbps according to target variable**



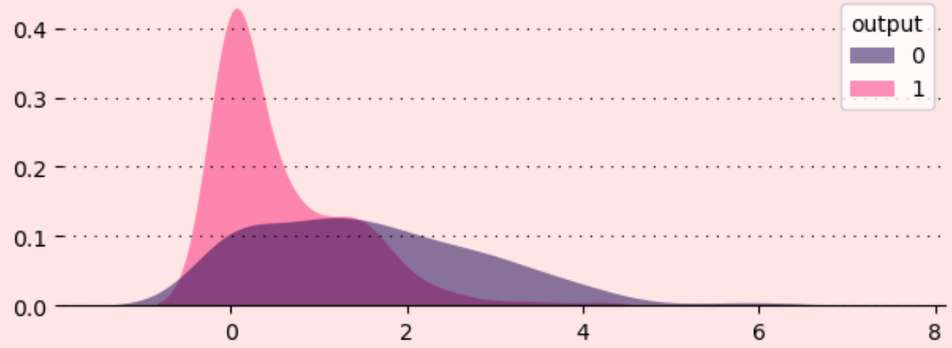

**Distribution of chol according to target variable**




**Distribution of thalachh according to target variable**




**Distribution of oldpeak according to target variable**




In [20]:

```
fig = plt.figure(figsize=(18,20))
gs = fig.add_gridspec(6,2)
gs.update(wspace=0.5, hspace=0.5)
ax0 = fig.add_subplot(gs[0,0])
ax1 = fig.add_subplot(gs[0,1])
ax2 = fig.add_subplot(gs[1,0])
ax3 = fig.add_subplot(gs[1,1])
ax4 = fig.add_subplot(gs[2,0])
ax5 = fig.add_subplot(gs[2,1])
ax6 = fig.add_subplot(gs[3,0])
ax7 = fig.add_subplot(gs[3,1])
ax8 = fig.add_subplot(gs[4,0])
ax9 = fig.add_subplot(gs[4,1])
ax10 = fig.add_subplot(gs[5,0])
ax11 = fig.add_subplot(gs[5,1])

background_color = "#ffe6e6"
color_palette = ["#800000","#8000ff","#6aac90","#150050","#FB2576"]
fig.patch.set_facecolor(background_color)
ax0.set_facecolor(background_color)
ax1.set_facecolor(background_color)
ax2.set_facecolor(background_color)
ax3.set_facecolor(background_color)
```

```
ax4.set_facecolor(background_color)
ax5.set_facecolor(background_color)
ax6.set_facecolor(background_color)
ax7.set_facecolor(background_color)
ax8.set_facecolor(background_color)
ax9.set_facecolor(background_color)
ax10.set_facecolor(background_color)
ax11.set_facecolor(background_color)

# Cp title
# 0 = Typical Angina, 1 = Atypical Angina, 2 = Non-anginal Pain, 3 = Asymptomatic
ax0.text(0.5,0.5,"Chest pain\ndistribution\n__________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax0.spines["bottom"].set_visible(False)
ax0.set_xticklabels([])
ax0.set_yticklabels([])
ax0.tick_params(left=False, bottom=False)
ax0.text(1,.5,"0 - Typical Angina\n1 - Atypical Angina\n2 - Non-anginal Pain\n3 - Asymptomatic",
        horizontalalignment = 'center',
         verticalalignment = 'center',
        fontsize = 14
        )

# Cp
ax1.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax1, data=df, x='cp',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax1.set_xlabel("")
ax1.set_ylabel("")

# Caa title
ax2.text(0.5,0.5,"Number of\nmajor vessels\n__________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax2.text(1,.5,"0 vessels\n1 vessel\n2 vessels\n3 vessels\n4vessels",
        horizontalalignment = 'center',
         verticalalignment = 'center',
        fontsize = 14
        )

ax2.spines["bottom"].set_visible(False)
ax2.set_xticklabels([])
```

