```
from google.colab import drive
drive.mount('/content/drive')
%cd /content/drive/MyDrive/Colab Notebooks
```

```
Mounted at /content/drive
/content/drive/MyDrive/Colab Notebooks
```

```
# === 1. Install necessary libraries ===
!pip install xgboost lightgbm scikit-learn matplotlib tensorflow

# === 2. Imports ===
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
from sklearn.feature_selection import mutual_info_classif
from lightgbm import LGBMClassifier
from sklearn.metrics import accuracy_score
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout

# Load your CSV from this path
df = pd.read_csv("CBioFiltered_Genes_Subset.csv")

# === 4. Preprocessing ===
df_cleaned = df.drop(columns=["Unnamed: 0", "batch"])
X = df_cleaned.drop(columns=["group"])
y = df_cleaned["group"].astype(int)

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

# === 5. Feature selection ===
rfc = RandomForestClassifier(n_estimators=100, random_state=42)
rfc.fit(X_train_scaled, y_train)
rfc_importance = rfc.feature_importances_

xgb = XGBClassifier(use_label_encoder=False, eval_metric='logloss', random_state=42)
xgb.fit(X_train_scaled, y_train)
xgb_importance = xgb.feature_importances_

mi = mutual_info_classif(X_train_scaled, y_train, random_state=42)

# Combine using voting
rfc_norm = rfc_importance / np.max(rfc_importance)
xgb_norm = xgb_importance / np.max(xgb_importance)
mi_norm = mi / np.max(mi)
combined_score = (rfc_norm + xgb_norm + mi_norm) / 3

feature_importance_df = pd.DataFrame({
    'Feature': X.columns,
    'RFC': rfc_norm,
    'XGBoost': xgb_norm,
    'MI': mi_norm,
    'MeanScore': combined_score
}).sort_values(by="MeanScore", ascending=False)

top_features = feature_importance_df.head(30)["Feature"].values

# Plot top features
plt.figure(figsize=(12, 8))
plt.barh(feature_importance_df.head(30)['Feature'], feature_importance_df.head(30)['MeanScore'], color='skyblue')
plt.xlabel("Importance Score (Normalized Average)")
plt.title("Top 20 Important Features (RFC + XGBoost + MI)")
plt.gca().invert_yaxis()
plt.tight_layout()
plt.show()

# === 6. Prepare top features for modeling ===
X_train_top = X_train_scaled[:, [X.columns.get_loc(f) for f in top_features]]
X_test_top = X_test_scaled[:, [X.columns.get_loc(f) for f in top_features]]

# === 7. Evaluate models ===

# Random Forest
```

```python
rfc_model = RandomForestClassifier(random_state=42)
rfc_model.fit(X_train_top, y_train)
rfc_pred = rfc_model.predict(X_test_top)
print("Random Forest Accuracy:", accuracy_score(y_test, rfc_pred))

# XGBoost
xgb_model = XGBClassifier(use_label_encoder=False, eval_metric='logloss', random_state=42)
xgb_model.fit(X_train_top, y_train)
xgb_pred = xgb_model.predict(X_test_top)
print("XGBoost Accuracy:", accuracy_score(y_test, xgb_pred))

# LightGBM
lgbm_model = LGBMClassifier(random_state=42)
lgbm_model.fit(X_train_top, y_train)
lgbm_pred = lgbm_model.predict(X_test_top)
print("LightGBM Accuracy:", accuracy_score(y_test, lgbm_pred))

# ANN (Keras)
model = Sequential()
model.add(Dense(64, input_dim=X_train_top.shape[1], activation='relu'))
model.add(Dropout(0.3))
model.add(Dense(32, activation='relu'))
model.add(Dense(1, activation='sigmoid'))  # Use '1' output for binary

model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
model.fit(X_train_top, y_train, epochs=50, batch_size=16, verbose=0)
ann_loss, ann_acc = model.evaluate(X_test_top, y_test, verbose=0)
print("ANN Accuracy:", ann_acc)
```

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Requirement already satisfied: lightgbm in /usr/local/lib/python3.11/dist-packages (4.5.0)
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.11/dist-packages (1.6.1)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.11/dist-packages (3.10.0)
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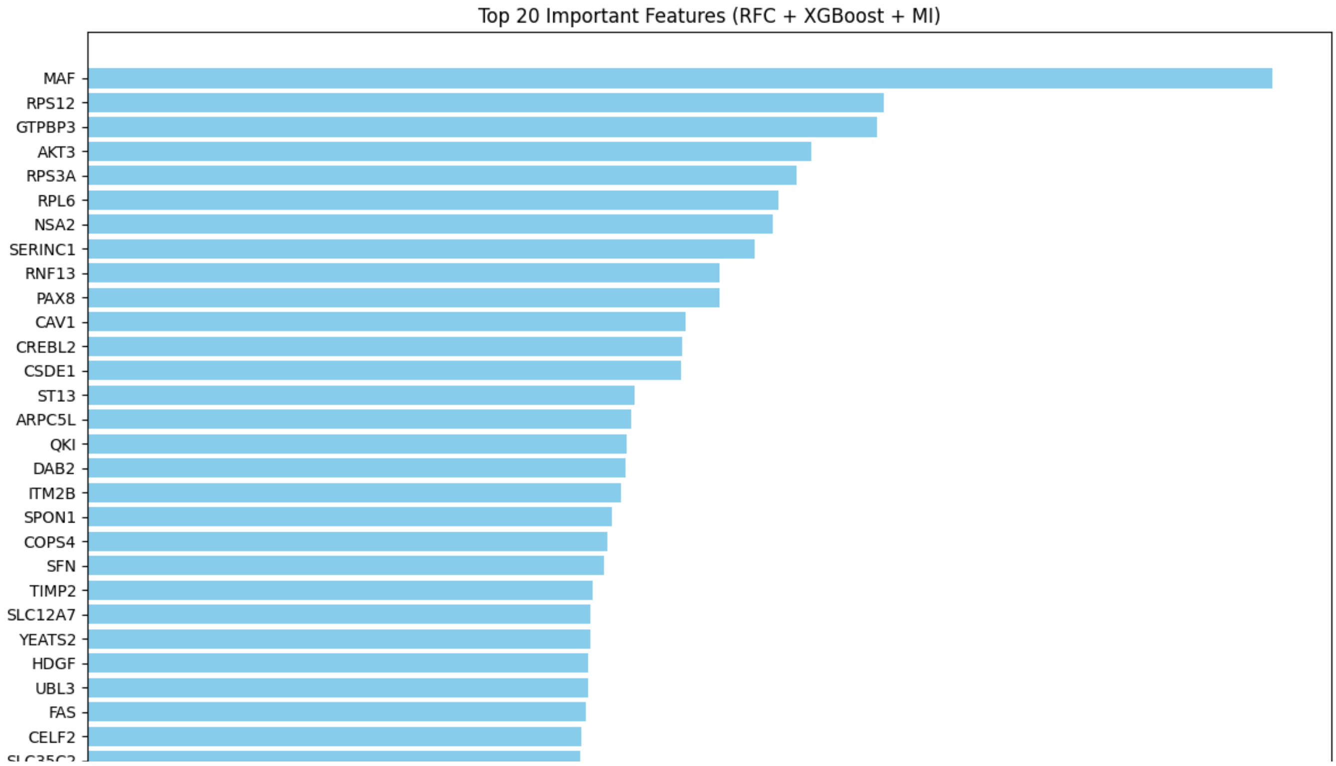
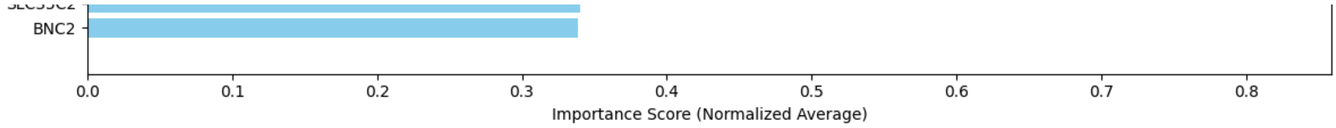
/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [04:41:28] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```






```
Random Forest Accuracy: 0.9327731092436975
XGBoost Accuracy: 0.9327731092436975
[LightGBM] [Info] Number of positive: 422, number of negative: 53
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing was 0.000204 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 4758
[LightGBM] [Info] Number of data points in the train set: 475, number of used features: 30
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.888421 -> initscore=2.074713
[LightGBM] [Info] Start training from score 2.074713
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [04:41:52] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensure_a
  warnings.warn(
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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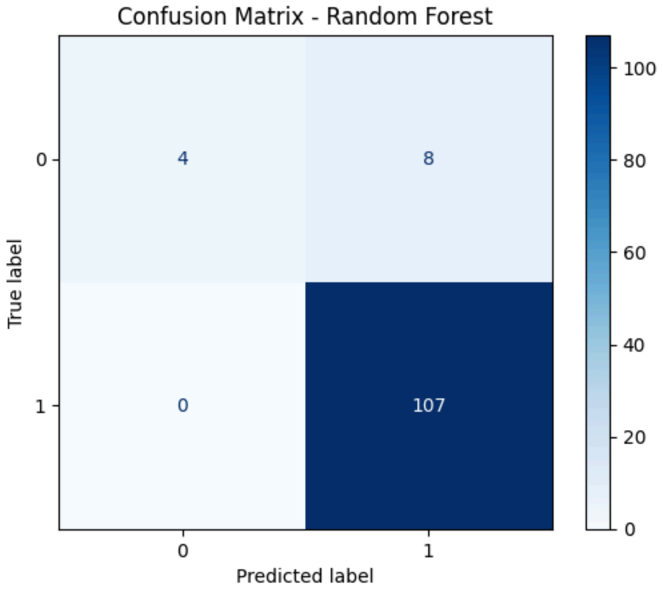
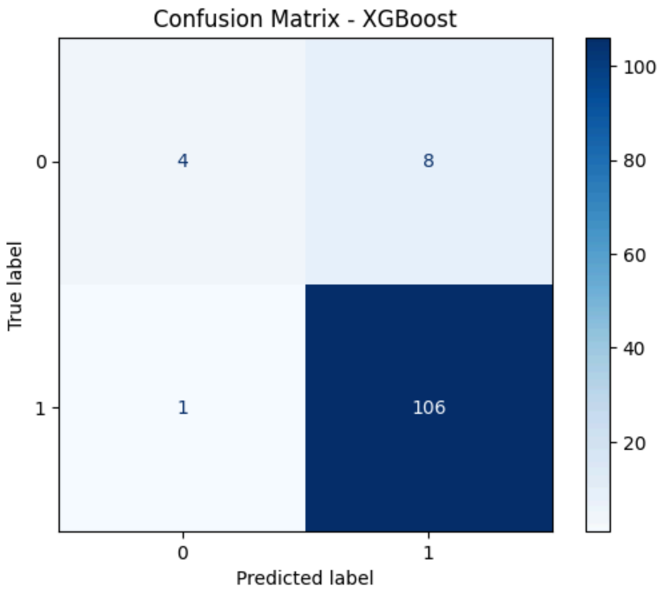
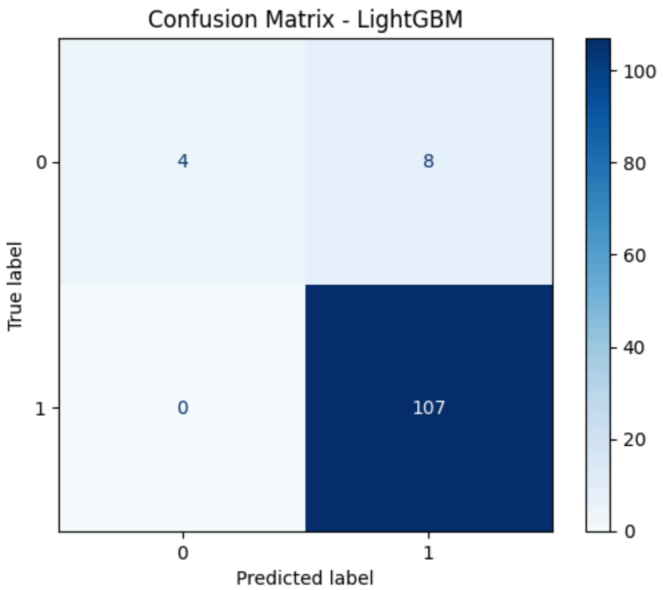
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
LightGBM Accuracy: 0.9411764705882353
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensure_a
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` arg
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
ANN Accuracy: 0.9747899174690247
```

```python
from sklearn.metrics import confusion_matrix, roc_curve, auc, ConfusionMatrixDisplay
import seaborn as sns

# Plotting function for ROC curves
def plot_roc_curves(models, model_names, X_test, y_test):
    plt.figure(figsize=(10, 7))
    for model, name in zip(models, model_names):
        if hasattr(model, "predict_proba"):
            y_proba = model.predict_proba(X_test)[:, 1]
        else:  # ANN model returns probability directly
            y_proba = model.predict(X_test).ravel()
        fpr, tpr, _ = roc_curve(y_test, y_proba)
        roc_auc = auc(fpr, tpr)
        plt.plot(fpr, tpr, label=f'{name} (AUC = {roc_auc:.2f})')

    plt.plot([0, 1], [0, 1], 'k--')
    plt.xlabel("False Positive Rate")
    plt.ylabel("True Positive Rate")
    plt.title("ROC Curves")
    plt.legend(loc="lower right")
    plt.grid(True)
    plt.show()

# Plotting function for confusion matrices
def plot_confusion_matrices(models, model_names, X_test, y_test):
    for model, name in zip(models, model_names):
        if name == "ANN":
            y_pred = (model.predict(X_test).ravel() > 0.5).astype(int)
        else:
            y_pred = model.predict(X_test)
        cm = confusion_matrix(y_test, y_pred)
        disp = ConfusionMatrixDisplay(confusion_matrix=cm)
        disp.plot(cmap='Blues')
        plt.title(f"Confusion Matrix - {name}")
        plt.show()

# List of models and their names
models = [rfc_model, xgb_model, lgbm_model, model]
model_names = ["Random Forest", "XGBoost", "LightGBM", "ANN"]

# Plot Confusion Matrices
plot_confusion_matrices(models, model_names, X_test_top, y_test)

# Plot ROC Curves
plot_roc_curves(models, model_names, X_test_top, y_test)
```

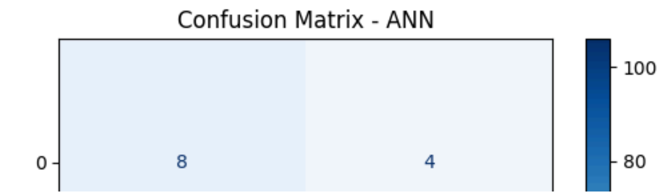


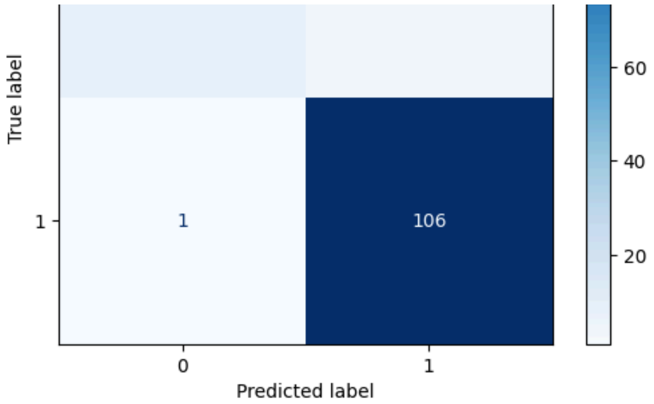



```
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensur
  warnings.warn(
```

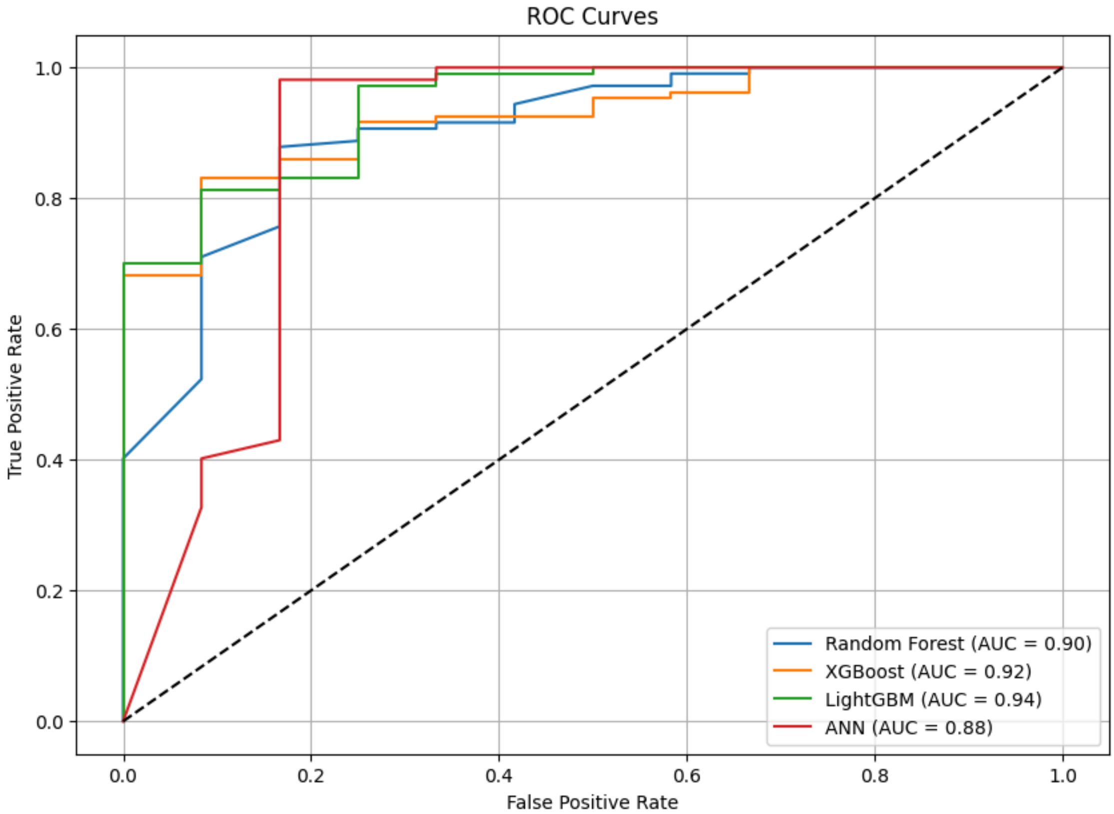



```
4/4 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step
```






```
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensur
  warnings.warn(
4/4 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
```

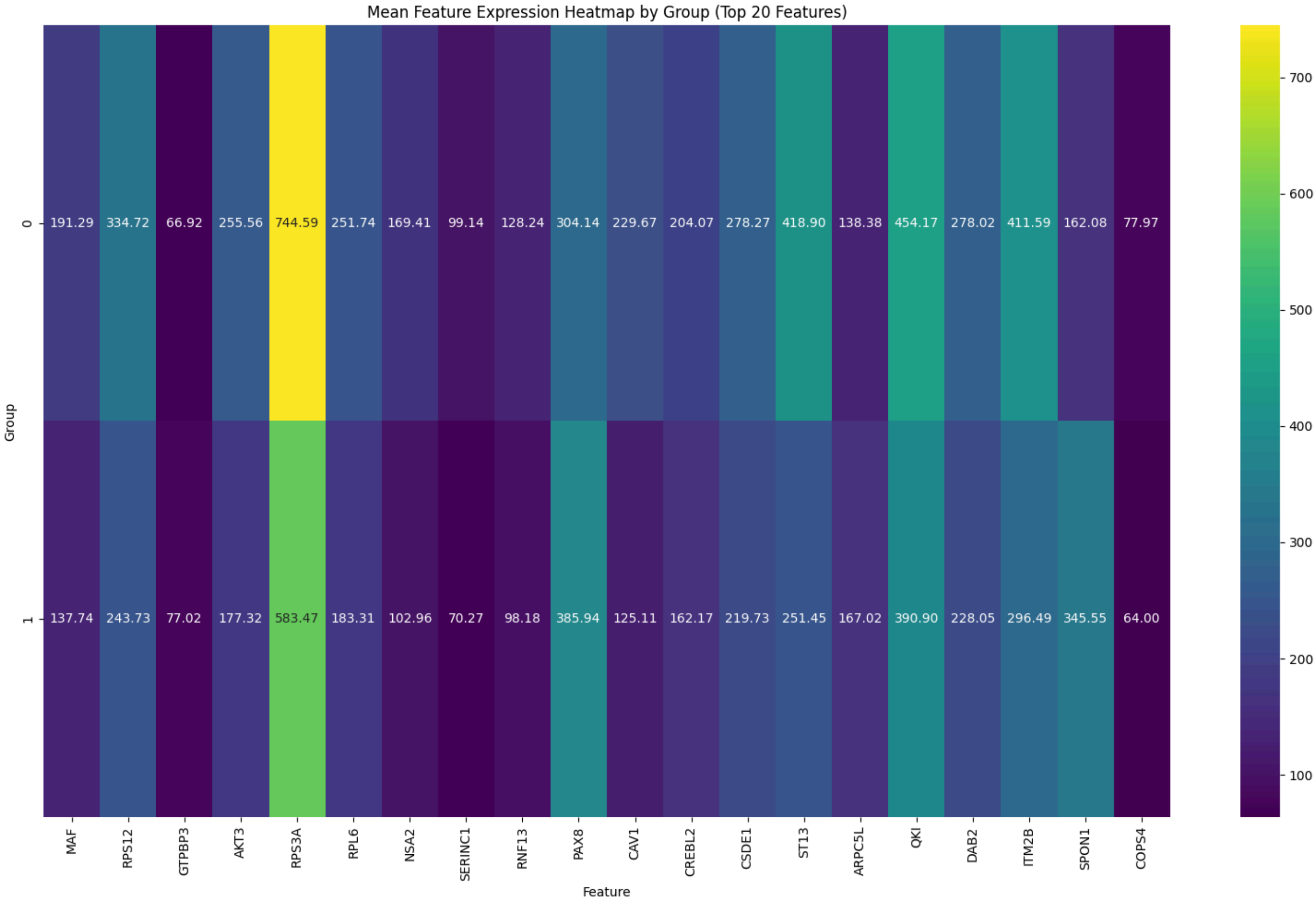


```
top_features = feature_importance_df.head(30)["Feature"].values



print("Top 20 features based on ensemble importance voting:")
for i, feature in enumerate(top_features, 1):
    print(f"{i}. {feature}")
```

```
Top 20 features based on ensemble importance voting:
1. MAF
2. RPS12
3. GTPBP3
4. AKT3
5. RPS3A
6. RPL6
7. NSA2
8. SERINC1
9. RNF13
10. PAX8
11. CAV1
12. CREBL2
13. CSDE1
14. ST13
15. ARPC5L
16. QKI
17. DAB2
18. ITM2B
19. SPON1
20. COPS4
21. SFN
22. TIMP2
23. SLC12A7
24. YEATS2
25. HDGF
26. UBL3
27. FAS
28. CELF2
29. SLC35C2
30. BNC2
```

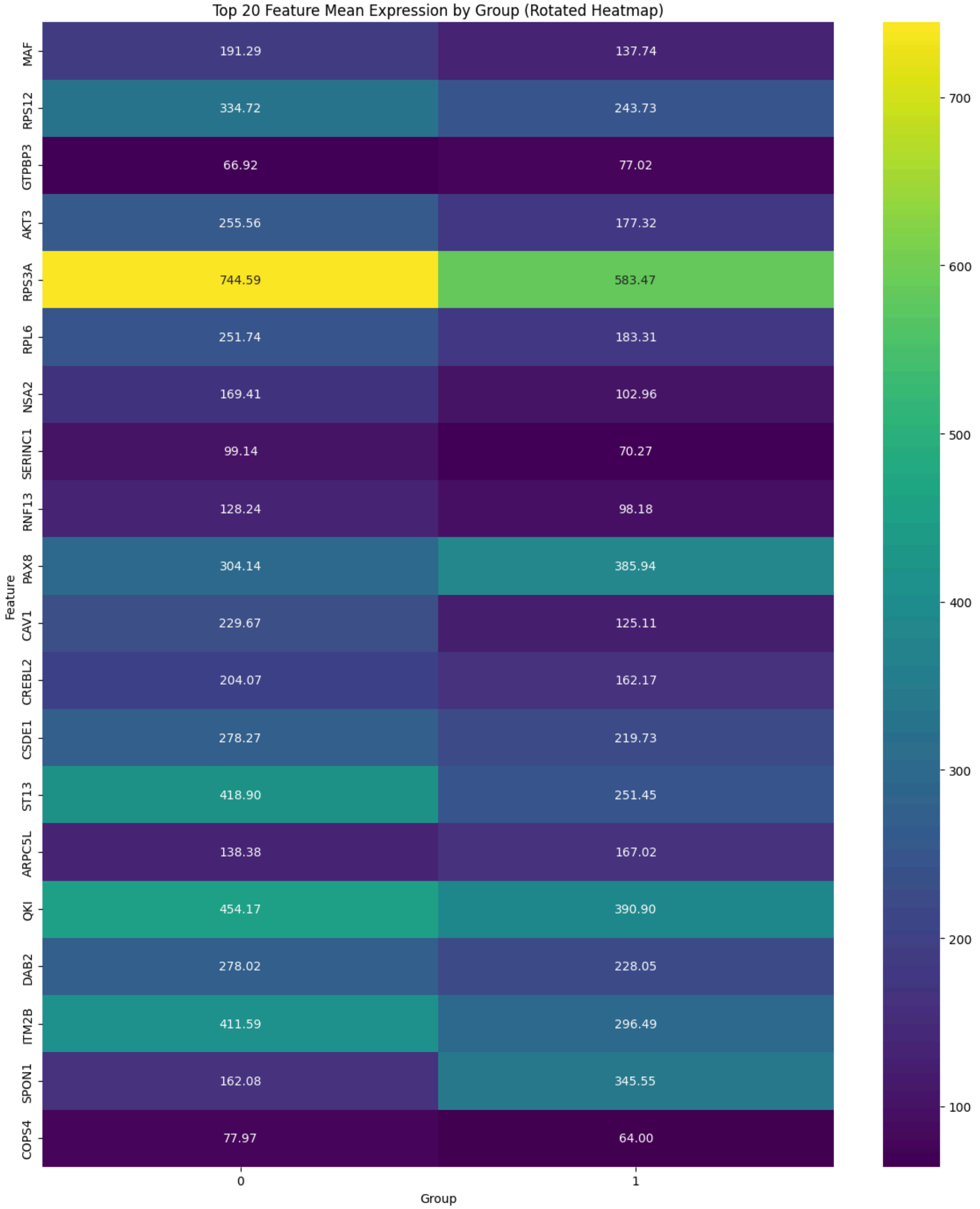
```
import seaborn as sns

# Select top 20 features from the original (unscaled) data for interpretability
X_top_20 = X[top_features]
X_top_20["group"] = y.values  # Add target label back

# Set up the plot
plt.figure(figsize=(16, 10))
sns.heatmap(X_top_20.groupby("group").mean(), cmap="viridis", annot=True, fmt=".2f", cbar=True)

plt.title("Mean Feature Expression Heatmap by Group (Top 20 Features)")
plt.xlabel("Feature")
plt.ylabel("Group")
plt.tight_layout()
plt.show()
```

```
<ipython-input-9-e210cb42eea1>:5: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus
  X_top_20["group"] = y.values  # Add target label back
```




```
import seaborn as sns

# Select and prepare top features
X_top_20 = X[top_features]
X_top_20["group"] = y.values

# Transpose the grouped mean for rotated heatmap
heatmap_data = X_top_20.groupby("group").mean().T

# Plot
plt.figure(figsize=(12, 14))
sns.heatmap(heatmap_data, cmap="viridis", annot=True, fmt=".2f", cbar=True)

plt.title("Top 20 Feature Mean Expression by Group (Rotated Heatmap)")
plt.xlabel("Group")
plt.ylabel("Feature")
plt.tight_layout()
plt.show()
```

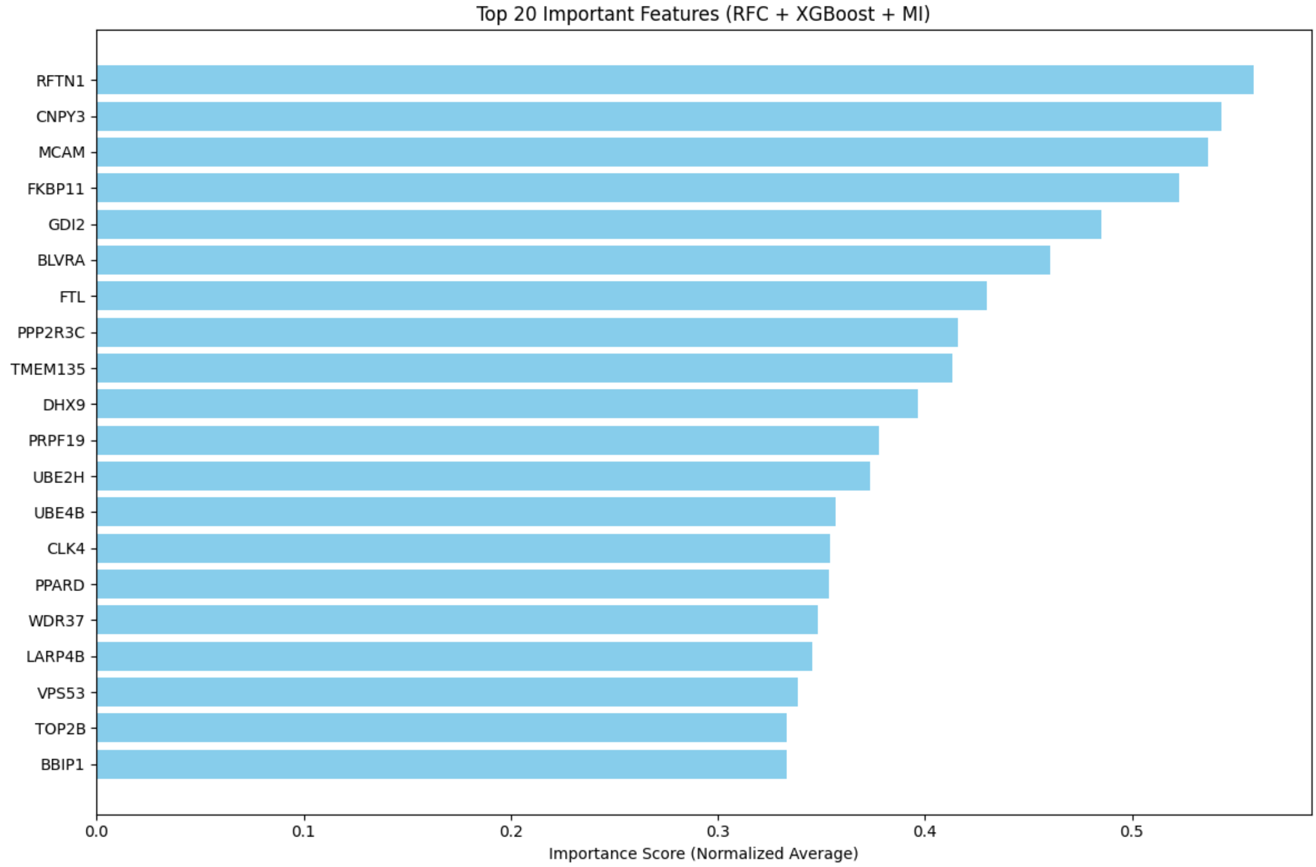
```
<ipython-input-10-67781f504875>:5: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-vers
  X_top_20["group"] = y.values
```



```
# === 2. Imports ===
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
from sklearn.feature_selection import mutual_info_classif
from lightgbm import LGBMClassifier
from sklearn.metrics import accuracy_score
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout

# === 3. Load Dataset ===
df = pd.read_csv("Predicted_OC_subset_with_labels.csv")

# === 4. Preprocessing ===
df_cleaned = df.drop(columns=["Unnamed: 0"], errors='ignore')  # Drop index col if exists
X = df_cleaned.drop(columns=["predicted_group"])  # Features
y = df_cleaned["predicted_group"].astype(int)     # Labels

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

# === 5. Feature selection via ensemble ===
rfc = RandomForestClassifier(n_estimators=100, random_state=42)
rfc.fit(X_train_scaled, y_train)
rfc_importance = rfc.feature_importances_

xgb = XGBClassifier(use_label_encoder=False, eval_metric='logloss', random_state=42)
xgb.fit(X_train_scaled, y_train)
xgb_importance = xgb.feature_importances_

mi = mutual_info_classif(X_train_scaled, y_train, random_state=42)

# Normalize and vote
rfc_norm = rfc_importance / np.max(rfc_importance)
xgb_norm = xgb_importance / np.max(xgb_importance)
mi_norm = mi / np.max(mi)
combined_score = (rfc_norm + xgb_norm + mi_norm) / 3

feature_importance_df = pd.DataFrame({
    'Feature': X.columns,
    'RFC': rfc_norm,
    'XGBoost': xgb_norm,
    'MI': mi_norm,
    'MeanScore': combined_score
}).sort_values(by="MeanScore", ascending=False)

top_features = feature_importance_df.head(30)["Feature"].values

# === 6. Visualize top features ===
plt.figure(figsize=(12, 8))
plt.barh(feature_importance_df.head(30)['Feature'], feature_importance_df.head(20)['MeanScore'], color='skyblue')
plt.xlabel("Importance Score (Normalized Average)")
plt.title("Top 20 Important Features (RFC + XGBoost + MI)")
plt.gca().invert_yaxis()
plt.tight_layout()
plt.show()

# === 7. Prepare top features for modeling ===
X_train_top = X_train_scaled[:, [X.columns.get_loc(f) for f in top_features]]
X_test_top = X_test_scaled[:, [X.columns.get_loc(f) for f in top_features]]

# === 8. Model Evaluations ===

# Random Forest
rfc_model = RandomForestClassifier(random_state=42)
rfc_model.fit(X_train_top, y_train)
rfc_pred = rfc_model.predict(X_test_top)
print("Random Forest Accuracy:", accuracy_score(y_test, rfc_pred))

# XGBoost
xgb_model = XGBClassifier(use_label_encoder=False, eval_metric='logloss', random_state=42)
xgb_model.fit(X_train_top, y_train)
xgb_pred = xgb_model.predict(X_test_top)
```

```
print("XGBoost Accuracy:", accuracy_score(y_test, xgb_pred))

# LightGBM
lgbm_model = LGBMClassifier(random_state=42)
lgbm_model.fit(X_train_top, y_train)
lgbm_pred = lgbm_model.predict(X_test_top)
print("LightGBM Accuracy:", accuracy_score(y_test, lgbm_pred))

# ANN using Keras
model = Sequential()
model.add(Dense(64, input_dim=X_train_top.shape[1], activation='relu'))
model.add(Dropout(0.3))
model.add(Dense(32, activation='relu'))
model.add(Dense(1, activation='sigmoid'))  # Binary classification

model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
model.fit(X_train_top, y_train, epochs=50, batch_size=16, verbose=0)
ann_loss, ann_acc = model.evaluate(X_test_top, y_test, verbose=0)
print("ANN Accuracy:", ann_acc)
```

```
/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [04:28:52] WARNING: /workspace/src/learner.cc:740: 
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```




```
Random Forest Accuracy: 0.4864864864864865
XGBoost Accuracy: 0.4594594594594595
[LightGBM] [Info] Number of positive: 72, number of negative: 74
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing was 0.000137 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 1508
[LightGBM] [Info] Number of data points in the train set: 146, number of used features: 30
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.493151 -> initscore=-0.027399
[LightGBM] [Info] Start training from score -0.027399
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
LightGBM Accuracy: 0.5675675675675675
/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [04:29:10] WARNING: /workspace/src/learner.cc:740: 
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensur
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensur
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` 
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
ANN Accuracy: 0.45945945382118225
```
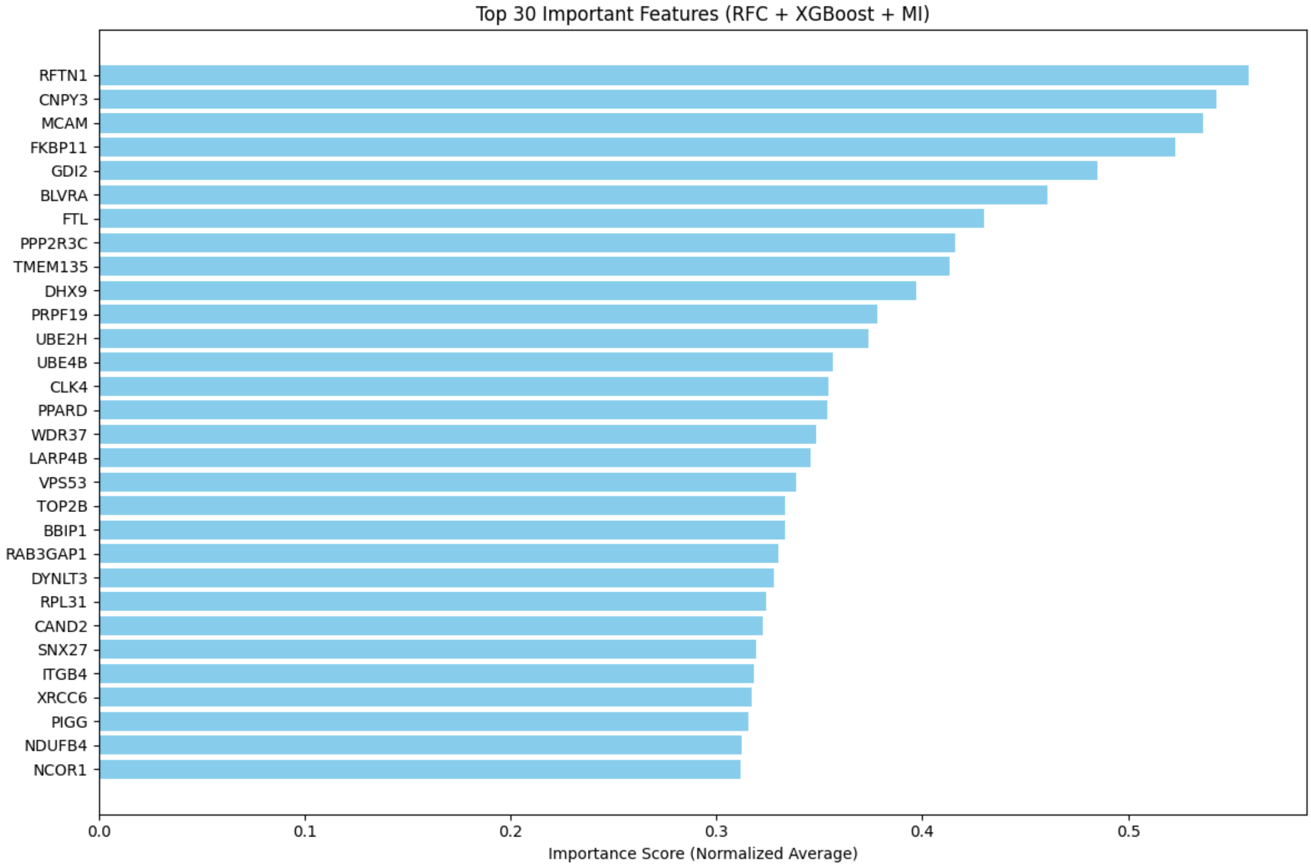

```python
# === 2. Imports ===
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.preprocessing import StandardScaler
from sklearn.ensemble import RandomForestClassifier, VotingClassifier
from xgboost import XGBClassifier
from sklearn.feature_selection import mutual_info_classif
from lightgbm import LGBMClassifier
from sklearn.metrics import accuracy_score
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout
from tensorflow.keras.callbacks import EarlyStopping

# === 3. Load Dataset ===
df = pd.read_csv("Predicted_OC_subset_with_labels.csv")

# === 4. Preprocessing ===
df_cleaned = df.drop(columns=["Unnamed: 0"], errors='ignore')  # Drop index col if exists
X = df_cleaned.drop(columns=["predicted_group"])  # Features
y = df_cleaned["predicted_group"].astype(int)     # Labels

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

# === 5. Feature selection via ensemble voting ===
rfc = RandomForestClassifier(n_estimators=100, random_state=42)
rfc.fit(X_train_scaled, y_train)
rfc_importance = rfc.feature_importances_

xgb = XGBClassifier(use_label_encoder=False, eval_metric='logloss', random_state=42)
xgb.fit(X_train_scaled, y_train)
xgb_importance = xgb.feature_importances_

mi = mutual_info_classif(X_train_scaled, y_train, random_state=42)

# Normalize and combine
rfc_norm = rfc_importance / np.max(rfc_importance)
xgb_norm = xgb_importance / np.max(xgb_importance)
mi_norm = mi / np.max(mi)
combined_score = (rfc_norm + xgb_norm + mi_norm) / 3

feature_importance_df = pd.DataFrame({
    'Feature': X.columns,
    'RFC': rfc_norm,
    'XGBoost': xgb_norm,
    'MI': mi_norm,
    'MeanScore': combined_score
}).sort_values(by="MeanScore", ascending=False)

top_features = feature_importance_df.head(30)["Feature"].values

# === 6. Visualize top features ===
plt.figure(figsize=(12, 8))
plt.barh(feature_importance_df.head(30)['Feature'], feature_importance_df.head(30)['MeanScore'], color='skyblue')
plt.xlabel("Importance Score (Normalized Average)")
plt.title("Top 30 Important Features (RFC + XGBoost + MI)")
plt.gca().invert_yaxis()
plt.tight_layout()
plt.show()

# === 7. Prepare data with selected features ===
X_train_top = X_train_scaled[:, [X.columns.get_loc(f) for f in top_features]]
X_test_top = X_test_scaled[:, [X.columns.get_loc(f) for f in top_features]]

# === 8. Hyperparameter Tuning for RF ===
param_grid = {
    'n_estimators': [100, 200],
    'max_depth': [None, 10, 20],
    'min_samples_split': [2, 5]
}

grid_search = GridSearchCV(RandomForestClassifier(random_state=42), param_grid, cv=3, scoring='accuracy', n_jobs=-1)
grid_search.fit(X_train_top, y_train)
best_rf = grid_search.best_estimator_
```

```
# === 9. Train XGBoost and LightGBM ===
xgb_model = XGBClassifier(use_label_encoder=False, eval_metric='logloss', random_state=42)
xgb_model.fit(X_train_top, y_train)

lgbm_model = LGBMClassifier(random_state=42)
lgbm_model.fit(X_train_top, y_train)

# === 10. Voting Classifier Ensemble ===
voting_model = VotingClassifier(estimators=[
    ('rf', best_rf),
    ('xgb', xgb_model),
    ('lgbm', lgbm_model)
], voting='soft')

voting_model.fit(X_train_top, y_train)
voting_pred = voting_model.predict(X_test_top)
print("Voting Classifier Accuracy:", accuracy_score(y_test, voting_pred))

# === 11. Improved ANN ===
model = Sequential()
model.add(Dense(128, input_dim=X_train_top.shape[1], activation='relu'))
model.add(Dropout(0.4))
model.add(Dense(64, activation='relu'))
model.add(Dropout(0.3))
model.add(Dense(32, activation='relu'))
model.add(Dense(1, activation='sigmoid'))  # Binary output

model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

early_stop = EarlyStopping(monitor='val_loss', patience=5, restore_best_weights=True)
model.fit(X_train_top, y_train, validation_split=0.2, epochs=100, batch_size=16, verbose=0, callbacks=[early_stop])

ann_loss, ann_acc = model.evaluate(X_test_top, y_test, verbose=0)
print("Improved ANN Accuracy:", ann_acc)
```

```
/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [03:35:38] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```




```
/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [03:36:09] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensur
  warnings.warn(
[LightGBM] [Info] Number of positive: 72, number of negative: 74
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing was 0.000156 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 1508
[LightGBM] [Info] Number of data points in the train set: 146, number of used features: 30
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.493151 -> initscore=-0.027399
[LightGBM] [Info] Start training from score -0.027399
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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/usr/local/lib/python3.11/dist-packages/xgboost/core.py:158: UserWarning: [03:36:10] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensur
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensur
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim`
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
[LightGBM] [Info] Number of positive: 72, number of negative: 74
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing was 0.000122 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 1508
[LightGBM] [Info] Number of data points in the train set: 146, number of used features: 30
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.493151 -> initscore=-0.027399
[LightGBM] [Info] Start training from score -0.027399
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
Voting Classifier Accuracy: 0.4594594594594595
Improved ANN Accuracy: 0.5945945978164673
```

```
# === Print Top 30 Features with Importances ===
print("\n=== Top 30 Features by Ensemble Importance ===")
print(feature_importance_df.head(30).to_string(index=False))
```

```
=== Top 30 Features by Ensemble Importance ===
 Feature      RFC  XGBoost       MI  MeanScore
   RFTN1 0.583471 0.417042 0.675741   0.558752
   CNPY3 0.951109 0.117479 0.560896   0.543161
    MCAM 0.428714 1.000000 0.180788   0.536501
  FKBP11 0.505867 0.763407 0.299585   0.522953
    GDI2 1.000000 0.082486 0.372769   0.485085
   BLVRA 0.646419 0.467693 0.267867   0.460660
     FTL 0.464914 0.000000 0.825350   0.430088
 PPP2R3C 0.585084 0.000000 0.662829   0.415971
 TMEM135 0.515351 0.000000 0.723869   0.413073
    DHX9 0.000000 0.657232 0.533063   0.396765
  PRPF19 0.000000 0.676384 0.457683   0.378022
   UBE2H 0.248739 0.000000 0.872064   0.373601
   UBE4B 0.319527 0.158539 0.592147   0.356738
    CLK4 0.561675 0.021279 0.479266   0.354074
   PPARD 0.375995 0.000000 0.685518   0.353837
   WDR37 0.516124 0.000000 0.529543   0.348556
  LARP4B 0.202867 0.209571 0.624410   0.345616
   VPS53 0.619001 0.013702 0.382622   0.338442
   TOP2B 0.000000 0.000000 1.000000   0.333333
   BBIP1 0.840277 0.158752 0.000000   0.333009
RAB3GAP1 0.163612 0.000000 0.825869   0.329827
  DYNLT3 0.223822 0.077134 0.682958   0.327971
   RPL31 0.000000 0.000000 0.971875   0.323958
   CAND2 0.348786 0.229128 0.389635   0.322516
   SNX27 0.252671 0.000000 0.704502   0.319058
   ITGB4 0.430054 0.000000 0.524527   0.318194
   XRCC6 0.000000 0.000000 0.950620   0.316873
    PIGG 0.307097 0.000000 0.639732   0.315610
  NDUFB4 0.000000 0.586018 0.351224   0.312414
   NCOR1 0.374605 0.043673 0.517302   0.311860
```

