CVD Capstone Final Draft

January 18, 2022

[1]:
```
import pandas as pd
import numpy as np
```

[2]:
```
df=pd.read_excel("data.xlsx")
print(df)
```

```
     age  sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  \
0     63    1   3       145   233    1        0      150      0      2.3
1     37    1   2       130   250    0        1      187      0      3.5
2     41    0   1       130   204    0        0      172      0      1.4
3     56    1   1       120   236    0        1      178      0      0.8
4     57    0   0       120   354    0        1      163      1      0.6
..   ...  ...  ..       ...   ...  ...      ...      ...    ...      ...
298   57    0   0       140   241    0        1      123      1      0.2
299   45    1   3       110   264    0        1      132      0      1.2
300   68    1   0       144   193    1        1      141      0      3.4
301   57    1   0       130   131    0        1      115      1      1.2
302   57    0   1       130   236    0        0      174      0      0.0

     slope  ca  thal  target
0        0   0     1       1
1        0   0     2       1
2        2   0     2       1
3        2   0     2       1
4        2   0     2       1
..     ...  ..   ...     ...
298      1   0     3       0
299      1   0     3       0
300      1   2     3       0
301      1   1     3       0
302      1   1     2       0

[303 rows x 14 columns]
```

[3]:
```
df.isnull()
```

[3]:
```
       age    sex     cp  trestbps   chol    fbs  restecg  thalach  exang  \
0    False  False  False     False  False  False    False    False  False
```

```
1    False  False  False     False  False  False    False    False  False
2    False  False  False     False  False  False    False    False  False
3    False  False  False     False  False  False    False    False  False
4    False  False  False     False  False  False    False    False  False
..     …      …    …         …      …      …        …        …      …
298  False  False  False     False  False  False    False    False  False
299  False  False  False     False  False  False    False    False  False
300  False  False  False     False  False  False    False    False  False
301  False  False  False     False  False  False    False    False  False
302  False  False  False     False  False  False    False    False  False

     oldpeak  slope     ca   thal  target
0      False  False  False  False   False
1      False  False  False  False   False
2      False  False  False  False   False
3      False  False  False  False   False
4      False  False  False  False   False
..       …      …    …      …       …
298    False  False  False  False   False
299    False  False  False  False   False
300    False  False  False  False   False
301    False  False  False  False   False
302    False  False  False  False   False

[303 rows x 14 columns]
```

[4]:
```
df.isnull().sum()
```

[4]:
```
age         0
sex         0
cp          0
trestbps    0
chol        0
fbs         0
restecg     0
thalach     0
exang       0
oldpeak     0
slope       0
ca          0
thal        0
target      0
dtype: int64
```

[5]:
```
# There are no missing values in the data
```

[6]:
```
duplicate = df[df.duplicated()]
print("Duplicate Rows :")
```

```
Duplicate Rows :
```

[7]:
```
duplicate
```

[7]:
```
     age  sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  \
164   38    1   2       138   175    0        1      173      0      0.0

     slope  ca  thal  target
164      2   4     2       1
```

[8]:
```
df.duplicated()
```

[8]:
```
0      False
1      False
2      False
3      False
4      False
       …
298    False
299    False
300    False
301    False
302    False
Length: 303, dtype: bool
```

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

[9]:
```
1
```

[10]:
```
df=df.drop_duplicates()
```

[11]:
```
df
```

[11]:
```
     age  sex  cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  \
0     63    1   3       145   233    1        0      150      0      2.3
1     37    1   2       130   250    0        1      187      0      3.5
2     41    0   1       130   204    0        0      172      0      1.4
3     56    1   1       120   236    0        1      178      0      0.8
4     57    0   0       120   354    0        1      163      1      0.6
..   …  …  ..       …   …  …      …       …    …       …
298   57    0   0       140   241    0        1      123      1      0.2
299   45    1   3       110   264    0        1      132      0      1.2
300   68    1   0       144   193    1        1      141      0      3.4
301   57    1   0       130   131    0        1      115      1      1.2
302   57    0   1       130   236    0        0      174      0      0.0
```

```
     slope  ca  thal  target
0        0   0     1       1
1        0   0     2       1
2        2   0     2       1
3        2   0     2       1
4        2   0     2       1
..     …  ..   …     …
298      1   0     3       0
299      1   0     3       0
300      1   2     3       0
301      1   1     3       0
302      1   1     2       0

[302 rows x 14 columns]
```

[12]:
```
# One duplicate removed from the data set
```

[13]:
```
df.mean()
```

[13]:
```
age          54.420530
sex           0.682119
cp            0.963576
trestbps    131.602649
chol        246.500000
fbs           0.149007
restecg       0.526490
thalach     149.569536
exang         0.327815
oldpeak       1.043046
slope         1.397351
ca            0.718543
thal          2.314570
target        0.543046
dtype: float64
```

[14]:
```
df.mode()
```

[14]:
```
    age  sex   cp  trestbps  chol  fbs  restecg  thalach  exang  oldpeak  \
0  58.0  1.0  0.0     120.0   197  0.0      1.0    162.0    0.0      0.0
1   NaN  NaN  NaN       NaN   204  NaN      NaN      NaN    NaN      NaN
2   NaN  NaN  NaN       NaN   234  NaN      NaN      NaN    NaN      NaN

   slope   ca  thal  target
0    2.0  0.0   2.0     1.0
1    NaN  NaN   NaN     NaN
2    NaN  NaN   NaN     NaN
```

[15]:
```
df.median()
```

[15]:
```
age          55.5
sex           1.0
cp            1.0
trestbps    130.0
chol        240.5
fbs           0.0
restecg       1.0
thalach     152.5
exang         0.0
oldpeak       0.8
slope         1.0
ca            0.0
thal          2.0
target        1.0
dtype: float64
```

[16]:
```
import statistics
```

[17]:
```
df.std()
```

[17]:
```
age          9.047970
sex          0.466426
cp           1.032044
trestbps    17.563394
chol        51.753489
fbs          0.356686
restecg      0.526027
thalach     22.903527
exang        0.470196
oldpeak      1.161452
slope        0.616274
ca           1.006748
thal         0.613026
target       0.498970
dtype: float64
```

[18]:
```
df.describe()
```

[18]:
```
              age         sex          cp    trestbps        chol         fbs  \
count  302.00000  302.000000  302.000000  302.000000  302.000000  302.000000
mean    54.42053    0.682119    0.963576  131.602649  246.500000    0.149007
std      9.04797    0.466426    1.032044   17.563394   51.753489    0.356686
min     29.00000    0.000000    0.000000   94.000000  126.000000    0.000000
25%     48.00000    0.000000    0.000000  120.000000  211.000000    0.000000
50%     55.50000    1.000000    1.000000  130.000000  240.500000    0.000000
```

```
75%     61.00000    1.000000    2.000000  140.000000  274.750000    0.000000
max     77.00000    1.000000    3.000000  200.000000  564.000000    1.000000

          restecg     thalach       exang     oldpeak       slope          ca  \
count  302.000000  302.000000  302.000000  302.000000  302.000000  302.000000
mean     0.526490  149.569536    0.327815    1.043046    1.397351    0.718543
std      0.526027   22.903527    0.470196    1.161452    0.616274    1.006748
min      0.000000   71.000000    0.000000    0.000000    0.000000    0.000000
25%      0.000000  133.250000    0.000000    0.000000    1.000000    0.000000
50%      1.000000  152.500000    0.000000    0.800000    1.000000    0.000000
75%      1.000000  166.000000    1.000000    1.600000    2.000000    1.000000
max      2.000000  202.000000    1.000000    6.200000    2.000000    4.000000

             thal      target
count  302.000000  302.000000
mean     2.314570    0.543046
std      0.613026    0.498970
min      0.000000    0.000000
25%      2.000000    0.000000
50%      2.000000    1.000000
75%      3.000000    1.000000
max      3.000000    1.000000
```

