# 3D PRINTED GYROID ELASTOMER AND SILICONE COMPOSITE FOR CONTROLLED ANISOTROPY SIMULATING HUMAN TISSUE

Presenter: Yu Ming Li
Co-Authors: Po-Han Chen[1], Raphaelle Paracuellos[1], Karcher Morris[1], Milan Makale[2], Jyoti Mayadev[2], and Frank E. Talke[1]

[1] Center for Memory and Recording Research
[2] Moores Cancer Center
University of California San Diego

CMRR Center for Memory and Recording Research

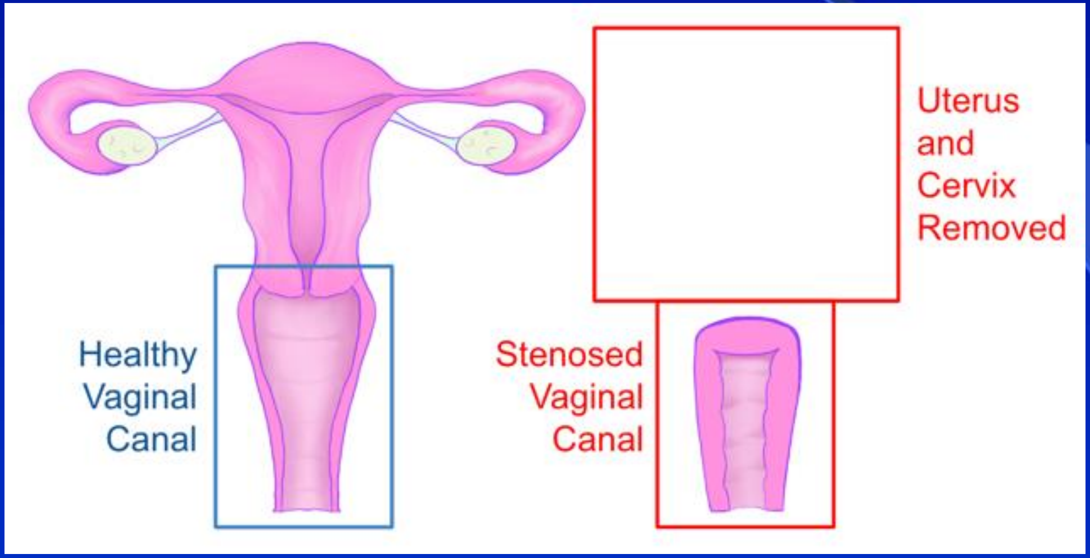
UC San Diego JACOBS SCHOOL OF ENGINEERING

# Outline

- Introduction
- Medical motivation
- Design of a composite material  to simulate nonlinearity and anisotropy of human tissue
- Composite Structure
- Experimental data
- Discussion
- Future Work

# Introduction

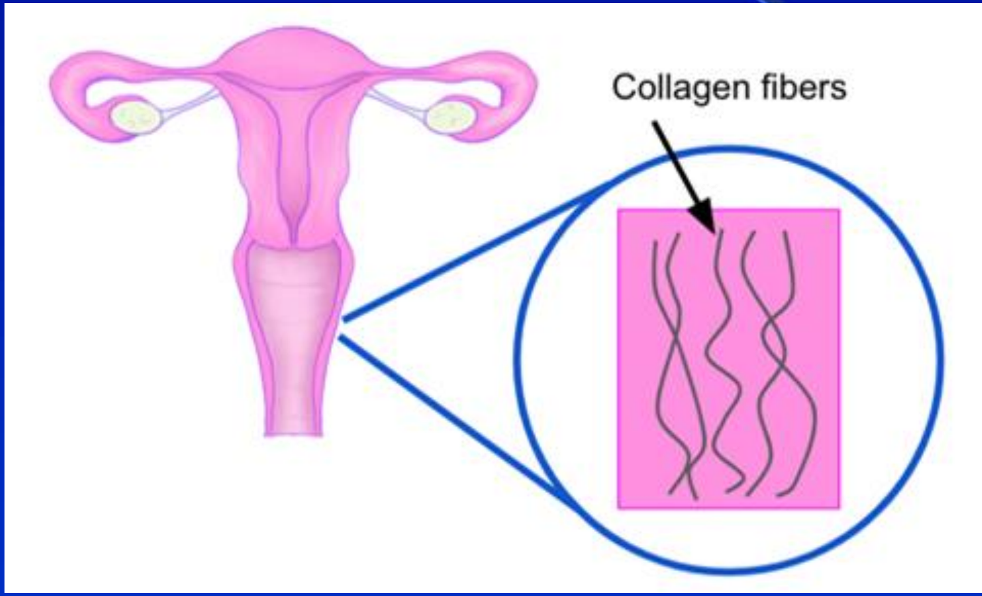
## Radiation Induced Vaginal Stenosis




- Common cervical cancer treatment complication
- Treatable with medical intervention
- Change of tissue morphology and properties
  - e.g. stiffening of the tissue

