



# An Integrated Experimental-Computational Approach for Multiscale Investigations of Atrioventricular Heart Valves With Applications to Individual-Optimized Surgery Planning

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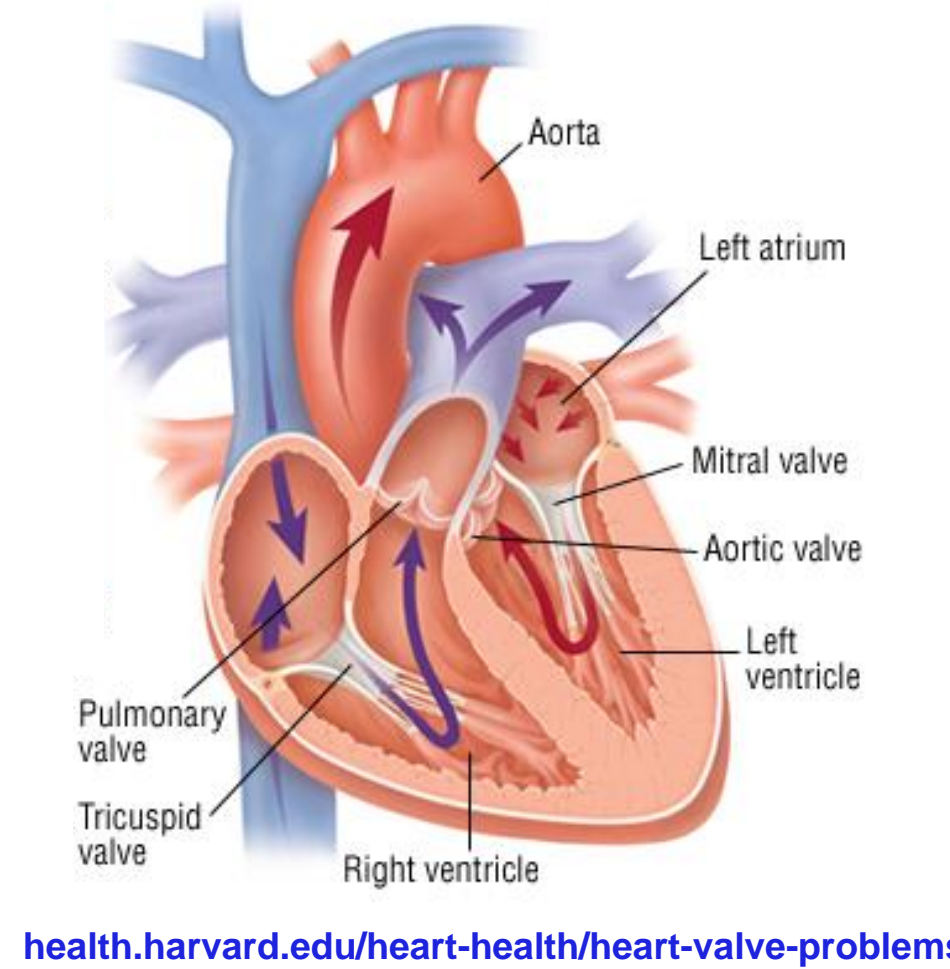


