Math 563 - 201: Mathematical models in cell biology: Schedule

Last modified: April 9, 2020

As of Mar 16, lectures will take place online due to Corona avoidance.

Lecture Notes (LN) are made available to students in the course. Assignments will be based (at least partly) on problem sets in the Lecture Notes.

A list of papers with background information will be provided in this table. References are on the last page.

Important Note: There are now two tracks for the homework assignments. Students in Math, Physics, Engineering, etc are expected to do the"Math HW". Students in cell biology or those who have little math are expected to complete only the "Bio HW" in the table below.

Week	Topic	Readings	Computations	Math HW	Bio HW	Comments
1: Jan 6-10	Intro, sizes, speeds, cell motion, Correlated random walks	[1, 2, 3] LN -1	Install Morpheus, Gnuplot, try out examples	HW1A: 1.3-1.5	HW1A: 1.1-1.4	try various Qs in LN1
2: Jan 13- 17	Dynamical systems, phase plane, Famous ODEs; Actin cytoskeleton, length and size distributions	[4] LN-2, LN-3	Run Morpheus on ODEs, decipher simple xml files	HW1B: 2.3, 2.4 2.5(a)	HW1B:2.1, 2.5(a) or 2.6, 2.10	Do other Qs for practice. **HW1AB due Jan 17, 5pm**
3: Jan 20-24	CPM, Hamiltonians, energy and forces – Intro; Comparison with other cell simulation types	[5], LN4	Run CPM simulations, single cells, pairs and larger cell groups; cell sorting	HW2A: 1.10, 3.2, 3.5, 3.7, 3.12	HW2A: 1.8, 3.1, 3.8, 3.10 or 3.12	
4: Jan 27-31	Polymerization ratchet, Cell shape: CRW actin branching (Grimm), the deBoer Act A model, Cell motility	[6, 7, 8], LN5, LN6	Run Act A model, cell division (simple multi-scale models)	HW2B 4.1, 4.3, 4.11, 4.15	HW2B 4.1, 4.7, 4.13, 4.15	**HW2AB due Jan 31, 5pm**
5: Feb 3-7	Morpheus Tutorial by Dresden group: Thurs Feb 6, no lecture on Monday			HW3A: 5.3, 5.4, 5.6, 6.7, 6.8	HW3A: 5.1, 5.2, 5.7, 5.8, 6.11, 6.12	
6: Feb 10-14	Reaction-diffusion equations, Morphogens	LN7, LN8	Morphogen gradients in Morpheus, Pattern formation in Morpheus - PDEs	HW 3B: 6.14, 7.3, 7.4, 7.5	HW 3B: 6.14, 7.1(a,c), 7.2, 7.5	**HW3AB due Feb19 (!!), 5pm NEW DATE!!**
Feb 18-21	Midterm Break					

Week	Topic	Readings	Computations	Math HW	Bio HW	Comments
7: Feb 24-28	More on diffusion, reaction; chemotaxis	LN8, LN9	Building up RD and chemotaxis in the Morpheus GUI from scratch	HW 4: Read and present LN9	HW 4: Read and present LN9	Due: in class on Mar 2; please submit slides or notes
8: Mar 2-6	Chemotaxis: from one cell to many; Intro to nonlocal models	LN9, [9]	Chemotaxis Simulations	HW5a: 8.2,8.3, 8.10	HW5a: 8.10, 8.11	"Project Pitch" due in class Mar 9
9: Mar 9-16	Finish Chemotaxis, Intro to Cell signaling and GTPases	LN9, LN10				HW5a-due Mar-13; Seminar: Ruuth Mar 11
10: Mar 16-20	Models for GTPase signaling, Wave-pinning (WP), Traveling waves	LN11, [10]	1D, 2D and irregular domains, NeighborhoodReporter	HW6a: 11.4(c), 11.8, 11.9, 11.12, 11.15	HW6a: 11.5, 11.8, 11.9, 11.11, 11.15	Class via Canvas Collaborate Ultra
11: Mar 23-27	Traveling waves, LPA, polarity models, Negative feedback and cycles, actin waves, mechanochemical models		Multiscale CPM models; Cells secreting attractant, cell division, death	HW6b: Takeaway list, Chapters 7-11	HW6b: Takeaway list, Chapters 7-11	Class via Canvas Collaborate Ultra; HW6 due Mar 27
12: Mar 30- Apr 3	From local to nonlocal models, Agent-Based models, Morse potentials	[11]	Morpheus agent-based simulations			Class via Canvas Collaborate Ultra
13: Apr 6-8 :	MT motors, QSS, and Fokker-Plank eqn Scaling and deciphering molecular assembly of MT (Flyvbjerg)	[12, 13]		Not HW: Takeaways from other chapters	Not HW: Takeaways from other chapters	Last day of classes: Apr 8 Pls submit Takeaways by May 1
Apr 10- 13	Easter Break					UBC closed
Apr 14- 24	Student Projects					Presented via Canvas Final project material due: Apr 27

