In [21]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split, StratifiedKFold, cross_val_sc
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline
from sklearn.impute import SimpleImputer
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
from sklearn.metrics import (confusion_matrix, classification_report,
                             roc_auc_score, roc_curve, accuracy_score)
import shap
import joblib
```

In [ ]:

```
#Load the dataset
df = pd.read_csv('blood.csv')
print("Rows, Columns:", df.shape)
df.head()
```

```
Rows, Columns: (748, 5)
```

Out[ ]:

	Recency	Frequency	Monetary	Time	Class
0	2	50	12500	99	1
1	0	13	3250	28	1
2	1	17	4000	36	1
3	2	20	5000	45	1
4	1	24	6000	77	0

In [ ]:

```
#Quick exploration
print("Columns and types:")
print(df.dtypes)
print("\nMissing values per column:")
print(df.isnull().sum())
print("\nBasic stats for numeric columns:")
display(df.describe().T)
```

```
Columns and types:
Recency      int64
Frequency    int64
Monetary     int64
Time         int64
Class        int64
dtype: object

Missing values per column:
Recency      0
Frequency    0
Monetary     0
Time         0
Class        0
dtype: int64

Basic stats for numeric columns:
```

	count	mean	std	min	25%	50%	75%	max
Recency	748.0	9.506684	8.095396	0.0	2.75	7.0	14.0	74.0
Frequency	748.0	5.516043	5.841825	1.0	2.00	4.0	7.0	50.0
Monetary	748.0	1378.676471	1459.826781	250.0	500.00	1000.0	1750.0	12500.0
Time	748.0	34.284759	24.380307	2.0	16.00	28.0	50.0	99.0
Class	748.0	0.237968	0.426124	0.0	0.00	0.0	0.0	1.0

In [25]:

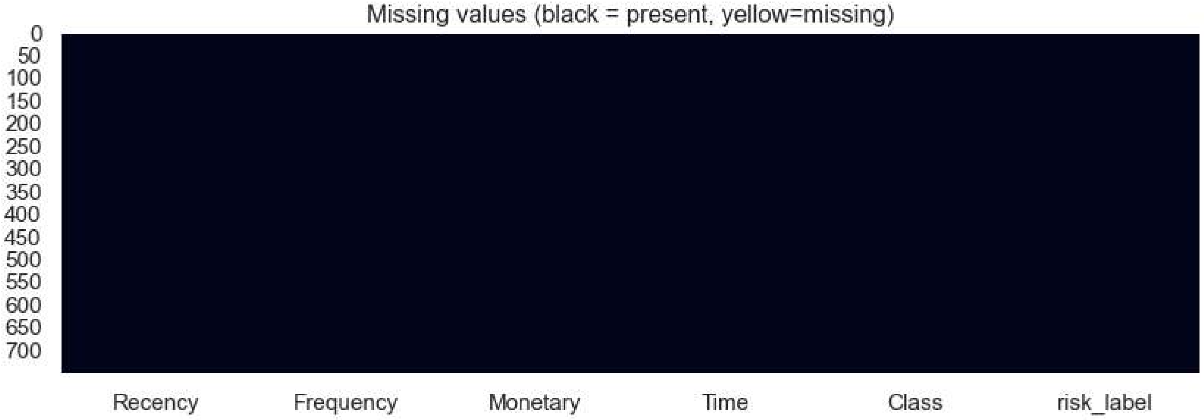
```python
if 'recommendation' in df.columns:
    target_col = 'recommendation'
elif 'disease' in df.columns:
    target_col = 'disease'
elif 'diabetes' in df.columns:
    target_col = 'diabetes'
else:
    numeric_cols = df.select_dtypes(include=np.number).columns.tolist()
    # heuristics — adapt to dataset columns
