

# CT-Based Osteoporosis Classification and Bone-Muscle Interaction Mapping Using Multiple Interpretable Machine Learning Models with the *BMI**Net* Framework

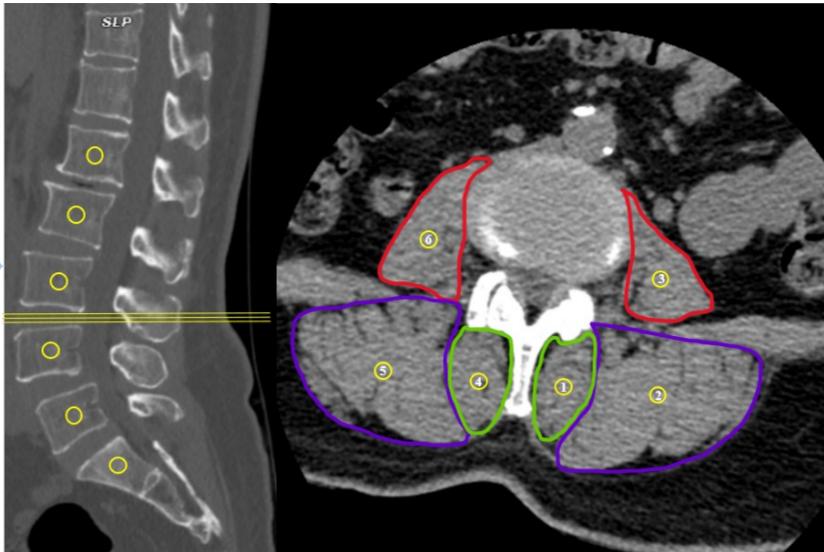
Spencer Wang  
Jun Du

## Data Preparation & Statistical Analysis

- ✓ 444 patients from the First Affiliated Hospital of Soochow University
- ✓ 315 females and 129 males
- ✓ Four stages: A, B, C, D

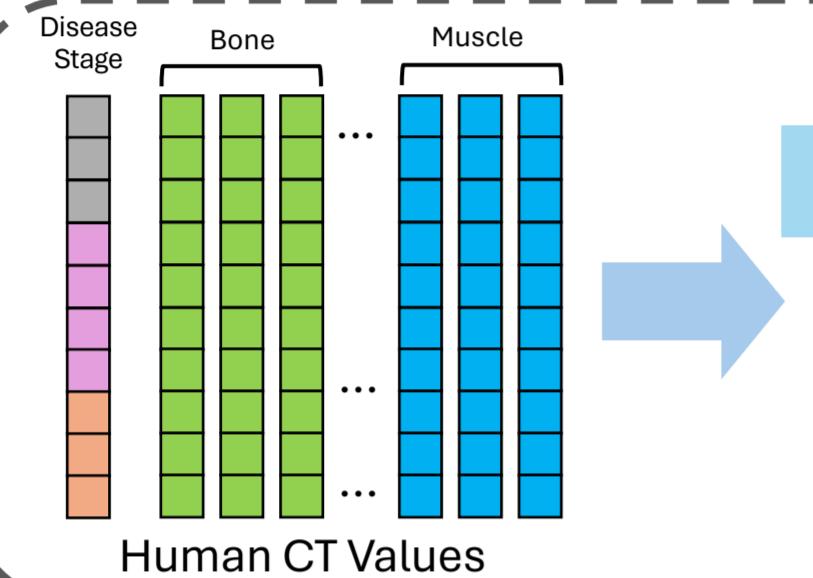
- ✓ Stage A: 104
- ✓ Stage B: 129
- ✓ Stage C: 79
- ✓ Stage D: 132

CT values of 6 bones and 30 muscles

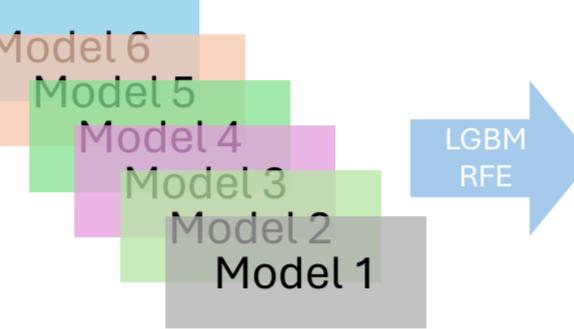


- Age Statistics
- Gender Statistics
- Tests
- ROC
- PCA/PLS-DA
- Correlations

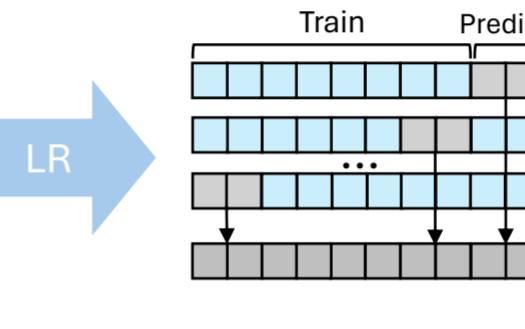
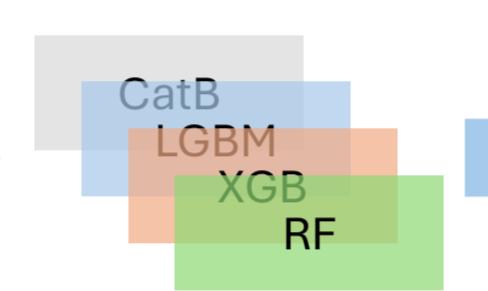
## Construction of Classification Model



