References

1. T. Cavalier-Smith. The origin of cells: a symbiosis between genes, catalysts, and membranes. *Cold Spring Harb Symp Quant Biol*, 52:805–824, 1987.
2. B. Hille. *Ion Channels of Excitable Membranes*. Sinauer Associates, Sunderland, MA, 2001.
3. J. Prebble. Peter mitchell and the ox phos wars. *Trends Biochem Sci*, 27:209–212, 2002.
4. Y. A. Hannun and L. M. Obeid. Principles of bioactive lipid signalling: lessons from sphingolipids. *Nat Rev Mol Cell Biol*, 9:139–150, 2008.
5. M. J. Berridge. Inositol trisphosphate and calcium signalling mechanisms. *Biochim Biophys Acta*, 1793:933–940, 2009.
6. B. Alberts, D. Bray, J. Lewis, M. Raff, K. Roberts, and J. D. Watson. *Molecular Biology of the Cell*. Garland Publishing,Inc., New York, 1994.
7. C. Bernsdorff, A. Wolf, R. Winter, and E. Gratton. Effect of hydrostatic pressure on water penetration and rotational dynamics in phospholipid-cholesterol bilayers. *Biophys J*, 72:1264–1277, 1997.
8. Y. Liu and J. F. Nagle. Diffuse scattering provides material parameters and electron density profiles of biomembranes. *Phys Rev E Stat Nonlin Soft Matter Phys*, 69, 2004.
9. H. J. Risselada and H. Grubmuller. How snare molecules mediate membrane fusion: recent insights from molecular simulations. *Curr Opin Struct Bio*, 22:187–196, 2012.
10. D. E. Chandler and J. E. Heuser. Arrest of membrane fusion events in mast cells by quick-freezing. *J Cell Biol*, 86:666–674, 1980.
11. R. L. Ornberg and T. S. Reese. Beginning of exocytosis captured by rapid-freezing of limulus amebocytes. *J Cell Biol*, 90:44–54, 1981.
12. L. V. Chernomordik, V. A. Frolov, E. Leikina, P. Bronk, and J. Zimmerberg. The pathway of membrane fusion catalyzed by influenza hemagglutinin: restriction of lipids, hemifusion, and lipidic fusion pore formation. *J Cell Biol*, 140:1369–1382, 1998.
13. C. G. Giraudo, C. Hu, D. You, A. M. Slovic, E. V. Mosharov, D. Sulzer, T. J. Melia, and J. E. Rothman. Snares can promote complete fusion and hemifusion as alternative outcomes. *J Cell Biol*, 170:249–260, 2005.
14. G. W. Kemble, T. Danieli, and J. M. White. Lipid-anchored influenza hemagglutinin promotes hemifusion, not complete fusion. *Cell*, 76:383–391, 1994.
15. X. Lu, F. Zhang, J. A. McNew, and Y. K. Shin. Membrane fusion induced by neuronal snares transits through hemifusion. *J Biol Chem*, 280:30538–30541, 2005.
16. S. Martens, M. M. Kozlov, and H. T. McMahon. How synaptotagmin promotes membrane fusion. *J Biol Chem*, 316:1205–1208, 2007.
17. G. B. Melikyan, J. M. White, and F. S. Cohen. Gpi-anchored influenza hemagglutinin induces hemifusion to both red blood cell and planar bilayer membranes. *J Cell Biol*, 131:679–691, 1995.

18. S. Qian and H. W. Huang. A novel phase of compressed bilayers that models the prestalk transition state of membrane fusion. *Biophys J*, 102:48–55, 2012.

19. L. Yang and H. W. Huang. Observation of a membrane fusion intermediate structure. *Science*, 297:1877–1879, 2002.

20. Y. Kozlovsky, L. V. Chernomordik, and M. M. Kozlov. Lipid intermediates in membrane fusion: formation, structure, and decay of hemifusion diaphragm. *Biophys J*, 83:2634–2651, 2002.

21. Y. A. Chizmadzhev, P. I. Kuzmin, D. A. Kumenko, J. Zimmerberg, and F. S. Cohen. Dynamics of fusion pores connecting membranes of different tensions. *Biophys J*, 78:2241–2256, 2000.

22. M. B Jackson. Minimum membrane bending energies of fusion pores. *J Membr Biol*, 231: 101–115, 2009.

23. P. M. Kasson and V. S. Pande. Control of membrane fusion mechanism by lipid composition: predictions from ensemble molecular dynamics. *PLoS Comput Biol*, 3:e220, 2007.

24. V. Knecht and S. J. Marrink. Molecular dynamics simulations of lipid vesicle fusion in atomic detail. *Biophys J*, 92:4254–4261, 2007.

