In [1]:
```
#Importing the dataset
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import warnings
warnings.filterwarnings('ignore')
from sklearn import metrics
from sklearn.metrics import precision_recall_fscore_support
from sklearn.metrics import classification_report
from sklearn.model_selection import cross_val_score
from sklearn.metrics import accuracy_score, classification_report, conf
usion_matrix, roc_curve, auc, mean_squared_error
from sklearn.model_selection import train_test_split
from sklearn.tree import DecisionTreeClassifier # Import Decision Tree
 Classifier
import seaborn
from sklearn.model_selection import learning_curve
from sklearn.model_selection import ShuffleSplit
from sklearn.metrics import roc_curve, auc
from IPython.display import Image
from sklearn import tree
#from dtreeplt import dtreeplt
import pydotplus
import pydot
from matplotlib.legend_handler import HandlerLine2D
import os
from graphviz import Source
from sklearn.tree import export_graphviz
from sklearn import model_selection
from sklearn.ensemble import RandomForestClassifier
from subprocess import call
from IPython.display import Image

df = pd.read_csv("breast-cancer-wisconsin.csv", low_memory = False)
```

In [2]:
```
!pip install pydotplus
```

```
!pip install pydot
#pip install git+https://github.com/nekoumei/dtreeplt.git
```

```
Requirement already satisfied: pydotplus in c:\programdata\anaconda3\li
b\site-packages (2.0.2)
Requirement already satisfied: pyparsing>=2.0.1 in c:\programdata\anaco
nda3\lib\site-packages (from pydotplus) (2.4.2)
Requirement already satisfied: pydot in c:\programdata\anaconda3\lib\si
te-packages (1.4.1)
Requirement already satisfied: pyparsing>=2.1.4 in c:\programdata\anaco
nda3\lib\site-packages (from pydot) (2.4.2)
```

In [3]:
```
#Checking for nulls
df.isnull().sum().max
```

Out[3]:
```
<bound method Series.max of id_number                          0
Clump_Thickness                 0
Uniformity_of_Cell_Size         0
Uniformity_of_Cell_Shape        0
Marginal_Adhesion               0
Single_Epithelial__Cell_Size    0
Bare_Nuclei                     0
Bland_Chromatin                 0
Normal_Nucleoli                 0
Mitoses                         0
Class                           0
dtype: int64>
```

In [4]:
```
# Dropping id_number
df=df.drop('id_number', axis=1)
df
```

Out[4]:

| | Clump_Thickness | Uniformity_of_Cell_Size | Uniformity_of_Cell_Shape | Marginal_Adhesion | Sin |
|---|---|---|---|---|---|
| 0 | 5 | 1 | 1 | 1 | |
| 1 | 5 | 4 | 4 | 5 | |
| 2 | 3 | 1 | 1 | 1 | |

| | Clump_Thickness | Uniformity_of_Cell_Size | Uniformity_of_Cell_Shape | Marginal_Adhesion | Sin |
|---|---|---|---|---|---|
| 3 | 6 | 8 | 8 | 1 | |
| 4 | 4 | 1 | 1 | 3 | |
| ... | ... | ... | ... | ... | |
| 694 | 3 | 1 | 1 | 1 | |
| 695 | 2 | 1 | 1 | 1 | |
| 696 | 5 | 10 | 10 | 3 | |
| 697 | 4 | 8 | 6 | 4 | |
| 698 | 4 | 8 | 8 | 5 | |

699 rows × 10 columns

In [5]:
```
df['Class'] = (df['Class'] > 3).astype(int)
df
```

Out[5]:

| | Clump_Thickness | Uniformity_of_Cell_Size | Uniformity_of_Cell_Shape | Marginal_Adhesion | Sin |
|---|---|---|---|---|---|
| 0 | 5 | 1 | 1 | 1 | |
| 1 | 5 | 4 | 4 | 5 | |
| 2 | 3 | 1 | 1 | 1 | |
| 3 | 6 | 8 | 8 | 1 | |
| 4 | 4 | 1 | 1 | 3 | |
| ... | ... | ... | ... | ... | |
| 694 | 3 | 1 | 1 | 1 | |
| 695 | 2 | 1 | 1 | 1 | |
| 696 | 5 | 10 | 10 | 3 | |
| 697 | 4 | 8 | 6 | 4 | |

| | Clump_Thickness | Uniformity_of_Cell_Size | Uniformity_of_Cell_Shape | Marginal_Adhesion | Sin |
|---|---|---|---|---|---|
| 698 | 4 | 8 | 8 | 5 | |

699 rows × 10 columns

In [6]:
```
df['Bare_Nuclei'].astype(str)
df = df[(df != '?').all(axis=1)]
df.shape
```

Out[6]: (683, 10)

In [7]:
```
X = df.drop('Class', axis=1)
y = df['Class']
X.shape
```

Out[7]: (683, 9)

In [8]:
```
# implementing train-test-split
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2
0, random_state=1, stratify=y)
```

