Bioheat and Mass Transfer Educational Initiatives for ASME K-17 Committee

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Outline of Presentation

- Summary of submitted bioheat and mass transfer syllabi from K-17 members
- Survey of texts adopted or used for bioheat and mass transfer courses
- Discussion of repository for sample problems
Course Syllabi in Bioheat and Mass Transfer

• K-17 membership surveyed
• Syllabi received from 16 courses
  - Grad and undergrad levels
  - Various degrees of detail included
• Composite data forms a basis for taxonomy
  - Possible controversy over boundaries of the field
  - Textbooks can add further structure
• Opportunity to discuss challenges and opportunities
<table>
<thead>
<tr>
<th>Institution</th>
<th>Faculty</th>
<th>UG/Grd</th>
<th>Technical Content</th>
<th>Text</th>
<th>Prequisites</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berkeley</td>
<td>Rubinsky</td>
<td>Ugrad</td>
<td>modeling bioheat</td>
<td>notes</td>
<td>PDE, thermo, heat trans</td>
<td>warm-blooded organisms, freezing, unique systems</td>
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<tr>
<td>CCNY</td>
<td>Weinbaum</td>
<td>Ugrad</td>
<td>cell and tissue transport</td>
<td>notes</td>
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<td>fluid and molecular transport</td>
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<tr>
<td>Cornell</td>
<td>Datta</td>
<td>Ugrad</td>
<td>heat and mass fundamentals</td>
<td>Datta</td>
<td>fluid mech corequisite</td>
<td>course matches full text</td>
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<tr>
<td>Cornell</td>
<td>Datta</td>
<td>Grad</td>
<td>computer-aided engineering</td>
<td></td>
<td></td>
<td>simulation software package</td>
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<tr>
<td>Duke</td>
<td>Fan</td>
<td>Ugrad</td>
<td>biofluid and mass transport</td>
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<td>Illinois</td>
<td>Chato</td>
<td></td>
<td>bioheat and mass transfer</td>
<td>Chato</td>
<td></td>
<td>chapter in Gautherie text (Clinical Thermology)</td>
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<td>Tsukuba, JP</td>
<td>Ishiguro</td>
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<td>heat and energy in living systems</td>
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<td>LSU</td>
<td>Devireddy</td>
<td>Ugrad</td>
<td>bioheat, mass, momentum</td>
<td>Cny, Fnr</td>
<td>fluid mech, heat transfer</td>
<td>micro, macro transport; bioheat eqn</td>
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<tr>
<td>Michigan St</td>
<td>Wright</td>
<td>Ugrad</td>
<td>biothermal processes</td>
<td>notes</td>
<td>heat transfer corequisite</td>
<td>biokinetic processes; bioheat eqn</td>
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<td>Bischof</td>
<td>UG/G</td>
<td>bioheat and mass transfer</td>
<td>Diller</td>
<td></td>
<td>ch.in Adv Heat Trans</td>
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<tr>
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<td>UG/G</td>
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<td>notes</td>
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<td>heat, mass, momentum transport applications</td>
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<tr>
<td>N. Car. Char</td>
<td>Lee</td>
<td>Ugrad</td>
<td>transport, materials, imaging</td>
<td>notes</td>
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<td>Pearce</td>
<td>Grad</td>
<td>therapeutic heating modes</td>
<td>notes</td>
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<td>modes of energy deposition in tissue, injury processes</td>
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<td>Texas</td>
<td>Diller</td>
<td>Ugrad</td>
<td>bioheat, mass, momentum</td>
<td>Cny, Fnr</td>
<td>thermo</td>
<td>introduction to bio applications of transport</td>
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<td>Texas</td>
<td>Diller</td>
<td>Grad</td>
<td>bioheat transfer</td>
<td>Inc &amp; DW</td>
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<td>bioheat eqn; numerical methods; research app licns</td>
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<tr>
<td>Texas</td>
<td>Diller</td>
<td>Grad</td>
<td>network thermodynamics</td>
<td>KM&amp;R</td>
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<td>bond graphs analysis in multi-energy biodomains</td>
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</table>
Survey of texts adopted or used for bioheat and mass transfer courses

• There has always been a paucity of learning materials in bioheat and mass transfer

• I have personally not found a text satisfactory for teaching this material

• Many courses are taught from notes or from a text with extensive supplementary material

• The following is a list of books that I and others have used as content sources for teaching bioheat and mass transfer
Texts Adopted for BHMT Courses