Binary Classification

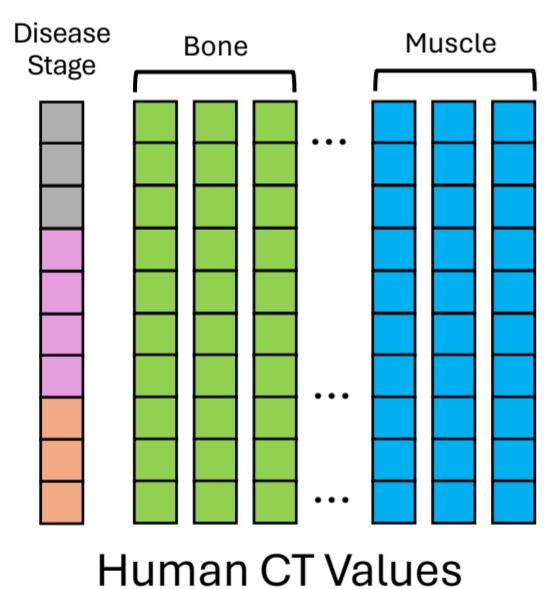


Stacking Model Search



Final Prediction Model

## Mechanism Mining of Overall Data

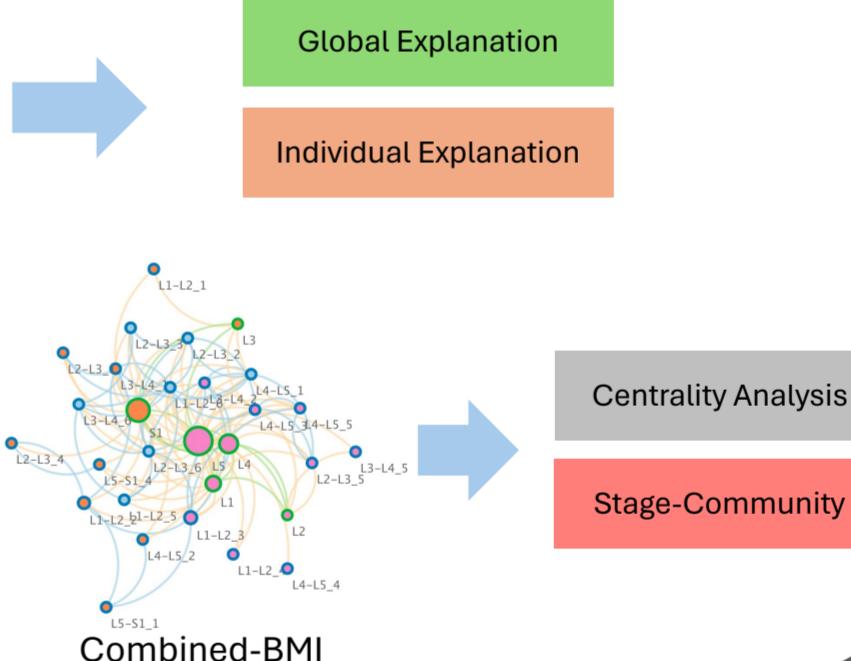
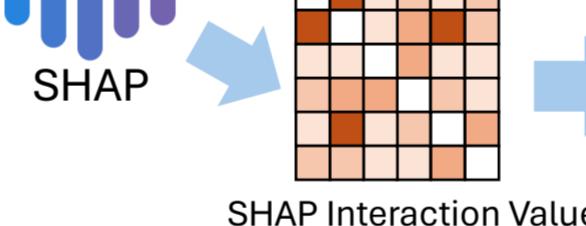
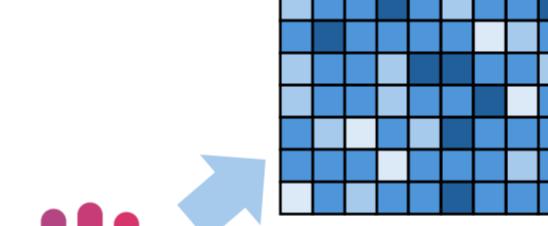


LGBM RFE

Selected Features



LGBM



## Python Package BMINet Development

pip install BMINet

GitHub

- Auto Bone/Muscle Selection
- Auto Model Construction & Evaluation
- Auto Single/Multiple Disease Stage Prediction
- Auto Interaction Network Construction & Analyzation
- Visualization