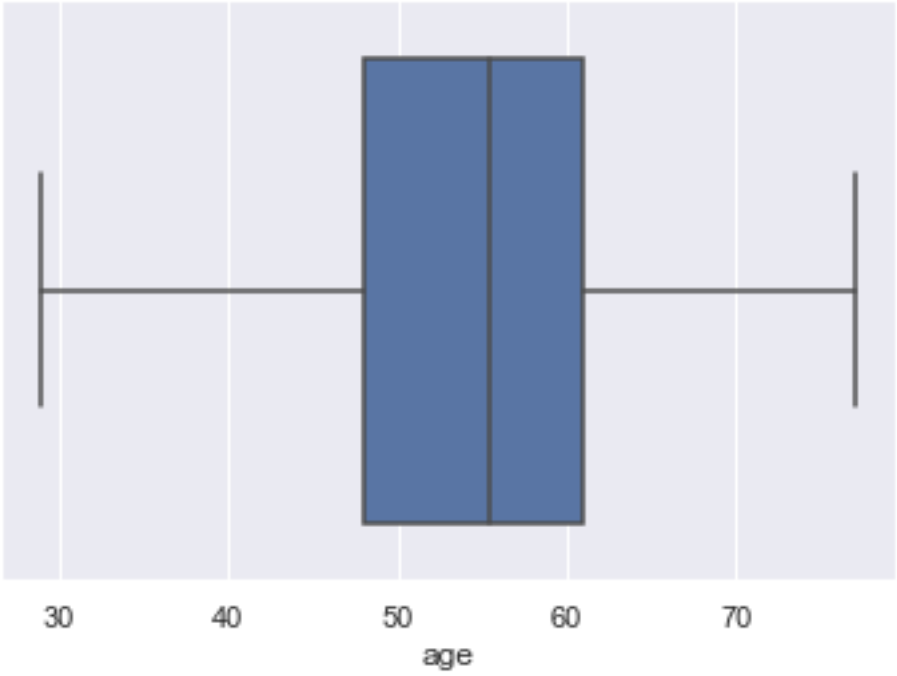
[19]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 302 entries, 0 to 302
Data columns (total 14 columns):
 #   Column    Non-Null Count  Dtype
---  ------    --------------  -----
 0   age       302 non-null    int64
 1   sex       302 non-null    int64
 2   cp        302 non-null    int64
 3   trestbps  302 non-null    int64
 4   chol      302 non-null    int64
 5   fbs       302 non-null    int64
 6   restecg   302 non-null    int64
 7   thalach   302 non-null    int64
 8   exang     302 non-null    int64
 9   oldpeak   302 non-null    float64
 10  slope     302 non-null    int64
 11  ca        302 non-null    int64
 12  thal      302 non-null    int64
 13  target    302 non-null    int64
dtypes: float64(1), int64(13)
memory usage: 35.4 KB
```

[20]:
```
import seaborn as sns #visualisation
import matplotlib.pyplot as plt #visualisation
%matplotlib inline
sns.set(color_codes=True)
```

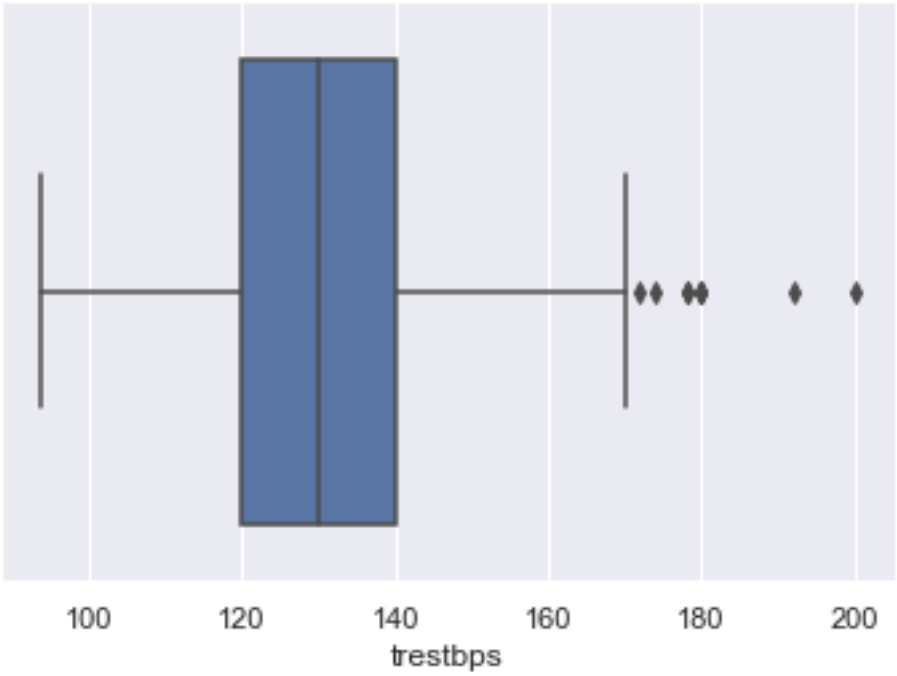
[21]:
```
sns.boxplot(x=df['age'])
```