25. H. H. Tsai, W. X. Lai, H. D. Lin, J. B. Lee, W. F. Juang, and W. H. Tseng. Molecular dynamics simulation of cation-phospholipid clustering in phospholipid bilayers: Possible role in stalk formation during membrane fusion. *Biochim Biophys Acta*, 1818:2742–2755, 2012.

26. K. Katsov, M. Muller, and M. Schick. Field theoretic study of bilayer membrane fusion: Ii. mechanism of a stalk-hole complex. *Biophys J*, 90:915–926, 2006.

27. M. Muller and M. Schick. An alternate path for fusion and its exploration by field-theoretic means. *Curr Top Membr*, 68:295–323, 2011.

28. J. C. Shillcock and R. Lipowsky. The computational route from bilayer membranes to vesicle fusion. *J Phys Condens Matter*, 18:S1191–1219, 2006.

29. A. F. Smeijers, A. J. Markvoort, K. Pieterse, and P. A. Hilbers. A detailed look at vesicle fusion. *J Phys Chem B*, 110:13212–13219, 2006.

30. S. J. Cox and B. Farrell. Estimating the time course of pore expansion during the spike phase of exocytotic release in mast cells of the beige mouse. *Bulletin of Mathematical Biology*, 64 (5):979–1010, 2002.

31. A. Efrat, L. V. Chernomordik, and M. M. Kozlov. Point-like protrusion as a prestalk intermediate in membrane fusion pathway. *Biophys J*, 92:L61–63, 2007.

32. Y. Kozlovsky, A. Efrat, D. P. Siegel, and M. M. Kozlov. Stalk phase formation: effects of dehydration and saddle splay modulus. *Biophys J*, 87:2508–2521, 2004.

33. P. I. Kuzmin, J. Zimmerberg, Y. A. Chizmadzhev, and F. S. Cohen. A quantitative model for membrane fusion based on low-energy intermediates. *Proc Natl Acad Sci USA*, 98:7235–7240, 2001.

34. D. P. Siegel. The gaussian curvature elastic energy of intermediates in membrane fusion. *Biophys J*, 95:5200–5215, 2008.

35. R. S. Eisenberg. Multiple scales in the simulation of ion channels and proteins. *The Journal of Physical Chemistry C*, 114:20719–20733, 2010.

36. W. L. Ash, M. R. Zlomislic, E. O. Oloo, and D. P. Tieleman. Computer simulations of membrane proteins. *Biochim Biophys Acta.*, 1666(1-2):158–189, 2004.

37. I. Bahar, T. R. Lezon, A. Bakan, and I. H. Shrivastava. Normal mode analysis of biomolecular structures: Functional mechanisms of membrane proteins. *Chem Rev.*, 110(3):1463–1497, 2010.

38. R. O. Dror, R. M. Dirks, J. P. Grossman, H. Xu, and D. E. Shaw. Biomolecular simulation: a computational microscope for molecular biology. *Annu Rev Biophys*, 41:429–452, 2012.

39. M. Stevens, J. Hoh, and T. Woolf. Insights into the molecular mechanism of membrane fusion from simulation: Evidence for the association of splayed tails. *Physical Review Letters*, 91 (18):188102, 2003.

40. R. Delgado-Buscalioni, K. Kremer, and M. Praprotnik. Coupling atomistic and continuum hydrodynamics through a mesoscopic model: application to liquid water. *J Chem Phys*, 131: 244107, 2009.

41. L. V. Chernomordik and M. M. Kozlov. Mechanics of membrane fusion. *Nat Struct Mol Biol*, 15:675–683, 2008.

42. V. S. Markin, M. M. Kozlov, and V. L. Borovjagin. On the theory of membrane fusion. the stalk mechanism. *Gen Physiol Biophys*, 3:361–377, 1984.

43. L. V. Chernomordik and J. Zimmerberg. Bending membranes to the task: structural intermediates in bilayer fusion. *Curr Opin Struct Biol*, 5:541–547, 1995.

44. R. J. Ryham, I. Berezovik, and F. S. Cohen. Aqueous viscosity is the primary source of friction in lipidic pore dynamics. *Biophys J*, 101(12), 2011.

45. Q. Du, C. Liu, R. Ryham, and X. Wang. Energetic variational approaches in modeling vesicle and fluid interactions. *Physica D.*, 238(9-10), 2009.

46. J. Shen and X. Yang. A phase-field model and its numerical approximation for two-phase incompressible flows with different densities and viscositites. *SIAM J. Sci. Comput.*, 32(3): 1159–1179, 2010.