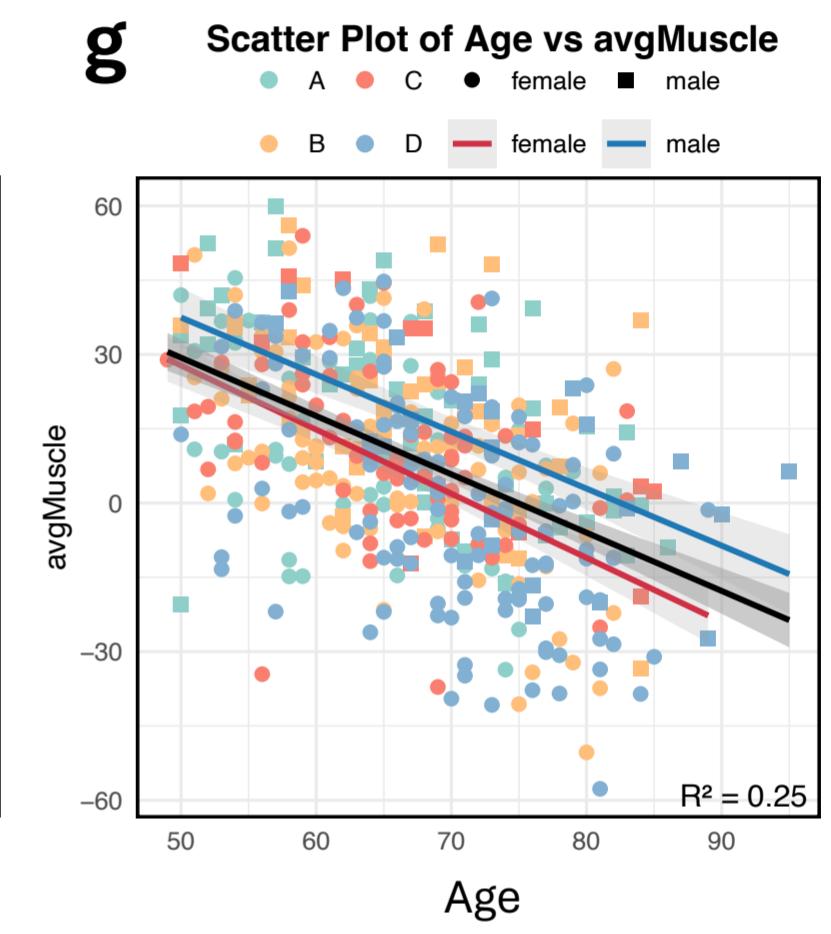
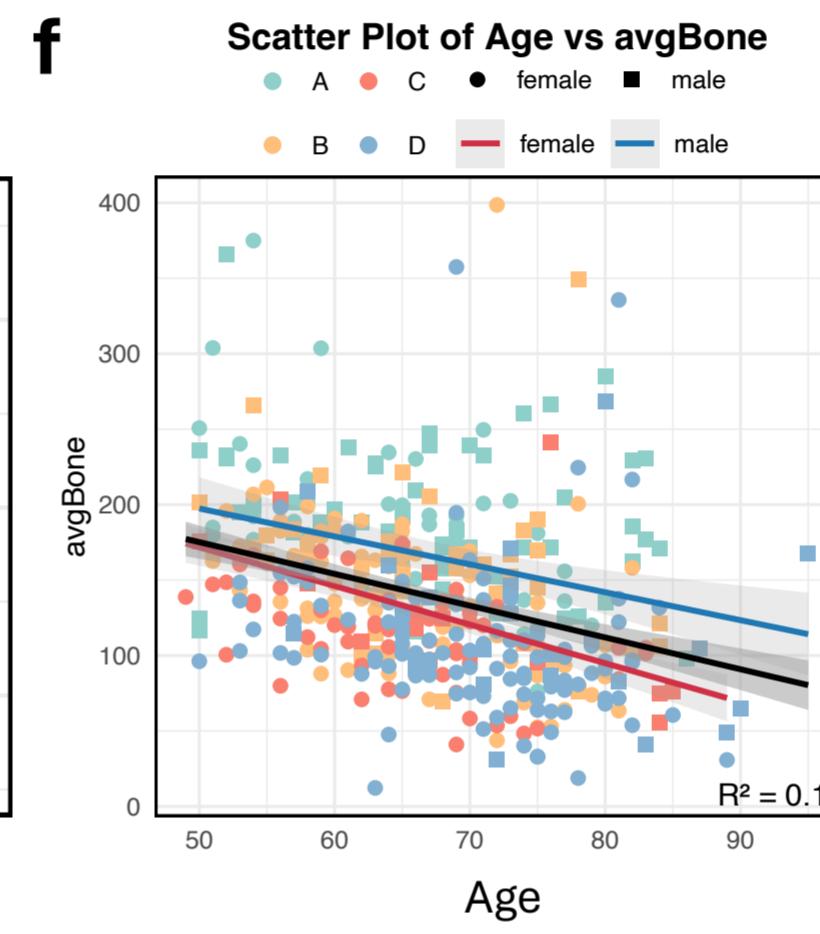