[21]:
```
<AxesSubplot:xlabel='age'>
```



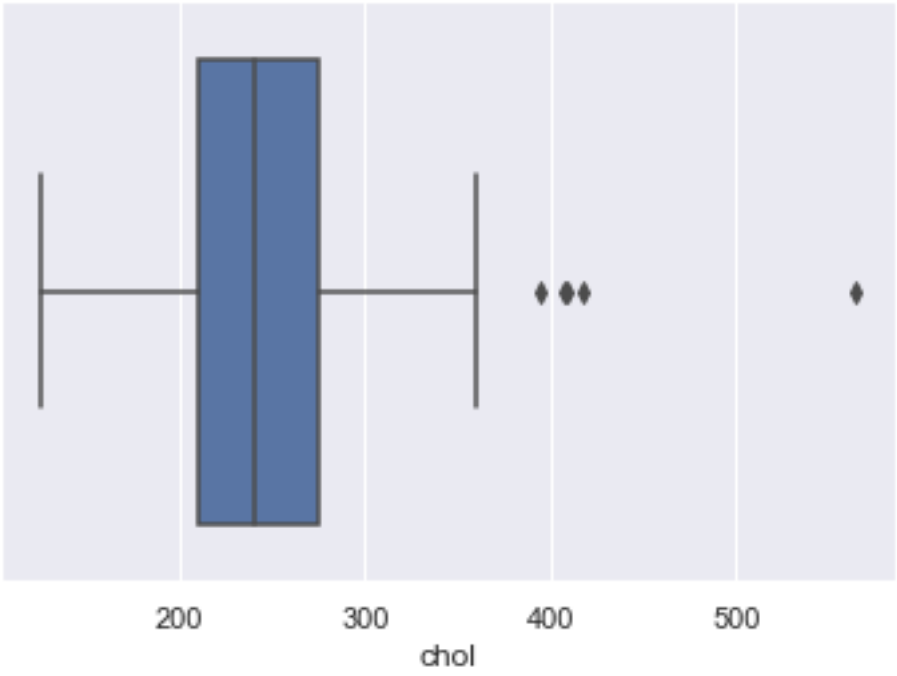
[22]:
```
sns.boxplot(x=df['trestbps'])
```

[22]:
```
<AxesSubplot:xlabel='trestbps'>
```



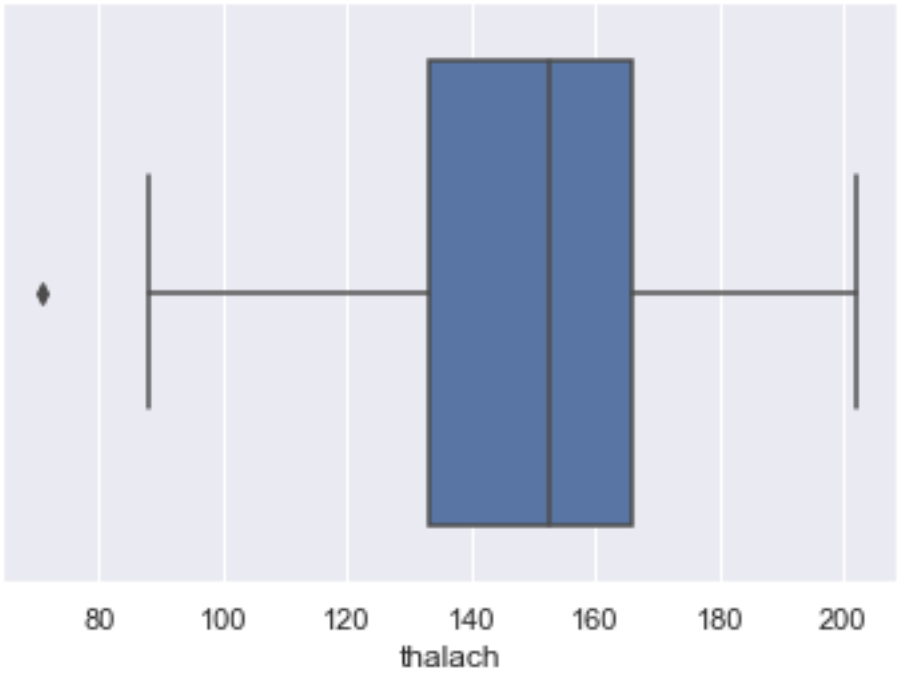
[23]:
```
sns.boxplot(x=df['chol'])
```

[23]: <AxesSubplot:xlabel='chol'>



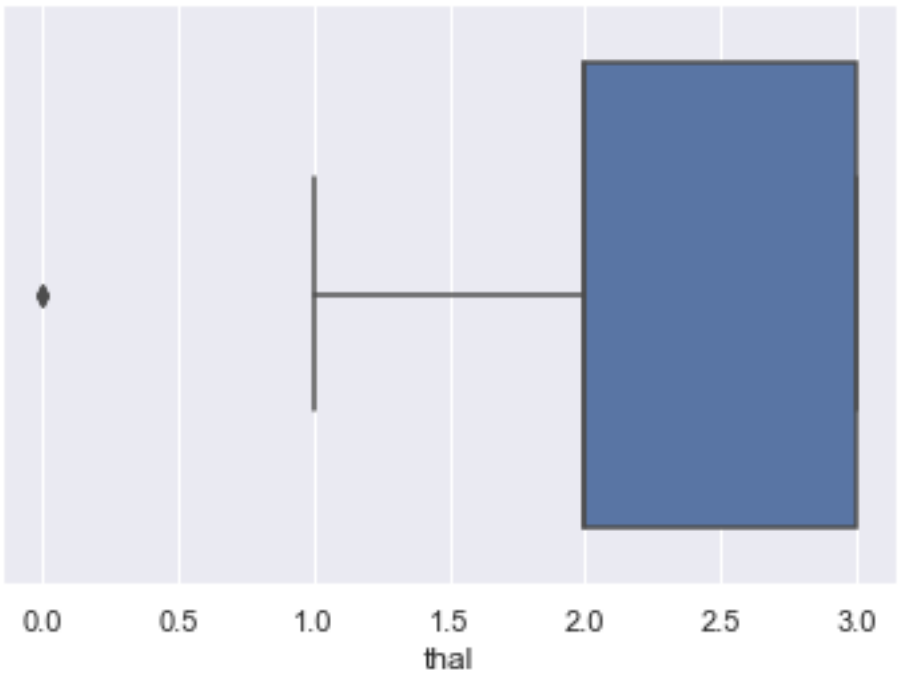
[24]:
```
sns.boxplot(x=df['thalach'])
```

[24]: <AxesSubplot:xlabel='thalach'>



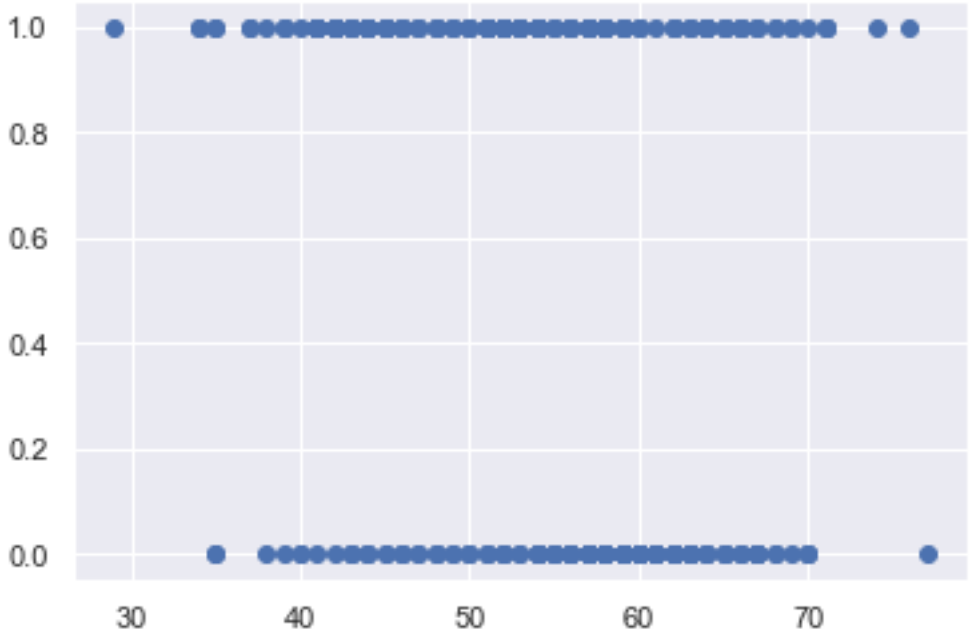
[25]:
```
sns.boxplot(x=df['thal'])
```

[25]: <AxesSubplot:xlabel='thal'>



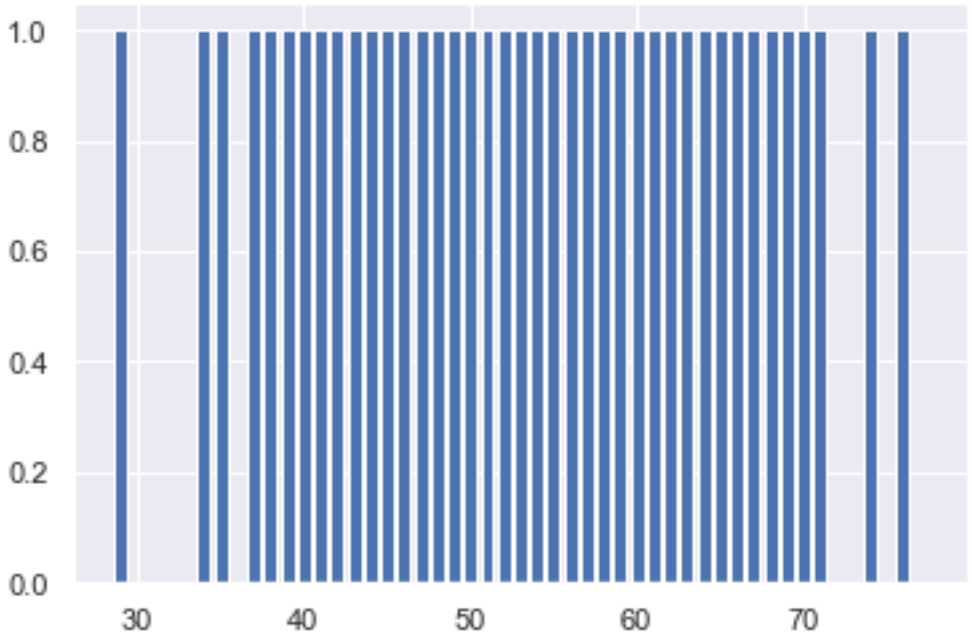
[28]:
```
plt.scatter(df['age'], df['target'])
```

[28]: <matplotlib.collections.PathCollection at 0x2136b1f9eb0>



[29]:
```
plt.bar(df['age'], df['target'])
```

[29]: <BarContainer object of 302 artists>



[30]:
```
categorical_values = []
for column in df.columns:
    print('==============================')
    print(f"{column} : {df[column].unique()}")
    if len(df[column].unique()) <= 10:
        categorical_values.append(column)
```

