GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 1999

Bioengineering
EXAM AREA

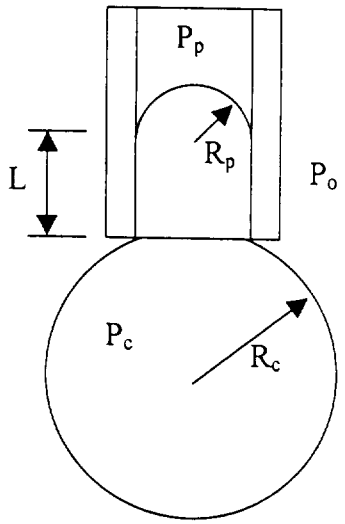
Assigned Number (DO NOT SIGN YOUR NAME)

- Please sign your name on the back of this page—

1999 Fall PhD Qualifying Exam

1. Cellular Biomechanics

In Cellular Biomechanics, we reviewed two broad models for deriving mechanical data from micropipet experiments. In both models, the micropipet was assumed to be very small relative to the cell size. If the micropipet size is not small compared to the cell size, we need to resort to a modified model. The figure to the right presents a schematic of a cell in a micropipet experiment, with labels for pressures (P) and geometry. P_o is the pressure of the extracellular fluid, P_c is the pressure in the cell, P_p is the pressure in the pipet. R_p is the radius of the pipet, L is the aspirated length of the cell minus R_p, and R_c is the radius of the cell. Use this figure to answer the following questions.



A. Develop a relationship between the internal cell pressure, the extracellular fluid pressure, and the tension in the cell membrane (a line tension: e.g. Newton/m). Be sure to include whatever force balances and diagrams are necessary for me to follow your reasoning.

B. Since it is difficult to measure the internal pressure in the cell during this experiment, please develop a relationship between the pipet pressure, the extracellular pressure, and the membrane tension. Be sure to include whatever force balances and diagrams are necessary for me to follow your reasoning.

C. What assumptions were necessary in order to develop the relationship in parts A and B? What relationship between the membrane and the cytoplasm was assumed?

D. Briefly describe why the size of the pipet relative to the cell would necessitate such a drastic change in models.

E. Describe how cell membrane properties might be determined from this type of experiment (in which the pipet size is not negligible with respect to the cell diameter).

1999 Fall PhD Qualifying Exam

2. Biofluid Mechanics

A. Identify the primary locations of atherosclerosis leading to arterial stenoses.

B. The normal superficial femoral artery has a diameter of 8 mm with a flow rate of 60 ml/min. Assume the kinematic viscosity of blood in larger vessels is 0.04 cm^2/s.

i. What types of analytical solutions are suitable for describing the flows in this artery?

ii. What are values for the important non-dimensional parameters for this flow?

C. If there is an 80% diameter stenosis in the SFA with an equivalent flow rate, what would the values for the non-dimensional parameters become?

D. Describe the changes in flow you would expect from the stenosis.

E. Diseased arteries may suddenly thrombose causing acute ischemia. Assume platelet adhesion is proportional to shear stress and coagulation is inversely proportional to shear stress.

Provide a hypothesis as to the hemodynamic mechanism of acute thrombosis and ischemia.

3. What are the primary functions of articular cartilage?

A. Briefly describe the compressive material properties of articular cartilage and the methods employed to quantify these properties.

B. How does articular cartilage composition and microstructure relate to its function and mechanical properties?

c. Utilize the simplified model shown below to assess whether or not the layer of articular cartilage in diarthroidal joints likely serves as a shock absorber during impact loading. What assumptions are made by this model. How would the parameters in your analysis change for a joint load applied at a very slow rate? Would this alter your conclusion about shock absorption?

F...Uniformly distributed joint load
AC...Articular cartilage
TB...Trabecular Bone
CB...Cortical Bone

Elastic Moduli (E):
- Cartilage: E
- Trab. Bone: 2E
- Cort. Bone: 200E

Cross-Sectional Areas (A):
- Cartilage: 4A
- Trab. Bone: 4A
- Cort. Bone: A