Date	Time	Team members	Project title
Monday April 20	1:30- 2:00	Beth	
	2:05 - 2:35	Naba	
	2:45 - 3:15	Madi and Delbert	
	3:20 - 3:50	Katie and Priye	
Monday April 27	1:30 - 2:00	Nicola	
	2:05 - 2:35	Laura	
	2:45 - 3:15	Tiam	
	3:20 - 3:50	Jenny and Fatemeh	

Table 1: Schedule for student project presentations

References

[1] Segel LA. Computing an organism. Proceedings of the National Academy of Sciences. 2001;98(7):3639–3640.

[2] Starruß, Jörn and de Back, Walter and Brusch, Lutz and Deutsch, Andreas. Morpheus: a user-friendly modeling environment for multiscale and multicellular systems biology. Bioinformatics. 2014;30(9):1331–1332.

[3] Purcell EM. Life at low Reynolds number. American journal of physics. 1977;45(1):3–11.

[4] Topp B, Promislow K, Devries G, Miura RM, T FINEGOOD D. A model of β-cell mass, insulin, and glucose kinetics: pathways to diabetes. Journal of theoretical biology. 2000;206(4):605–619.

[5] Magno R, Grieneisen VA, Marée AF. The biophysical nature of cells: potential cell behaviours revealed by analytical and computational studies of cell surface mechanics. BMC biophysics. 2015;8(1):8.

[6] Peskin CS, Odell GM, Oster GF. Cellular motions and thermal fluctuations: the Brownian ratchet. Biophysical journal. 1993;65(1):316–324.

[7] Grimm H, Verkhovsky A, Mogilner A, Meister JJ. Analysis of actin dynamics at the leading edge of crawling cells: implications for the shape of keratocyte lamellipodia. European Biophysics Journal. 2003;32(6):563–577.

[8] Niculescu I, Textor J, De Boer RJ. Crawling and gliding: a computational model for shape-driven cell migration. PLoS computational biology. 2015;11(10):e1004280.

[9] Keller EF, Segel LA. Initiation of slime mold aggregation viewed as an instability. Journal of theoretical biology. 1970;26(3):399–415.

[10] Mori Y, Jilkine A, Edelstein-Keshet L. Wave-pinning and cell polarity from a bistable reaction-diffusion system. Biophys J. 2008;94(9):3684–3697.

[11] Carrillo JA, Colombi A, Scianna M. Adhesion and volume constraints via nonlocal interactions determine cell organisation and migration profiles. Journal of theoretical biology. 2018;445:75–91.

[12] Bressloff PC, Newby JM. Stochastic models of intracellular transport. Reviews of Modern Physics. 2013;85(1):135.

[13] Flyvbjerg H, Jobs E, Leibler S. Kinetics of self-assembling microtubules: an" inverse problem" in biochemistry. Proceedings of the National Academy of Sciences. 1996;93(12):5975–5979.