```
==============================
age : [63 37 41 56 57 44 52 54 48 49 64 58 50 66 43 69 59 42 61 40 71 51 65 53
 46 45 39 47 62 34 35 29 55 60 67 68 74 76 70 38 77]
==============================
sex : [1 0]
==============================
cp : [3 2 1 0]
==============================
trestbps : [145 130 120 140 172 150 110 135 160 105 125 142 155 104 138 128 108
134
 122 115 118 100 124  94 112 102 152 101 132 148 178 129 180 136 126 106
 156 170 146 117 200 165 174 192 144 123 154 114 164]
==============================
chol : [233 250 204 236 354 192 294 263 199 168 239 275 266 211 283 219 340 226
 247 234 243 302 212 175 417 197 198 177 273 213 304 232 269 360 308 245
```

```
 208 264 321 325 235 257 216 256 231 141 252 201 222 260 182 303 265 309
 186 203 183 220 209 258 227 261 221 205 240 318 298 564 277 214 248 255
 207 223 288 160 394 315 246 244 270 195 196 254 126 313 262 215 193 271
 268 267 210 295 306 178 242 180 228 149 278 253 342 157 286 229 284 224
 206 167 230 335 276 353 225 330 290 172 305 188 282 185 326 274 164 307
 249 341 407 217 174 281 289 322 299 300 293 184 409 259 200 327 237 218
 319 166 311 169 187 176 241 131]
==============================
fbs : [1 0]
==============================
restecg : [0 1 2]
==============================
thalach : [150 187 172 178 163 148 153 173 162 174 160 139 171 144 158 114 151
161
 179 137 157 123 152 168 140 188 125 170 165 142 180 143 182 156 115 149
 146 175 186 185 159 130 190 132 147 154 202 166 164 184 122 169 138 111
 145 194 131 133 155 167 192 121  96 126 105 181 116 108 129 120 112 128
 109 113  99 177 141 136  97 127 103 124  88 195 106  95 117  71 118 134
  90]
==============================
exang : [0 1]
==============================
oldpeak : [2.3 3.5 1.4 0.8 0.6 0.4 1.3 0.  0.5 1.6 1.2 0.2 1.8 1.  2.6 1.5 3.
2.4
 0.1 1.9 4.2 1.1 2.  0.7 0.3 0.9 3.6 3.1 3.2 2.5 2.2 2.8 3.4 6.2 4.  5.6
 2.9 2.1 3.8 4.4]
==============================
slope : [0 2 1]
==============================
ca : [0 2 1 3 4]
==============================
thal : [1 2 3 0]
==============================
target : [1 0]
```

[31]:
```
categorical_values
```

[31]:
```
['sex', 'cp', 'fbs', 'restecg', 'exang', 'slope', 'ca', 'thal', 'target']
```

[32]:
```
df.describe()
```

[32]:

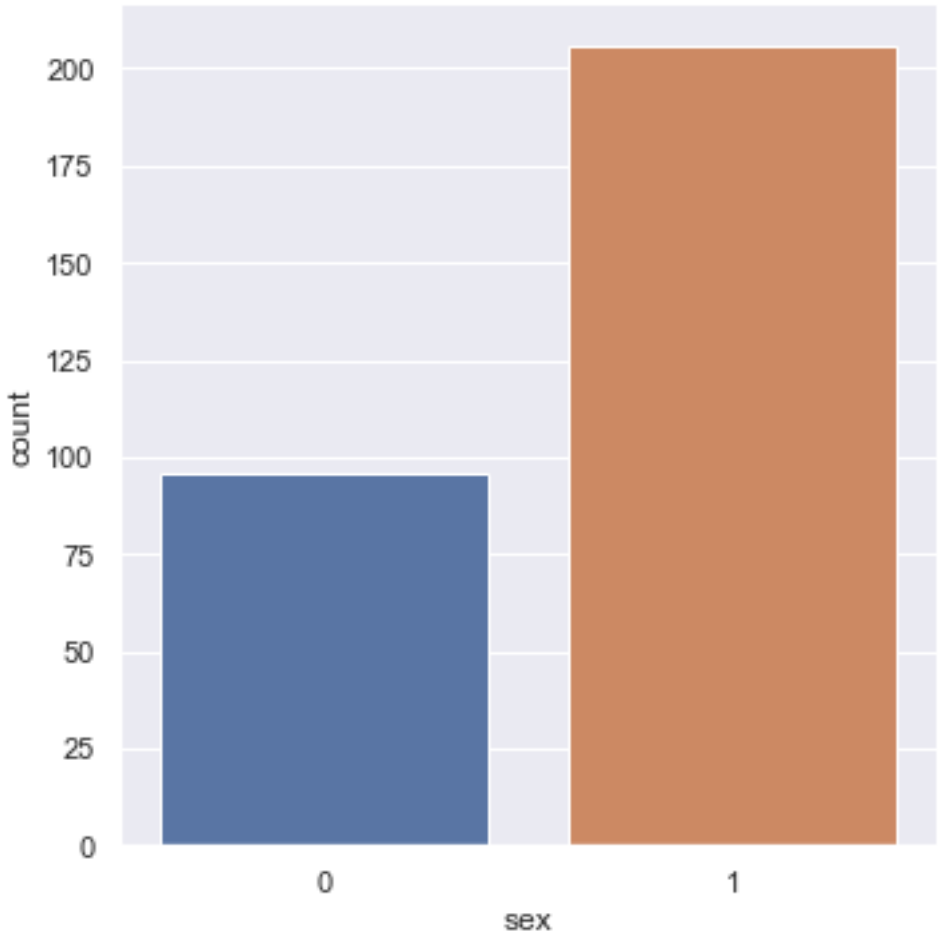
	age	sex	cp	trestbps	chol	fbs	\
count	302.00000	302.000000	302.000000	302.000000	302.000000	302.000000	
mean	54.42053	0.682119	0.963576	131.602649	246.500000	0.149007	
std	9.04797	0.466426	1.032044	17.563394	51.753489	0.356686	
min	29.00000	0.000000	0.000000	94.000000	126.000000	0.000000	
25%	48.00000	0.000000	0.000000	120.000000	211.000000	0.000000	
50%	55.50000	1.000000	1.000000	130.000000	240.500000	0.000000	

```
75%     61.00000    1.000000    2.000000  140.000000  274.750000    0.000000
max     77.00000    1.000000    3.000000  200.000000  564.000000    1.000000

          restecg     thalach       exang     oldpeak       slope          ca  \
count  302.000000  302.000000  302.000000  302.000000  302.000000  302.000000
mean     0.526490  149.569536    0.327815    1.043046    1.397351    0.718543
std      0.526027   22.903527    0.470196    1.161452    0.616274    1.006748
min      0.000000   71.000000    0.000000    0.000000    0.000000    0.000000
25%      0.000000  133.250000    0.000000    0.000000    1.000000    0.000000
50%      1.000000  152.500000    0.000000    0.800000    1.000000    0.000000
75%      1.000000  166.000000    1.000000    1.600000    2.000000    1.000000
max      2.000000  202.000000    1.000000    6.200000    2.000000    4.000000

             thal      target
count  302.000000  302.000000
mean     2.314570    0.543046
std      0.613026    0.498970
min      0.000000    0.000000
25%      2.000000    0.000000
50%      2.000000    1.000000
75%      3.000000    1.000000
max      3.000000    1.000000
```

[33]:
```
sns.factorplot('sex', data=df, kind='count')
```

```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\categorical.py:3704:
UserWarning: The `factorplot` function has been renamed to `catplot`. The
original name will be removed in a future release. Please update your code. Note
that the default `kind` in `factorplot` (`'point'`) has changed `'strip'` in
`catplot`.
  warnings.warn(msg)
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

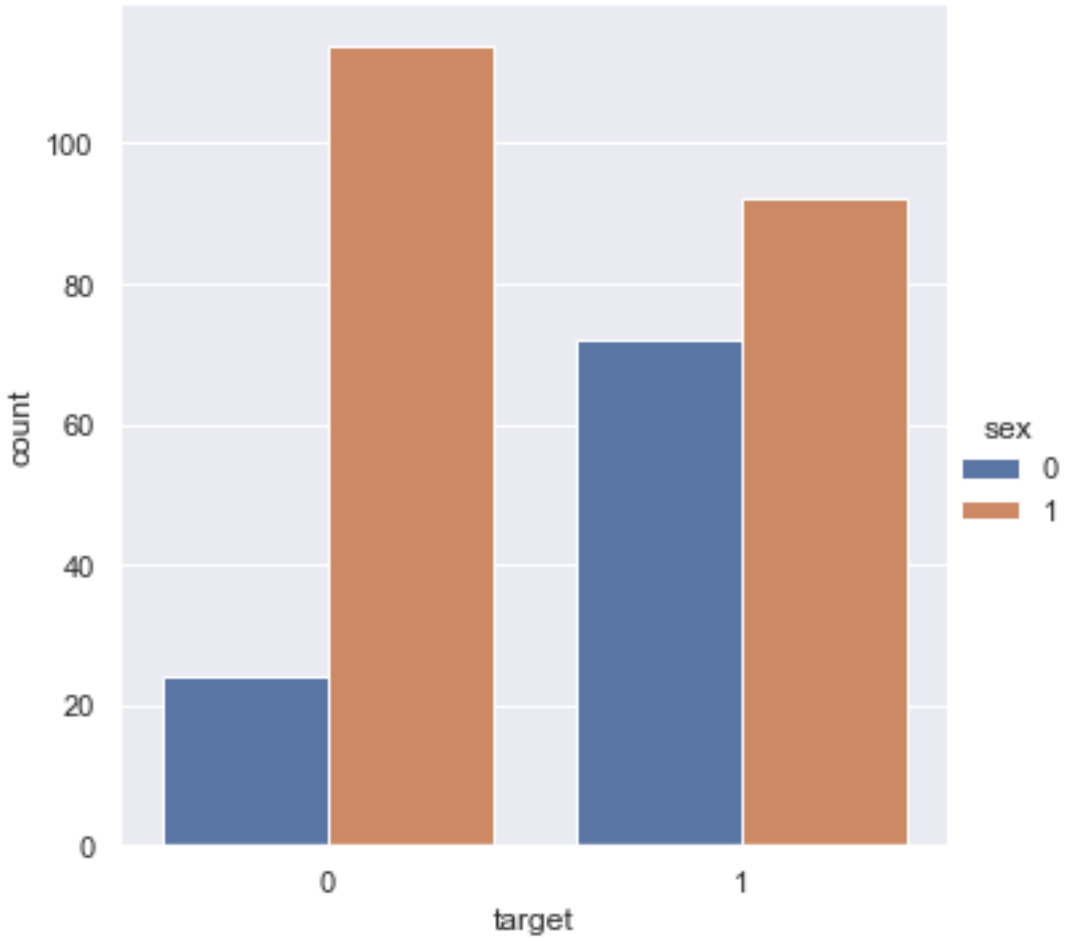
[33]:
```
<seaborn.axisgrid.FacetGrid at 0x2136aea9c70>
```