# Vaginal Tissue Properties

## Radiation Induced Vaginal Stenosis

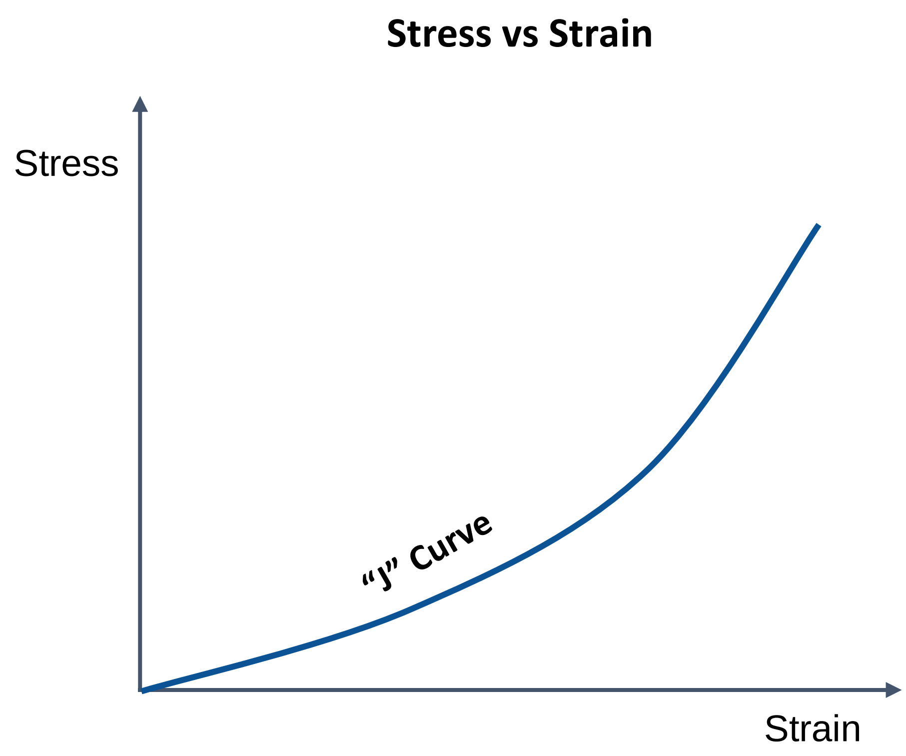


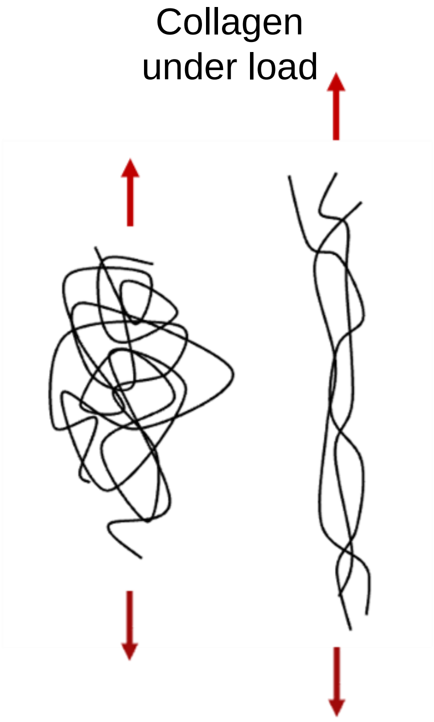

- Variating mechanical properties across the vaginal canal
- Strain stiffening
- Anisotropic

# Motivation

**Achieving accurate mechanical properties for a vaginal analog is crucial for developing effective treatments and medical devices for gynecological disorders.**

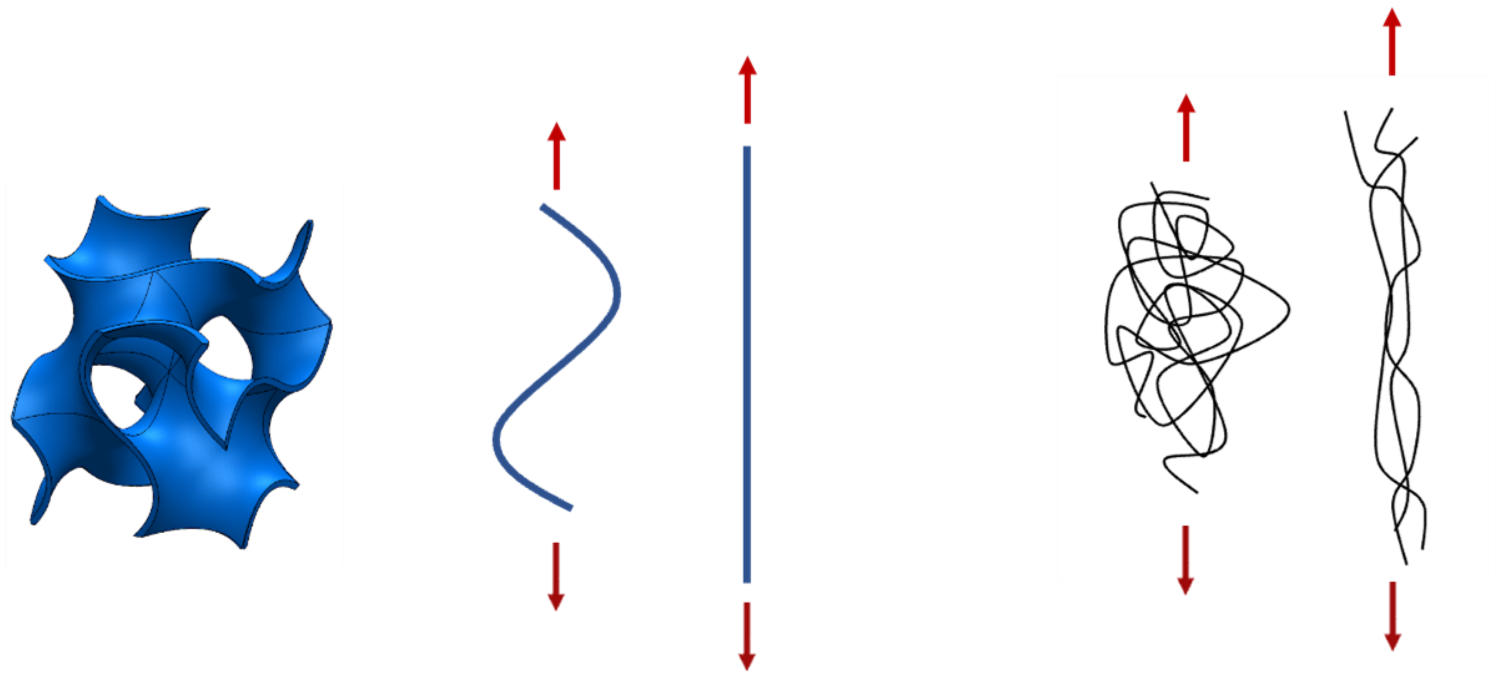
# Mechanical Properties of Tissue




Strain hardening and anisotropy induced by collagen unraveling and fiber orientation in tissue