- 1998, Ronald Fournier
  - rfourni@uoft02.utoledo.edu
- Solute transport
- Oxygen transport
- Blood flow
- Pharmacokinetic analysis
- Extracorporeal devices
- Tissue engineering
- Bioartificial organs
Texts Adopted for BHMT Courses

- Ashim K. Datta
  - Cornell Univ.
  - akd1@cornell.edu
- 2002, Marcel Dekker
- ISBN: 0824707753
Texts Adopted for BHMT Courses

- 1976, Marcel Dekker
- Out of print
- Introductory treatment
- Homework and example problems
- Solutions manual
- Was essentially the only available book for two decades
- Many students find this text frustrating to learn from
Texts Adopted for BHMT Courses

• 2000, CRC Press
• ISBN: 0-8493-9581-X
• *Bioheat Transfer* chapter by Diller, Valvano, Pearce
• 64 pp.
• 2 appendices by Ken Holmes – compilation of thermal conductivities and blood perfusion for many tissues and organs
Texts Adopted for BHMT Courses

- 1988, McGrath & Diller
- ASME Press edited volume
- 20 chapters
  - Basic applications
  - Engineering contributions
- Entire focus is low temperature bioheat transfer
Texts Adopted for BHMT Courses

- 1995, Plenum Press
- Edited monograph
- 26 chapters – 7 thermal
- Overview; Conduction eq.
- Time constant approximation
- Thermal properties & perfusion
- Temperature measurements
- Photothermal radiometry
- Rate processes & thermal damage
Texts Adopted for BHMT Courses

- 1968; ASME WAM papers
- John Chato - Editor
- Eight papers
- Chato – original “k” & “α” measurement analysis
- Cooper & Trezek – initial cryosurgery analysis
- Fanger et al. – human thermal comfort analysis
- Guy et al. – therapeutic electromagnetic heating
Texts Adopted for BHMT Courses

- 1996, edited volume by UC Berkeley faculty
- Oxford Univ. Press
- One bioheat chapter by Boris Rubinsky, 24 pp.
- Broad but brief coverage of topics
- 17 unsolved problems
Texts Adopted for BHMT Courses

- 1985, Plenum Press
- ISBN: 0-306-41597-6 (v.1)
- ISBN: 0-306-41695-6 (v.2)
- 2 volume edited monograph
- 28 chapters
- 3 appendices
- Comprehensive coverage of subject at time of writing
Texts Adopted for BHMT Courses

- Fluid dynamics
- Thermodynamics
- Heat transfer
- Flow visualization
- Mass transfer
- Worked examples and homework problems
Texts Adopted for BHMT Courses

- 1972, Wiley
- Basic physiology
- Transport in blood vessels
- Transcapillary exchange
- Compartmental exchange
- Organ function
- Chemical interactions
- Monograph format
Texts Adopted for BHMT Courses

- 1974, Wiley
- Blood viscosity
- Rheology
- Microvascular flow
- Heat and mass transfer effects
- Clinical applications
- Solved example problems
Texts Adopted for BHMT Courses

- 1974, Iowa State Press
- ISBN: 0-8138-0195-8
- 8 chapters
- Basic thermodynamics
- Cons. energy in closed and open biological systems.
- Cons. mass
- Fundamentals of heat and mass transfer
- Biological applications
- Worked examples
Texts Adopted for BHMT Courses

- 1986, Springer Verlag
- ISBN: 0-387-16370-0
- New version in the works
- Focus on bio-phenomena
- Thermodynamics
- Free & facilitated diffusion
- Active transport
- Membrane transport
- Gas transport
- No problems
Texts Adopted for BHMT Courses

• 1974, Wiley
• 12 Chapters
• Organized according to topics in momentum and mass transfer
• Worked example problems
• Homework problems, some with partial answers
Texts Adopted for BHMT Courses

- *Advances in Heat Transfer, 22, 1992*
- ISBN: 0-12-020022-8
- John Chato – History of Bioheat, pp. 1-18
- Cal Charny – Math Models, pp. 19-156
- Ken Diller – Bioheat Processes, pp. 157-358
Problem Repository

• Several issues to address
  - Whether to establish
  - Where and how it could be implemented and maintained
  - Security and limited access
  - Support costs

• Example problems – contributed by KRD
  - See handouts
  - Membrane transport
  - Viscometry
Concluding Thoughts

• Bioheat and mass transfer is being taught at a rapidly increasing number of institutions

• In many cases it is being offered in the context of a basic course in transport fundamentals, rather than as a special/advanced application of transport

• There is a long standing paucity of learning materials, especially those that treat bioheat transfer

• ASME provides the primary venue for organizing BHMT faculty for possible collaborative efforts