[34]:
```
sns.factorplot('target', data=df, hue='sex', kind='count')
```

```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\categorical.py:3704:
UserWarning: The `factorplot` function has been renamed to `catplot`. The
original name will be removed in a future release. Please update your code. Note
that the default `kind` in `factorplot` (`'point'`) has changed `'strip'` in
`catplot`.
  warnings.warn(msg)
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

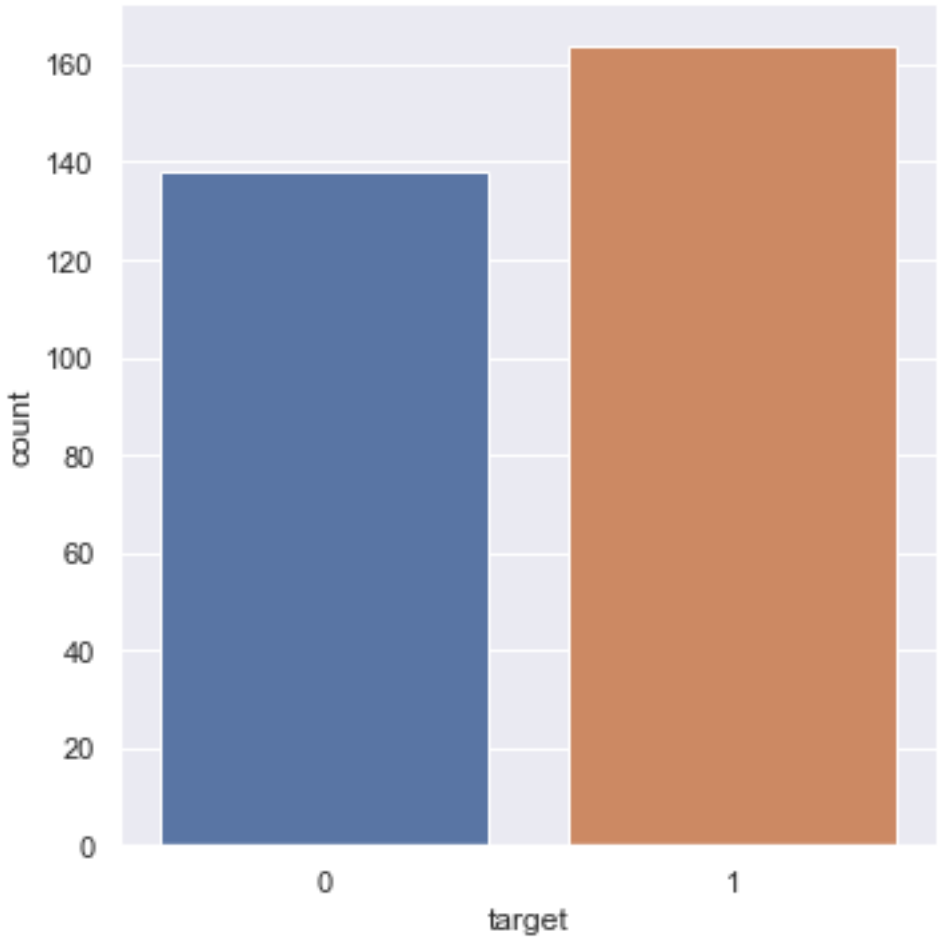
[34]:
```
<seaborn.axisgrid.FacetGrid at 0x2136b2a4670>
```



[35]:
```
sns.factorplot('target', data=df, kind='count')
```

```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\categorical.py:3704:
UserWarning: The `factorplot` function has been renamed to `catplot`. The
original name will be removed in a future release. Please update your code. Note
that the default `kind` in `factorplot` (`'point'`) has changed `'strip'` in
`catplot`.
  warnings.warn(msg)
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

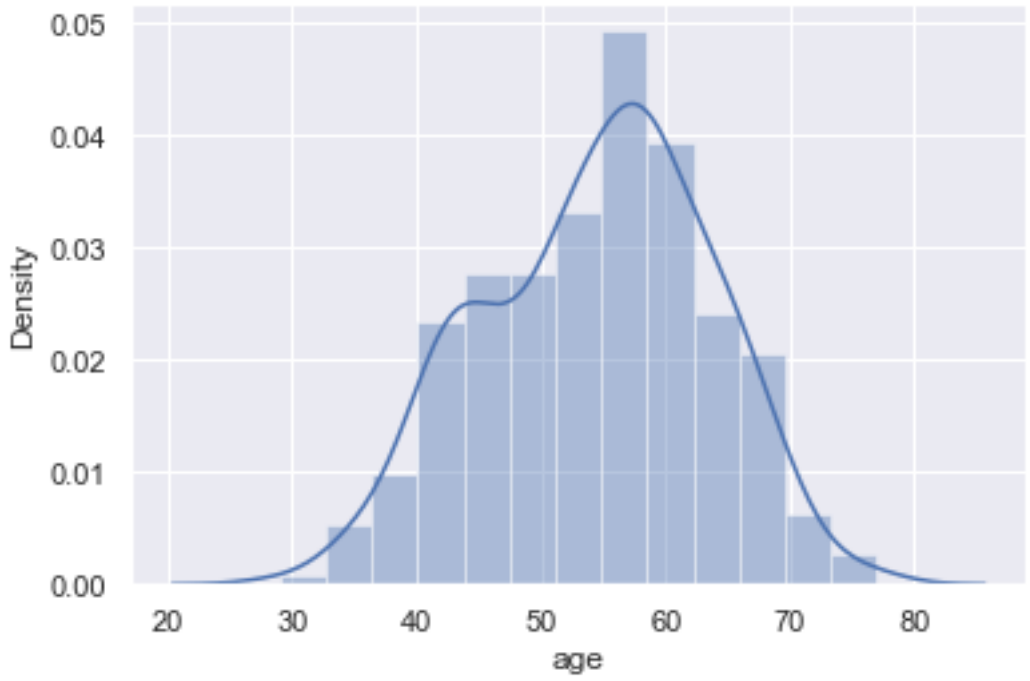
[35]:
```
<seaborn.axisgrid.FacetGrid at 0x2136b6a1f10>
```



[41]:
```
sns.distplot(df['age'])
```

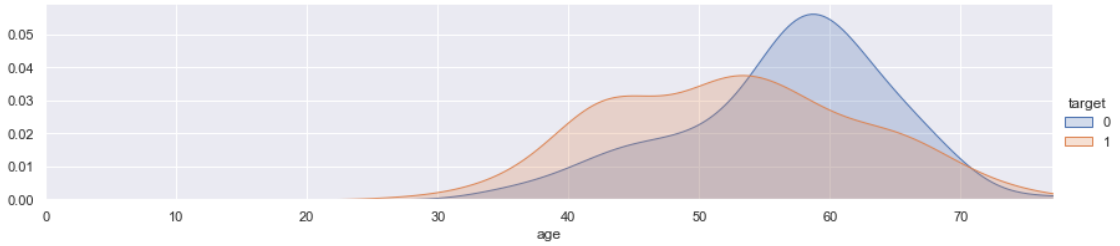
```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\distributions.py:2551:
FutureWarning: `distplot` is a deprecated function and will be removed in a
future version. Please adapt your code to use either `displot` (a figure-level
function with similar flexibility) or `histplot` (an axes-level function for
histograms).
  warnings.warn(msg, FutureWarning)
```