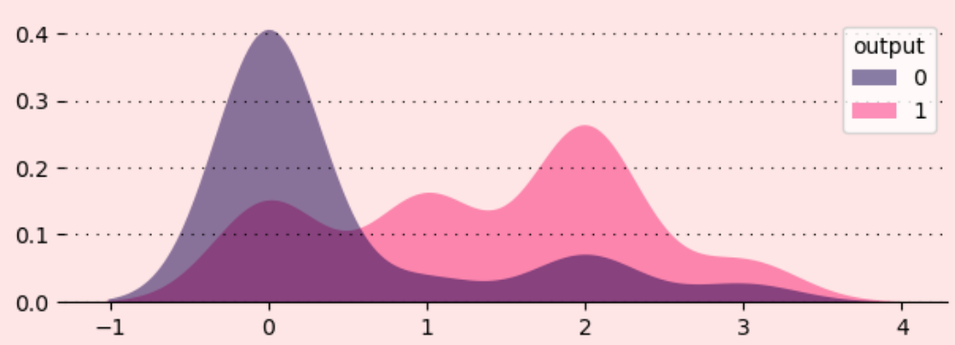
```
ax2.set_yticklabels([])
ax2.tick_params(left=False, bottom=False)

# Caa
ax3.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax3, data=df, x='caa',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax3.set_xlabel("")
ax3.set_ylabel("")

# Sex title
ax4.text(0.5,0.5,"Heart Attack\naccording to\nsex\n_____",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax4.text(1,.5,"0 - Female\n1 - Male",
        horizontalalignment = 'center',
         verticalalignment = 'center',
        fontsize = 14
        )
ax4.spines["bottom"].set_visible(False)
ax4.set_xticklabels([])
ax4.set_yticklabels([])
ax4.tick_params(left=False, bottom=False)

# Sex
ax5.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.countplot(ax=ax5,data=df,x='sex',palette=["#150050","#FB2576"], hue='output')
ax5.set_xlabel("")
ax5.set_ylabel("")

# Thall title
ax6.text(0.5,0.5,"Distribution of thall\naccording to\n target variable\n__________",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax6.text(1,.5,"Thalium Stress\nTest Result\n0, 1, 2, 3",
        horizontalalignment = 'center',
         verticalalignment = 'center',
        fontsize = 14
        )
ax6.spines["bottom"].set_visible(False)
ax6.set_xticklabels([])
ax6.set_yticklabels([])
ax6.tick_params(left=False, bottom=False)
```

```
# Thall
ax7.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.kdeplot(ax=ax7, data=df, x='thall',hue="output", fill=True,palette=["#150050","#FB2576"], alpha=.5, linewidth=0)
ax7.set_xlabel("")
ax7.set_ylabel("")

# Thalachh title
ax8.text(0.5,0.5,"Boxen plot of\nthalachh wrt\noutcome\n_______",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax8.text(1,.5,"Maximum heart\nrate achieved",
        horizontalalignment = 'center',
         verticalalignment = 'center',
        fontsize = 14
        )

ax8.spines["bottom"].set_visible(False)
ax8.set_xticklabels([])
ax8.set_yticklabels([])
ax8.tick_params(left=False, bottom=False)

# Thalachh
ax9.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.boxenplot(ax=ax9, data=df,x='output',y='thalachh',palette=["#150050","#FB2576"])
ax9.set_xlabel("")
ax9.set_ylabel("")



# Exng title
ax10.text(0.5,0.5,"Strip Plot of\nexng vs age\n______",
        horizontalalignment = 'center',
        verticalalignment = 'center',
        fontsize = 18,
        fontweight='bold',
        fontfamily='serif',
        color='#000000')
ax10.text(1,.5,"Exercise induced\nangina\n0 - No\n1 - Yes",
        horizontalalignment = 'center',
         verticalalignment = 'center',
        fontsize = 14
        )
ax10.spines["bottom"].set_visible(False)
ax10.set_xticklabels([])
ax10.set_yticklabels([])
```

```
ax10.tick_params(left=False, bottom=False)


# Exng
ax11.grid(color='#000000', linestyle=':', axis='y', zorder=0,  dashes=(1,5))
sns.stripplot(ax=ax11, data=df,x='exng',y='age',hue='output',palette=["#150050","#FB2576"])
ax9.set_xlabel("")
ax9.set_ylabel("")

for i in ["top","left","right"]:
    ax0.spines[i].set_visible(False)
    ax1.spines[i].set_visible(False)
    ax2.spines[i].set_visible(False)
    ax3.spines[i].set_visible(False)
    ax4.spines[i].set_visible(False)
    ax5.spines[i].set_visible(False)
    ax6.spines[i].set_visible(False)
    ax7.spines[i].set_visible(False)
    ax8.spines[i].set_visible(False)
    ax9.spines[i].set_visible(False)
    ax10.spines[i].set_visible(False)
    ax11.spines[i].set_visible(False)
```