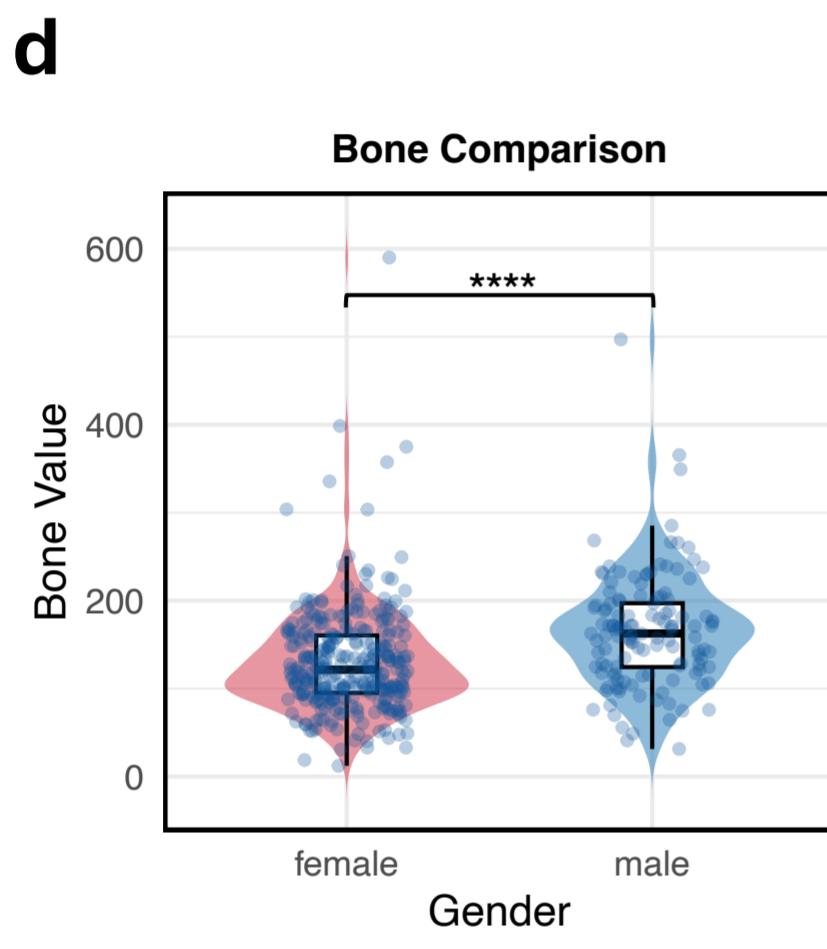
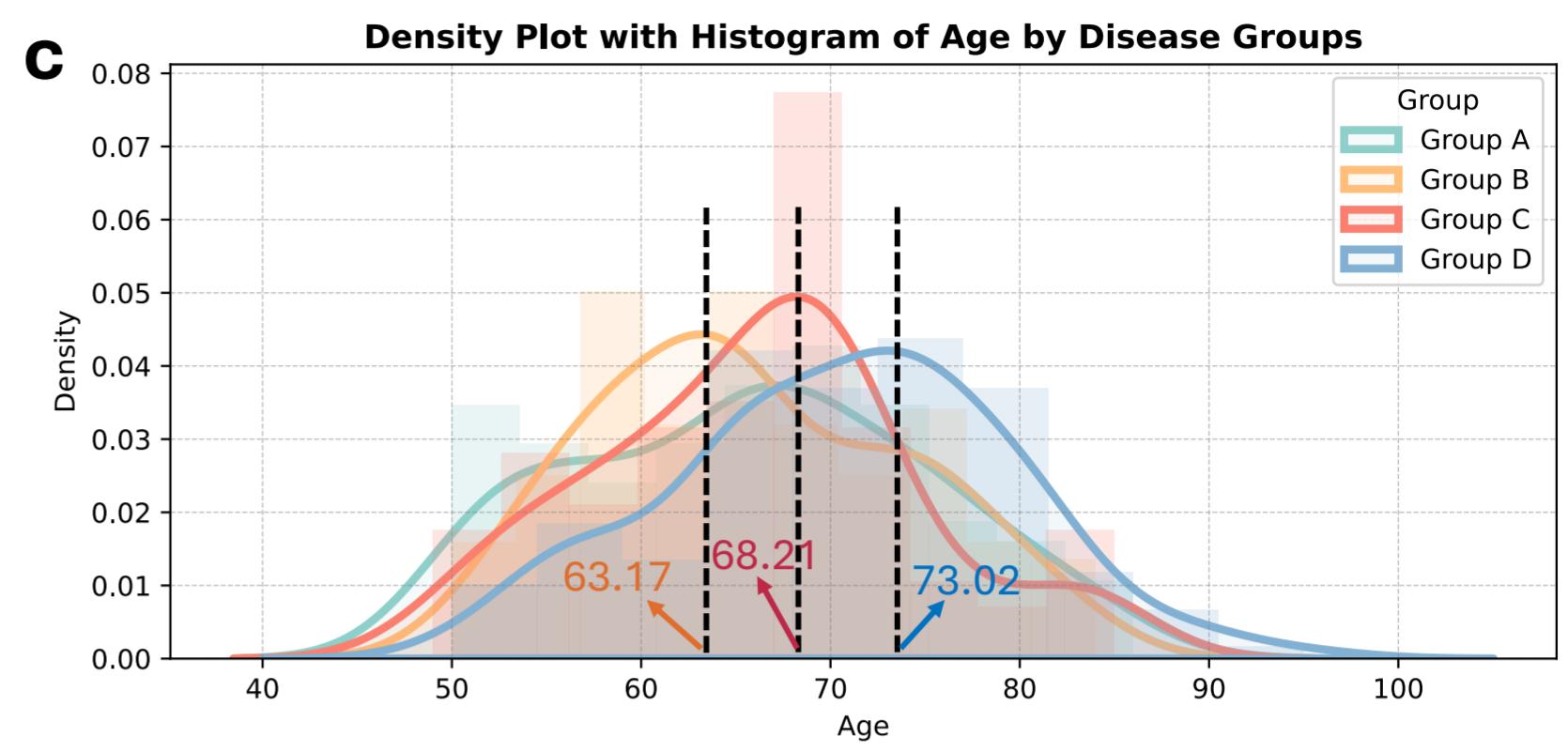