In [9]:
```
# Create Decision Tree classifer object
dtc = DecisionTreeClassifier(criterion='gini')

# Train Decision Tree Classifer
dtc = dtc.fit(X_train,y_train)

#Predict the response for test dataset
y_pred = dtc.predict(X_test)
```

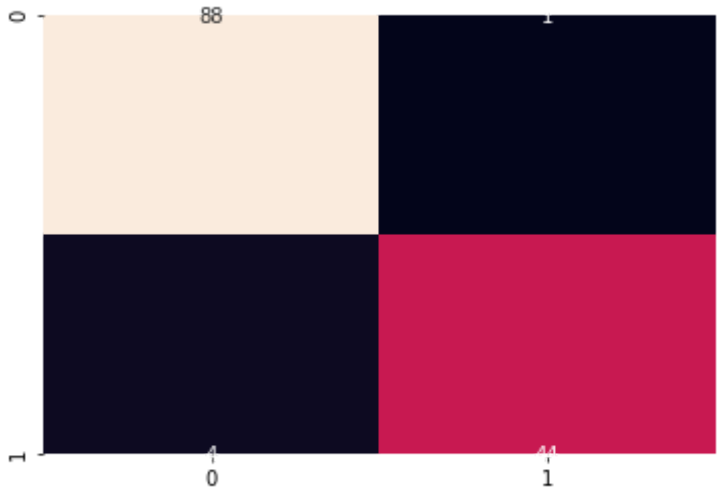
In [10]:
```
dtc_cv_score = cross_val_score(dtc, X, y, cv=10)
```

In [11]:
```
print("=== Confusion Matrix ===")
print(confusion_matrix(y_test, y_pred))
print('\n')
```

```
print("=== Classification Report ===")
print(classification_report(y_test, y_pred))
print('\n')
print("Accuracy: Single Decisiton Tree",metrics.accuracy_score(y_test,
y_pred))
```

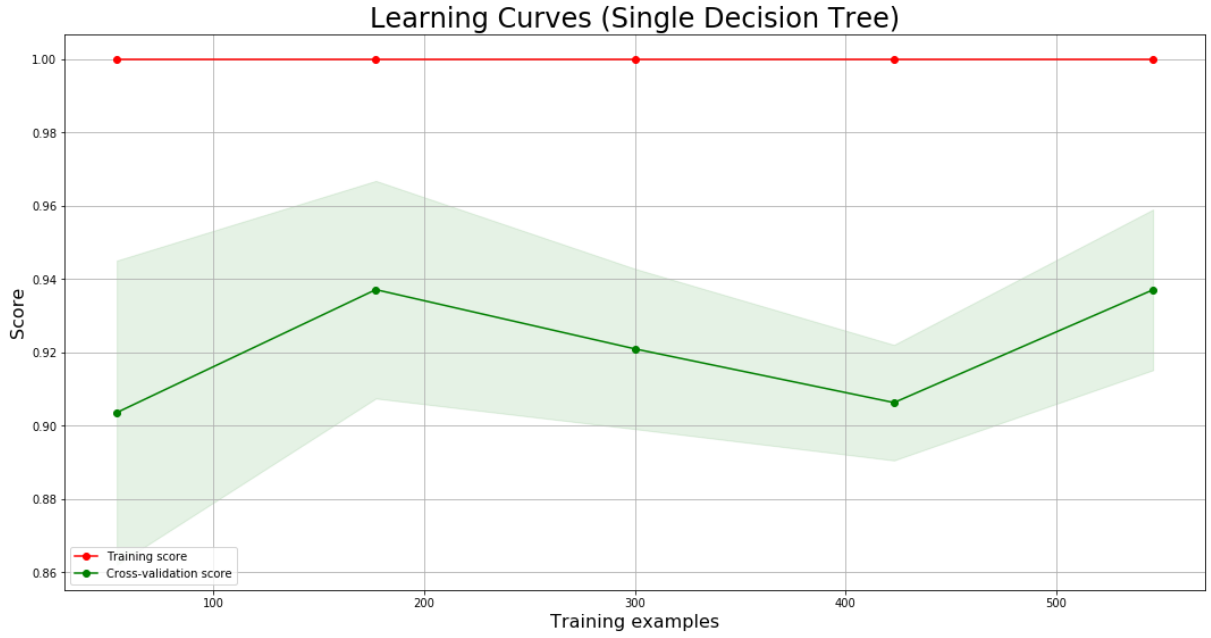
```
=== Confusion Matrix ===
[[88  1]
 [ 4 44]]


=== Classification Report ===
              precision    recall  f1-score   support

           0       0.96      0.99      0.97        89
           1       0.98      0.92      0.95        48

    accuracy                           0.96       137
   macro avg       0.97      0.95      0.96       137
weighted avg       0.96      0.96      0.96       137



Accuracy: Single Decisiton Tree 0.9635036496350365
```

