GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2000

Bioengineering
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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

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The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

Bioengineering Written Qualifying Exam, Spring 2000

Question #1

Blood flow in the adult human cardiovascular system is complicated.

Hemodynamics must consider many factors such as particulate fluid with non-Newtonian viscosity, three-dimensionality, unsteadiness, secondary flow behavior, and branching.

I. Describe the most prominent fluid mechanic factors that must be included in the analysis of the following flow situations.

II. Describe which factors may be assumed to be small and eliminated in a first order analysis.

III. Provide an estimate of the Reynolds numbers and Womersley parameters for these flow situations.
   A. Capillary flow
   B. Superior vena cava flow
   C. Carotid bifurcation flow
   D. Superficial femoral artery flow

Question #2

I. Draw typical stress-strain curves for compressive failure tests of cortical and trabecular bone (6 mm^3 samples). Compare and contrast cortical and trabecular bone in terms of structure, function, composition, and mechanical properties.

II. Stereological principles are used to quantify parameters of trabecular bone microstructure and develop empirical structure-function relationships.

A. Describe how the three independent stereological parameters of trabecular bone microstructure are estimated. What factor(s) influence the accuracy of the estimates?
B. Which parameter is the best predictor of trabecular bone modulus and strength?
C. Can stereological parameters explain all the variation in trabecular bone mechanical properties? Why or Why not?

Question #3

The Buxbaum/Heidemann model of the elongation of the axon under axial tension assumes that the length of the axon is determined by the length of the microtubules in the axon. They further hypothesize that the growth rate of the microtubule (and hence the axon) is a balance between the compressive force on the microtubules and the energy necessary to add a tubulin dimer.

I. Describe the energy necessary to add a tubulin dimer to the microtubule, assuming a formation similar to Buxbaum and Heidemann (the compressive force is transferred to the microtubule via a protein 'cap'). Please be as detailed as possible and label (or define) all of your variables. Do not be so concerned about regurgitating the formulas as much as including all of the energy sources.

II. The model described above does not include the affects of the dynamic instability inherent in microtubules. Describe dynamic instability and postulate how it would manifest itself in a plot of growth rate versus axial tension on the axon. Please support your statements with descriptive text and sketch a rough plot of growth rate versus applied tension.

III. Buxbaum and Heidemann's model assumes that the axon can be structurally simplified to a parallel series of microtubules when it is under compression. Describe how other components of the cytoskeleton might contribute to the overall compressive stiffness and/or strength of the axon and include the mechanism(s) of action.

IV. Describe an experiment that could be accomplished with current technology that would determine whether the maximum growth rate (the maximum rate at which an axon will grow (and the corresponding tension) before it begins to thin and break) is limited by the availability of free tubulin dimers or whether it is limited by the rate at which tubulin dimers can be added to the microtubule. Be as specific as possible and explain your rationale.