Lulu Qian

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Research Interests

I am interested in engineering molecular systems with intelligent behaviors – at the basic level, such as recognizing molecular events from the environment, processing information, making decisions and taking actions; at the advanced level, such as learning and evolving – to explore the principles of molecular programs that nature creates, to embed control within biochemical systems that directly interact with molecules, and eventually, to re-create artificial molecular programs that approach the complexity and sophistication of life itself.

For each molecular system that I engineer, my research will encompass three directions: (1) As a theorist, I will develop an abstraction and a systematic construction for designing molecules, study the computational power of the system, and characterize the system with modeling and simulations. (2) As an experimentalist, I will demonstrate the theoretical approach by building examples of the designed system in the lab, examine the engineering principles with feedback from the experimental results, and improve the implementation based on what we learn from the data. (3) As a programmer, I will write software to automatically translate arbitrary examples in the system at the function level to DNA implementations at the sequence level, thus providing tools for other researchers to apply my approach to other applications.

Education and Academic Positions

Visiting Fellow at the Wyss Institute — Host: *Peng Yin*
Harvard Medical School, Boston, USA — February, 2012 – present

Senior Postdoctoral Scholar in Bioengineering — Advisor: *Jehoshua Bruck*
California Institute of Technology, Pasadena, USA — January, 2011 – present

Postdoctoral Scholar in Bioengineering — Advisors: *Erik Winfree and Jehoshua Bruck*
California Institute of Technology, Pasadena, USA — January, 2008 – December, 2010

Ph.D. in Biochemistry and Molecular Biology — Advisor: *Lin He*
Shanghai Jiao Tong University, Shanghai, China — September, 2004 – November, 2007
Thesis: Molecular computing and nanotechnology based on DNA self-assembly

B.Eng. in Biomedical Engineering
Southeast University, Nanjing, China — September, 1998 – June, 2002

Refereed Publications (* co-first authors)

1. L. Qian, E. Winfree, and J. Bruck. Neural network computation with DNA strand displacement cascades. ***Nature***, 475:368-372, 2011.
   News and Views: "DNA and the brain" by Anne Condon, *Nature*, 475:304-305.
   Media coverage: msnbc News, CBS News, Discovery News, CNET News, Daily Mail, The Hindu, International Business Times, Science Daily, Science 2.0, etc.
2. L. Qian and E. Winfree. Scaling up digital circuit computation with DNA strand displacement cascades. ***Science***, 332:1196-1201, 2011.
   Perspective: "Scaling up DNA computation" by John Reif, *Science*, 332:1156-1167. News and Views: "DNA computes a square root" by Yaakov Benenson, *Nature Nanotechnology*, 6:465-467.
   Media coverage: BBC News, Los Angeles Times, Nature News, Discovery News, Popular Science, Popular Mechanics, New Scientist, Science News, PC World, etc.
3. L. Qian and E. Winfree. A simple DNA gate motif for synthesizing large-scale circuits. ***Journal of the Royal Society Interface***, 8:1281-1297, 2011. Conference version appeared in A. Goel, F. C. Simmel and P. Sosik, editors, ***DNA Computing and Molecular Programming***, LNCS, volume 5347, pages 70-89, Springer, 2009.
4. L. Qian, D. Soloveichik, and E. Winfree. Efficient Turing-universal computation with DNA polymers. In Y. Sakakibara and Y. Mi, editors, ***DNA Computing and Molecular Programming***, LNCS, volume 6518, pages 123-140, Springer, 2011.
5. Z. Zhang, Y. Wang, C. Fan, C. Li, Y. Li, L. Qian, Y. Fu, Y. Shi, J. Hu, and L. He. Asymmetric DNA origami for spatially addressable and index-free solution-phase DNA chips. ***Advanced Materials***, 22:2672-2675, 2010.
6. L. Qian*, J. Zhao*, Y. Shi, X. Zhao, G. Feng, F. Xu, S. Zhu, and L. He. Brain-derived neurotrophic factor and risk of schizophrenia: an association study and meta-analysis. ***Biochemical and biophysical research communications***, 353:738-743, 2007.
7. J. Zhao*, L. Qian*, Q. Liu, Z. Zhang, and L. He. DNA addition using linear self-assembly. ***Chinese Science Bulletin***, 52:1462-1467, 2007.
8. L. Qian, Y. Wang, Z. Zhang, J. Zhao, D. Pan, Y. Zhang, Q. Liu, C. Fan, J. Hu, and L. He. Analogic China map constructed by DNA. ***Chinese Science Bulletin***, 51:2973-2976, 2006.
9. J. Xie, Y. Bai, L. Qian, L. Cui, X. Sun, and Z. Lu. A computer simulation system of DNA-binding protein experiment based on dsDNA microarray. ***Acta Biophysica Sinica***, 19:156-160, 2003.

Total citation: 220 (Google Scholar)

Manuscripts in Preparation

1. L. Qian, D. Soloveichik, and E. Winfree. Efficient Turing-universal computation with DNA polymers. Note: this will be a journal version of publication [4] that is invited for submission to ***Journal of the Royal Society Interface***.
2. L. Qian and E. Winfree. Debugging DNA strand displacement circuits: a detective story.
   Note: we discuss the pathways and methods for experimentally debugging DNA circuits that use strand displacement reactions as an underlying mechanism. The spirit of this work is to always treat failed experiments as a detective story: never get bored when you are stuck with an inconceivable result, instead, have fun looking deeper into the mystery and exploring the clue behind it.