# Composite for Tissue Analog

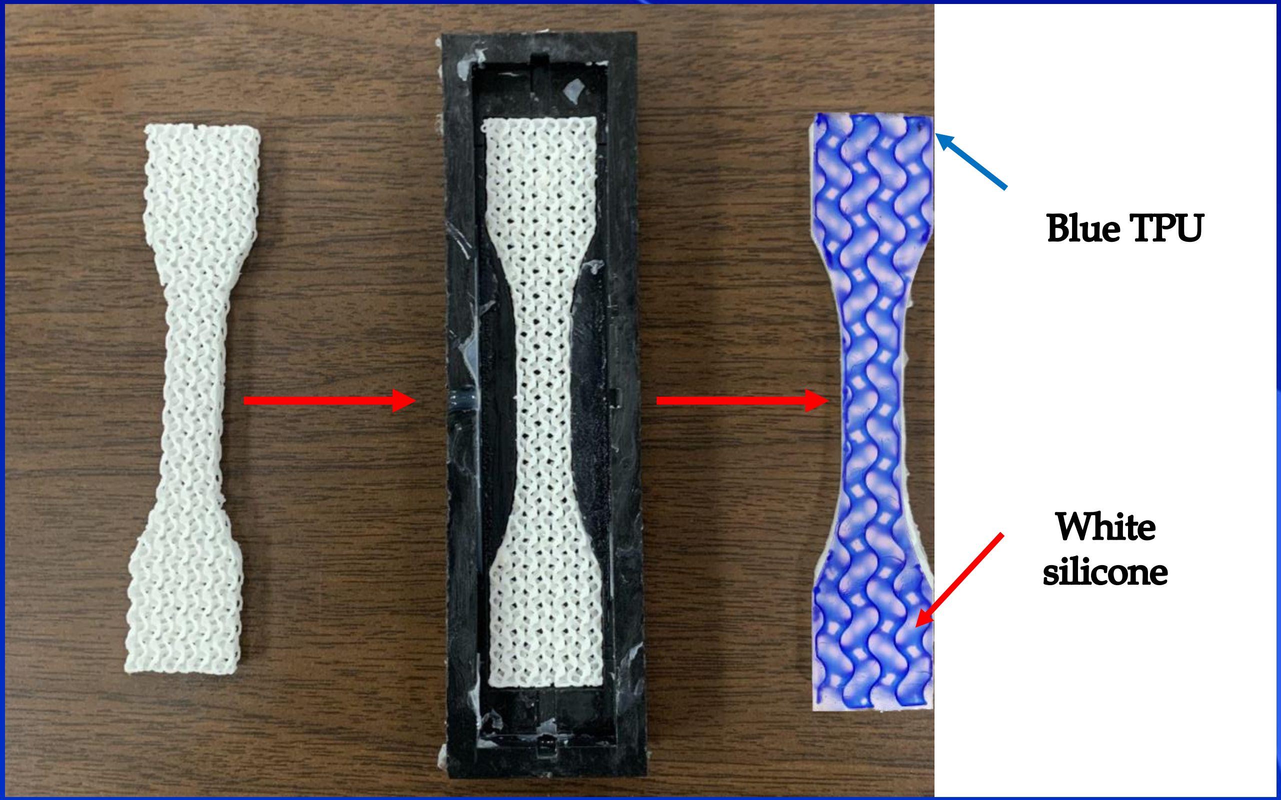


Use of geometric structure for strain stiffening and anisotropy

# Research Goal

- The goal of this research is to simulate the anisotropic and strain stiffening properties of human tissue.
- The material developed will be used for the design of vaginal phantoms to assist medical device development and training of physicians.