[41]:
```
<AxesSubplot:xlabel='age', ylabel='Density'>
```



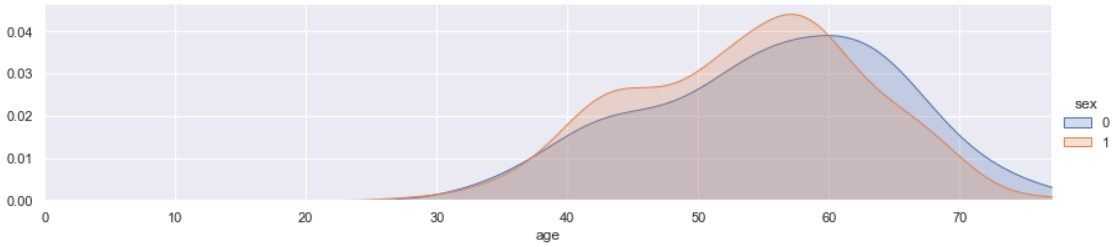
[38]:
```
fig = sns.FacetGrid(df, hue="target", aspect=4)
fig.map(sns.kdeplot, 'age', shade=True)
oldest = df['age'].max()
fig.set(xlim=(0, oldest))
fig.add_legend()
```

[38]: <seaborn.axisgrid.FacetGrid at 0x2136bb5ac70>



[39]:
```
fig = sns.FacetGrid(df, hue="sex", aspect=4)
fig.map(sns.kdeplot, 'age', shade=True)
oldest = df['age'].max()
fig.set(xlim=(0, oldest))
fig.add_legend()
```

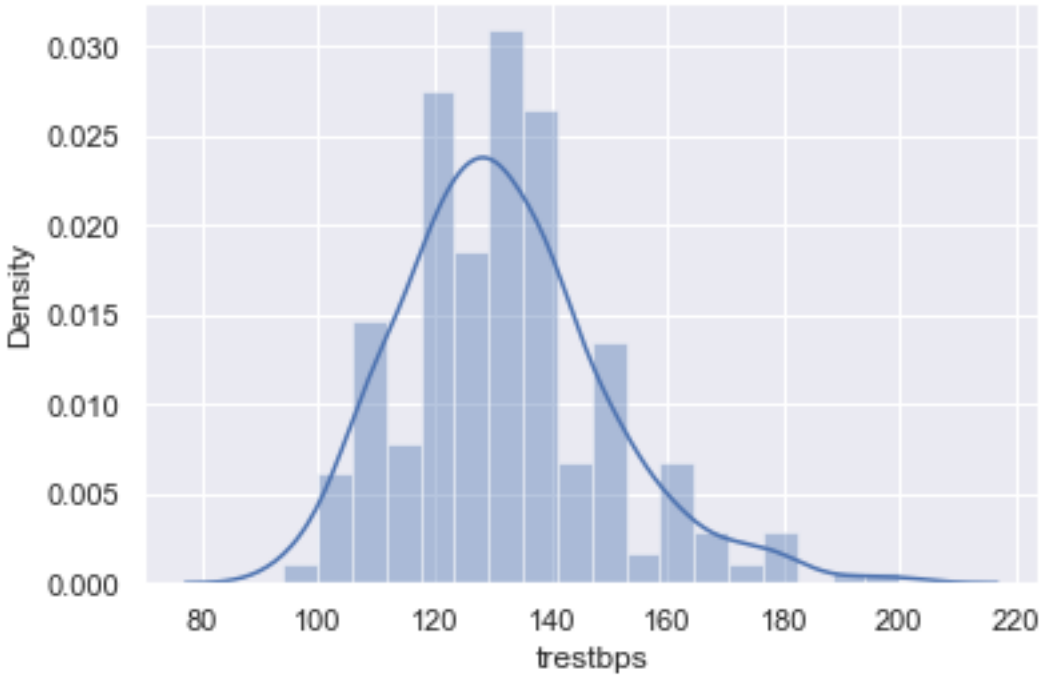
[39]: <seaborn.axisgrid.FacetGrid at 0x2136b7e5fa0>



[40]:
```
sns.distplot(df['trestbps'])
```

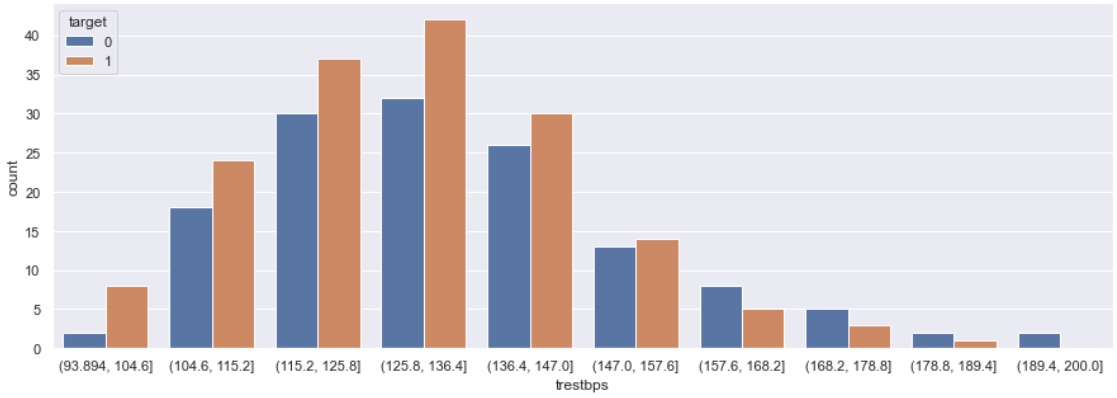
```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\distributions.py:2551:
FutureWarning: `distplot` is a deprecated function and will be removed in a
future version. Please adapt your code to use either `displot` (a figure-level
function with similar flexibility) or `histplot` (an axes-level function for
histograms).
  warnings.warn(msg, FutureWarning)
```

[40]: <AxesSubplot:xlabel='trestbps', ylabel='Density'>



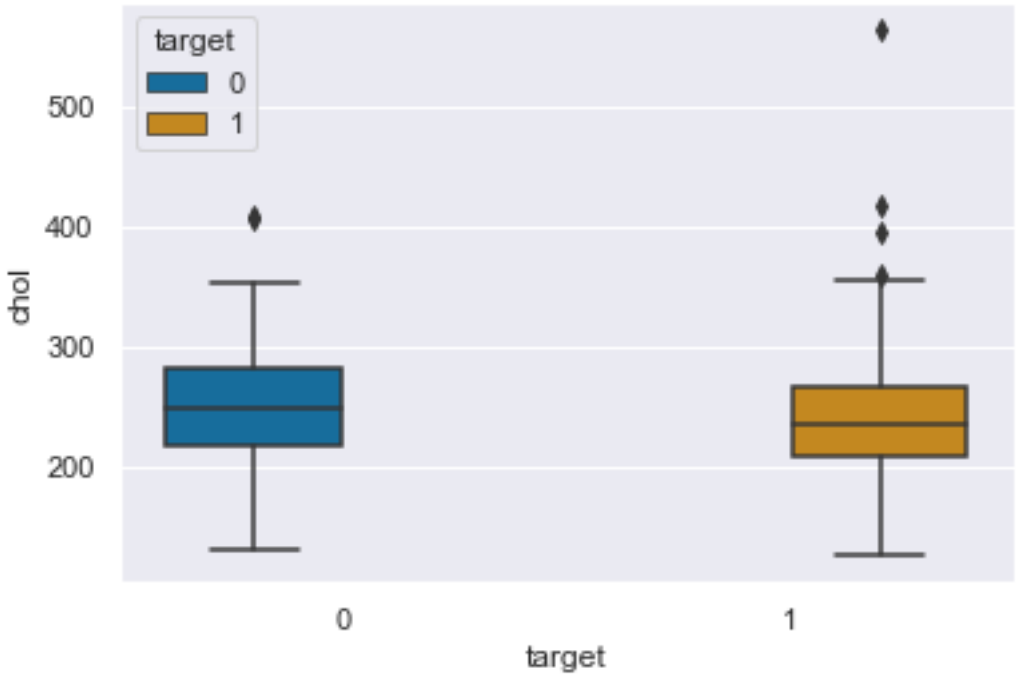
[43]:
```
f, ax = plt.subplots(figsize=(15, 5))
sns.countplot(data=df, x=pd.cut(df['trestbps'], 10), hue='target')
```

[43]: <AxesSubplot:xlabel='trestbps', ylabel='count'>



[47]:
```
sns.boxplot(y='chol', x='target',
                data=df,
                palette="colorblind",
                hue='target')
```