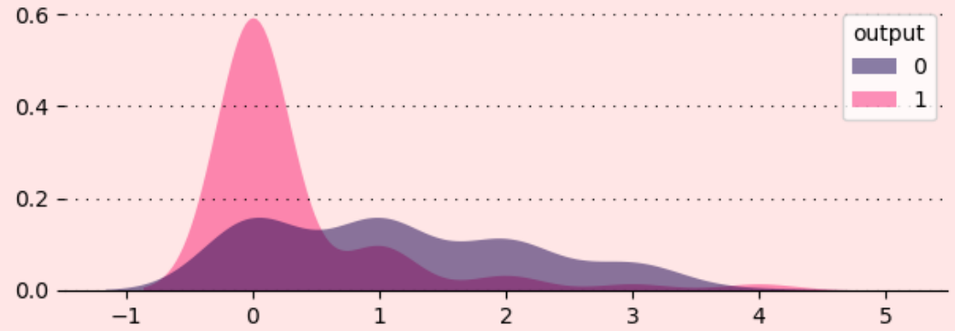
**Chest pain distribution**

0 - Typical Angina
1 - Atypical Angina
2 - Non-anginal Pain
3 - Asymptomatic



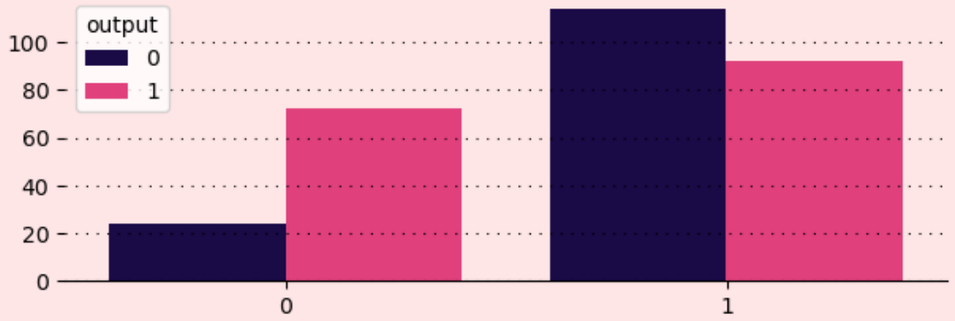

**Number of major vessels**

0 vessels
1 vessel
2 vessels
3 vessels
4vessels



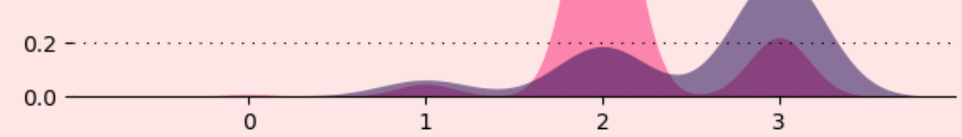

**Heart Attack according to sex**

0 - Female
1 - Male



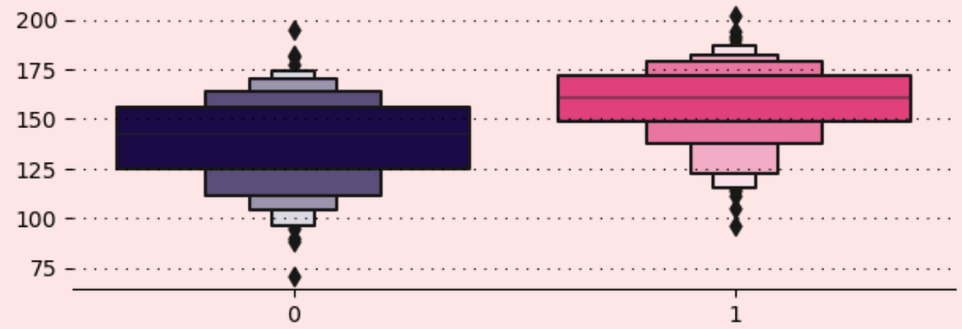

**Distribution of thall according to target variable**

Thalium Stress Test Result
0, 1, 2, 3



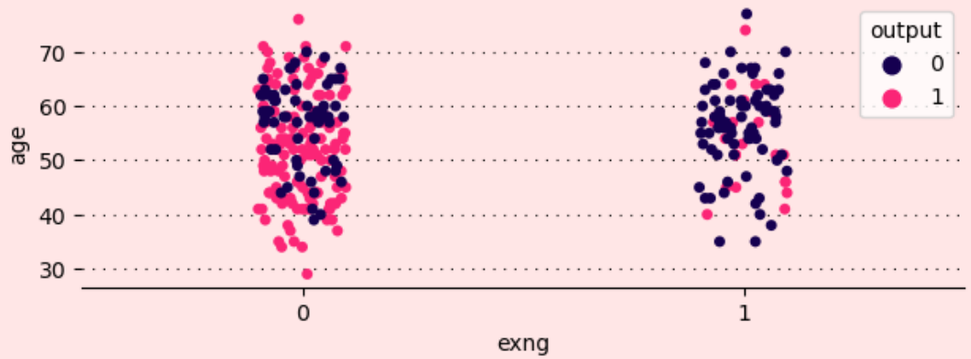

**Boxen plot of thalachh wrt outcome**

Maximum heart rate achieved

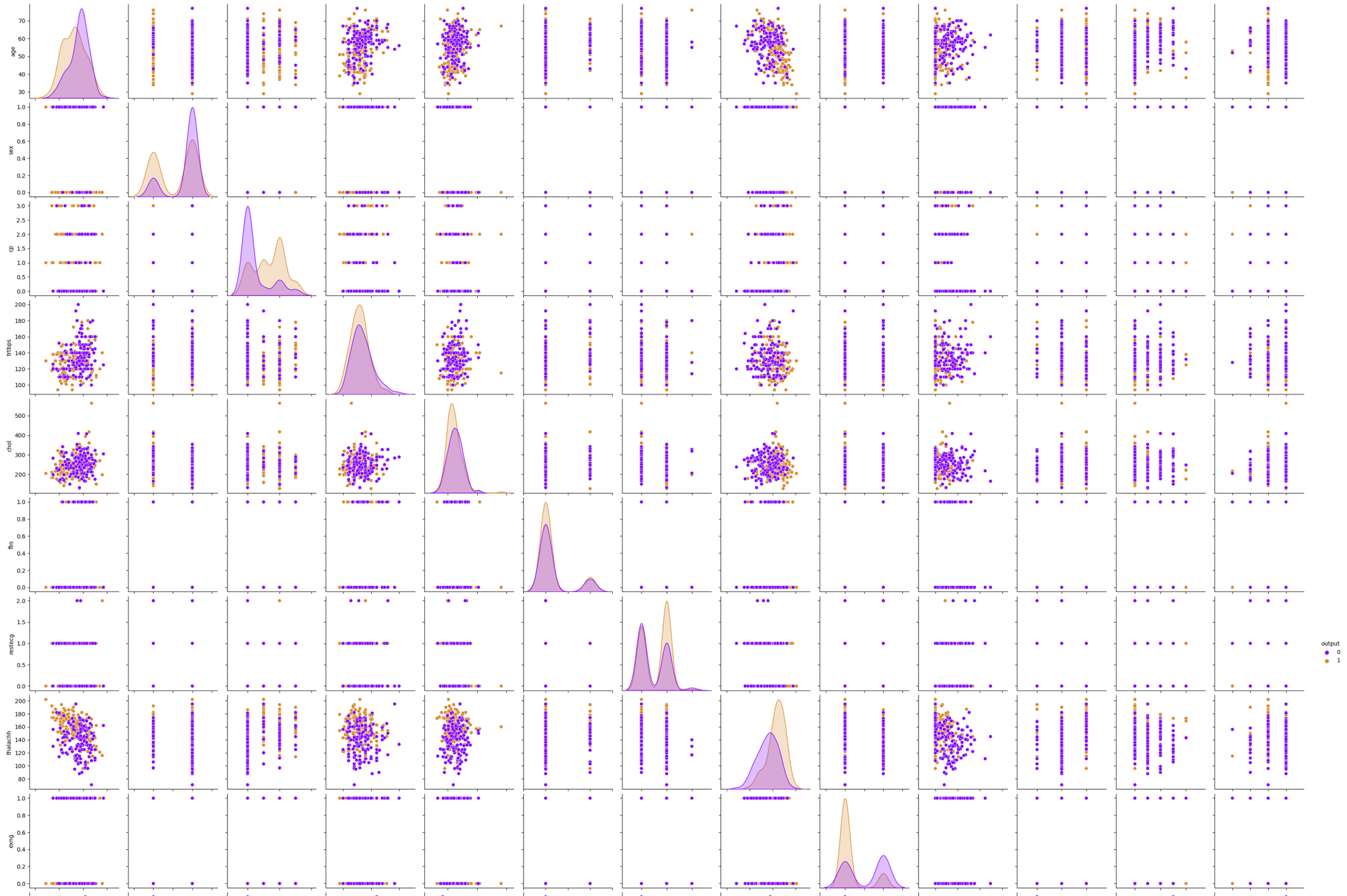


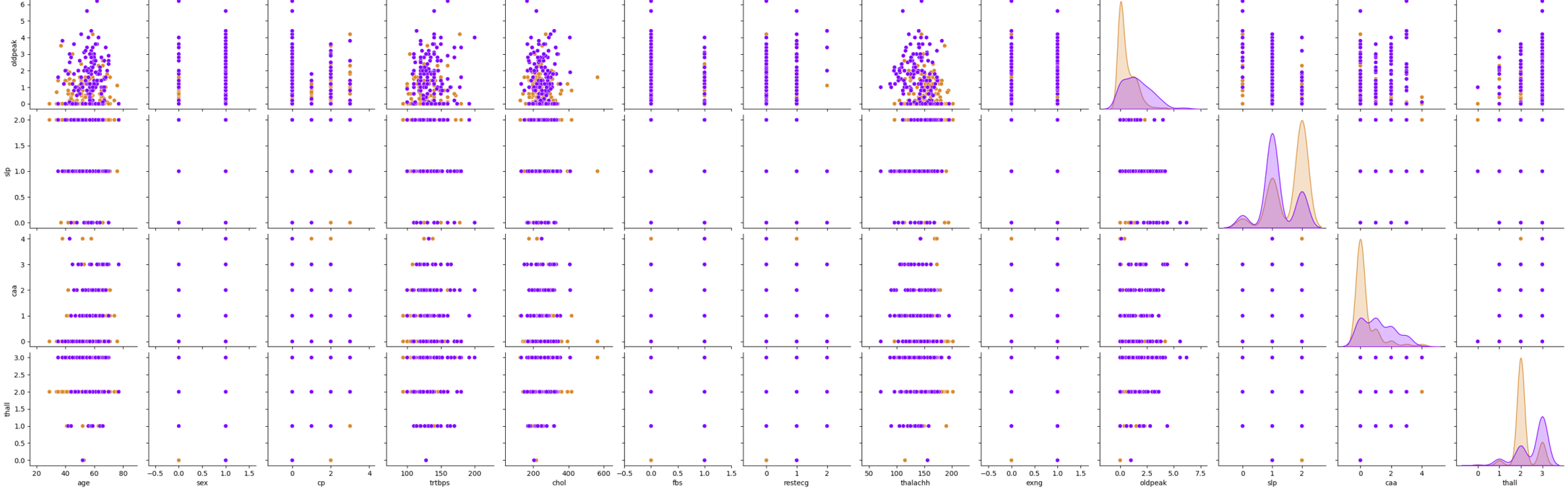

**Strip Plot of exng vs age**

Exercise induced angina
0 - No
1 - Yes




In [21]:
```