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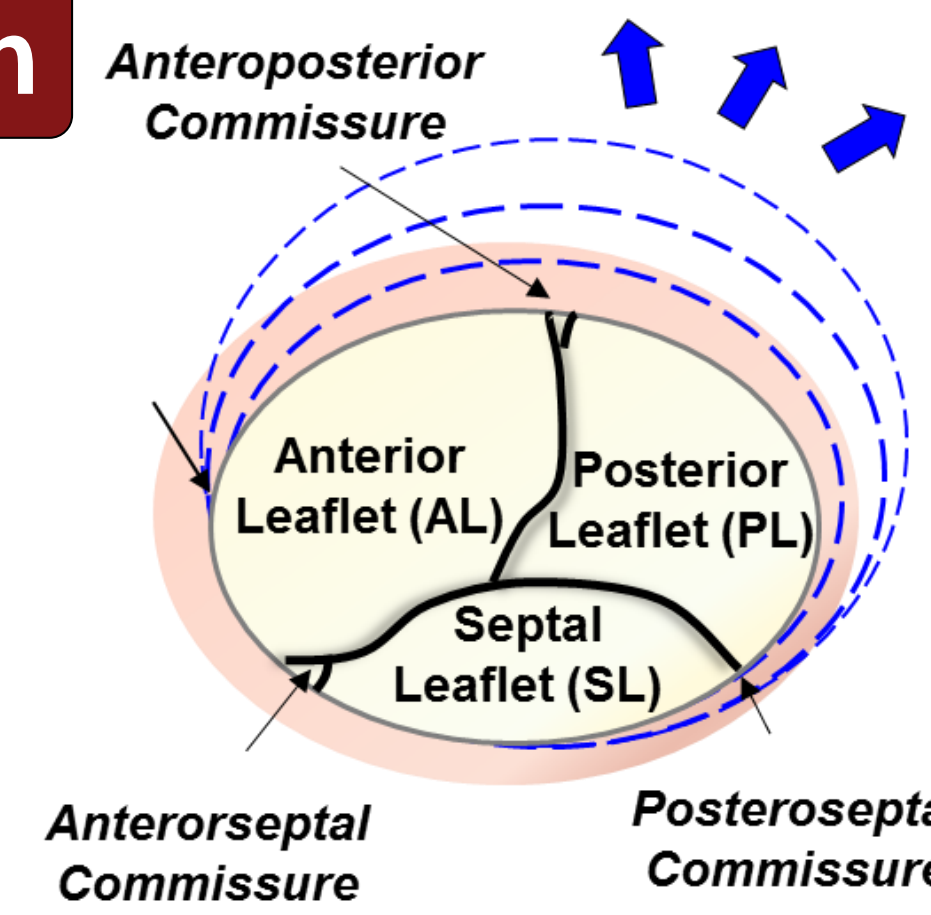
## Heart Valves and Their Function

- Four heart valves are located in the heart to regulate unidirectional blood flow.
- Fully leaflet closure is critical to ensure the heart is not overworked, causing further damage.



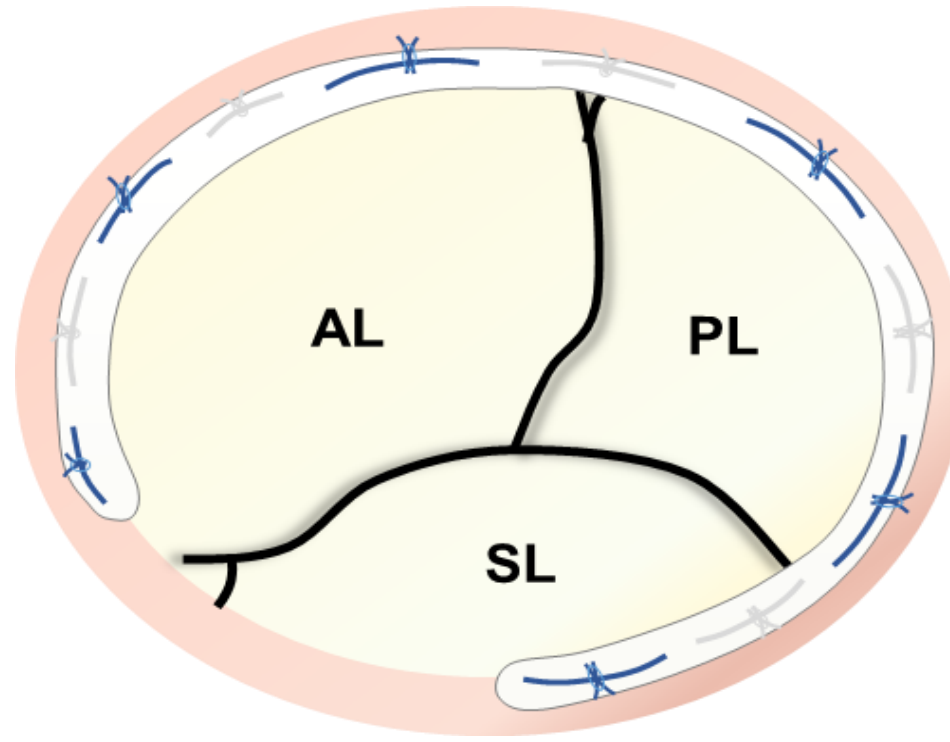
## Valvular Heart Disease – Regurgitation

- Inability of leaflet closure deteriorates the heart function for preventing the corresponding backflow.
- Heart valve regurgitation is a compounding complication, with symptoms oftentimes lowering the quality of life.



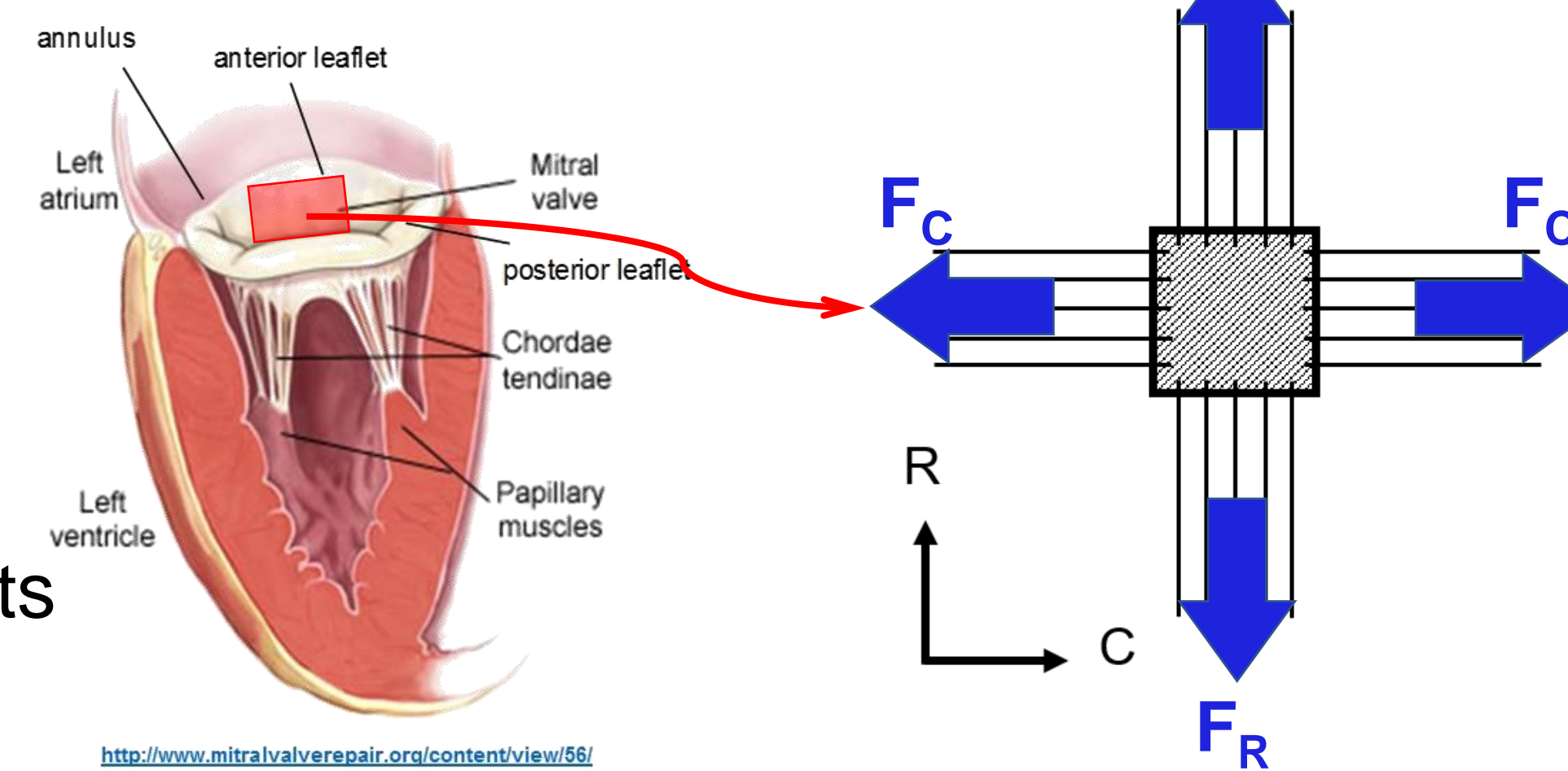
## Surgical Repair for Heart Valve Regurgitation

- Surgical installation of an annuloplasty ring around the valve leaflets restores the original shape and proper leaflet closure.
- **Recurrence rate approaches 15%-20% 3-5 years after initial surgical repair.**<sup>[1-3]</sup>



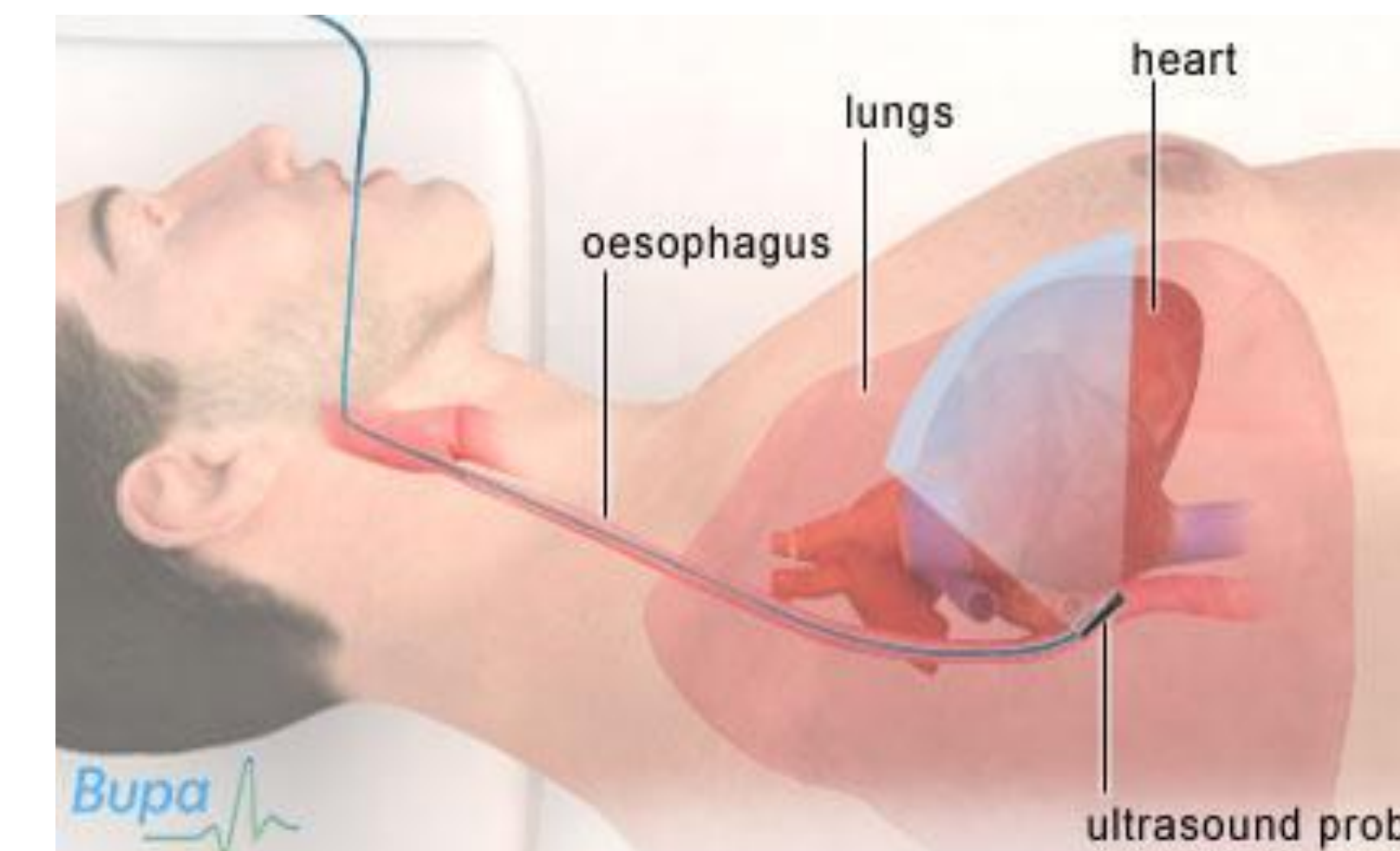
## Characterization of Biomechanical Properties of Heart Valve Leaflets

- Accurate computational models demand extensive characterization of the biomechanical properties of the heart valve leaflet tissues.
- The intricate microstructure of the leaflets results in a complex mechanical response, which cannot be simply characterized by unidirectional testing.
- We can comprehensively capture this complex mechanical behavior of the leaflets by performing biaxial mechanical testing with simulated physiological loads.

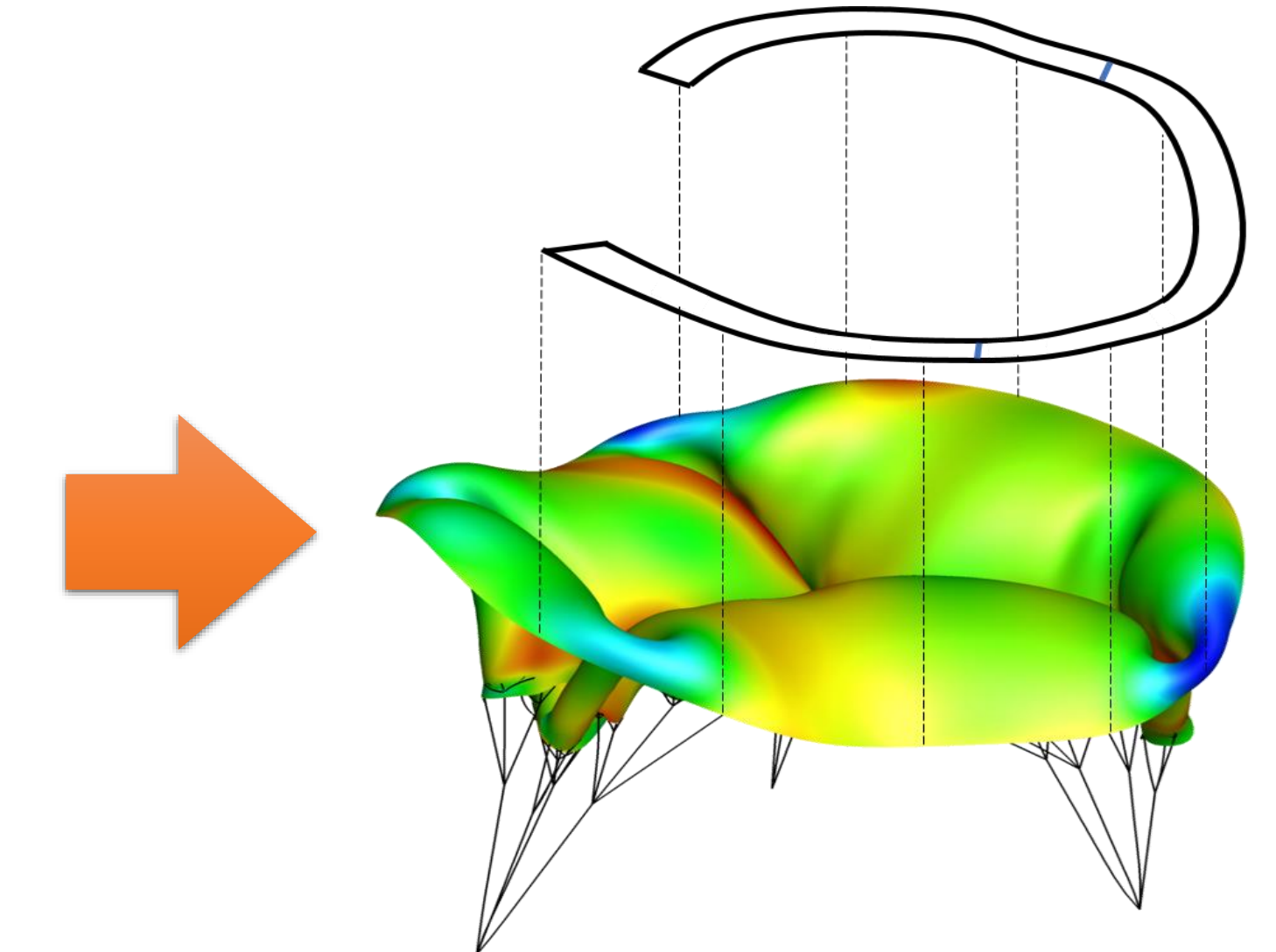


## Societal Impact: Patient-Specific Surgery Planning

- The developed computational model will be extended for investigations into patient-specific modelling of the heart valves.
- These investigations enable **patient-specific, simulation-informed**, pre-surgical recommendations to improve the durability of valve surgical repair.
- The increase in repair durability and longevity will significantly benefit the ~50,000 Americans who undergo treatment annually.



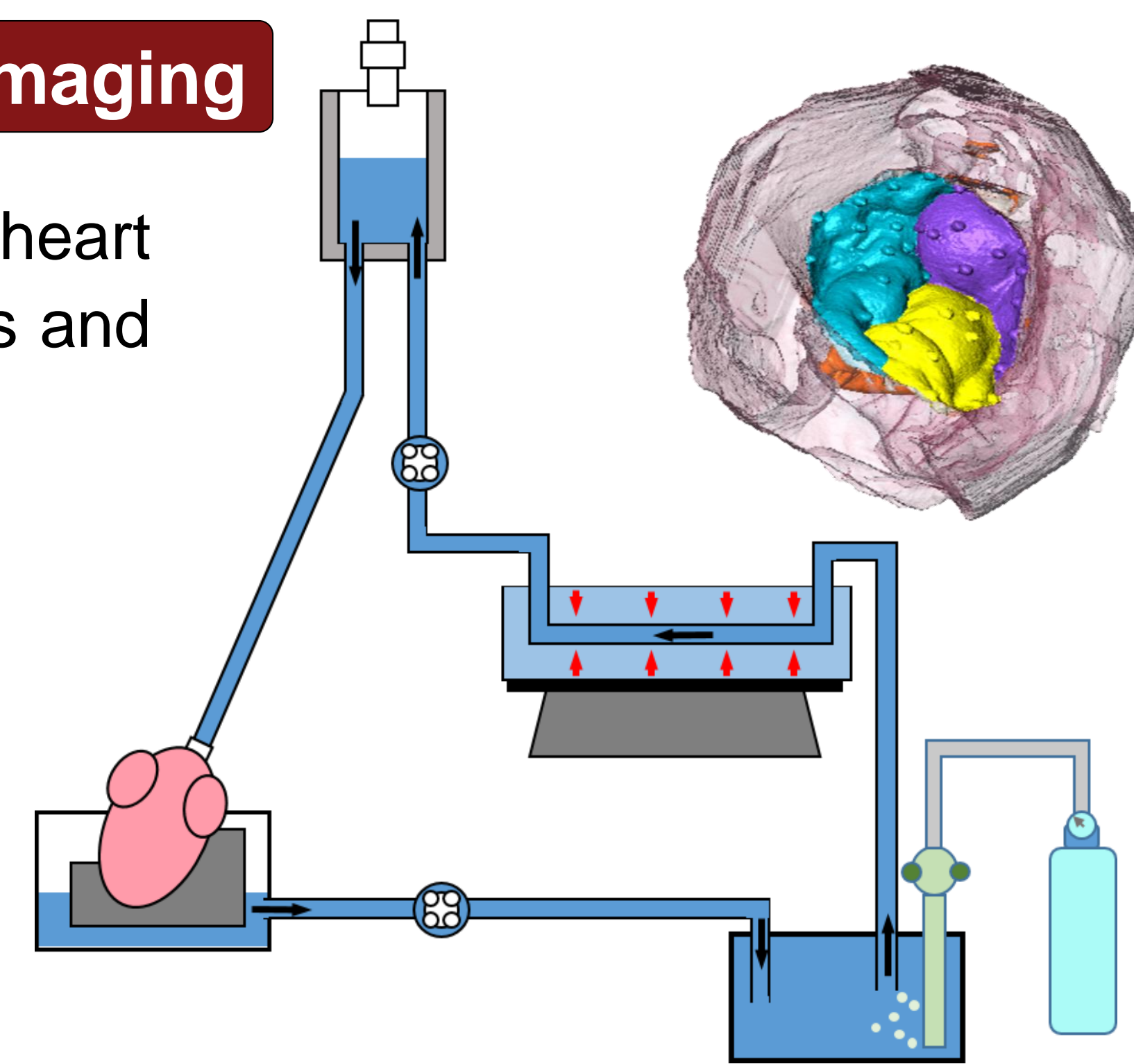
Echocardiograph Imaging of Heart Valves



Patient-Specific Annuloplasty Design

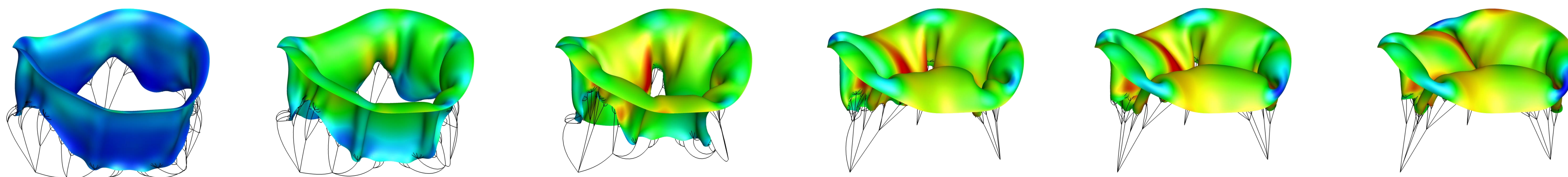
## Ex-Vivo Beating Heart Apparatus for Functional Cardiac MR Imaging

- The Langendorff beating heart model facilitates ex-vivo investigations into the heart function; however, it has typically been used in small animal studies, such as for rats and rabbits, but is not comparable to human anatomy.
- Imaging of living animals can obscure leaflet geometry and does not provide key modeling parameters such as ventricle pressure and heart temperature.
- Combining the previously developed Langendorff beating heart apparatus with high-resolution MR imaging for large animal hearts (e.g., pig or sheep), we can obtain high-fidelity valve geometries for more accurate modeling.



## Multiscale Computational Model for Patient-Specific Heart Valve Surgery Simulations

- 3D multiscale computational models will be developed using the previously acquired mechanical data and valve geometry.
- These developed computational models will provide insight into the effect of tissue-level modifications (annuloplasty repair or valve regurgitation) on the underlying microstructure and overall organ function.
- Furthermore, the developed multiscale model will elucidate mechanisms behind regurgitation initiation and progression.



## Acknowledgments

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## References

- [1] Condado, et al., *Journal of Interventional Cardiology*, 16(6):523-534, 2003.
- [2] Flameng, et al., *Circulation*, 107(12):1609-1613, 2003.
- [3] Taramasso, et al., *European Heart Journal*, 38(9):639-647, 2016.