[47]: <AxesSubplot:xlabel='target', ylabel='chol'>

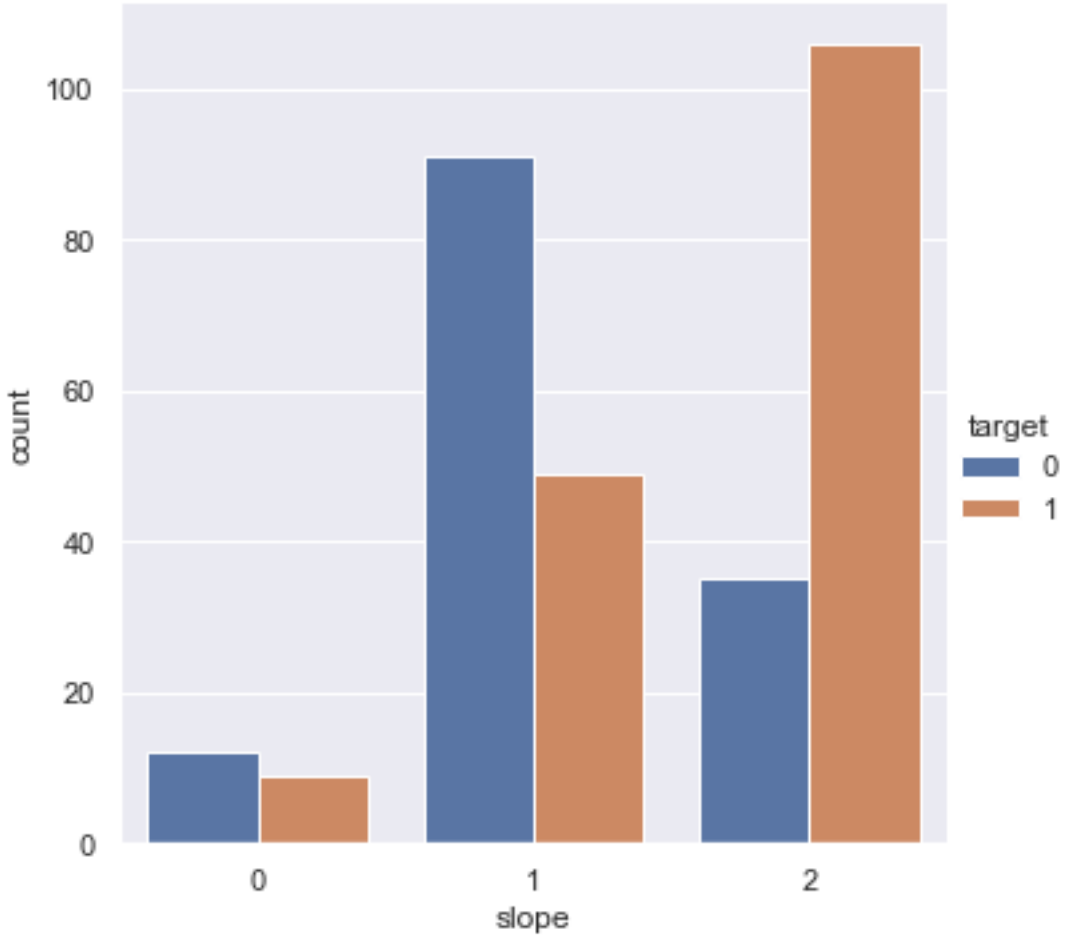


[48]:
```
# there seems to be an even distrbutution between our target and cholesterol␣
↪variables. Those with CVD have more outliers than those without.
```

[50]:
```
sns.factorplot('slope', data=df, hue='target', kind='count')
```

```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\categorical.py:3704:
UserWarning: The `factorplot` function has been renamed to `catplot`. The
original name will be removed in a future release. Please update your code. Note
that the default `kind` in `factorplot` (`'point'`) has changed `'strip'` in
`catplot`.
  warnings.warn(msg)
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

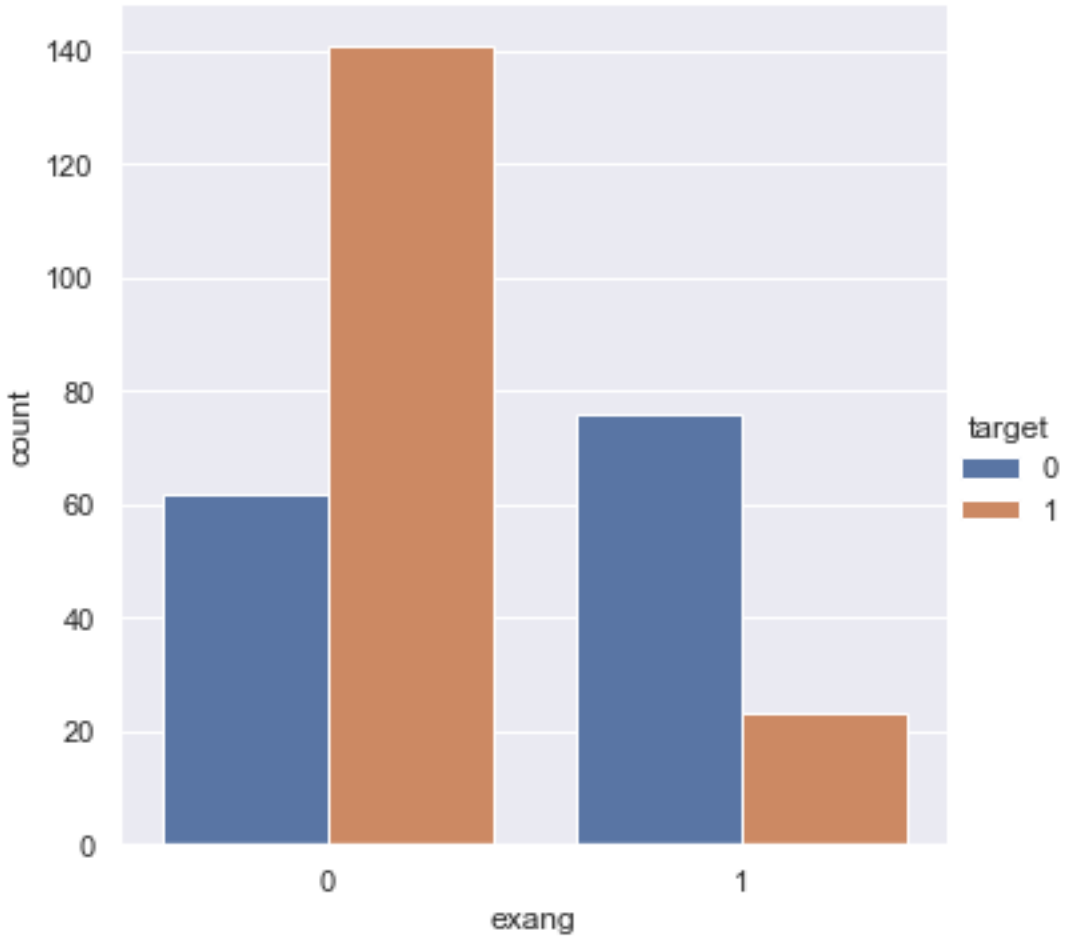
[50]:
```
<seaborn.axisgrid.FacetGrid at 0x2136cfc87c0>
```



[51]:
```
sns.factorplot('exang', data=df, hue='target', kind='count')
```

```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\categorical.py:3704:
UserWarning: The `factorplot` function has been renamed to `catplot`. The
original name will be removed in a future release. Please update your code. Note
that the default `kind` in `factorplot` (`'point'`) has changed `'strip'` in
`catplot`.
  warnings.warn(msg)
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