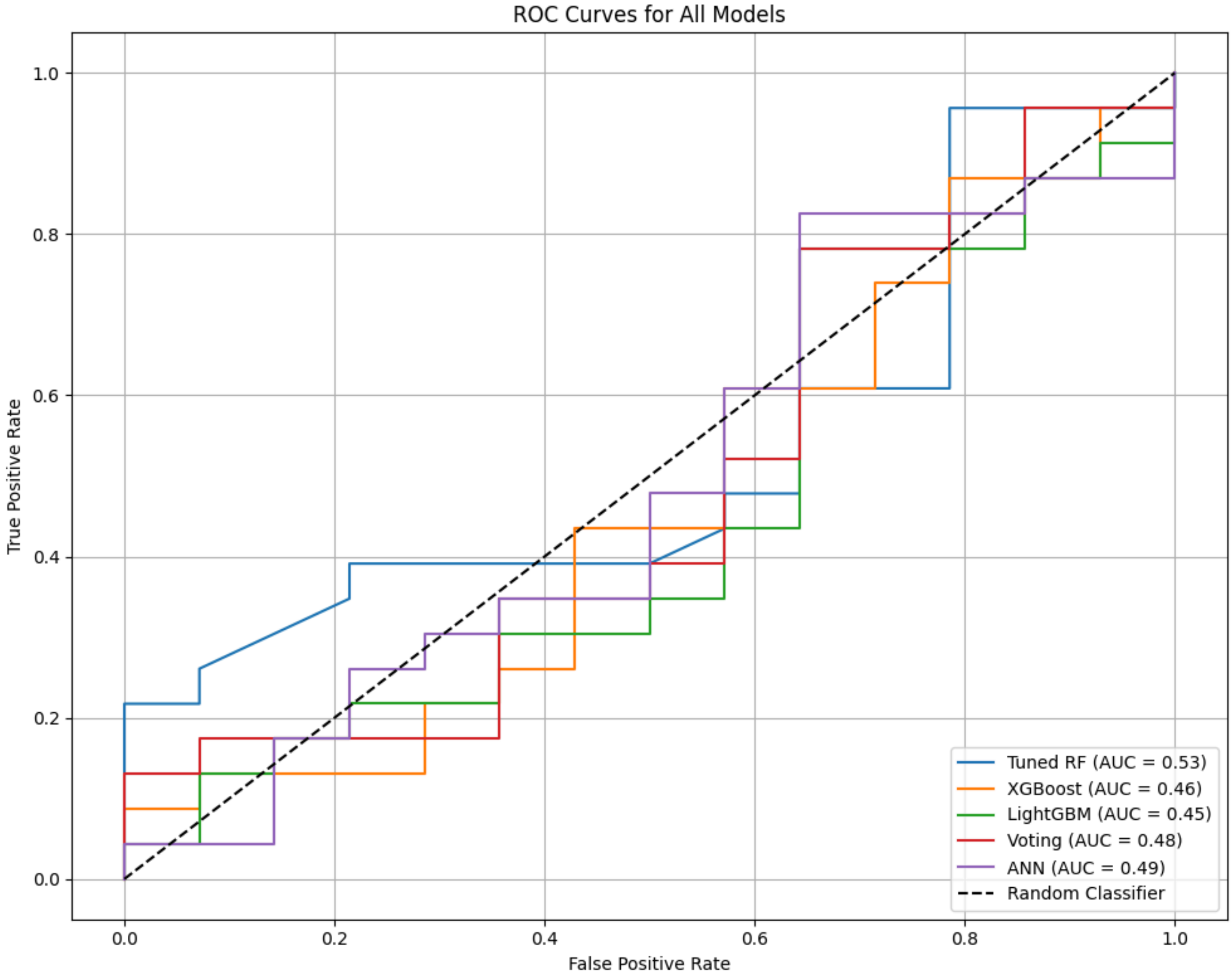
```
from sklearn.metrics import classification_report, confusion_matrix

# === Helper function to evaluate a model ===
def evaluate_model(name, model, X_test, y_test):
    preds = model.predict(X_test)
    print(f"\n=== {name} ===")
    print("Accuracy:", accuracy_score(y_test, preds))
    print("Classification Report:")
    print(classification_report(y_test, preds))
    print("Confusion Matrix:")
    print(confusion_matrix(y_test, preds))

# Evaluate Random Forest (best_rf from GridSearch)
evaluate_model("Tuned Random Forest", best_rf, X_test_top, y_test)

# Evaluate XGBoost
evaluate_model("XGBoost", xgb_model, X_test_top, y_test)

# Evaluate LightGBM
evaluate_model("LightGBM", lgbm_model, X_test_top, y_test)

# Evaluate Voting Classifier
evaluate_model("Voting Classifier (Ensemble)", voting_model, X_test_top, y_test)

# Evaluate ANN separately (sigmoid output thresholded)
ann_pred_prob = model.predict(X_test_top).flatten()
ann_pred = (ann_pred_prob > 0.5).astype(int)
print("\n=== ANN (Keras) ===")
print("Accuracy:", accuracy_score(y_test, ann_pred))
print("Classification Report:")
print(classification_report(y_test, ann_pred))
print("Confusion Matrix:")
print(confusion_matrix(y_test, ann_pred))
```

```
=== Tuned Random Forest ===
Accuracy: 0.4864864864864865
Classification Report:
              precision    recall  f1-score   support

           0       0.33      0.36      0.34        14
           1       0.59      0.57      0.58        23

    accuracy                           0.49        37
   macro avg       0.46      0.46      0.46        37
```

```
weighted avg       0.49      0.49      0.49        37

Confusion Matrix:
[[ 5  9]
 [10 13]]

=== XGBoost ===
Accuracy: 0.4594594594594595
Classification Report:
              precision    recall  f1-score   support

           0       0.35      0.50      0.41        14
           1       0.59      0.43      0.50        23

    accuracy                           0.46        37
   macro avg       0.47      0.47      0.46        37
weighted avg       0.50      0.46      0.47        37

Confusion Matrix:
[[ 7  7]
 [13 10]]

=== LightGBM ===
Accuracy: 0.5675675675675675
Classification Report:
              precision    recall  f1-score   support

           0       0.42      0.36      0.38        14
           1       0.64      0.70      0.67        23

    accuracy                           0.57        37
   macro avg       0.53      0.53      0.53        37
weighted avg       0.56      0.57      0.56        37

Confusion Matrix:
[[ 5  9]
 [ 7 16]]

=== Voting Classifier (Ensemble) ===
Accuracy: 0.4594594594594595
Classification Report:
              precision    recall  f1-score   support

           0       0.31      0.36      0.33        14
           1       0.57      0.52      0.55        23
```

```
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt

# === Function to plot ROC ===
def plot_roc_curves(models, model_names, X_test, y_test):
    plt.figure(figsize=(10, 8))

    for model, name in zip(models, model_names):
        if name == "ANN":
            y_scores = model.predict(X_test).flatten()
        else:
            try:
                y_scores = model.predict_proba(X_test)[:, 1]
            except:
                y_scores = model.decision_function(X_test)

        fpr, tpr, _ = roc_curve(y_test, y_scores)
        roc_auc = auc(fpr, tpr)
        plt.plot(fpr, tpr, label=f'{name} (AUC = {roc_auc:.2f})')

    # Plot base line
    plt.plot([0, 1], [0, 1], 'k--', label='Random Classifier')
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('ROC Curves for All Models')
    plt.legend(loc='lower right')
    plt.grid(True)
    plt.tight_layout()
    plt.show()

# === Plot all ROC curves ===
plot_roc_curves(
    models=[best_rf, xgb_model, lgbm_model, voting_model, model],
    model_names=["Tuned RF", "XGBoost", "LightGBM", "Voting", "ANN"],
    X_test=X_test_top,
    y_test=y_test
)
```

```
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensure_a
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/sklearn/utils/deprecation.py:151: FutureWarning: 'force_all_finite' was renamed to 'ensure_a
  warnings.warn(
2/2 ━━━━━━━━━━━━━━━━━━━━ 0s 59ms/step
```




```
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt

# === Function to plot ROC ===
def plot_roc_curves(models, model_names, X_test, y_test):
    plt.figure(figsize=(10, 8))

    for model, name in zip(models, model_names):
        if name == "ANN":
            y_scores = model.predict(X_test).flatten()
        else:
            try:
                y_scores = model.predict_proba(X_test)[:, 1]
            except:
                y_scores = model.decision_function(X_test)

        fpr, tpr, _ = roc_curve(y_test, y_scores)
        roc_auc = auc(fpr, tpr)
        plt.plot(fpr, tpr, label=f'{name} (AUC = {roc_auc:.3f})')

    plt.plot([0, 1], [0, 1], 'k--', label='Random Classifier')
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('ROC Curves for All Models (No Voting)')
    plt.legend(loc='lower right')
    plt.grid(True)
    plt.tight_layout()
    plt.show()

# === Use the function for your trained models ===
plot_roc_curves(
    models=[best_rf, xgb_model, lgbm_model, model],
    model_names=["Tuned RF", "XGBoost", "LightGBM", "ANN"],
    X_test=X_test_top,
```