47. S. Osher and R. Fedkiw. *The Level Set Method and Dynamic Implicit Surfaces*. Springer-Verlag, New York, NY, 2002.

48. R. Tsai and S. Osher. Level set methods and their applications in image science. *Commun. Math. Sci.*, 1(4):623–656, 2003.

49. J. Sethian. *Level Sets Methods and Fast Marching Methods*, volume 3 of *Cambridge Monograph on Applied and Computational Mathematics*. Cambridge University Press, Cambridge, U.K., 1986.

50. J. Sohn, Y.-H. Tseng, S. Li, A. Voigt, and J. Lowengrub. Dynamics of multicomponent vesicles in a viscous fluid. *Journal of Computational Physics*, 229(1):119–144, 2010.

51. P. M. Vlahovska, Y.-N. Young, G. Danker, and C. Misbah. Dynamics of a non-spherical microcapsule with incompressible interface in shear flow. *J. Fluid Mechanics*, 678:221–247, 2011.

52. A. Fogelson and R. Guy. Immersed-boundary-typed models of intravascular platelet aggregation. *Computer Methods in Applied Mechanics and Engineering*, 197:2087–2104, 2008.

53. J. S. Lowengrub, J.-J. Xu, and A. Voigt. Surface phase separation and flow in a simple model of multicomponent. *Fluid Dynamics and Materials Processing*, 3(1):1–19, 2007.

54. C. Peskin. The immersed boundary method. *Acta Numerica*, 11:479–517, 2002.

55. L. A. Miller. Fluid dynamics of ventricular filling in the embryonic heart. *Cell Biochem. Biophys.*, 61(1):33–45, 2011.

56. G. Guidoboni, R. Glowinski, and M. Pasquali. Operator splitting for the numerical solution of free surface flow at low capillary numbers. *J. Comput. Appl. Math.*, 232(1):72–81, 2009.

57. M. Pasquali and L. E. Scriven. Free surface flows of polymer solutions with models based on conformation tensor. *J. Non-Newtonian Fluid Mech.*, 108:363–409, 2002.

58. J. R. Vélez-Corderoa, D. S'amanoa, P. Yue, J. J. Feng, and R. Zenit. Hydrodynamic interaction between a pair of bubbles ascending in shear-thinning inelastic fluids. *J. Non-Newtonian Fluid Mech*, 166:118–132, 2011.

59. E. de Giorgi. *Some remarks on Γ-convergence and least squares methods*, volume 5 of *Progress in Nonlinear Differential Equations and their Applications*. Birkhäuser, 1991.

60. Q. Du, C. Liu, and X. Wang. A phase field approach in the numerical study of the elastic bending energy for vesicle membranes. *Journal of Computational Physics*, 198:450–468, 2004.

61. M. Röger and R. Schätzle. On a modified conjecture of degiorgi. *Mathematische Zeitschrift*, 254:675–714, 2006.

62. P. G. de Gennes and J. Prost. *The Physics of Liquid Crystals*. Clarendon Press, Oxford, U.K., 1993.

63. F.-H. Lin and C. Liu. Nonparabolic dissipative systems modeling the flow of liquid crystals. *Communications in Pure and Applied Mathematics*, XLVIII:1–37, 1995.

64. Q. Shen, C. Liu, and M. C. Calderer. Axisymmetric configurations of bipolar liquid crystal droplets. *Contin. Mech. Thermodyn.*, 14(4):363–375, 2002.

65. C. Liu and J. Shen. On liquid crystal flows with free-slip boundary conditions. *Discrete and Continuous Dynamic Systems*, 7(2):307–318, 2001.

66. C. Liu and N. Walkington. Approximation of liquid crystal flows. *SIAM J. Numer. Anal.*, 7(3): 725–741, 2000.

67. X. Yang, J. Feng, C. Liu, and J. Shen. Numerical simulations of jet pinching-off and drop formation using an energetic variational phase-field method. *J. Comput. Phys.*, 218:417–428, 2006.

68. X.-P. Wang, T. Qian, and P. Sheng. Moving contact line on chemically patterned surfaces. *Journal of Fluid Mechanics*, 605:59–78, 2008.

69. Y. Kozlovsky and M. M. Kozlov. Stalk model of membrane fusion: Solution of energy crisis. *Biophys J*, 82, 2002.

70. V. S. Markin and J. P. Albanesi. Membrane fusion: stalk model revisited. *Biophys J*, 82: 693–712, 2002.

71. W. E, W. Ren, and E. Vanden-Eijnden. String method for the study of rare events. *PHYSICAL REVIEW B*, 66:052301, 2002.

72. W. E, W. Ren, and E. Vanden-Eijnden. Energy landscape and thermally activated switching of submicron-sized ferromagnetic elements. *J. Appl. Phys.*, 93:2275–2282, 2003.