sns.pairplot(df,hue='output',palette = ["#8000ff","#da8829"])
plt.show()
```


age
sex
cp
trtbps
chol
fbs
restecg
thalachh
exng
output
0
1




# 4. Data Preprocessing

## 4.1 Conclusions from the EDA

1. There are no NaN values in the data.
2. There are certain outliers in all the continuous features.
3. The data consists of more than twice the number of people with `sex` = 1 (Male) than `sex` = 0 (Female).
4. There is no apparent linear correlation between continuous variable according to the heatmap.
5. The scatterplot heatmap matrix suggests that there might be some correlation between `output` and `cp`, `thalachh` and `slp`.
6. It is intuitive that elder people might have higher chances of heart attack but according to the distribution plot of `age` wrt `output`, it is evident that this isn't the case.
7. According to the distribution plot of `thalachh` wrt `output`, people with higher maximum heart rate achieved have higher chances of heart attack.
8. According to the distribution plot of `oldpeak` wrt `output`, people with lower pevious peak achieved have higher chances of heart attack.
9. The plot *3.2.4* tells about the following -
    - People with Non-Anginal chest pain, that is with `cp` = 2 have higher chances of heart attack.
    - People with 0 major vessels, that is with `caa` = 0 have high chance of heart attack.
    - People with `sex` = 1 have higher chance of heart attack.
    - People with `thall` = 2 have much higher chance of heart attack.

- People with no exercise induced angina, that is with `exng` = 0 have higher chance of heart attack.