    risk = pd.Series(0, index=df.index)
    if 'cholesterol' in df.columns:
        risk = risk | (df['cholesterol'] > 240)
    if 'blood_glucose' in df.columns:
        risk = risk | (df['blood_glucose'] > 126)
    for c in ['systolic_bp','blood_pressure','bp_sys']:
        if c in df.columns:
            risk = risk | (df[c] > 140)
    df['risk_label'] = risk.astype(int)
    target_col = 'risk_label'
    print("Created synthetic target 'risk_label' - please adapt if you have a real
```

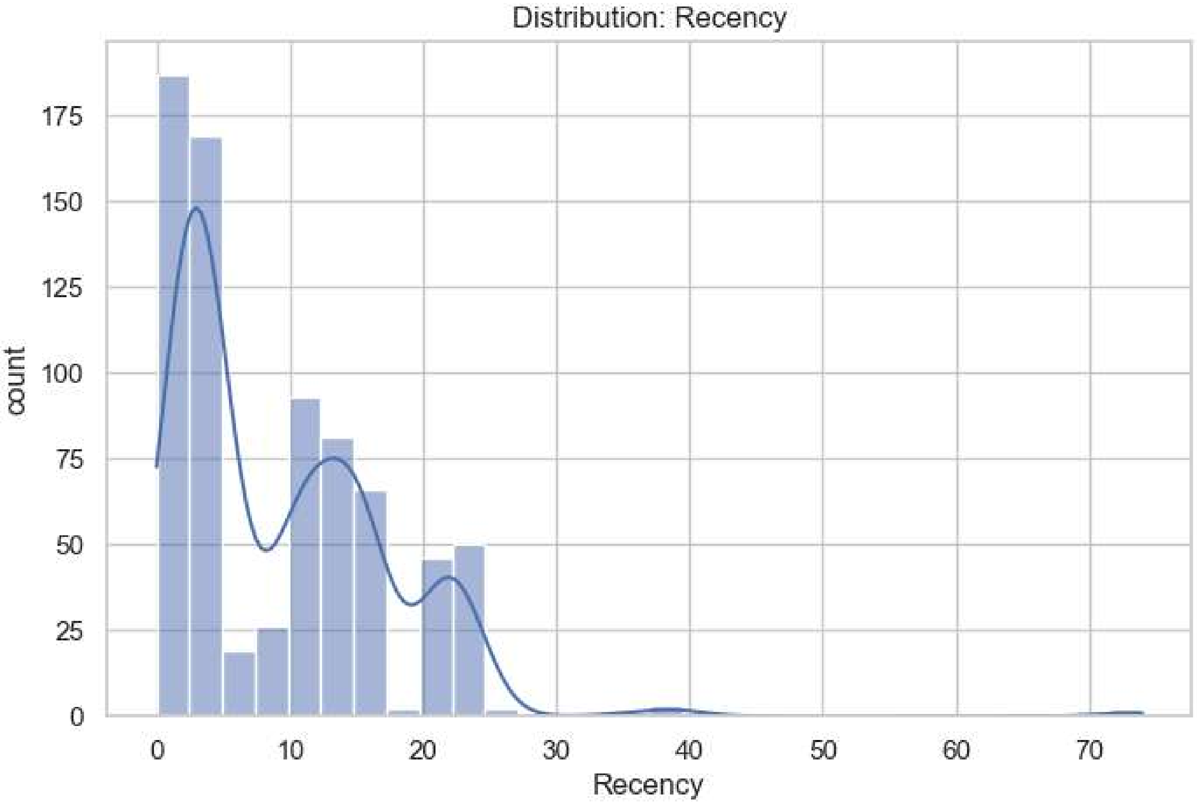
```
Created synthetic target 'risk_label' - please adapt if you have a real label.
```

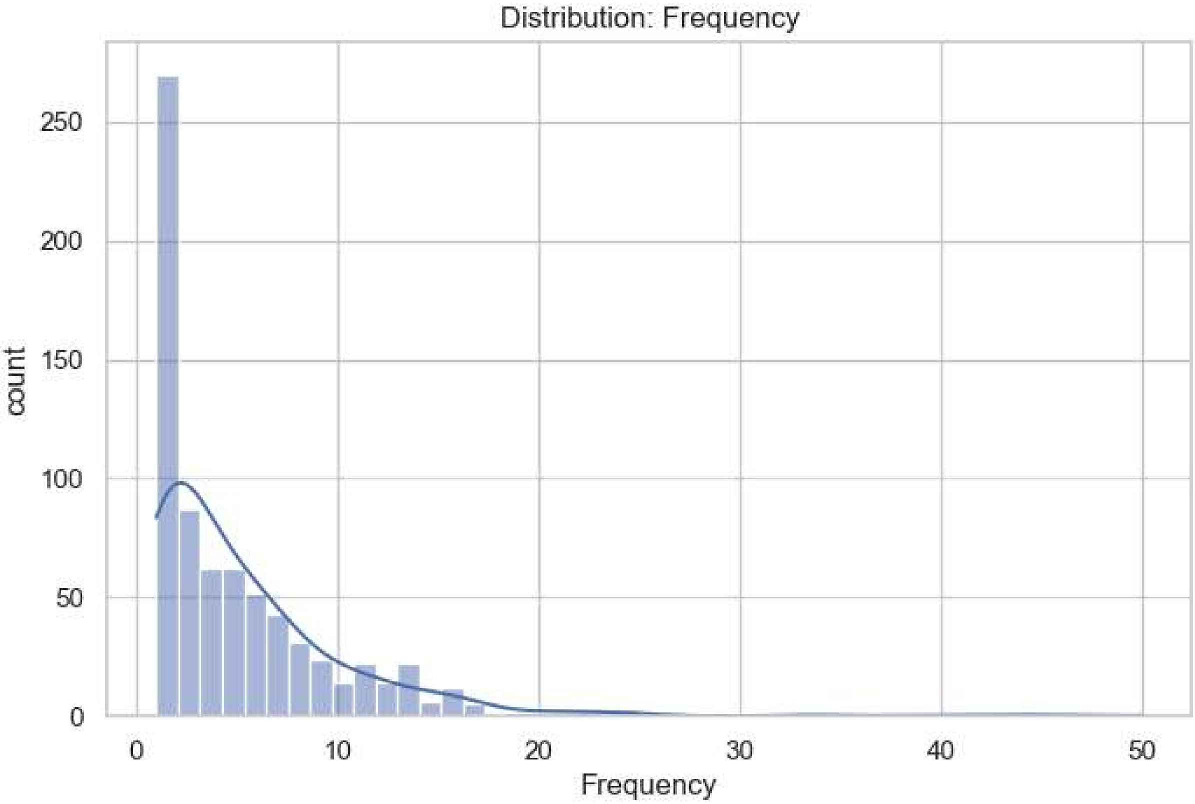
In [26]:

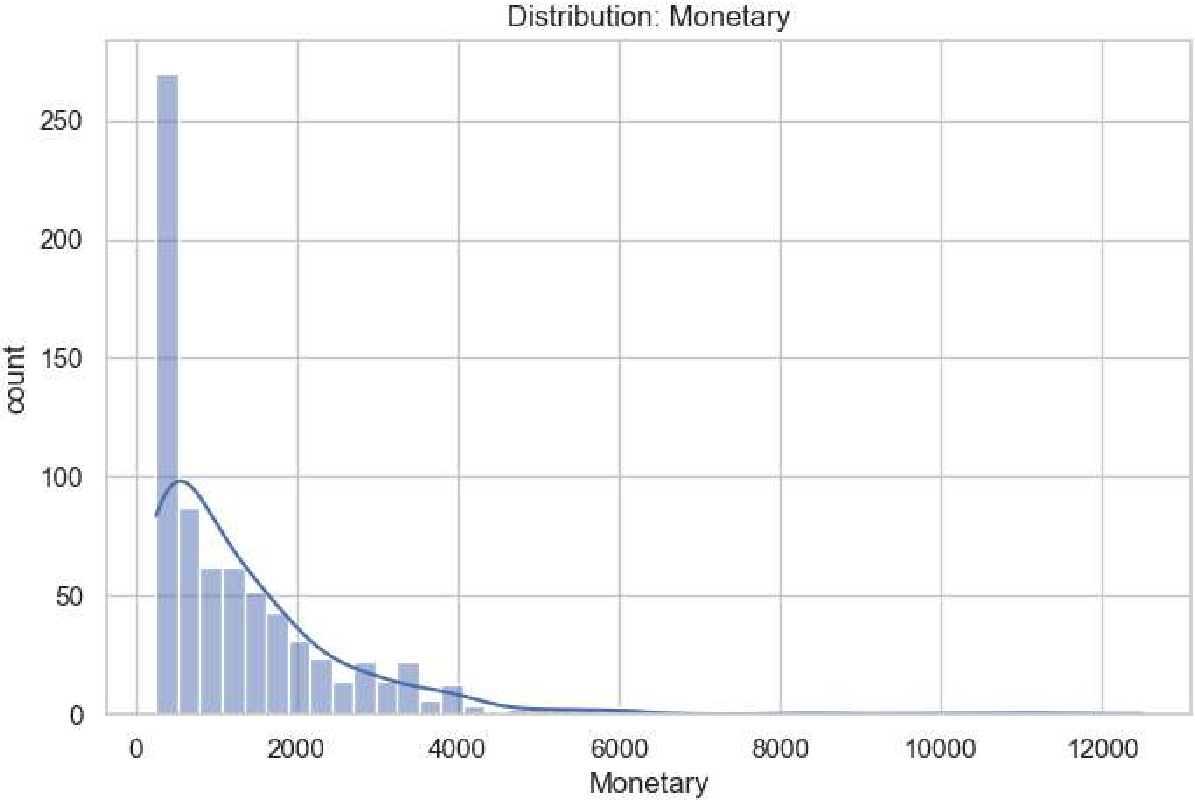
```python
#EDA
#Missing value heatmap
plt.figure(figsize=(10,3))
sns.heatmap(df.isnull(), cbar=False)
```

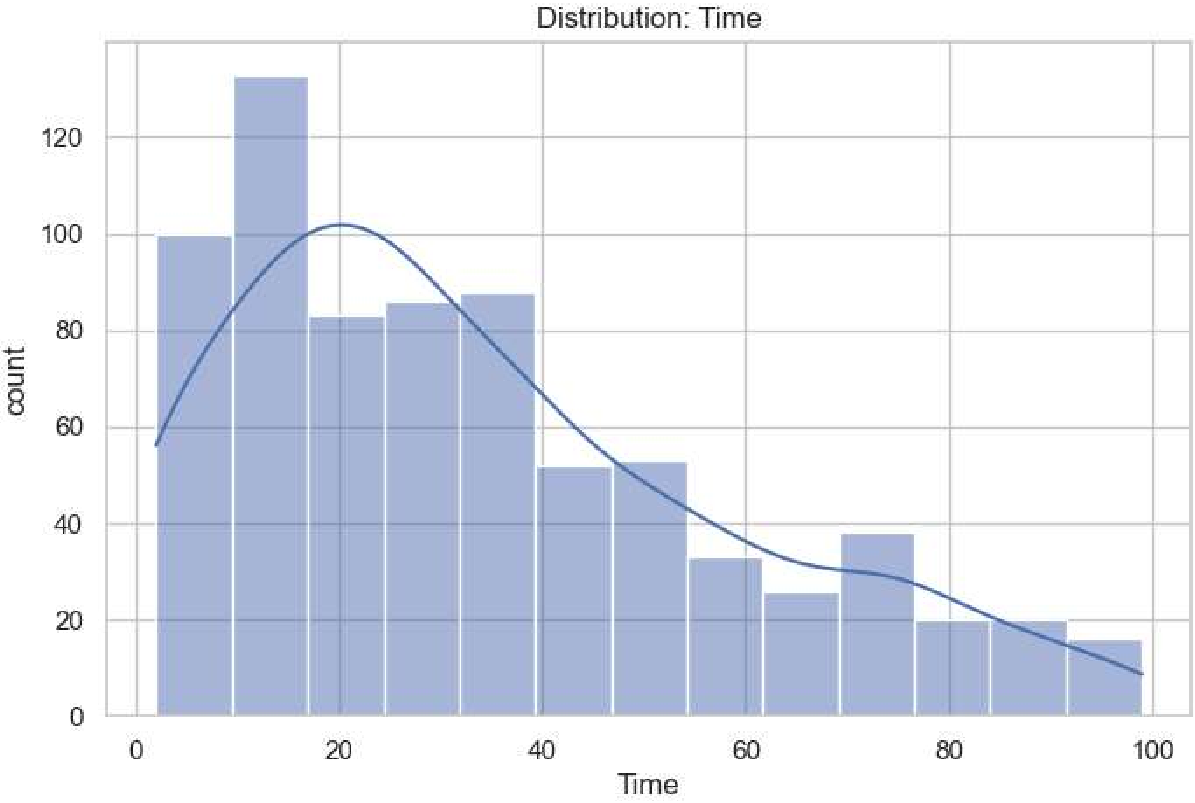
```
plt.title("Missing values (black = present, yellow=missing)")
plt.show()