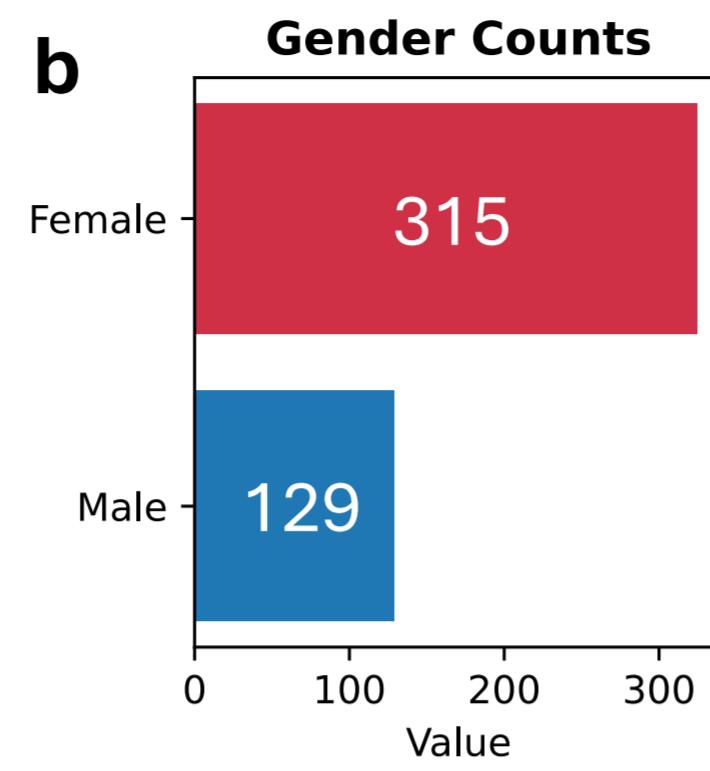
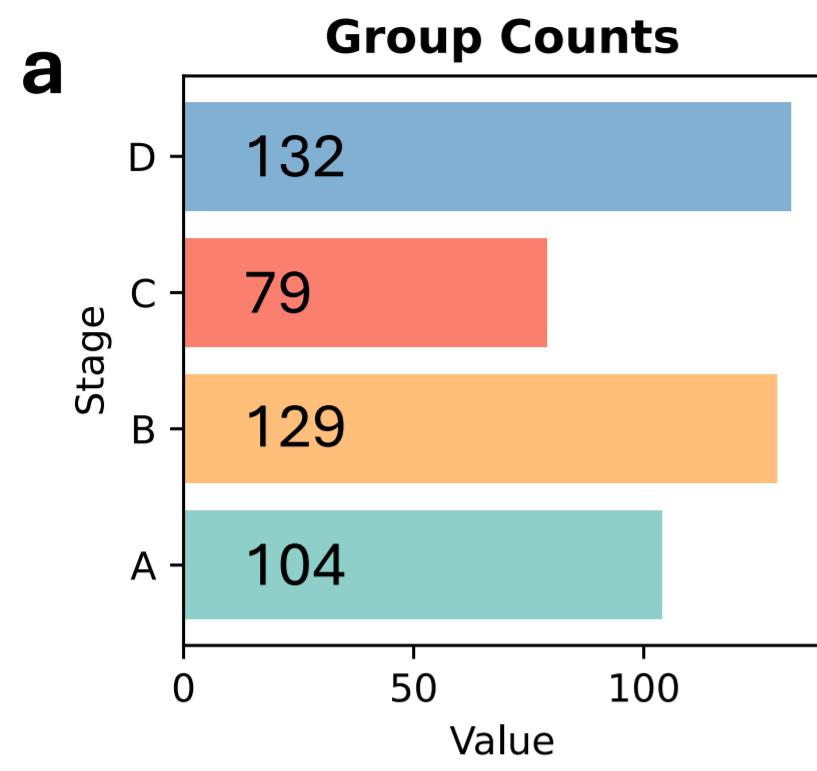
Install