73. W. E, W. Ren, and E. Vanden-Eijnden. Minimum action method for the study of rare events. *Comm. Pure Appl. Math.*, 57(5):637–656, 2004.

74. R. Hardt, D. Kinderlehrer, and F.-H. Lin. Existence and partial regularity of static liquid crystal configurations. *Commun. Math. Phys.*, 105:547–570, 1986.

75. L. Simon. Existence of surfaces minimizing the willmore functional. *Comm. Anal. Geom.*, 1 (2):281–326, 1993.

76. T. J. Willmore. *Riemannian geometry*. Oxford Science Publications, The Clarendon Press Oxford University Press, New York, 1993.

77. W. E, W. Ren, and E. Vanden-Eijnden. Simplified and improved string method for computing the minimum energy paths in barrier-crossing events. *J Chem Phys*, 2007.

78. Q. Du, C. Liu, and X. Wang. Simulating the deformation of vesicle membranes under elastic bending energy in three dimensions. *J. Computational Phys.*, 212(2):757–777, 2005.

79. Q. Du, M. Li, and C. Liu. Analysis of a phase field navier-stokes vesicle-fluid interaction model. *DCDS B*, 8(3):539–556, 2007.

80. J. Kim and J. S. Lowengrub. Phase field modeling and simulation of three-phase flows. *Interfaces and Free Boundaries*, 7(4):435–466, 2005.

81. X. Wang and Q. Du. Modeling and simulations of multi-component lipid membranes and open membranes via diffuse interface approaches. *J. Math. Biol.*, 56(3):347–371, 2008.

82. Q. Du, C. Liu, and X. Wang. Retrieving topological information for phase field models. *SIAM J. Appl. Math.*, 65(6):1913–1932, 2005.

83. Q. Du, C. Liu, R. Ryham, and X. Wang. Diffuse interface approximations for capturing the euler number: Relaxation and renormalization. *Comm. Math. Sci*, 7:233–242, 2007.

84. S. Gemmrich and N. Nigam. *A boundary integral strategy for the Laplace-Beltrami Dirichlet problem on the sphere S^2*. Frontiers of Applied and Computational Mathematics. World Scientific, 2008.

85. M. M. Kozlov, S. Leikin, and R. P. Rand. Bending, hydration and interstitial energies quantitatively account for the hexagonal-lamellar-hexagonal reentrant phase transition in dioleoylphosphatidylethanolamine. *Biophys J*, 67:1603–1611, 1994.

86. S. Brenner and R. Scott. *The Mathematical Theory of Finite Element Methods*, volume 15 of *Texts in Applies Mathematics*. Springer, New York, 2002.

87. D. Edwards, H. Brenner, and D. T. Wasan. *Interfacial Transport Processes and Rheology*. Butterworth-Heinemann, Boston, 1991.

88. D. E. Chandler. Interfaces and the driving force of hydrophobic assembly. *Nature*, 437:640–647, 2005.

89. S. Leikin, V. A. Parsegian, D. C. Rau, and R. P. Rand. Hydration forces. *Annu Rev Phys Chem*, 44:369–395, 1993.

90. H. Goldstein. *Classical Mechanics*. Addison-Wesley Publishing Company, Reading, MA., 1950.

91. B. V. Deryaguin and A. V. Prokhorov. On the thoeory of the rupture of black films. *J. Colloid Interfac Sci*, 81:108–115, 1981.

92. F. Brochard, P. G. de Gennes, and O. Sandre. Transient pores in stretched vesicles: role of leakout. *Physica A*, 278(1-2):32–51, 2000.

93. T. Portet and R. Dimova. A new method for measuring edge tension and stability of lipid bilayers: Effect of membrane composition. *Biophys J*, 99:3264–3273, 2010.

94. E. Karatekin, O. Sandre, H. Guitouni, N. Borghi, P. H. Puech, and F. Brochard-Wyart. Cascades of transient pores in giant vesicles: Line tension and transport. *Biophys J*, 84, 2003.

95. N. Rodriguez, S. Cribier, and F. Pincet. Transition from long- to short-lived transient pores in giant vesicles in an aqueous medium. *Phys Rev E Stat Nonlin Soft Matter Physi*, 74:061902, 2006.

96. M. A. Bahri, B. J. Heyne, P. Hans, A. E. Seret, A. A. Mouithys-Mickalad, and M. D. Hoebeke. Quantification of lipid bilayer effective microviscosity and fluidity effect induced by propofol. *Biophys Chem*, 114:53–61, 2005.

97. R. J. Ryham, F. S. Cohen, and R. S. Eisenberg. A dynamic model of open vesicles in fluids. *Communications in Mathematical Sciences*, 10(4):1273–1285, 2012.