#Numeric distributions for top numeric columns
num_cols = df.select_dtypes(include=np.number).columns.tolist()
num_cols = [c for c in num_cols if c != target_col][:6]  # show up to 6
for c in num_cols:
    plt.figure()
    sns.histplot(df[c].dropna(), kde=True)
    plt.title(f"Distribution: {c}")
    plt.xlabel(c)
    plt.ylabel("count")
    plt.show()
```

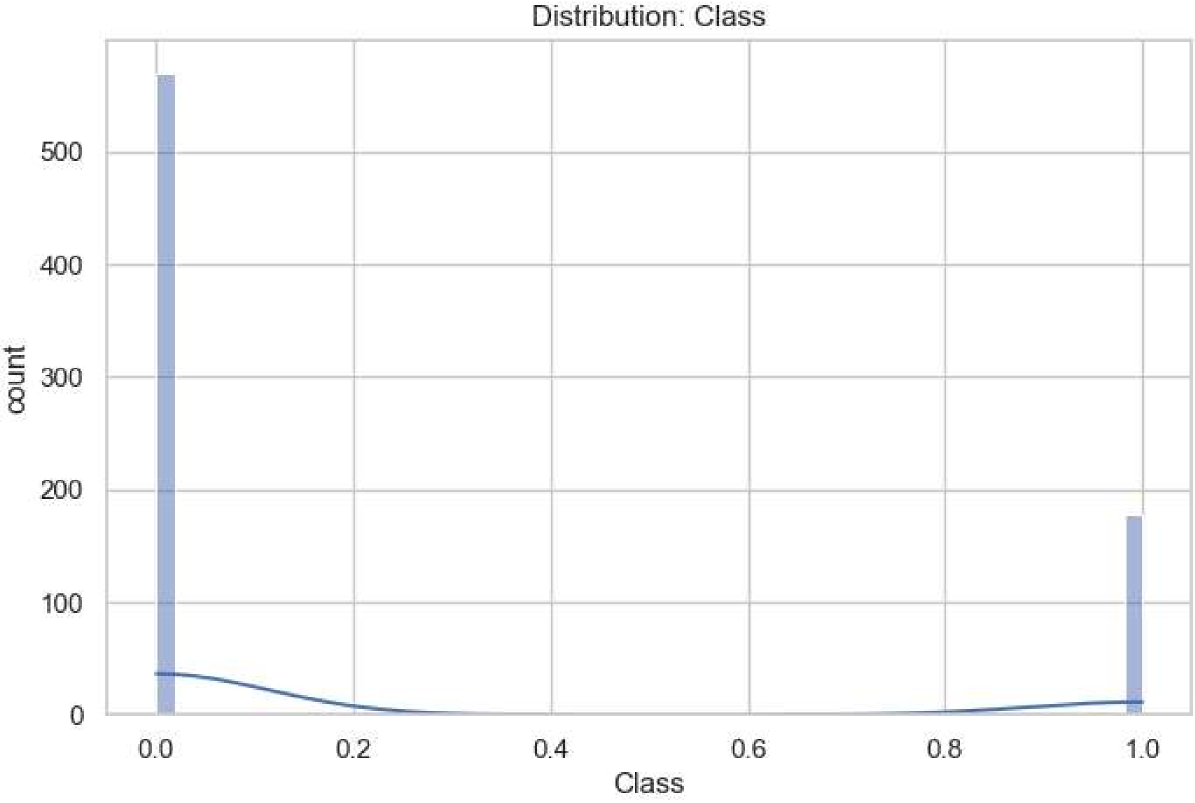





Distribution: Frequency
count
250
200
150
100
50
0
0
10
20
30
40
50
Frequency

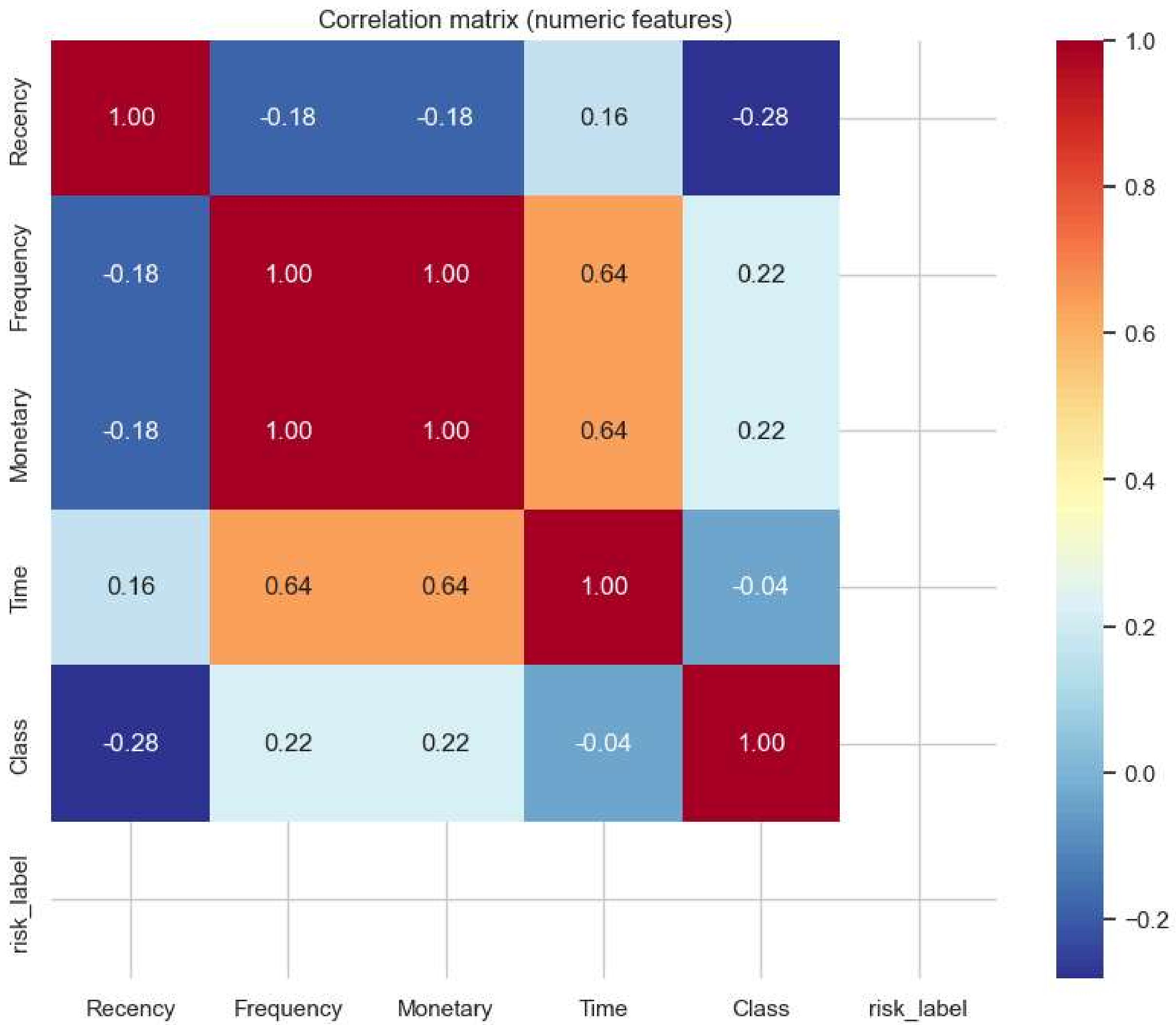

Distribution: Monetary
count
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
12000
Monetary





In [27]:

```
#Correlation heatmap
corr = df.select_dtypes(include=np.number).corr()
plt.figure(figsize=(10,8))
sns.heatmap(corr, annot=True, fmt=".2f", cmap="RdYlBu_r", square=False)
plt.title("Correlation matrix (numeric features)")
plt.show()
```



In [ ]:

```
#Preprocessing pipeline
feature_cols = [c for c in df.columns if c != target_col]

numeric_features = df[feature_cols].select_dtypes(include=np.number).columns.tolist
categorical_features = [c for c in feature_cols if c not in numeric_features]

numeric_transformer = Pipeline(steps=[
    ('imputer', SimpleImputer(strategy='median')),
    ('scaler', StandardScaler())
])

categorical_transformer = Pipeline(steps=[
    ('imputer', SimpleImputer(strategy='most_frequent')),
    ('onehot', OneHotEncoder(handle_unknown='ignore', sparse_output=False))
])

preprocessor = ColumnTransformer(
    transformers=[
        ('num', numeric_transformer, numeric_features),
        ('cat', categorical_transformer, categorical_features)
    ],
    remainder='drop'  # drop other columns if any
)
```

In [55]:

```
#Train/test split
X = df[feature_cols]
y = df[target_col]
X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, stratify=y, random_state=42
)
print("Train/test sizes:", X_train.shape, X_test.shape)
```

```
Train/test sizes: (598, 5) (150, 5)
```

In [ ]:

```
#Model training: RandomForest , XGBoost
y_train = y_train.astype(int)
y_test = y_test.astype(int)

rf_pipeline = Pipeline(steps=[
    ('preprocessor', preprocessor),
    ('clf', RandomForestClassifier(n_estimators=200, random_state=42))
])

xgb_pipeline = Pipeline(steps=[
    ('preprocessor', preprocessor),
    ('clf', XGBClassifier(
        objective='binary:logistic',
        eval_metric='logloss',
        use_label_encoder=False,
        base_score=0.5,
        random_state=42
    ))
])
```

In [ ]:

```
# Cross-validate quickly
cv = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)

print("RF CV accuracy:",
      cross_val_score(rf_pipeline, X_train, y_train, cv=cv, scoring='accuracy').mea

print("XGB CV accuracy:",
      cross_val_score(xgb_pipeline, X_train, y_train, cv=cv, scoring='accuracy').me

# Fit best model
best_pipeline = rf_pipeline
best_pipeline.fit(X_train, y_train)
```

```
RF CV accuracy: 1.0
XGB CV accuracy: 1.0
```

Out[ ]:

▾ **Pipeline**

▼ Parameters

	steps	[('preprocessor', ...), ('clf', ...)]
	transform_input	None
	memory	None
	verbose	False

▾ **preprocessor: ColumnTransformer**

▼ Parameters

	transformers	[('num', ...), ('cat', ...)]
	remainder	'drop'
	sparse_threshold	0.3
	n_jobs	None
	transformer_weights	None
	verbose	False
	verbose_feature_names_out	True
	force_int_remainder_cols	'deprecated'

▾ **num**

['Recency', 'Frequency', 'Monetary', 'Time', 'Class']

▾ SimpleImputer ?

▼ Parameters

	missing_values	nan
	strategy	'median'
	fill_value	None
	copy	True
	add_indicator	False
	keep_empty_features	False

▾ StandardScaler ?

▾ **cat**

[]

▾ SimpleImpute

▼ Parameters

	missing_values
	strategy
	fill_value
	copy
	add_indicator
	keep_empty_features

▾ OneHotEncode

▼ Parameters

📋	copy	True
📋	with_mean	True
📋	with_std	True

▼ Parameters

📋	categories
📋	drop
📋	sparse_output
📋	dtype
📋	handle_unknown
📋	min_frequency
📋	max_categories
📋	feature_name_combiner

▾ RandomForestClassifier ?

▼ Parameters

📋	n_estimators	200
📋	criterion	'gini'
📋	max_depth	None
📋	min_samples_split	2
📋	min_samples_leaf	1
📋	min_weight_fraction_leaf	0.0
📋	max_features	'sqrt'
📋	max_leaf_nodes	None
📋	min_impurity_decrease	0.0
📋	bootstrap	True
📋	oob_score	False
📋	n_jobs	None
📋	random_state	42
📋	verbose	0
📋	warm_start	False
📋	class_weight	None
📋	ccp_alpha	0.0

⧉	max_samples	None
⧉	monotonic_cst	None

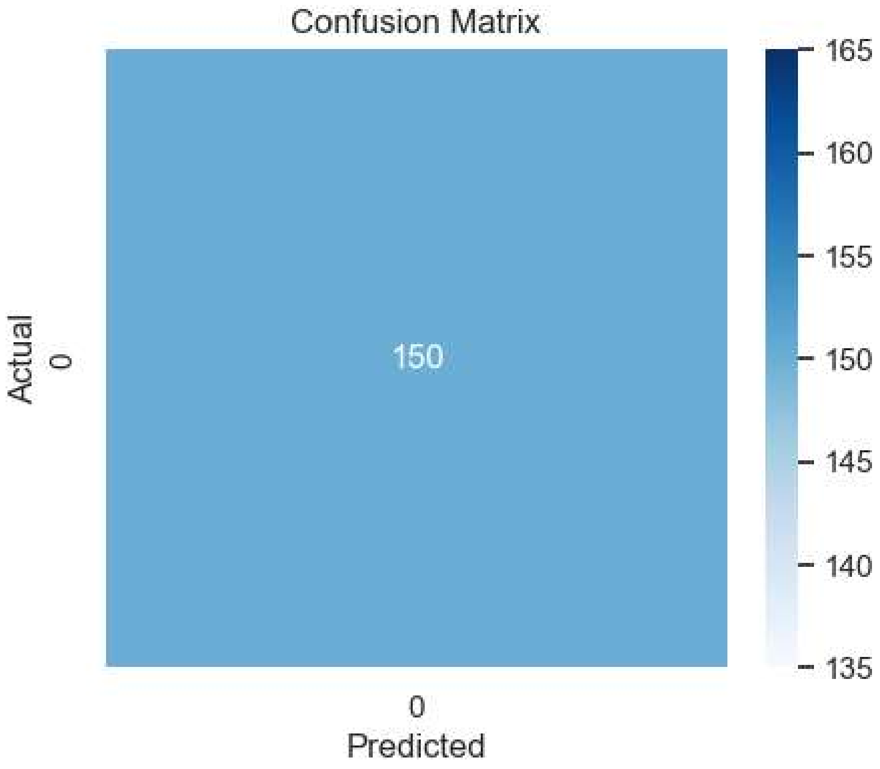
In [ ]:

```
y_proba = None
try:
    y_proba = best_pipeline.predict_proba(X_test)[:,1]
except Exception:
    pass

print("Accuracy:", accuracy_score(y_test, y_pred))
print("Classification report:")
print(classification_report(y_test, y_pred))
```

```
Accuracy: 1.0
Classification report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00       150

    accuracy                           1.00       150
   macro avg       1.00      1.00      1.00       150
weighted avg       1.00      1.00      1.00       150
```

In [ ]:

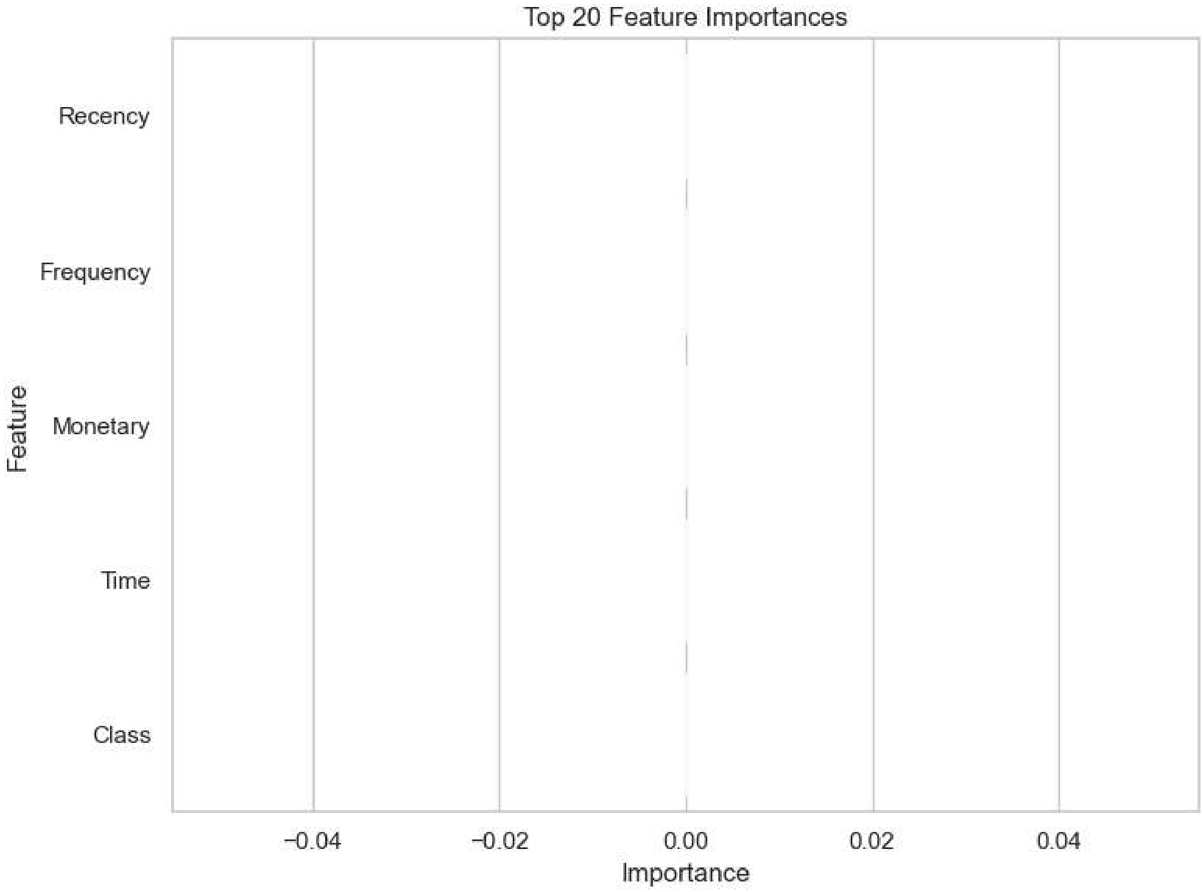
```
# Confusion matrix
cm = confusion_matrix(y_test, y_pred)
plt.figure(figsize=(5,4))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel("Predicted")
plt.ylabel("Actual")
plt.title("Confusion Matrix")
plt.show()
```



In [ ]:
```
#ROC Curve
best_pipeline.fit(X_train, y_train)