# Composite Structure

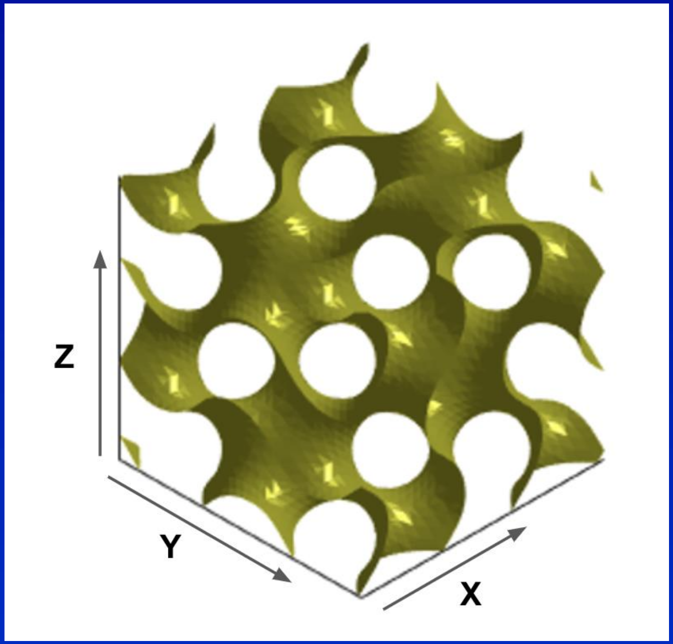



3D printed TPU scaffolding

Mold with liquid silicone resin

Resultant material

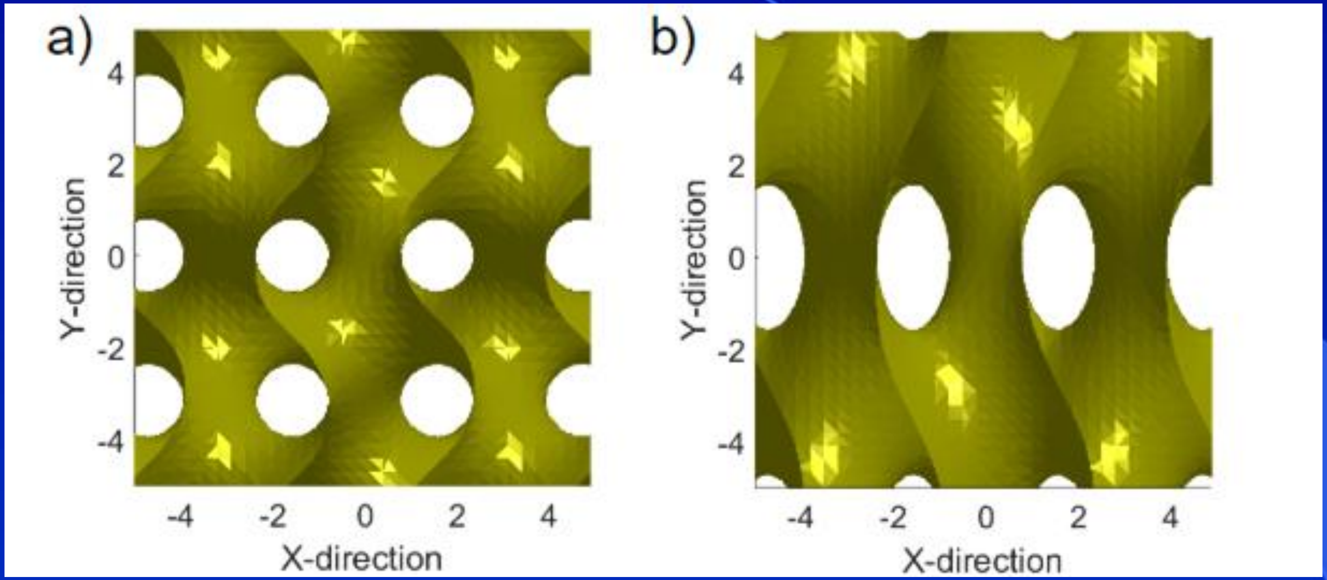
# 3D Printed Scaffolds




$$t = \sin\left(\frac{2\pi x}{a}\right)\cos\left(\frac{2\pi y}{b}\right) + \sin\left(\frac{2\pi y}{b}\right)\cos\left(\frac{2\pi z}{c}\right) + \sin\left(\frac{2\pi z}{c}\right)\cos\left(\frac{2\pi x}{a}\right)$$

- Allows for geometric variation
- Mathematically defined structure
- Tunable geometric anisotropy
- a, b, and c, represents unit cell length

# 3D Printed Scaffolds

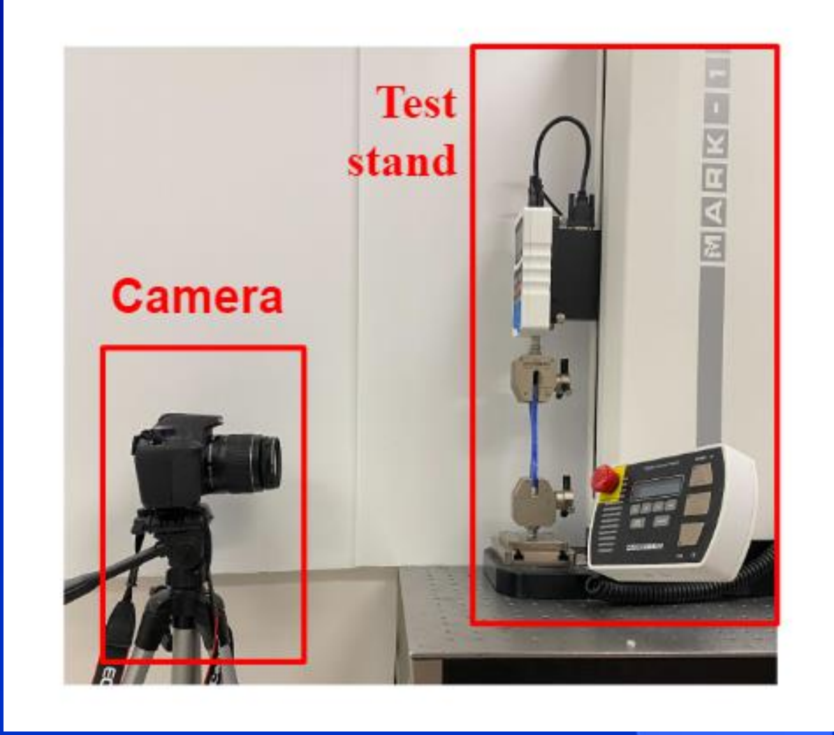


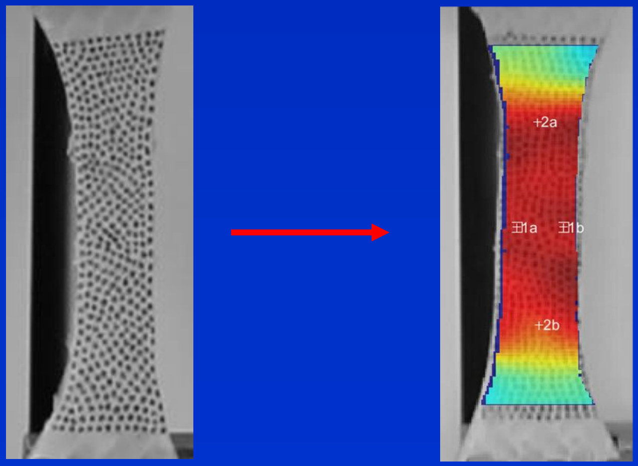

$$t = sin\left(\frac{2\pi x}{a}\right) cos\left(\frac{2\pi y}{b}\right) + sin\left(\frac{2\pi y}{b}\right) cos\left(\frac{2\pi z}{c}\right) + sin\left(\frac{2\pi z}{c}\right) cos\left(\frac{2\pi x}{a}\right)$$

a) Isotropic gyroid structure: a = b = c = 1
b) Anisotropic gyroid structure: a = c = 1, b = 2