In [12]:
```
cm_dtc=confusion_matrix(y_test, y_pred)
seaborn.heatmap(cm_dtc, annot=True,cbar=False)
plt.show()
```



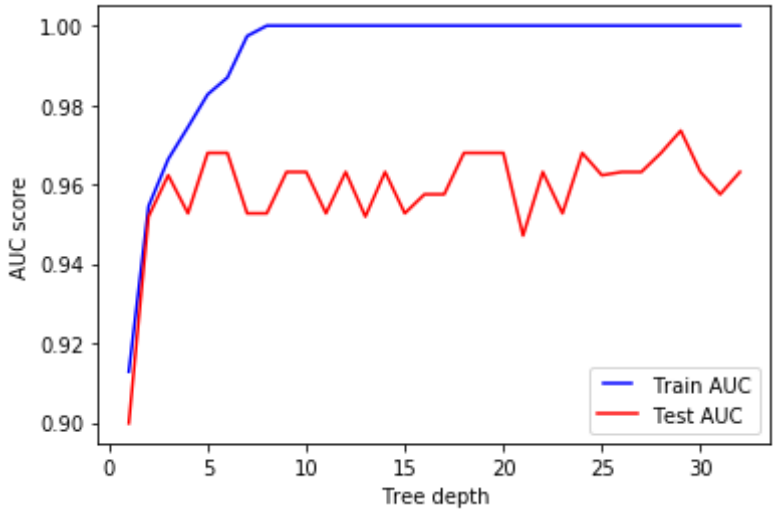

In [13]:
```
def plot_learning_curve(dtc, title, X, y, ylim=None, cv=None,
                        n_jobs=1, train_sizes=np.linspace(.1, 1.0, 5),
scoring='accuracy'):

    plt.figure(figsize=(18,9))
    plt.title(title, fontsize=24)
    if ylim is not None:
        plt.ylim(*ylim)
    plt.xlabel("Training examples", fontsize=16)
    plt.ylabel("Score", fontsize=16)
    train_sizes, train_scores, test_scores = learning_curve(
        dtc, X, y, cv=cv, n_jobs=n_jobs, train_sizes=train_sizes)
    train_scores_mean = np.mean(train_scores, axis=1)
    train_scores_std = np.std(train_scores, axis=1)
    test_scores_mean = np.mean(test_scores, axis=1)
    test_scores_std = np.std(test_scores, axis=1)
    plt.grid()

    plt.fill_between(train_sizes, train_scores_mean - train_scores_std,
                     train_scores_mean + train_scores_std, alpha=0.1,
                     color="r")
    plt.fill_between(train_sizes, test_scores_mean - test_scores_std,
                     test_scores_mean + test_scores_std, alpha=0.1, col
```

```
or="g")
    plt.plot(train_sizes, train_scores_mean, 'o-', color="r",
             label="Training score")
    plt.plot(train_sizes, test_scores_mean, 'o-', color="g",
             label="Cross-validation score")

    plt.legend(loc="best")
    return plt


title = "Learning Curves (Single Decision Tree)"
# Cross validation with 100 iterations to get smoother mean test and tr
ain
# score curves, each time with 20% data randomly selected as a validati
on set.
cv = ShuffleSplit(n_splits=100, test_size=0.2, random_state=0)

plot_learning_curve(dtc, title, X, y, cv=5)

plt.show()
```



In [14]:
```
false_positive_rate, true_positive_rate, thresholds = roc_curve(y_test,
 y_pred)
roc_auc = auc(false_positive_rate, true_positive_rate)
```

In [15]:
```
max_depths = np.linspace(1, 32, 32, endpoint=True)
train_results = []
test_results = []
for max_depth in max_depths:
    dtc = DecisionTreeClassifier(max_depth=max_depth, criterion='gini')
    dtc.fit(X_train, y_train)
    train_pred = dtc.predict(X_train)
    false_positive_rate, true_positive_rate, thresholds = roc_curve(y_t
rain, train_pred)
    roc_auc = auc(false_positive_rate, true_positive_rate)
   # Add auc score to previous train results
    train_results.append(roc_auc)
    y_pred = dtc.predict(X_test)
    false_positive_rate, true_positive_rate, thresholds = roc_curve(y_t
est, y_pred)
    roc_auc = auc(false_positive_rate, true_positive_rate)
    # Add auc score to previous test results
    test_results.append(roc_auc)
line1, = plt.plot(max_depths, train_results, 'b', label='Train AUC')
line2, = plt.plot(max_depths, test_results, 'r', label='Test AUC')
plt.legend(handler_map={line1: HandlerLine2D(numpoints=2)})
plt.ylabel('AUC score')
plt.xlabel('Tree depth')
plt.figure(figsize=(20,10))
plt.show()
```




```
<Figure size 1440x720 with 0 Axes>
```