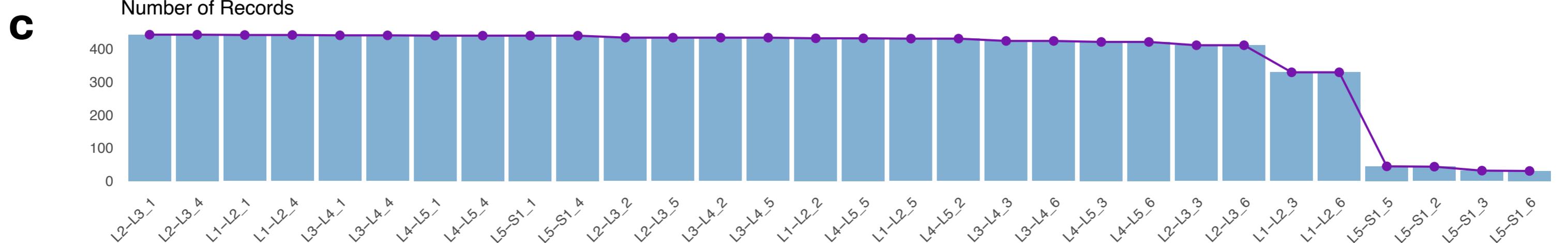
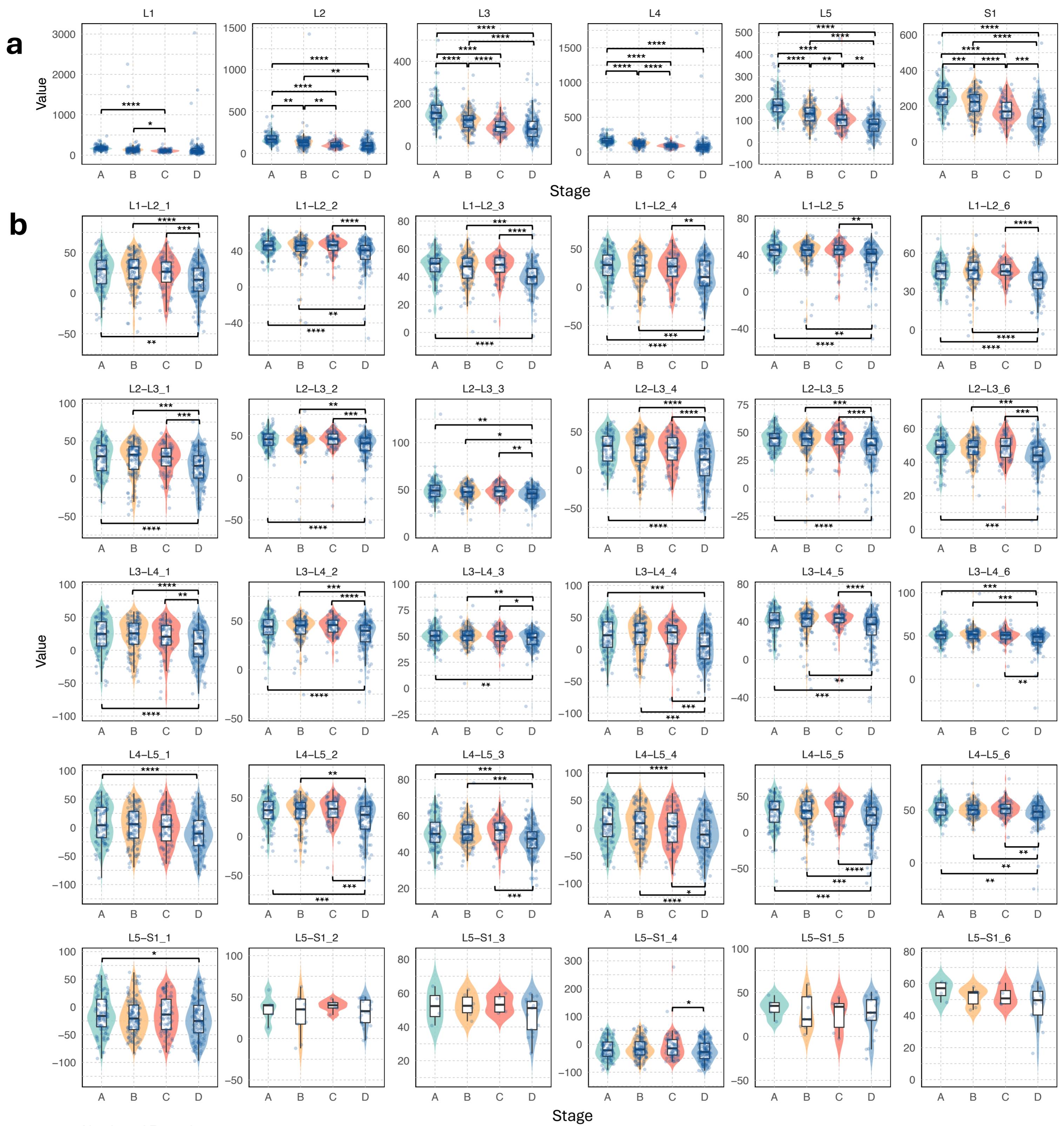
Function