# Experimental Setup

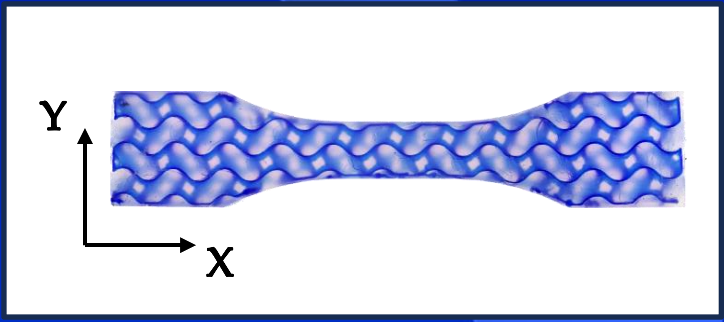
- Uniaxial tensile tester
- Digital Image Correlation: contactless strain measurement
- High resolution strain and displacement data



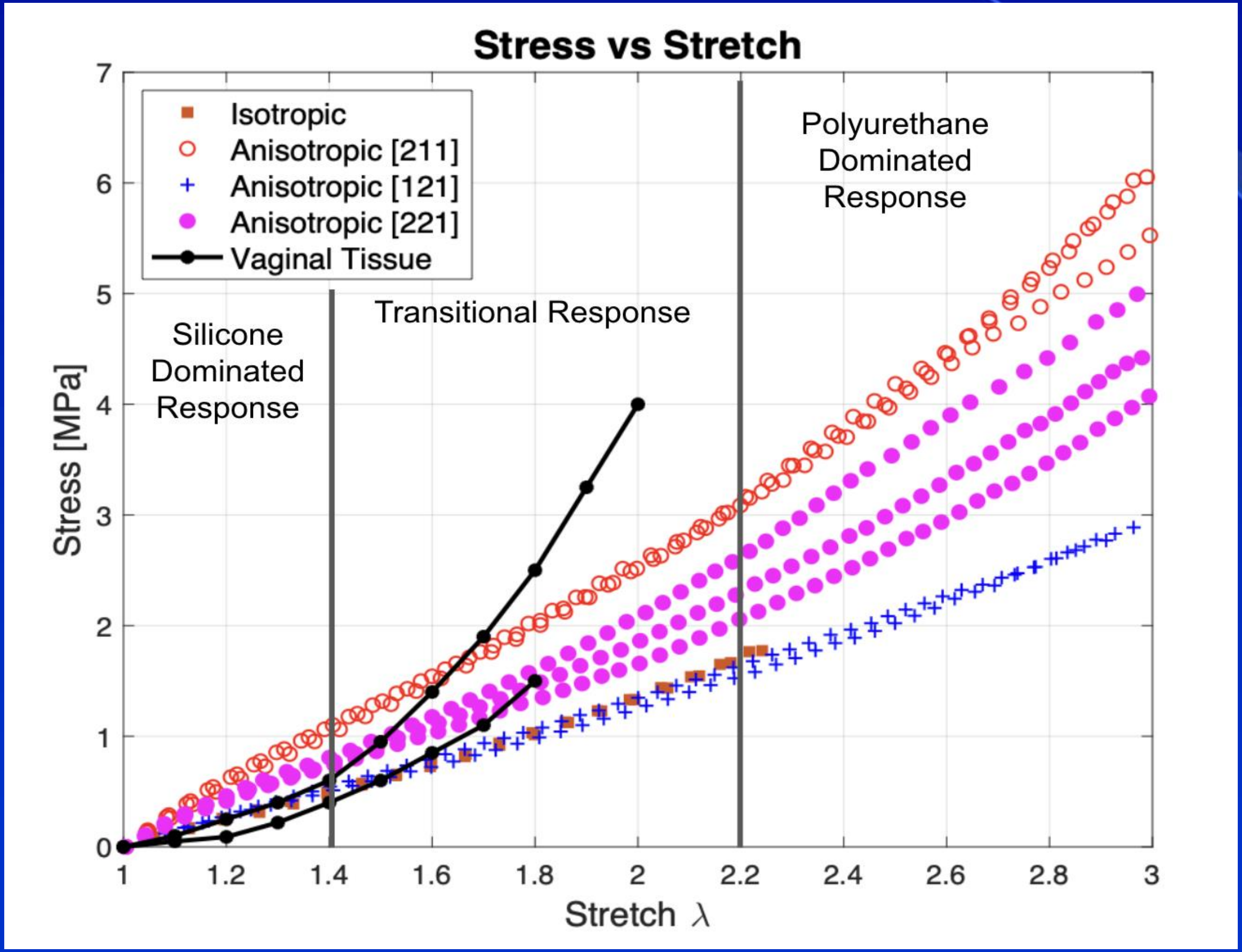
# Test Coupon Configurations

1. Isotropic gyroid
2. Anisotropic x-distorted gyroid coupon with a=2, b=1, c=1
3. Anisotropic y-distorted gyroid coupon with a=1, b=2, c=1
4. Anisotropic x and y-distorted gyroid coupon with a=2, b=2, c=1