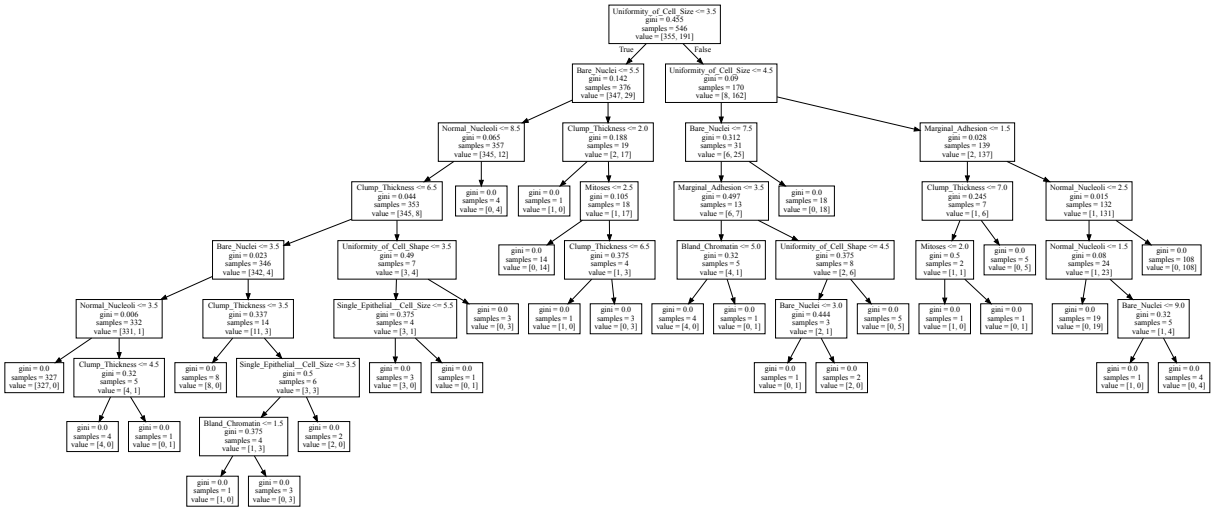
In [16]:
```
features=list(df.columns.values)
target=features[-1]
features=features[0:-1]
```

In [17]:
```
# Create DOT data
#dtree = dtreeplt(dtc, feature_names=features,target_names=target)

# Draw graph
#fig = dtree.view()
```

In [18]:
```
os.environ["PATH"] += os.pathsep + 'C:/Program Files (x86)/Graphviz2.38/bin/bin'
```

In [19]:
```
graph = Source( export_graphviz(dtc, out_file=None, feature_names=X.columns))
graph
```

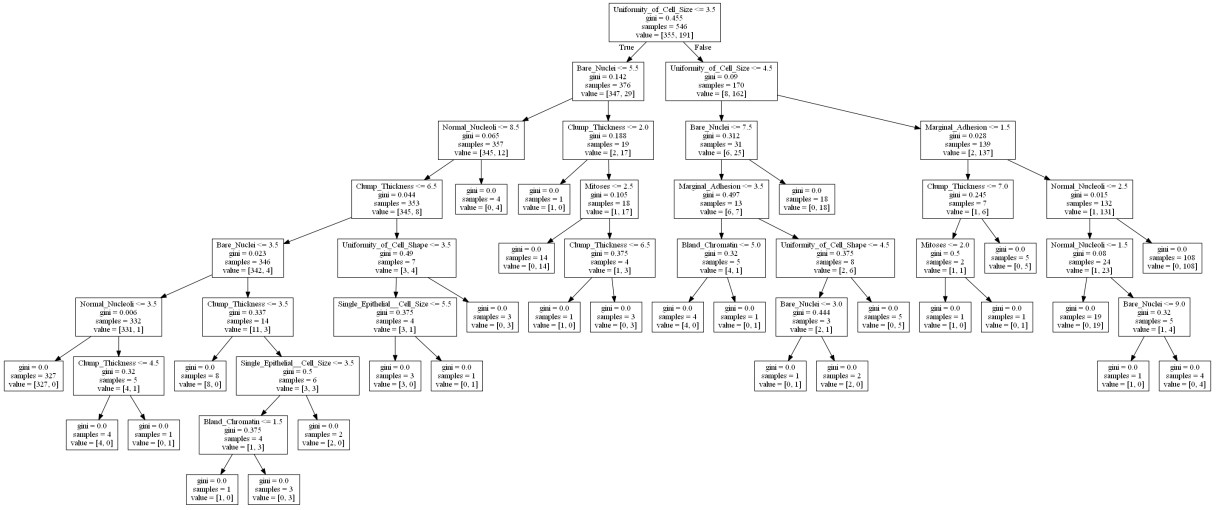
Out[19]:




In [20]:
```
graph.format = 'png'
```

In [21]:
```
png_byte = graph.pipe(format='png')
Image(png_byte)
```

Out[21]:



In [22]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2
0, random_state=1, stratify=y)
# random forest model creation
rfc = RandomForestClassifier(n_estimators=5, criterion='gini')
rfc.fit(X_train,y_train)
# predictions
y_pred = rfc.predict(X_test)
```

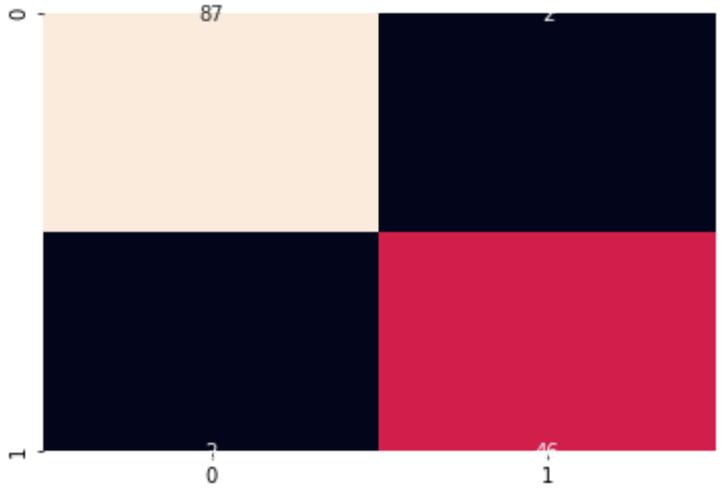
In [23]:
```
rfc_cv_score = cross_val_score(rfc, X, y, cv=10)
```

In [24]:
```
print("=== Confusion Matrix ===")
print(confusion_matrix(y_test, y_pred))
print('\n')
print("=== Classification Report ===")
print(classification_report(y_test, y_pred))
print('\n')
print("Accuracy: Random Forest",metrics.accuracy_score(y_test, y_pred))
```

```
=== Confusion Matrix ===
[[87  2]
 [ 2 46]]


=== Classification Report ===
              precision    recall  f1-score   support

           0       0.98      0.98      0.98        89
           1       0.96      0.96      0.96        48

    accuracy                           0.97       137
   macro avg       0.97      0.97      0.97       137
weighted avg       0.97      0.97      0.97       137



Accuracy: Random Forest 0.9708029197080292
```

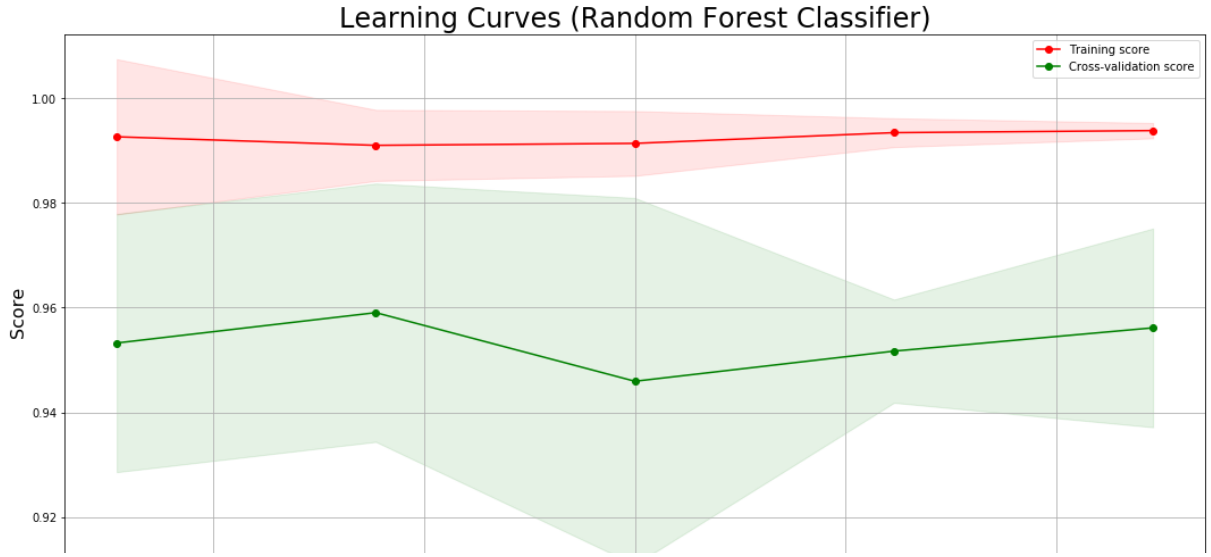
In [25]:
```
cm_rfc=confusion_matrix(y_test, y_pred)
```

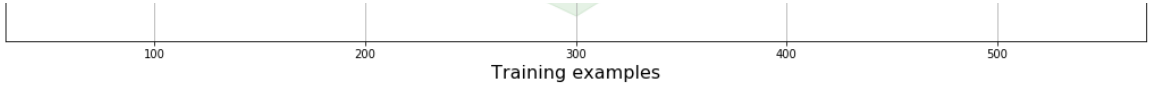
```
seaborn.heatmap(cm_rfc, annot=True,cbar=False)
plt.show()
```



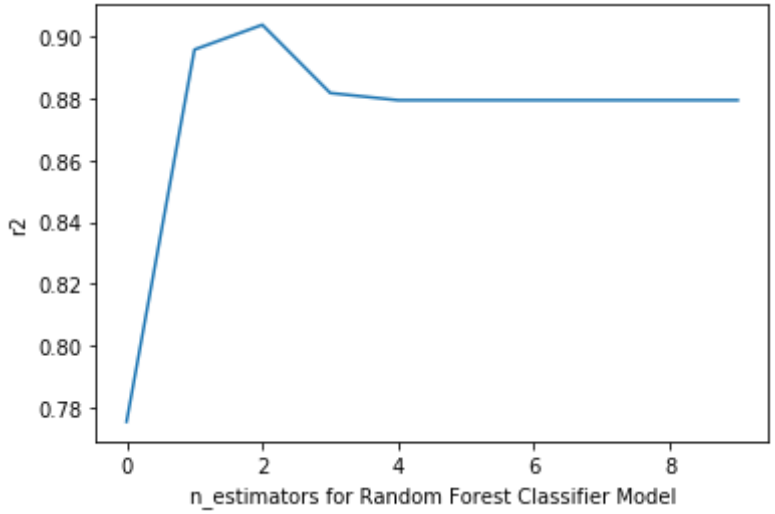

In [26]:
```
def plot_learning_curve(rfc, title, X, y, ylim=None, cv=None,
                        n_jobs=1, train_sizes=np.linspace(.1, 1.0, 5),
scoring='accuracy'):

    plt.figure(figsize=(18,9))
    plt.title(title, fontsize=24)
    if ylim is not None:
        plt.ylim(*ylim)
    plt.xlabel("Training examples", fontsize=16)
    plt.ylabel("Score", fontsize=16)
    train_sizes, train_scores, test_scores = learning_curve(
        rfc, X, y, cv=cv, n_jobs=n_jobs, train_sizes=train_sizes)
    train_scores_mean = np.mean(train_scores, axis=1)
    train_scores_std = np.std(train_scores, axis=1)
    test_scores_mean = np.mean(test_scores, axis=1)
    test_scores_std = np.std(test_scores, axis=1)
    plt.grid()

    plt.fill_between(train_sizes, train_scores_mean - train_scores_std,
                     train_scores_mean + train_scores_std, alpha=0.1,
```

```
                        color="r")
    plt.fill_between(train_sizes, test_scores_mean - test_scores_std,
                     test_scores_mean + test_scores_std, alpha=0.1, col
or="g")
    plt.plot(train_sizes, train_scores_mean, 'o-', color="r",
             label="Training score")
    plt.plot(train_sizes, test_scores_mean, 'o-', color="g",
             label="Cross-validation score")

    plt.legend(loc="best")
    return plt


title = "Learning Curves (Random Forest Classifier)"
# Cross validation with 100 iterations to get smoother mean test and tr
ain
# score curves, each time with 20% data randomly selected as a validati
on set.
cv = ShuffleSplit(n_splits=100, test_size=0.2, random_state=0)

plot_learning_curve(rfc, title, X, y, cv=5)

plt.show()
```



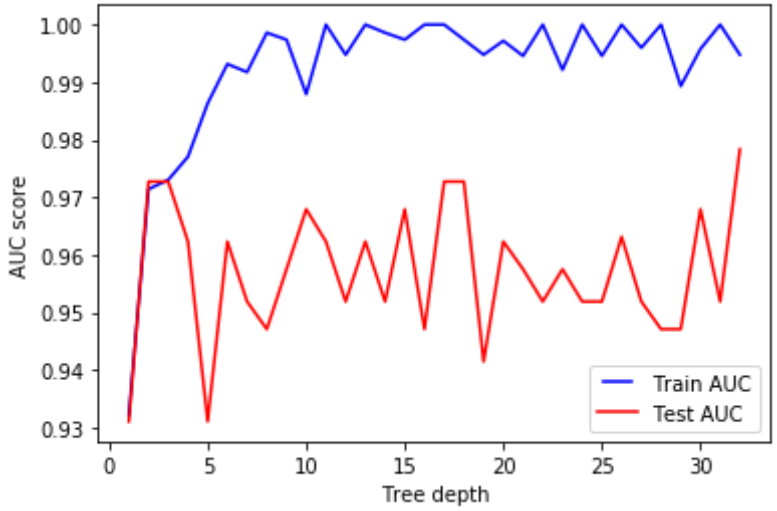



In [27]:
```
# plot showing incresing R² as n_estimators is increased from 1 to 9.
preds = np.stack([t.predict(X_test) for t in rfc.estimators_])
plt.ylabel("r2")
plt.xlabel("n_estimators for Random Forest Classifier Model")
preds[:,0], np.mean(preds[:,0])
plt.plot([metrics.r2_score(y_test, np.mean(preds[:i+1], axis=0)) for i
in range(10)]);
```




In [28]:
```
max_depths = np.linspace(1, 32, 32, endpoint=True)
train_results = []
test_results = []
for max_depth in max_depths:
    rfc = RandomForestClassifier(max_depth=max_depth, criterion='gini')
    rfc.fit(X_train, y_train)
    train_pred = rfc.predict(X_train)
    false_positive_rate, true_positive_rate, thresholds = roc_curve(y_t
rain, train_pred)
    roc_auc = auc(false_positive_rate, true_positive_rate)
   # Add auc score to previous train results
```

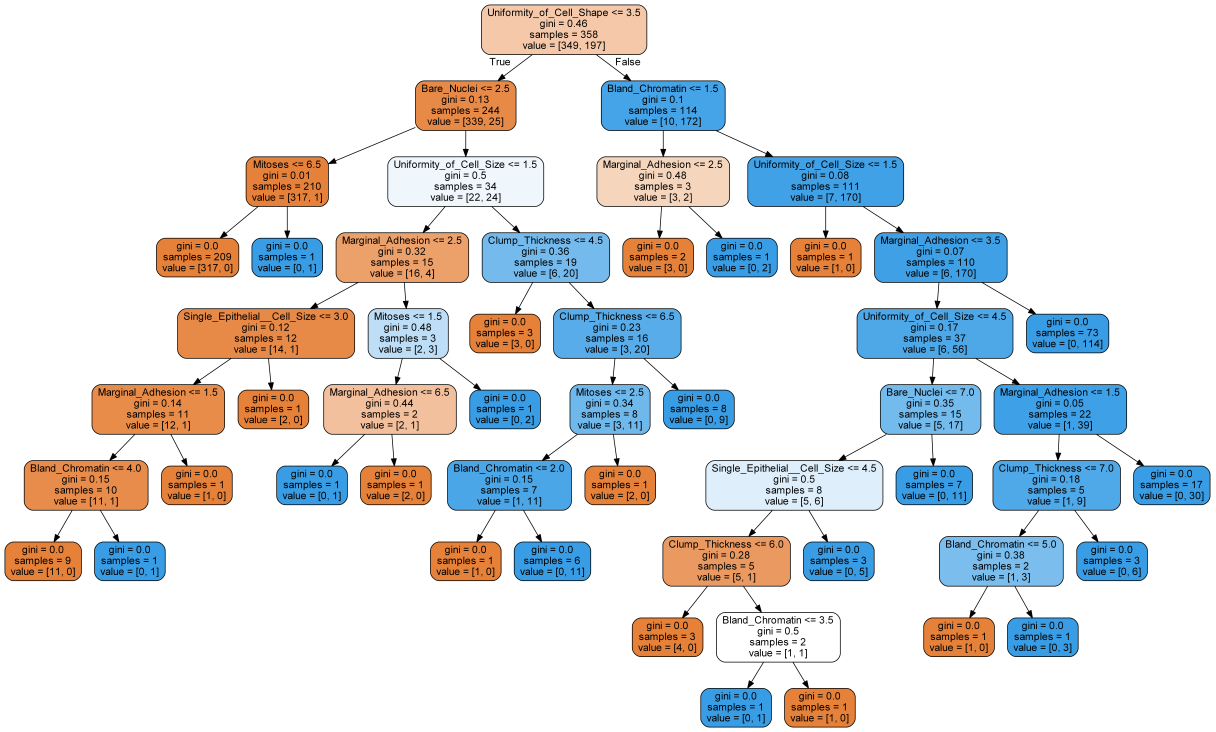
```
    train_results.append(roc_auc)
    y_pred = rfc.predict(X_test)
    false_positive_rate, true_positive_rate, thresholds = roc_curve(y_t
est, y_pred)
    roc_auc = auc(false_positive_rate, true_positive_rate)
    # Add auc score to previous test results
    test_results.append(roc_auc)
line1, = plt.plot(max_depths, train_results, 'b', label='Train AUC')
line2, = plt.plot(max_depths, test_results, 'r', label='Test AUC')
plt.legend(handler_map={line1: HandlerLine2D(numpoints=2)})
plt.ylabel('AUC score')
plt.xlabel('Tree depth')
plt.show()
```




In [29]:
```
# Extract single tree
estimator = rfc.estimators_[2]



# Export as dot file
export_graphviz(estimator, out_file='tree.dot',feature_names=X.columns,

                rounded = True, proportion = False,
```

```
                precision = 2, filled = True)

# Convert to png using system command (requires Graphviz)

call(['dot', '-Tpng', 'tree.dot', '-o', 'tree.png', '-Gdpi=600'])

# Display in jupyter notebook

Image(filename = 'tree.png')
```

Out[29]:

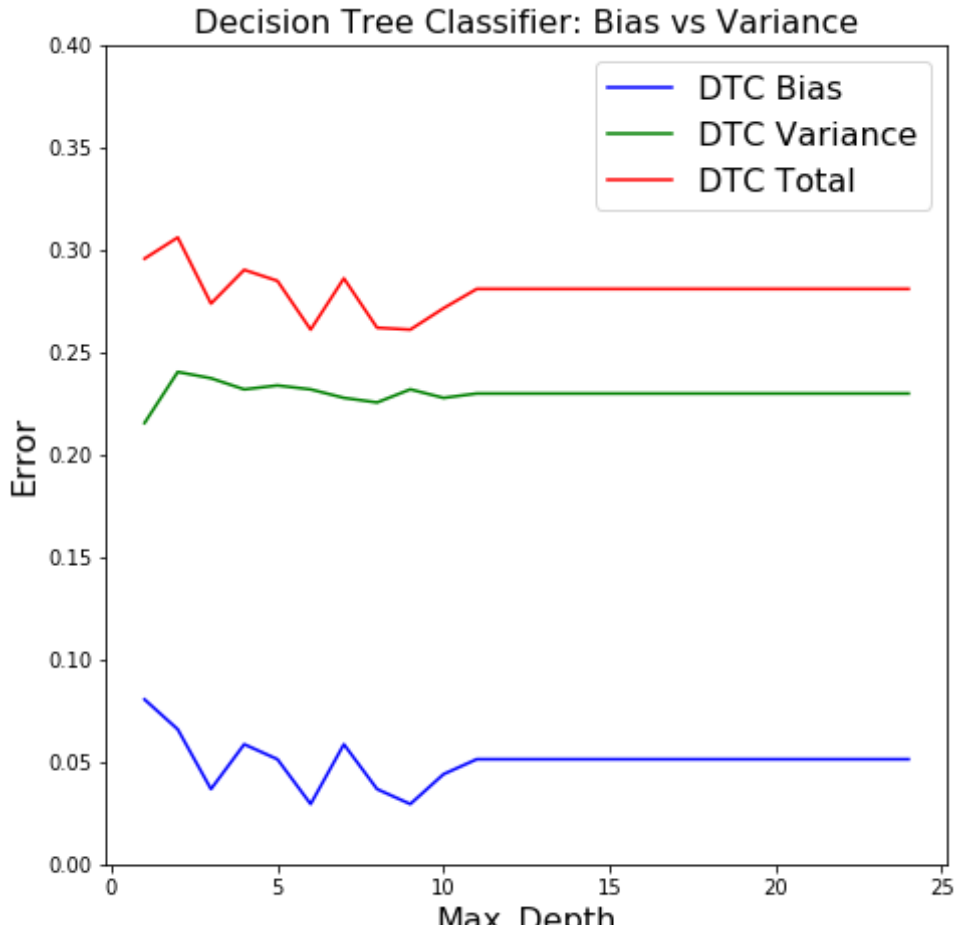



In [31]:

```
#Bias and Variance Functions

def bias(y_predict,y):
    y_predict = np.array(y_predict)
    y = np.array(y)
    return np.mean(np.power((y_predict-y),2))
```

```
def variance(y_predict,y):
    y_predict = np.array(y_predict)
    return np.var(y_predict)

#Decision Tree Classification Bias and Variance
max_depth_DTC = np.arange(1,25)

bias_DTC = []
var_DTC = []
err_DTC = []

err_DTC_list_test = []
err_DTC_list_training = []
err_tot_DTC_list = []

model_DTC = DecisionTreeClassifier(random_state=42)
model_DTC.set_params(criterion = 'gini',
                     max_depth = 4,
                     max_features = 'sqrt')

for entry in max_depth_DTC:
    model_DTC.set_params(max_depth = entry)
    model_DTC.fit(X_train, y_train)
    predicted_y_DTC_test = model_DTC.predict(X_test)
    predicted_y_DTC_train = model_DTC.predict(X_train)
    bias_DTC.append(bias(predicted_y_DTC_test,y_test))
    var_DTC.append(variance(predicted_y_DTC_test,y_test))
    err_DTC.append(bias(predicted_y_DTC_test,y_test)+variance(predicted
_y_DTC_test,y_test))

    err_DT_test_variable =mean_squared_error(y_test,predicted_y_DTC_tes
t)
    err_DT_training_variable = mean_squared_error(y_train, predicted_y_
DTC_train)
    err_DT_tot_variable = err_DT_test_variable + err_DT_training_variab
le
    err_DTC_list_test.append(err_DT_test_variable)
    err_DTC_list_training.append(err_DT_training_variable)
    err_tot_DTC_list.append(err_DT_tot_variable)
```

```
plt.figure(figsize=(7.5,7.5))
plt.plot(max_depth_DTC, bias_DTC,color='b')
plt.plot(max_depth_DTC, var_DTC,color='g')
plt.plot(max_depth_DTC, err_DTC,color='r')
plt.legend(['DTC Bias', 'DTC Variance', 'DTC Total'], loc='upper right'
,fontsize=16)
plt.title('Decision Tree Classifier: Bias vs Variance',fontsize=16)
plt.ylabel('Error',fontsize=16)
plt.xlabel('Max_Depth',fontsize=16)
plt.ylim(0,0.4)
plt.show()
```



max_depth