[51]:
```
<seaborn.axisgrid.FacetGrid at 0x2136d01cf70>
```

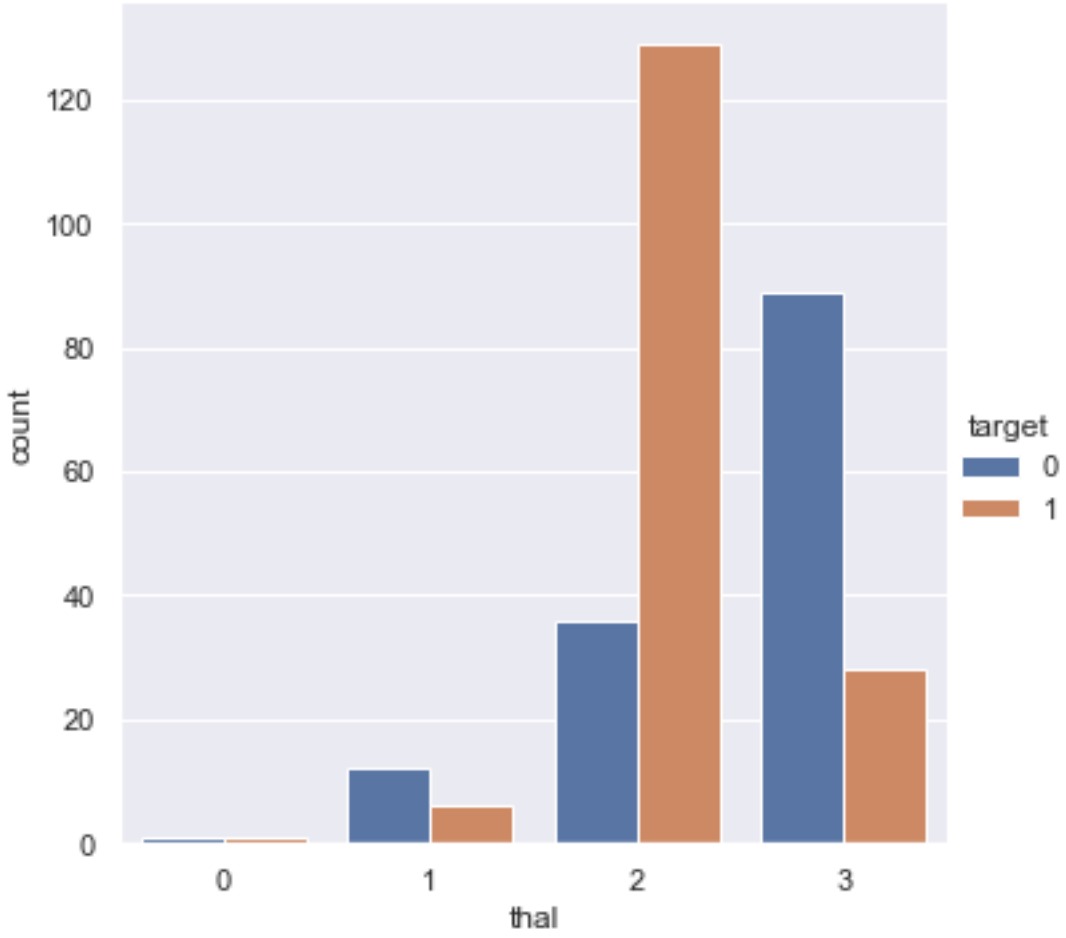


[52]:
```
# People with a downslope during peak exercise are at a greater risk for CVD.
```

[53]:
```
sns.factorplot('thal', data=df, hue='target', kind='count')
```

```
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\categorical.py:3704:
UserWarning: The `factorplot` function has been renamed to `catplot`. The
original name will be removed in a future release. Please update your code. Note
that the default `kind` in `factorplot` (`'point'`) has changed `'strip'` in
`catplot`.
  warnings.warn(msg)
C:\Users\nicme\anaconda3\lib\site-packages\seaborn\_decorators.py:36:
FutureWarning: Pass the following variable as a keyword arg: x. From version
0.12, the only valid positional argument will be `data`, and passing other
arguments without an explicit keyword will result in an error or
misinterpretation.
  warnings.warn(
```

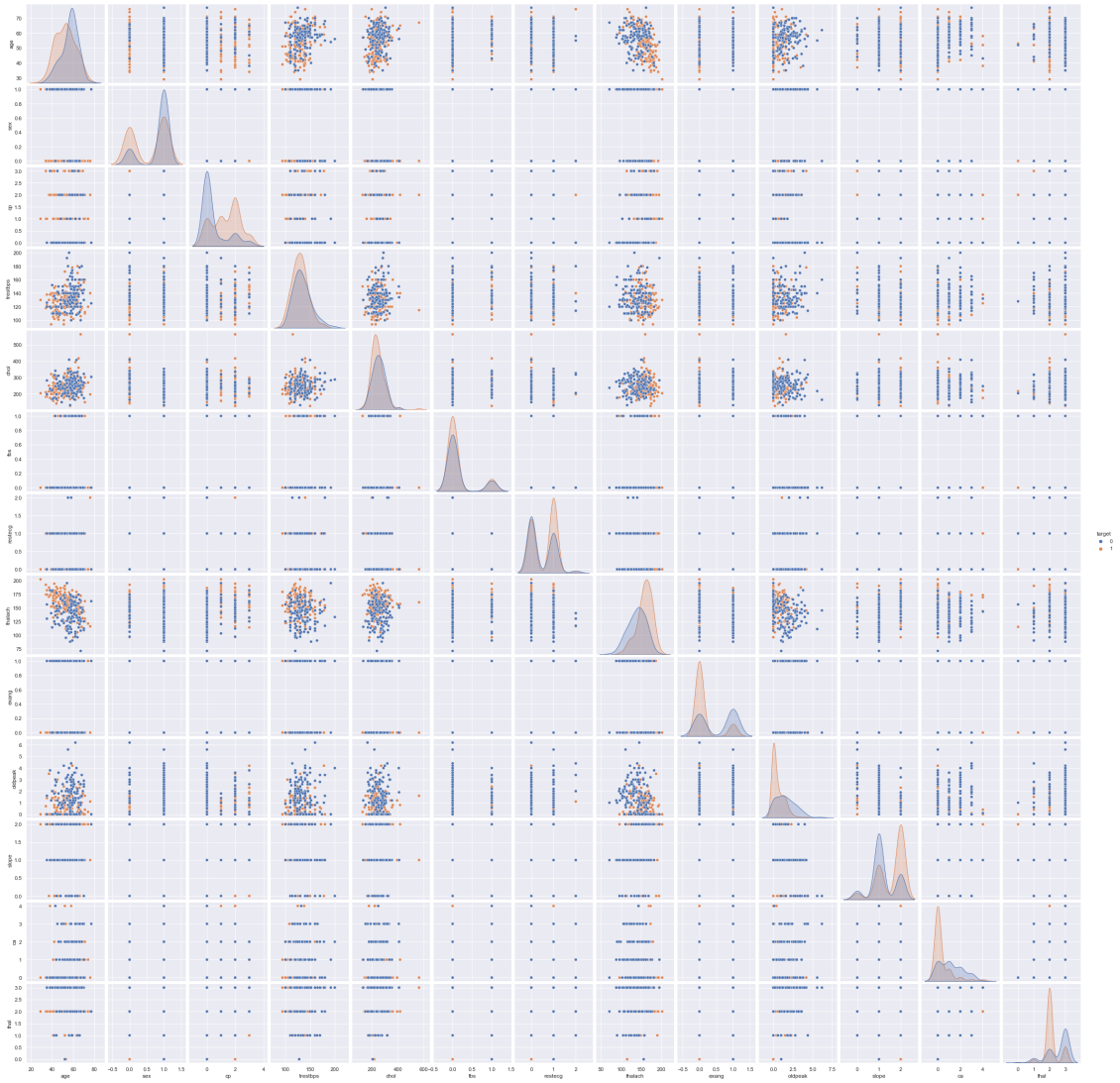
[53]:
```
<seaborn.axisgrid.FacetGrid at 0x2136b980c70>
```



[54]:
```
# People with a fixed defect have higher occurances of CVD.
```

[55]:
```
sns.pairplot(df , hue='target')
```

[55]: <seaborn.axisgrid.PairGrid at 0x2136d1102b0>



[65]:
```
from sklearn.utils import shuffle
from sklearn.model_selection import train_test_split
```

[67]:
```
df = df.dropna()
```

```
df = df.drop(columns = ['oldpeak', 'slope', 'ca', 'thal', 'fbs', 'restecg',␣
 ↪'exang'])
df = df.rename(columns = {'age': 'age', 'sex': 'gender', 'cp': 'chest pain',␣
 ↪'trestbps': 'blood pressure', 'chol': 'cholestrol level', 'thalach': 'max␣
 ↪heart rate', })
df.head()
```

[67]:

	age	gender	chest pain	blood pressure	cholestrol level	max heart rate	target
0	63	1	3	145	233	150	1
1	37	1	2	130	250	187	1
2	41	0	1	130	204	172	1
3	56	1	1	120	236	178	1
4	57	0	0	120	354	163	1

[78]:
```
df = shuffle(df)
x_train, x_test, y_train, y_test = train_test_split(df.iloc[:, :-1], df.iloc[:,␣
 ↪-1], test_size=0.3)
```

[79]:
```
from sklearn.linear_model import LogisticRegression
```

[80]:
```
model = LogisticRegression()
```

[81]:
```
model.fit(x_train, y_train)
```

[81]:
```
LogisticRegression()
```

[82]:
```
print(model.score(x_train,y_train))
print(model.score(x_test,y_test))
```

```
0.7819905213270142
0.7912087912087912
```

[83]:
```
y_pred = model.predict(x_test)
print('Accuracy of logistic regression on test set:{:.2f}'.format(model.
 ↪score(x_test, y_test)))
```

```
Accuracy of logistic regression on test set:0.79
```

[84]:
```
from sklearn.metrics import confusion_matrix
confusion_matrix = confusion_matrix(y_test, y_pred)
print(confusion_matrix)
```

```
[[31 12]
 [ 7 41]]
```