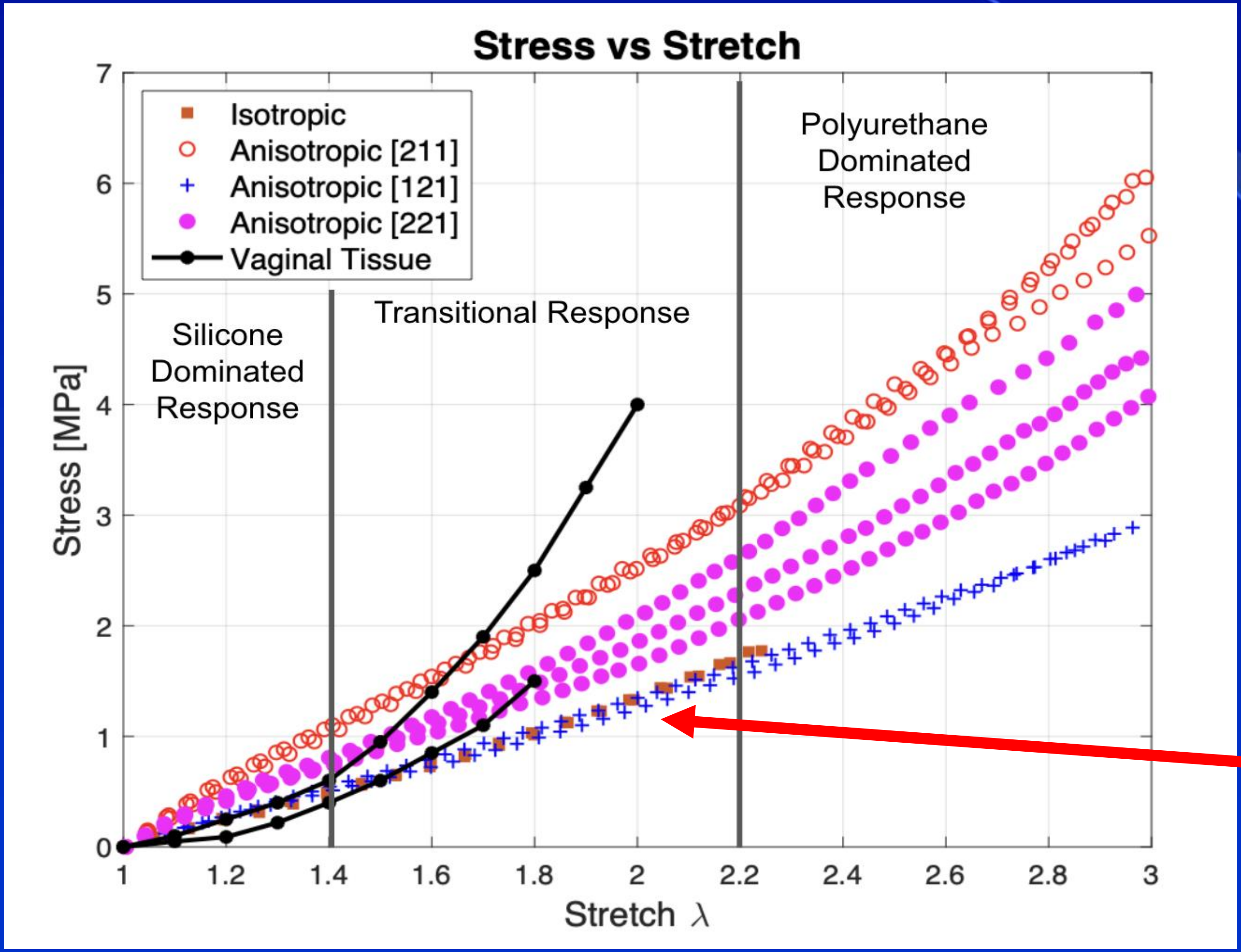


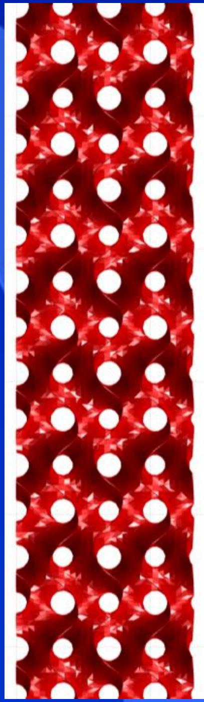

Isotropic Coupon

# Material testing results



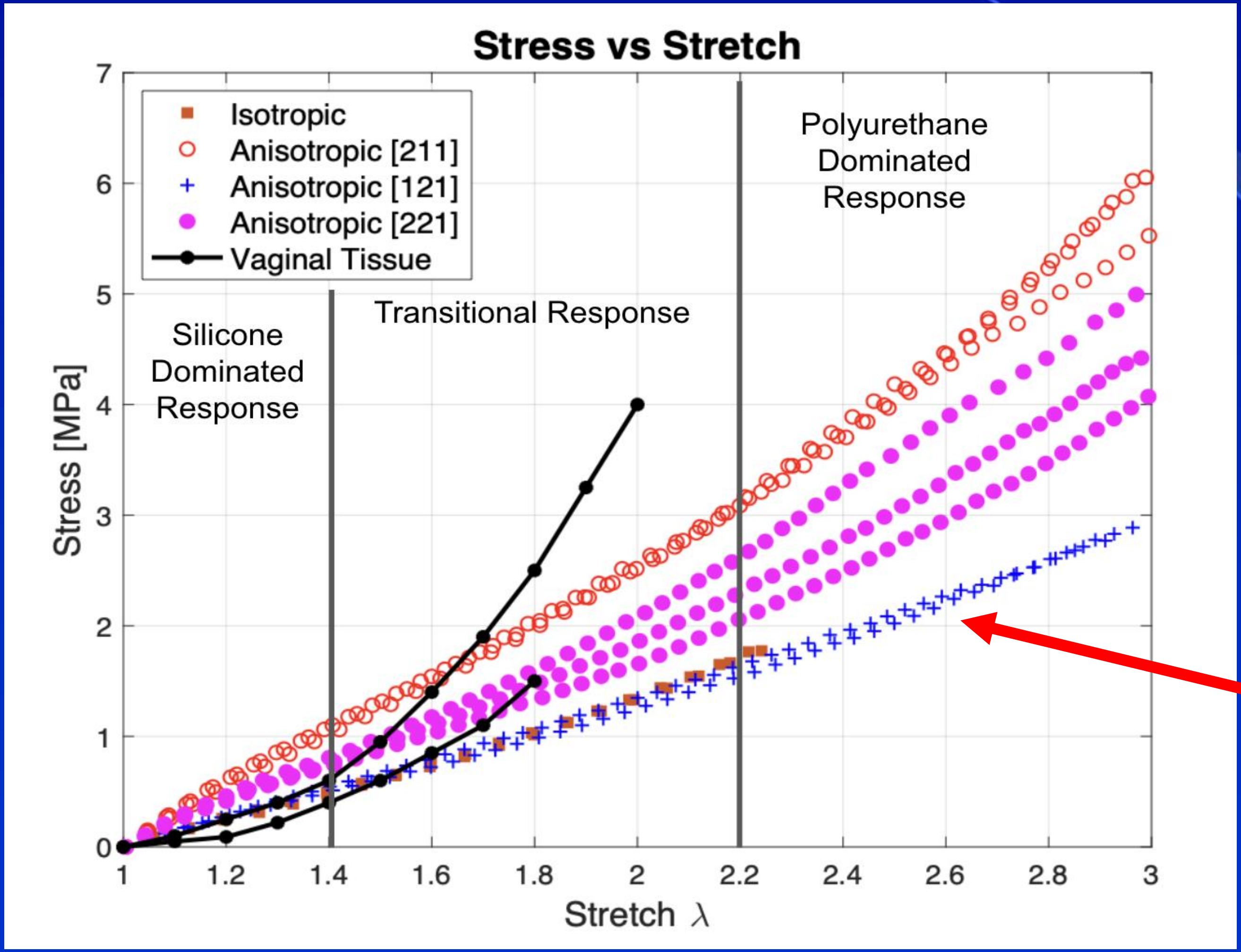
# Material testing results

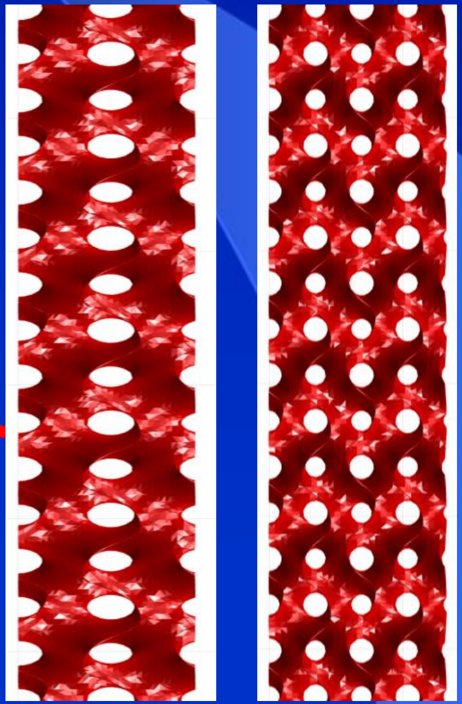


Isotropic

# Material testing results

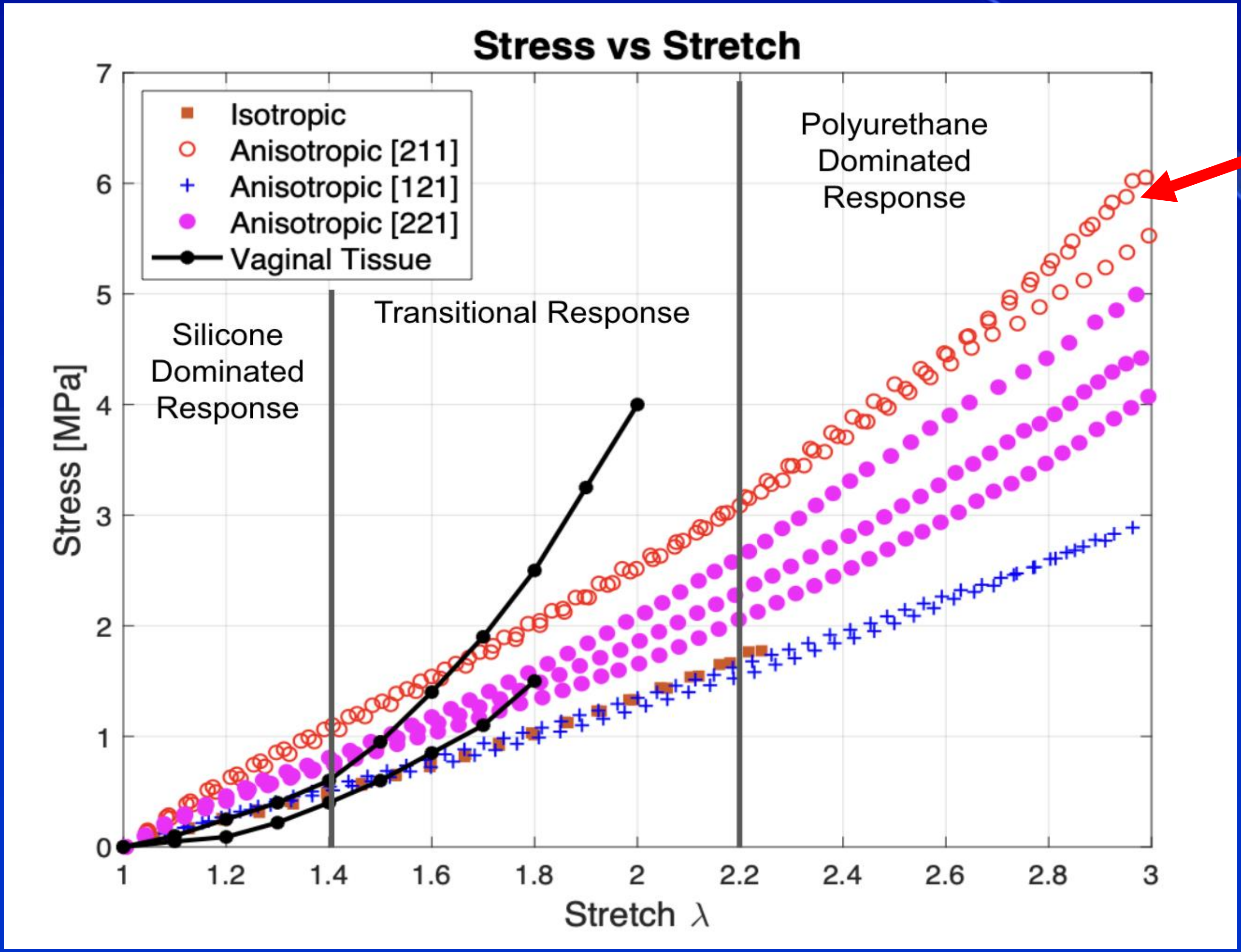


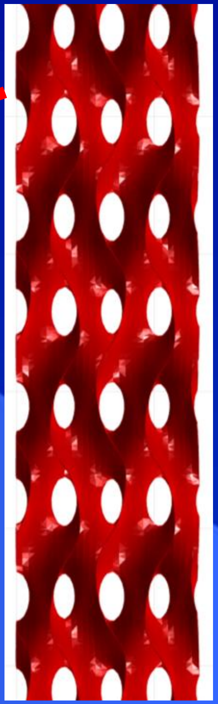



[121] Anisotropic

Isotropic

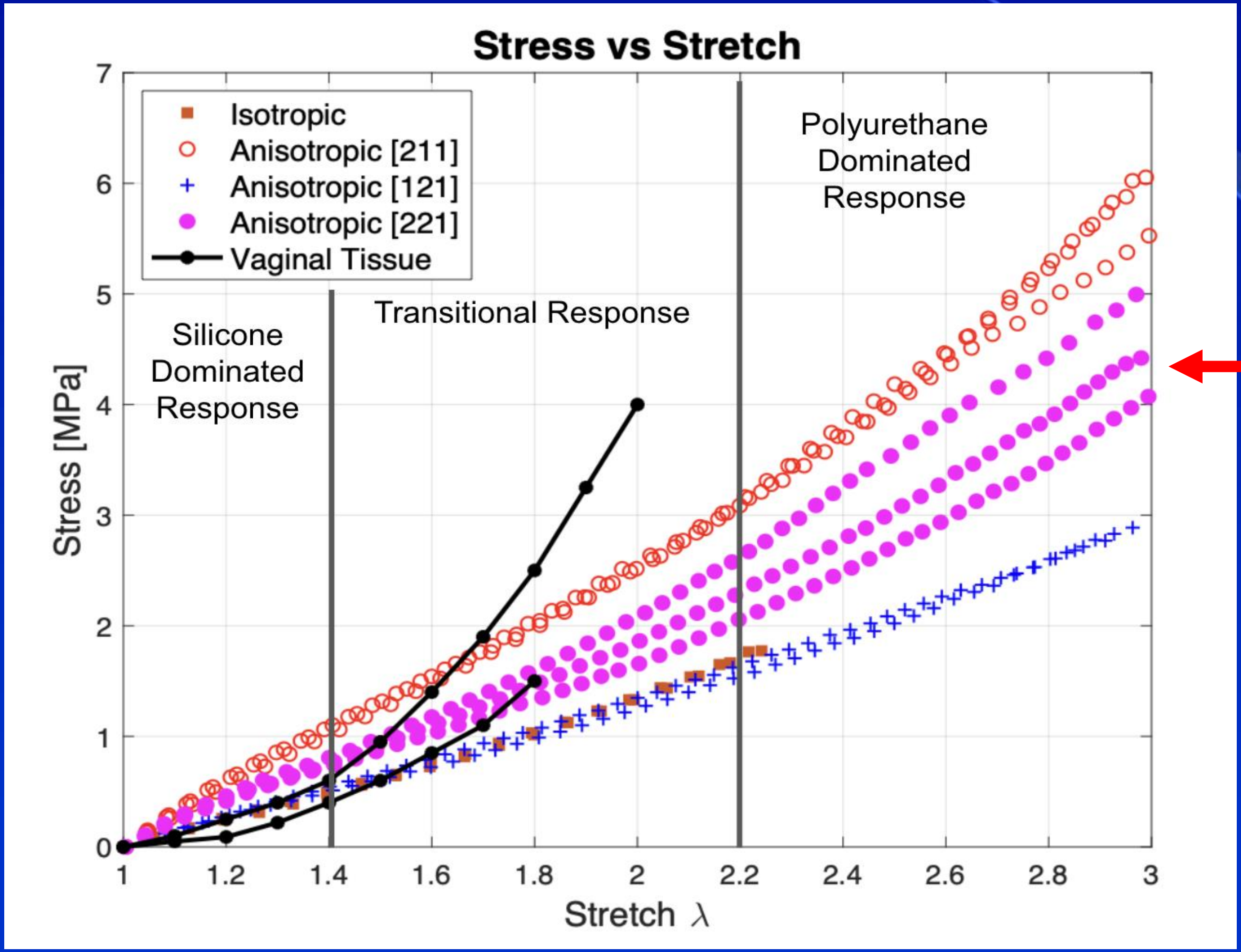