if hasattr(best_pipeline, "predict_proba") and len(np.unique(y_test)) == 2:
    y_proba = best_pipeline.predict_proba(X_test)[:, 1]
    fpr, tpr, _ = roc_curve(y_test, y_proba)
    auc = roc_auc_score(y_test, y_proba)
    plt.figure(figsize=(6,5))
    plt.plot(fpr, tpr, label=f"AUC={auc:.3f}", linewidth=2)
    plt.plot([0,1],[0,1],'--', alpha=0.6)
    plt.xlabel("False Positive Rate")
    plt.ylabel("True Positive Rate")
    plt.title("ROC Curve")
    plt.legend()
    plt.grid(alpha=0.3)
    plt.show()
else:
    if not hasattr(best_pipeline, "predict_proba"):
        print("Model does not support probability predictions.")
    else:
        print("Cannot plot ROC — y_test does not contain both classes:", np.unique(
```

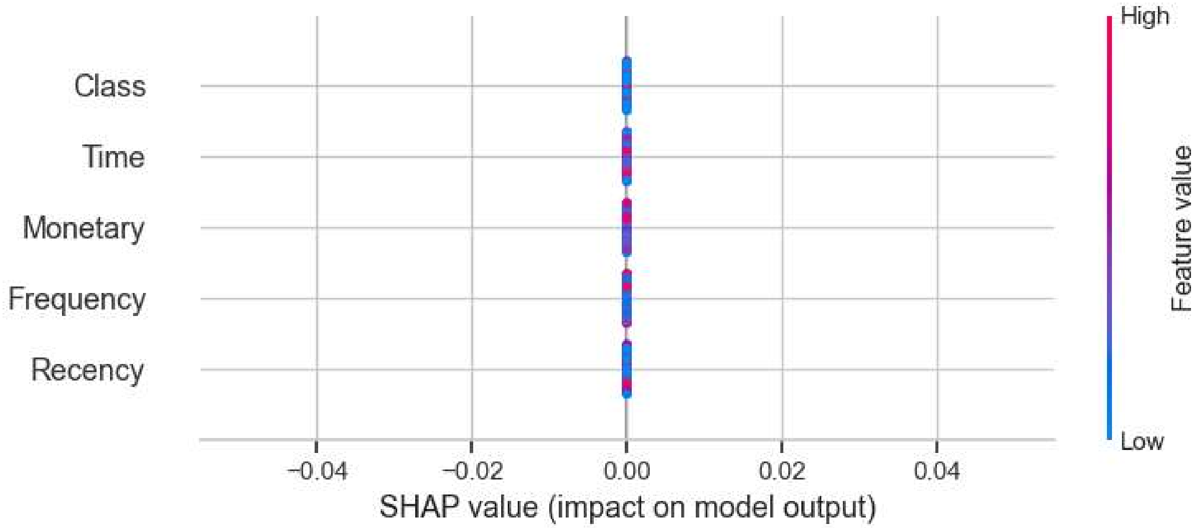
```
Cannot plot ROC — y_test does not contain both classes: [0]
```

In [ ]:
```
#Feature importance
pre = best_pipeline.named_steps['preprocessor']

num_feats = numeric_features

cat_feats = []
if categorical_features:
    ohe = pre.named_transformers_['cat'].named_steps['onehot']
    cat_names = ohe.get_feature_names_out(categorical_features)
    cat_feats = list(cat_names)
all_feats = num_feats + cat_feats

clf = best_pipeline.named_steps['clf']
importances = clf.feature_importances_
feat_imp = pd.Series(importances, index=all_feats).sort_values(ascending=False).hea

plt.figure(figsize=(8,6))
sns.barplot(x=feat_imp.values, y=feat_imp.index)
plt.title("Top 20 Feature Importances")
plt.xlabel("Importance")
plt.ylabel("Feature")
plt.tight_layout()
plt.show()
```



In [ ]:

```
#SHAP explanations
explainer = shap.Explainer(clf, pre.transform(X_train).astype(float))

X_shap = pre.transform(X_test).astype(float)
shap_values = explainer(X_shap[:200])

shap.summary_plot(shap_values, features=X_shap[:200], feature_names=all_feats, show
```



In [ ]:

```
#Recommendation generator
def generate_recommendation(single_row_df):
    """
    Input: single row pandas DataFrame with the same columns as original X
    Output: human readable recommendation
    """
    pred = best_pipeline.predict(single_row_df)[0]

    mapping = {
        0: "Low risk: Maintain current healthy habits; annual checkup recommended."
        1: "Elevated risk: Schedule a doctor visit for assessment; consider lifesty
    }

    return mapping.get(pred, f"Predicted label {pred}. Consult clinician for person

example = X_test.iloc[[0]]
print(generate_recommendation(example))
```

```
Low risk: Maintain current healthy habits; annual checkup recommended.
```