



# A Constrained Mixture Model of Sarcomere Turnover in Cardiomyocytes for Organ-Scale Cardiac Growth and Remodeling

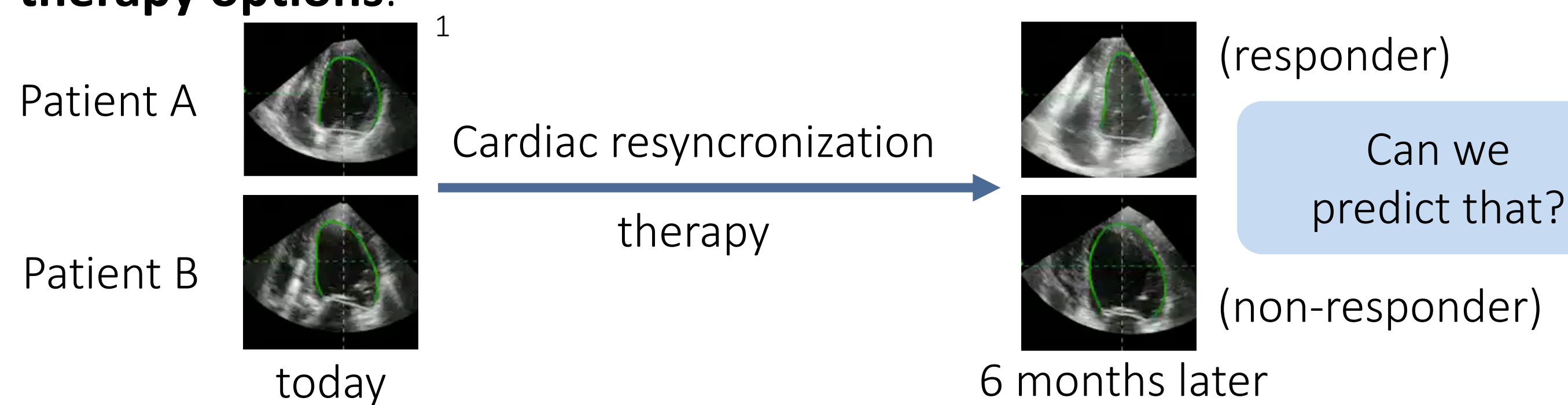
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## Introduction

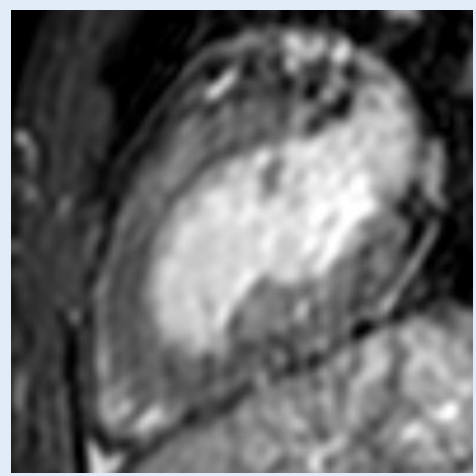
- Cardiac growth and remodeling occur in various situations throughout a human's life (e.g. between birth and adulthood, during pregnancy or exercise).
- Disease-induced stimuli (e.g. myocardial infarction, aortic stenosis or hypertension) often result in **pathologic maladaptive growth and remodeling** that develop towards heart failure.
- A predictive computational model has the potential to **identify patients at risk of heart failure** and assess or even **improve their personalized therapy options**.



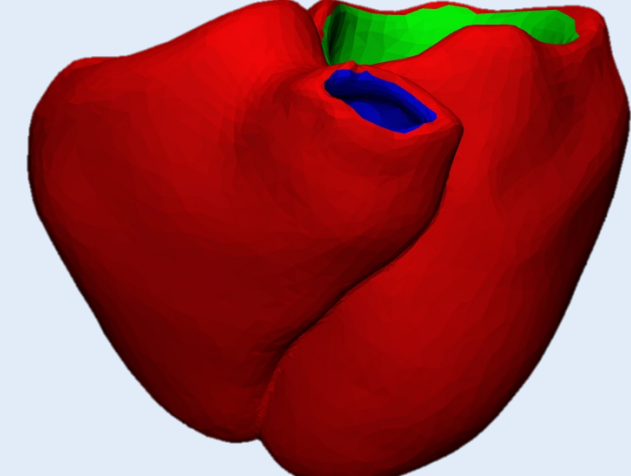
## Computational Model

### Preprocessing

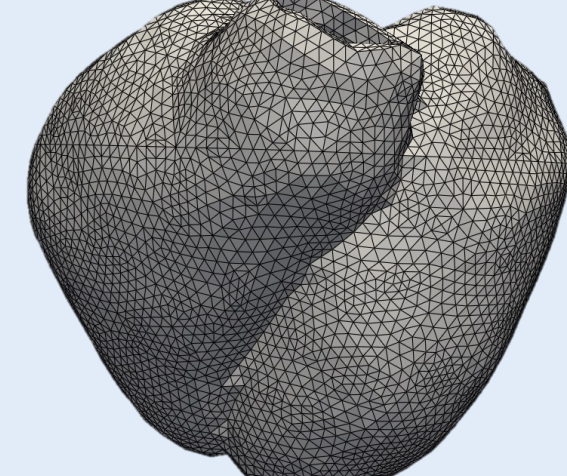
#### Patient data<sup>2</sup>



#### Segmentation<sup>3</sup>

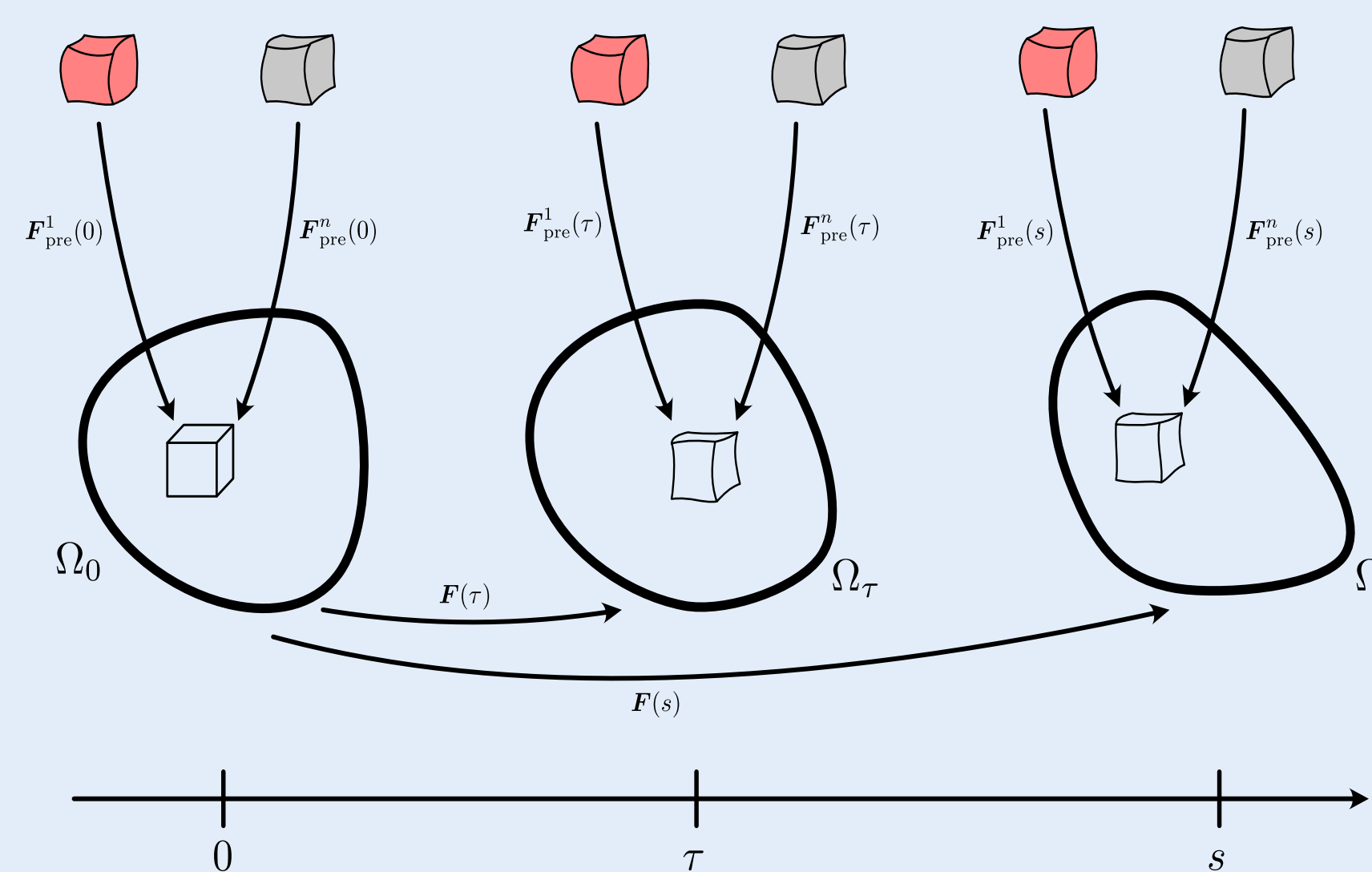


#### Meshing



### Constrained mixture model [1, 2]

- Mixture consists of **multiple structurally relevant constituents** that are **chemically cross linked**
- Constituents do **turnover** (continuous deposition and degradation of mass)



#### Mass production

$$\dot{\rho}_0^i = \rho_0^i \left[ \frac{1}{T^i} + k_{\sigma}^i \frac{\sigma^i - \sigma_h^i}{\sigma_h^i} \right]$$

#### Mass degradation

$$\dot{q}_{-}^{i,\tau} = \frac{q_{-}^{i,\tau}}{T^i}$$

### Constituents:

#### Collagen fibers

- 4 fiber families
- Quasi 1D-fibers
- Fung type strain energy function [3]

#### Cardiomyocytes

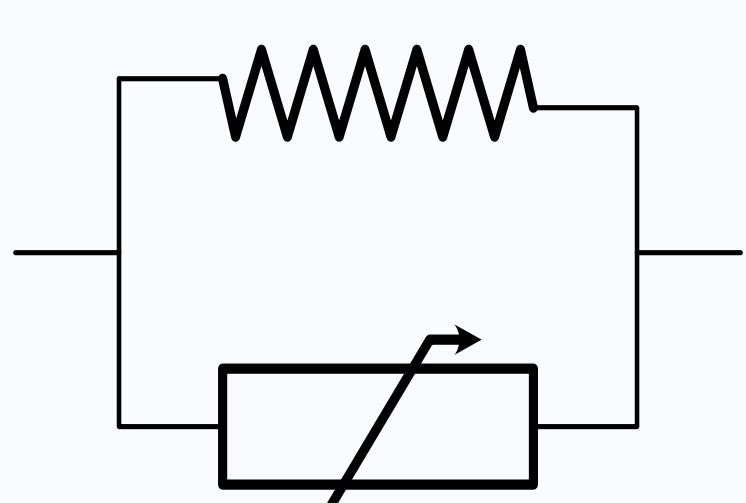
- Quasi 1D-fiber
- Stress response determined by Sarcomere model

#### Elastin matrix

- No deposition of functional elastin
- No degradation or damage

### Sarcomere model

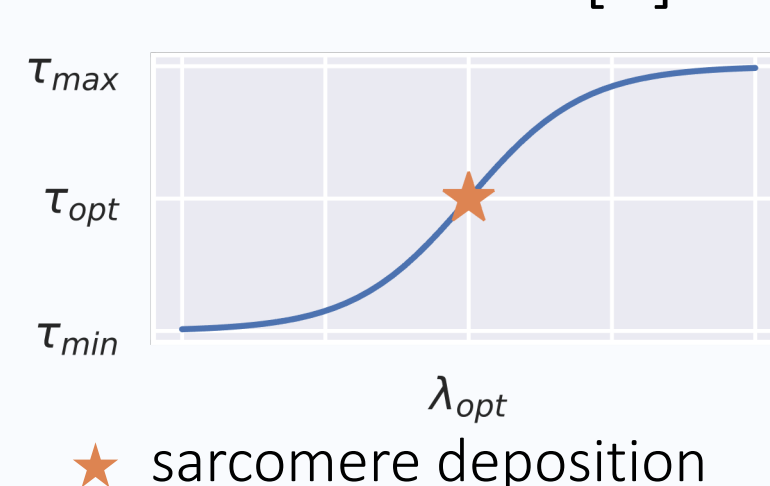
#### Rheological model



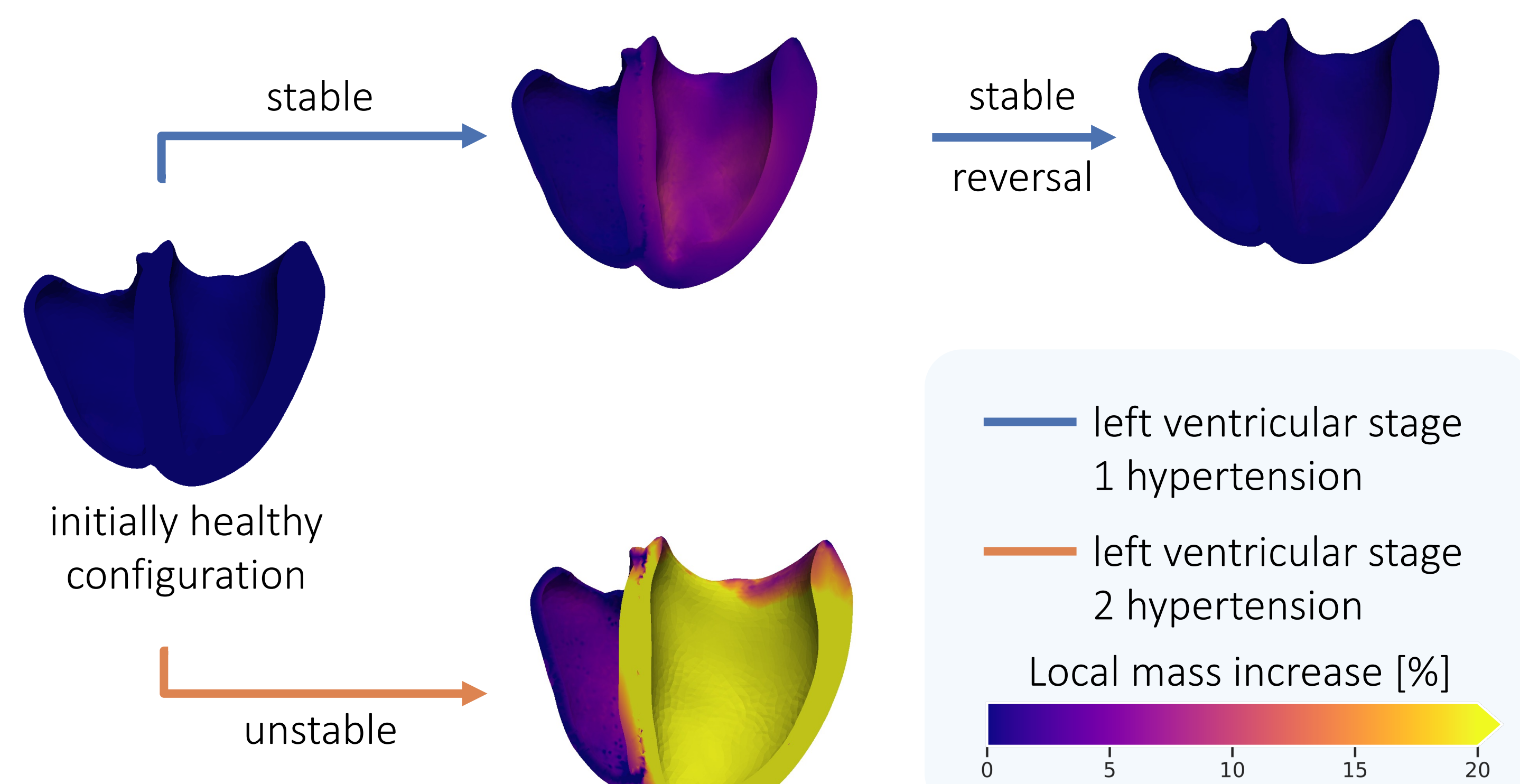
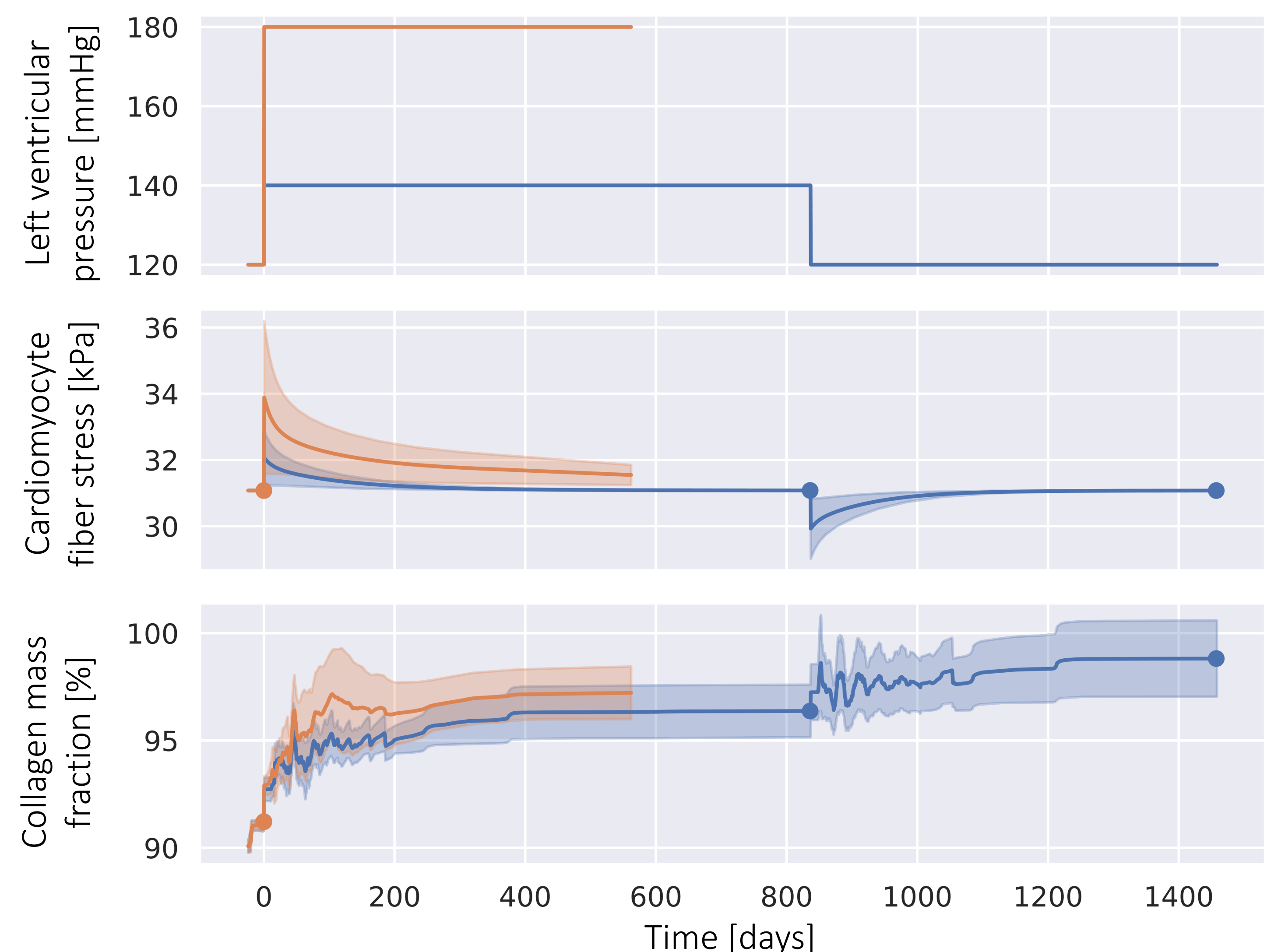
#### Elastic response

- Fung type strain energy function [3]
- Homeostatic prestretch

#### Stretch dependent active stress [4]



## Results



## Ongoing and future work

### What can cardiomyocytes sense?

To incorporate the interconnection between collagen strands and individual cardiomyocytes, we investigate coupled growth stimuli, i.e. cardiomyocytes can not only sense their current stress, but also the stress of the extracellular matrix.

### Experimental validation

Experimental data from biomimetic cultures of living myocardium [5] will be used to verify our model on tissue patch scale and long-term magnetic resonance imaging data of patients for the organ-scale.

## References

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<sup>1</sup> Ultrasound images by Carolin Sonne, German Heart Center, Germany

<sup>2</sup> MRI courtesy by R. Chabiniok, J. Harmer, E. Sammut, King's College London, UK

<sup>3</sup> Segmentation by Florian Holzberger, Technical University of Munich, Germany

## Partners and Financiers



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