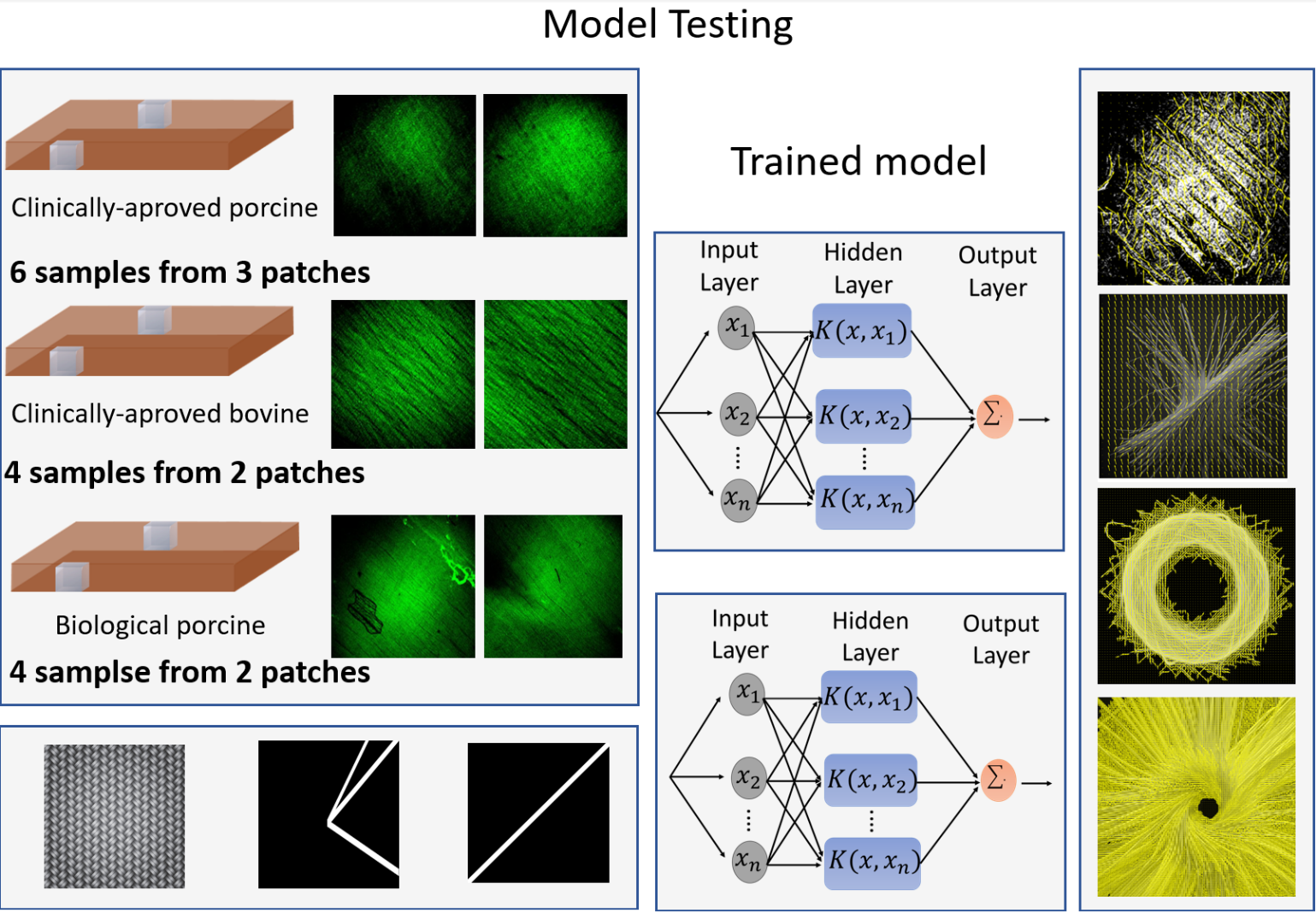


**Supplementary 1.** *Overview of the model training pipeline for 3D cardiovascular fiber orientation analysis. Top left: Confocal images were obtained from 15 biological samples across five different pericardial patches (clinically approved porcine, biological porcine, and bovine pericardium). Each sample was divided into smaller regions (50×50 voxels) to extract local fiber orientation features. Bottom left: Synthetic fiber images were generated using a diffusion model based on input text prompts, followed by segmentation into 50×50 voxel regions. Right: The extracted data were used to train machine learning and deep learning models. Here, an example architecture (e.g., Support Vector Regression with kernel function K(x,xi) is illustrated, consisting of input, hidden, and output layers to produce the trained model.*



**Supplementary 2.** *Model testing workflow for evaluating fiber orientation prediction performance on biological and synthetic samples. Left: Confocal microscopy images from clinically approved porcine (6 samples from 3 patches), clinically approved bovine (4 samples from 2 patches), and biological porcine pericardium (4 samples from 2 patches) were used as the biological test set. Additionally, synthetic images representing structured fiber orientations (e.g., braiding, straight lines, and angular patterns) were used to evaluate the model’s geometric sensitivity. Middle: The trained model, including kernel-based regression architecture (e.g., SVR), was applied to these test inputs. Right: Predicted fiber orientation visualizations demonstrating the model’s ability to accurately capture complex and diverse fiber architectures across different test domains.*