3. L. Qian, H. Chen, and E. Winfree. Asynchronous cellular automata implemented with spatially-organized DNA-based chemical reaction networks.
   Note: we propose a theoretical framework that uses DNA strand displacement cascades to implement chemical reaction networks on the surface of a DNA nanostructure and create programmable dynamic spatial behaviors similar to asynchronous cellular automata.
4. D. Wilhelm, L. Qian, and J. Bruck. Stochastic circuits in DNA.
   Note: this is experimental work that I supervised by graduate student Daniel Wilhelm.
5. T. Weiss, L. Qian, and E. Winfree. Using DNA circuits to detect and amplify non-nucleic-acid signals.
   Note: this is experimental work that I supervised by undergraduate student Talia Weiss.
6. Y. L. Lee, Z. Chen, S. Doroudi, G. Izatt, S. Wittman, D. Woods, N. Srinivas, L. Qian, and E. Winfree. DNA robots that sort molecular targets on a two-dimensional nanostructure.
   Note: this is experimental work that I supervised by a team of five undergraduate students as part of the BIOMOD competition (http://biomod.net/).

Academic Talks

1. University of Oxford, Physics (Oxford, UK, Jul 2011).
2. 3rd Molecular Programming Project Workshop (Friday Harbor, WA, Jun 2011).
3. International Conference on the Statistical Mechanics and Computation of DNA Self-Assembly (Mariehamn, Finland, May 2011).
4. 8th Conference on the Foundations of Nanoscience (Snowbird, UT, Apr 2011).
5. 9th International Conference on Unconventional Computation (Tokyo, Japan, Jun 2010).
6. 16th Conference on DNA Computing and Molecular Programming (Hong Kong, Jun 2010).
7. 7th Conference on the Foundations of Nanoscience (Snowbird, UT, Apr 2010).
8. Institute of Biological Engineering Annual Conference (Cambridge, MA, Mar 2010).
9. University of Minnesota, Electrical & Computer Engineering (Minneapolis, MN, Jan 2010).
10. 2nd Molecular Programming Project Workshop (Oxnard, CA, Jan 2010).
11. University of British Columbia, Computer Science (Vancouver, Canada, Dec 2009).
12. Boise State University, Materials Science & Engineering (Boise, ID, Sep 2009).
13. 15th Conference on DNA Computing and Molecular Programming (Fayetteville, AR, Jun 2009).
14. 6th Conference on the Foundations of Nanoscience (Snowbird, UT, Apr 2009).
15. National Center for Nanoscience and Technology (Beijing, China, Apr 2009).
16. 1st Molecular Programming Project Workshop (Oxnard, CA, Jan 2009).
17. University of Science and Technology of China, Chemistry (Hefei, China, Oct 2008).
18. Shanghai Jiao Tong University, Bio-X Center (Shanghai, China, Oct 2008).
19. 17th International Workshop on Logic & Synthesis (Lake Tahoe, CA, Jun 2008).

Supervised Students

1. Graduate student: Daniel Wilhelm (with Jehoshua Bruck).
2. Undergraduate students: Amy Proctor, Talia Weiss, Yae Lim Lee, Zibo Chen, Shayan Doroudi, Sarah Wittman, Gregory Izatt (with Erik Winfree).

Outreach

1. An online compiler that can automatically translate an arbitrary feedforward digital circuit into its equivalent DNA circuit. The compiler will generate the sequence of every DNA strand, and provide simulations to predict the circuit behavior. So anyone can design their own DNA circuit, order it by submitting the sequences to a biotech company such as Integrated DNA Technologies, and try it out in the lab.
   http://dna.caltech.edu/SeesawCompiler/
2. A YouTube video that provides a whimsical explanation of my research developing molecular systems that perform information processing tasks, aimed at a general audience such as scientists in other field, graduate and undergraduate students, and even smart high school kids.
   The seesaw magic book: the computational power of DNA molecules:
   http://www.youtube.com/watch?v=G2Ljgkh_v40
3. Another YouTube video that provides an animated explanation of my research building artificial neural networks out of interacting DNA molecules, for a general audience.
   Building a tiny "DNA brain":
   http://www.youtube.com/watch?v=N_VisNOKQMc (Part I: design)
   http://www.youtube.com/watch?v=fgGBZZYEm_Y (Part II: experiments)

Awards and Recognition

1. Burroughs Wellcome Fund Career Award at the Scientific Interface, 2012 – present
2. Southeast University Comprehensive Scholarship, 1999 – 2001
3. Exchange Student (top 7 students out of ~800) to Billanook College in Australia, 1996
4. Second Prize of National Programming Olympiad (senior high school), 1996
5. Second Prize of National Mathematics Olympiad (elementary school), 1992

Academic Service

1. Refereeing for *Nature*, *Angewandte Chemie*, *Chemical Science*, *Neural Computation*, *Acta Biophysica Sinica*.
2. Chairing the Thursday Poster Blitz Session at the 8th Conference on the Foundations of Nanoscience (Snowbird, UT, Apr 2011).