# Material testing results

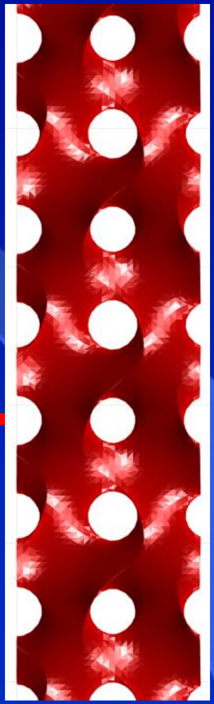


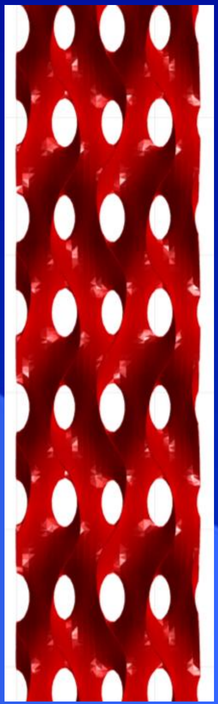
**[211] Anisotropic**

# Material testing results



[221]
Anisotropic



[211]
Anisotropic

# Summary

- Nonlinear strain-stiffening behavior
- Gyroid controlled anisotropy
  - Coupon [211] showed stiffer stress-strain response despite lower TPU content compared to control
- Coupon [121]'s similar response to isotropic coupons suggests distortions aligning with the direction of applied load account for the majority of behavior
- Coupon [221]'s higher stiffness implies aspect ration of in-plane and out-of-plane gyroid cell size contributes to stress response

# Future Work

- FEM studies on gyroid geometry and composite
- Investigation of silicone-gyroid configurations to generate higher strain stiffening rates at smaller deformations.
- 3D deformation study of cylindrical composite vaginal model

# Thank you!