## 4.2 Packges

In [22]:
```
# Scaling
from sklearn.preprocessing import RobustScaler

# Train Test Split
from sklearn.model_selection import train_test_split

# Models
import torch
import torch.nn as nn
from sklearn.svm import SVC
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import GradientBoostingClassifier

# Metrics
from sklearn.metrics import accuracy_score, classification_report, roc_curve

# Cross Validation
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import GridSearchCV

print('Packages imported...')
```

```
Packages imported...
```

## 4.3 Making fetures model ready

### 4.3.1 Scaling and Encoding

In [28]:
```
#Create copy of dataframe
df1= df


#Define the columens to be Encoded and Scaled
cat_cols = ['sex','exng','caa','cp','fbs','restecg','slp','thall']
con_cols = ["age","trtbps","chol","thalachh","oldpeak"]


#Encoding the categoriacl columens
df1= pd.get_dummies(df1,columns=cat_cols, drop_first=True)
```

```
#Define the fetures and the targets
X= df1.drop(["output"],axis=1)
Y= df1[["output"]]


# instantiating the scaler
scaler = RobustScaler()


#Scaling the Continuous fetures
X[con_cols] = scaler.fit_transform(X[con_cols])
print("The head of con_cols")
X.head()
```

```
The head of con_cols
```

Out[28]:

| | age | trtbps | chol | thalachh | oldpeak | sex_1 | exng_1 | caa_1 | caa_2 | caa_3 | ... | cp_2 | cp_3 | fbs_1 | restecg_1 | restecg_2 | slp_1 | slp_2 | thall_1 | thall_2 | thall_3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 0.576923 | 0.75 | -0.117647 | -0.076336 | 0.9375 | 1 | 0 | 0 | 0 | 0 | ... | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| **1** | -1.423077 | 0.00 | 0.149020 | 1.053435 | 1.6875 | 1 | 0 | 0 | 0 | 0 | ... | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| **2** | -1.115385 | 0.00 | -0.572549 | 0.595420 | 0.3750 | 0 | 0 | 0 | 0 | 0 | ... | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| **3** | 0.038462 | -0.50 | -0.070588 | 0.778626 | 0.0000 | 1 | 0 | 0 | 0 | 0 | ... | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| **4** | 0.115385 | -0.50 | 1.780392 | 0.320611 | -0.1250 | 0 | 1 | 0 | 0 | 0 | ... | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |

5 rows × 22 columns

### 4.3.2 Training

In [61]:

```
X_train, X_test, Y_train, Y_test = train_test_split(X,Y, test_size = 0.2, random_state = 42)
print("The shape of X_train is      ", X_train.shape)
print("The shape of X_test is       ",X_test.shape)
print("The shape of Y_train is      ",Y_train.shape)
print("The shape of Y_test is       ",Y_test.shape)
```

```
The shape of X_train is       (241, 22)
The shape of X_test is        (61, 22)
The shape of Y_train is       (241, 1)
The shape of Y_test is        (61, 1)
```

# 5. Modeling

# 5.1 Liner Classifiers

## 5.1.1 Support Vector Machine

In [62]:
```
# Instantiating the object and fitting
clf = SVC(kernel='linear', C=1, random_state=42).fit(X_train,Y_train)

# Predicting
Y_pred = clf.predict(X_test)

# Printing the test accuracy
print("The test accuracy score of Support Vector Machine is ", accuracy_score(Y_test, Y_pred))
```

```
The test accuracy score of Support Vector Machine is  0.8360655737704918
```

## 5.1.2 Hyperparameter tuning of SVC

In [63]:
```
# instantiating the object
svm = SVC()

# setting a grid - not so extensive
parameters = {"C":np.arange(1,10,1),'gamma':[0.00001,0.00005, 0.0001,0.0005,0.001,0.005,0.01,0.05,0.1,0.5,1,5]}

# instantiating the GridSearchCV object
searcher = GridSearchCV(svm, parameters)

# fitting the object
searcher.fit(X_train, Y_train)

# the scores
print("The best params are :", searcher.best_params_)
print("The best score is   :", searcher.best_score_)

# predicting the values
Y_pred = searcher.predict(X_test)

# printing the test accuracy
print("The test accuracy score of SVM after hyper-parameter tuning is ", accuracy_score(Y_test, Y_pred))
```

```
The best params are : {'C': 5, 'gamma': 0.05}
The best score is   : 0.8586734693877551
The test accuracy score of SVM after hyper-parameter tuning is  0.9016393442622951
```

In [ ]: