Modeling the Effects of Increased Glucose Concentration on Intraocular Pressure

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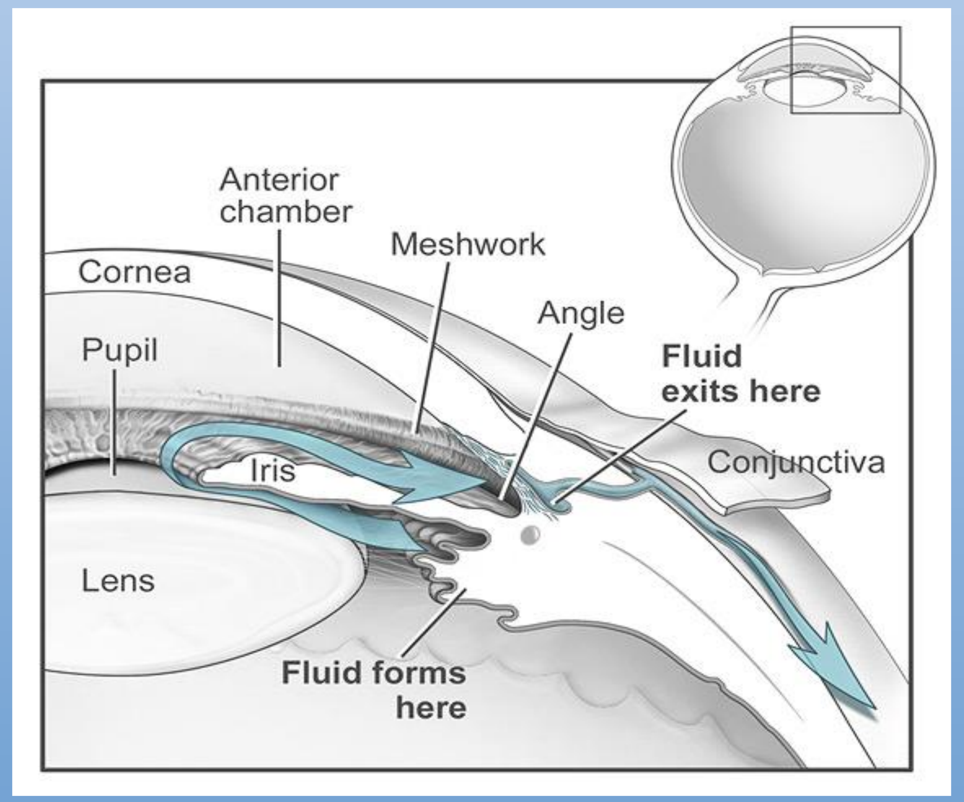
Overview

- Glucoma: 2nd leading cause of blindness worldwide and in the U.S.
- Open-Angle Glaucoma: most common amongst various types of glaucoma
- Risk Factor: high Intraocular Pressure (IOP), which is regulated by flow of aqueous humor in anterior chamber
- Strong correlation between those with diabetes and developing glaucoma
- Fibronectin production
  - -> glucose
  - -> IOP



http://www.lef.org/protocols/images/glaucoma_02-big.jpg

Objective

1. Model IOP under different glucose concentrations in aqueous humor using simulation software
2. Develop parallel code to solve equations which produces results comparable to commercial software

Methods

Modified Navier-Stokes equation (consider buoyancy):

$$\rho\bar{v}\cdot\nabla\bar{v} = -\nabla p + \mu\nabla^2\bar{v} + \rho_0\bar{g}\beta\left(T - T_{ref}\right)$$

Continuity of AH for steady and incompressible flow:

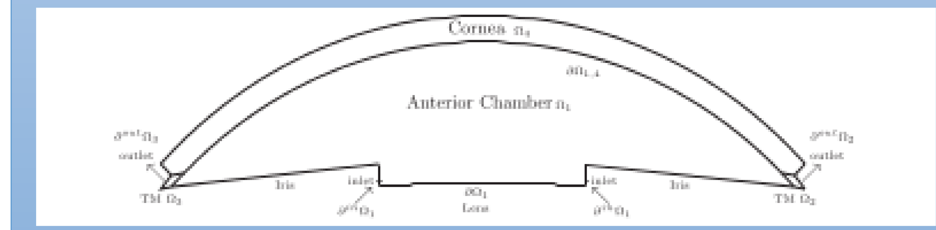
$$\nabla\cdot\bar{v} = 0$$

Convective and diffusive transport of energy:

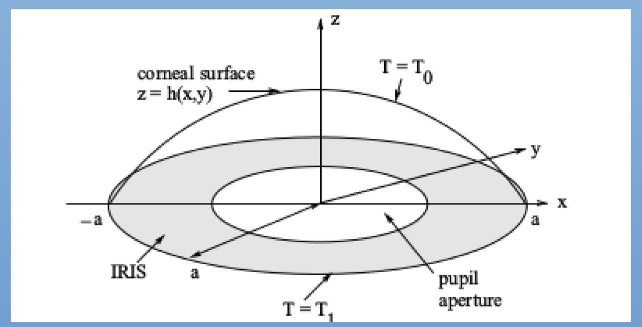
$$\rho C_p\bar{v}\cdot\nabla T = k\nabla^2 T$$

Permeability of trabecular meshwork and Schlemm's canal

$$\alpha = \frac{\mu}{\Delta p}\Delta e\bar{v} - f(g_c)$$



2D model of the human eye. (J.A. Ferreria et. al. ,2014)



Fitt and Gonzalez (2006)

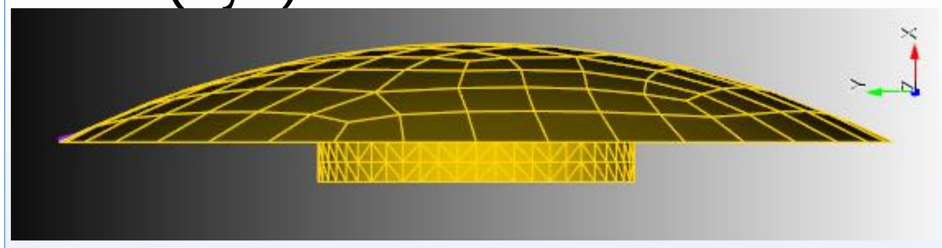
Tools

Hardware:
- Star1 (serial)
- Darter (parallel)

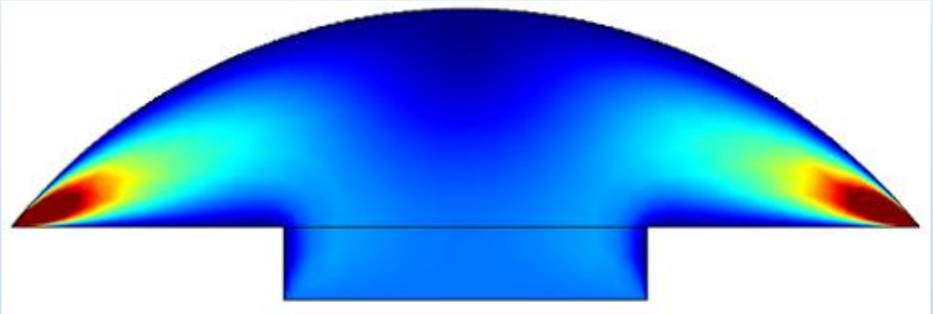
Software:
- FEATool
- Deal.II – FEM software library
- Cubit – mesh generator
- Comsol Multiphysics Tool

Results

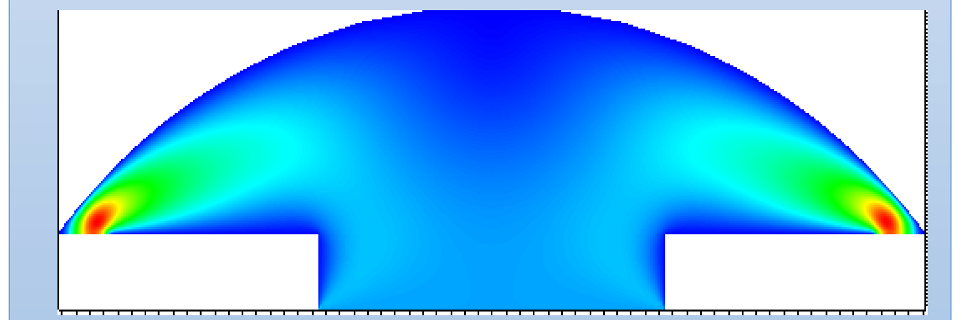
Mesh (eye): Cubit



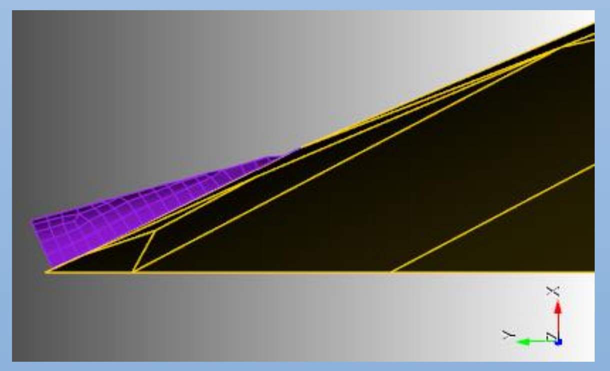
Velocity: Comsol



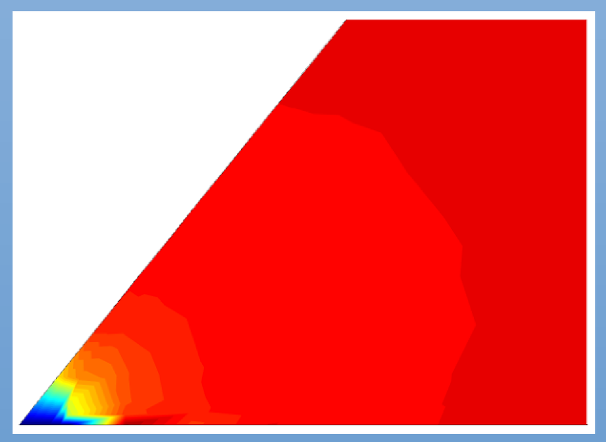
Velocity: Deal.II



Mesh (schlemm's canal): Cubit



Pressure: Comsol



Analysis

The results obtained from COMSOL are consistent with the results from Ferreira et al., which does not include the buoyancy factor. The consistency allow us to further expand our model into more complicated ones. The 2-D Navier-Stokes example found in the Deal.II package was modified to fit our mesh and conditions. These results are consistent with the COMSOL output.

Future Work

Future simulations will include the buoyancy factor and create a more complex structure of the eye to make the model/results more realisitic. Parallel code using Trilinos packages is currently being developed in order to solve the Laplace equation. Once this is completed, the code will be expanded to fit our model.

References

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