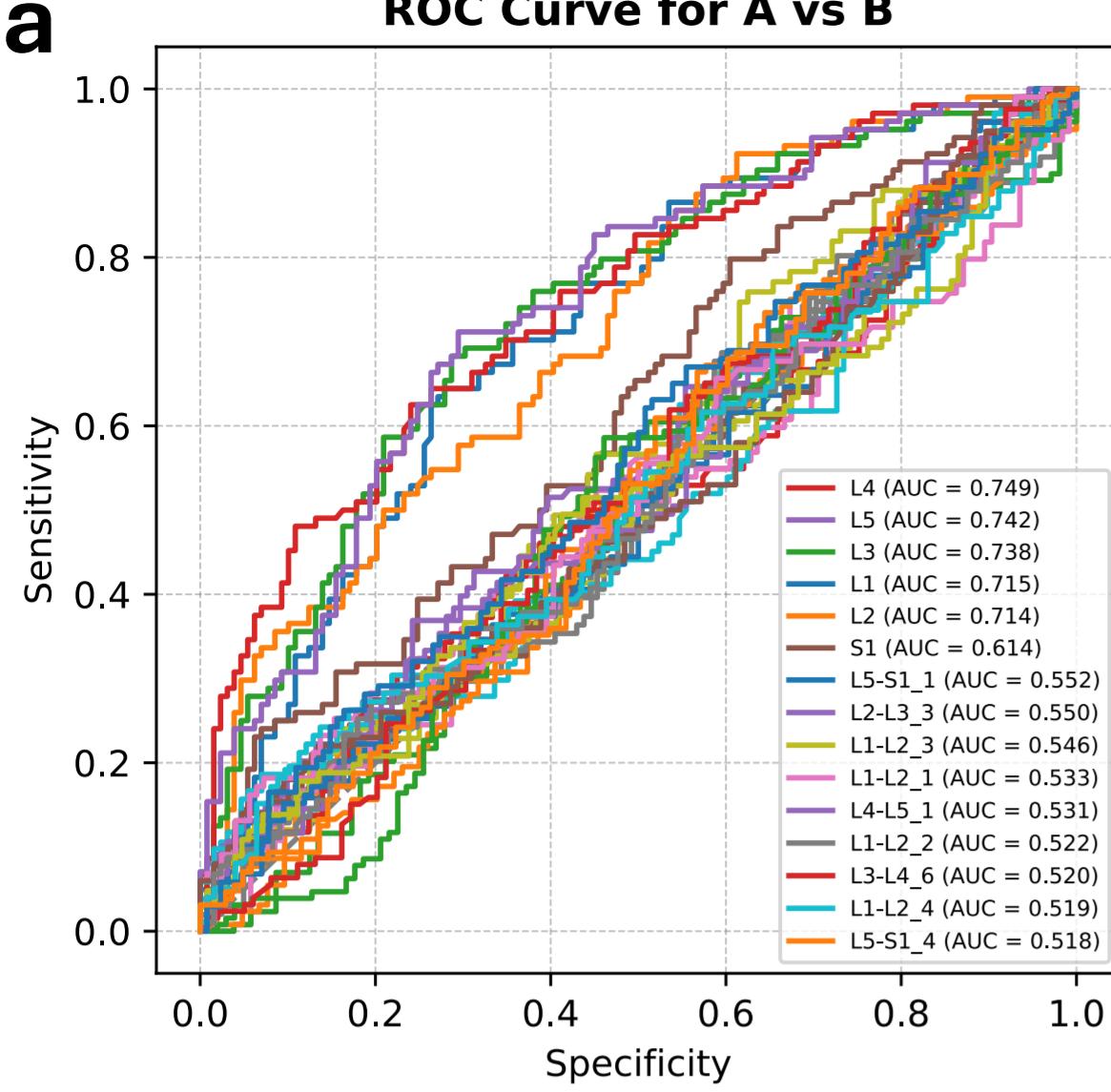
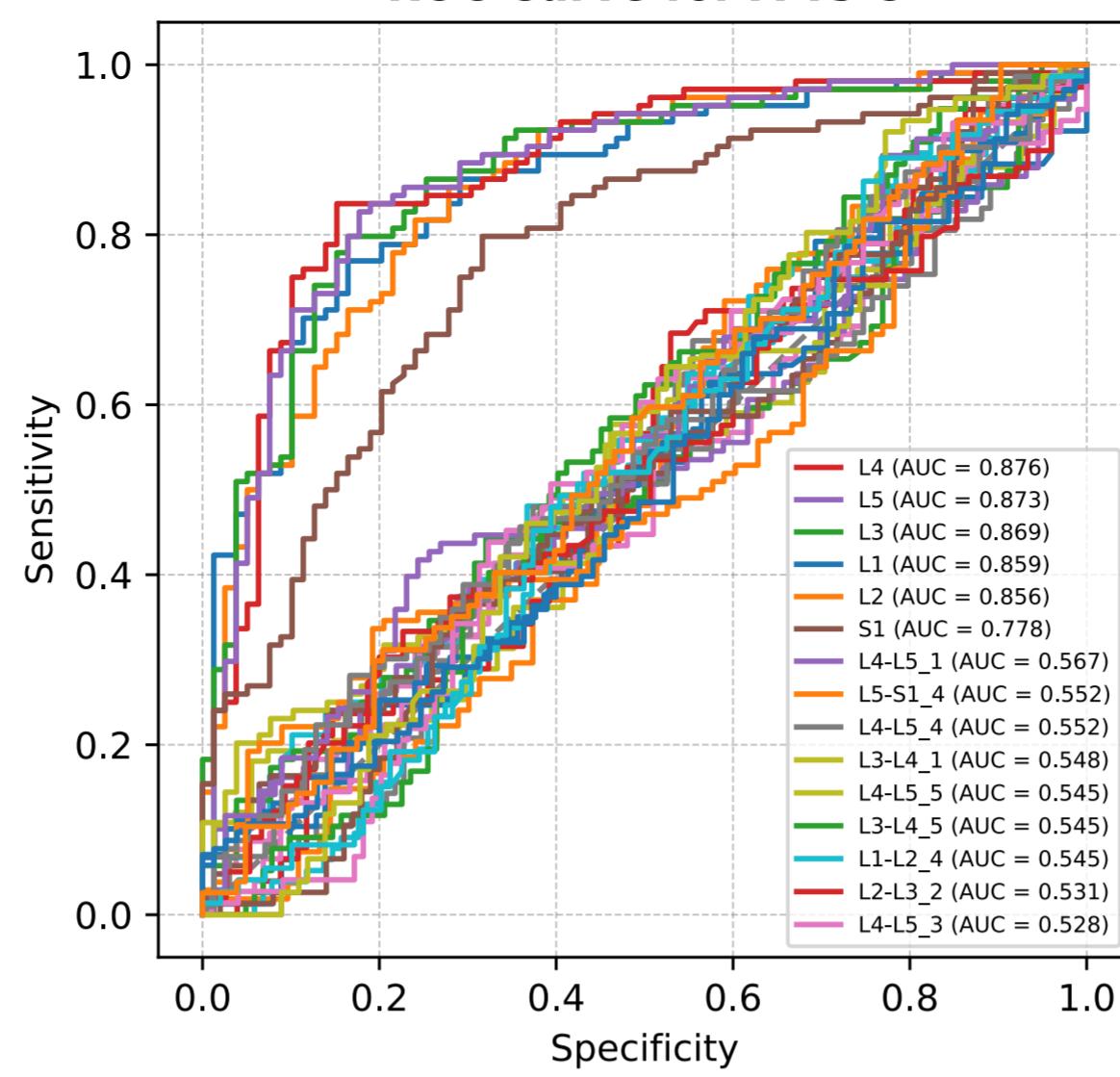


Usage

- FeatureSelector()
- StackingModel()
- SHAPVisualizer()
- NetworkConstructor()
- NetworkMetrics()
- NetworkVisualizer()
- BMINet.plot()





**a****ROC Curve for A vs C****ROC Curve for A vs D**

Sensitivity

Specificity

Legend:

- L5 (AUC = 0.921)
- L4 (AUC = 0.876)
- S1 (AUC = 0.849)
- L3 (AUC = 0.847)
- L2 (AUC = 0.829)
- L1 (AUC = 0.745)
- L1-L2\_3 (AUC = 0.723)
- L1-L2\_6 (AUC = 0.713)
- L1-L2\_2 (AUC = 0.694)
- L2-L3\_5 (AUC = 0.667)
- L3-L4\_1 (AUC = 0.662)
- L3-L4\_4 (AUC = 0.660)
- L1-L2\_4 (AUC = 0.657)
- L2-L3\_6 (AUC = 0.657)

**ROC Curve for B vs D**

Sensitivity

Specificity

Legend:

- L5 (AUC = 0.783)
- S1 (AUC = 0.774)
- L4 (AUC = 0.739)
- L1-L2\_6 (AUC = 0.710)
- L3 (AUC = 0.696)
- L2-L3\_4 (AUC = 0.676)
- L3-L4\_4 (AUC = 0.673)
- L1-L2\_1 (AUC = 0.669)
- L2 (AUC = 0.669)
- L1-L2\_3 (AUC = 0.666)
- L2-L3\_1 (AUC = 0.662)
- L1-L2\_2 (AUC = 0.661)
- L2-L3\_5 (AUC = 0.659)
- L2-L3\_6 (AUC = 0.658)
- L3-L4\_1 (AUC = 0.658)

**ROC Curve for B vs C**

Sensitivity

Specificity

Legend:

- L4 (AUC = 0.688)
- L3 (AUC = 0.682)
- L5 (AUC = 0.679)
- S1 (AUC = 0.674)
- L1 (AUC = 0.659)
- L2 (AUC = 0.658)
- L1-L2\_1 (AUC = 0.559)
- L4-L5\_5 (AUC = 0.556)
- L3-L4\_1 (AUC = 0.549)
- L1-L2\_3 (AUC = 0.548)
- L2-L3\_2 (AUC = 0.548)
- L4-L5\_4 (AUC = 0.545)
- L3-L4\_6 (AUC = 0.545)
- L4-L5\_1 (AUC = 0.544)
- L5-S1\_1 (AUC = 0.544)
- L2-L3\_3 (AUC = 0.544)

**ROC Curve for C vs D**

Sensitivity

Specificity

Legend:

- L1-L2\_6 (AUC = 0.743)
- L1-L2\_3 (AUC = 0.714)
- L1-L2\_2 (AUC = 0.688)
- L3-L4\_5 (AUC = 0.684)
- L2-L3\_4 (AUC = 0.675)
- L2-L3\_2 (AUC = 0.673)
- L2-L3\_5 (AUC = 0.673)
- L3-L4\_2 (AUC = 0.672)
- L4-L5\_5 (AUC = 0.665)
- L2-L3\_6 (AUC = 0.659)
- L4-L5\_3 (AUC = 0.659)
- L2-L3\_1 (AUC = 0.656)
- L1-L2\_5 (AUC = 0.655)
- L3-L4\_4 (AUC = 0.655)
- L5 (AUC = 0.653)

**b**

**PCA Plot of Disease Groups**

PC2

PC1

**c**

**PLS-DA Plot of Disease Groups**

PC2

PC1

**d**

**Correlation Heatmap**

Legend:

- L5.S1\_1
- L5.S1\_4
- S1
- L1
- L2
- L5
- L3
- L4
- L4.L5\_3
- L4.L5\_6
- L2.L3\_3
- L2.L3\_6
- L3.L4\_3
- L3.L4\_6
- L4.L5\_2
- L4.L5\_5
- L1.L2\_2
- L1.L2\_5
- L1.L2\_6
- L2.L3\_2
- L2.L3\_5
- L3.L4\_2
- L3.L4\_5
- L4.L5\_1
- L4.L5\_4
- L1.L2\_1
- L1.L2\_4
- L2.L3\_1
- L2.L3\_4
- L3.L4\_1
- L3.L4\_4

