

# Lixue Cheng

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## EDUCATION

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### California Institute of Technology

Pasadena, CA

Ph.D. in Chemistry, with Prof. Tom Miller & Prof. Bill Goddard

Mar 2022

Thesis: Accurate and transferable molecular-orbital-based machine learning for molecular modeling [\[Link\]](#)

### University of Wisconsin-Madison

Madison, WI

Bachelor of Sciences in Honors, GPA: 3.933/4.0

May 2016

Majors: Chemistry (Honor), Mathematics (Honor), Biochemistry, Molecular Biology.

Minor (Certificate): Computer Sciences

## RESEARCH INTERESTS

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Apply computational and mathematical tools to improve the chemistry and biology study strategies.

### (1) AI for electronic structure

- Deep Quantum Monte Carlo (DeepQMC)
- Molecular-orbital-based machine learning (MOB-ML, Miller group, [Theme twitter thread](#))
- TransOrb (In preparation, with Goddard group)

### (2) AI for quantum algorithms

- Quantum computing for quantum chemistry
- Optimization algorithms for variational quantum algorithms

### (3) AI for biology

- Molecular computing and nucleic acid design (INSPIRE, Miller group)
- Bayesian optimization for experimental design (ODBO, Tencent Quantum Lab, [Repo](#))

### (4) AI for science Education

## RESEARCH AND TEACHING EXPERIENCES

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### Microsoft Research AI4Science Lab (Berlin)

June 2023–Present

*Researcher*

**AI for electronic structure & DeepQMC**

**Tencent Quantum Lab, Tencent**

July 2022–April 2023

*Research scientist*

- Developing AI tools for quantum computing, quantum chemistry and biology

**Miller Group, California Institute of Technology**

August 2017–Mar 2022

*PhD student*

**MOB-ML: Molecular Orbital-Based Machine Learning**

- Use the molecular orbital representations to predict the molecular energies via ML tools to give high accuracy as wave function theory method but a low computational cost as density functional theory method.
- Perform electronic structure calculations and quantum simulations for different molecular systems.
- Develop different supervised and unsupervised learning methodologies to model different molecular properties.
- Develop a ML module in open-source quantum chemistry software (*entos*) and build a MOB-ML database.

**TranOrb (migrated to Goddard group): Transferable Electronic Structure Learning via General Orbital Information**

**INSPIRE: Computational Parameterization of Nucleic Acid Secondary Structure Models**

- Combine ML tools with molecular dynamics (MD) to derive new thermodynamics and kinetics nucleic acid models with secondary structure information.
- Develop and revise ML algorithms that can improve the efficiency of the strategy.
- Perform MD simulations for different nucleic acid reaction systems as a source of data for ML model.

**Record Group, University of Wisconsin-Madison**

January 2013–July 2017

*Undergraduate researcher*

**Interpreting and predicting Hofmeister salt ion, polyol, PEG and sugar effects on biopolymer processes using solubility assay and solute-partitioning model**

- Design and lead projects using solubility experiments to measure different solutes-biomolecule interactions.
- Recruit and mentor other undergraduate students to collect solute–nucleobase thermodynamics data.
- Develop mathematical models and analyze the data to interpret functional group chemical interactions.
- Determine interaction constants between different bases and different solutes and apply them to predict and interpret solute-biopolymer interaction and drug solubility data.

**Math studies supervised by Qin Li, University of Wisconsin-Madison**

August 2015–May 2016

*Undergraduate researcher*

**Randomized Singular Value Decomposition algorithm for low rank matrices & its numerical applications**

- Reprove and improve the theorems in the literature as a mathematical exercise.
- Develop MATLAB codes to implement the algorithm studied in the literature and perform numerical tests.

- Compare and analyze the numerical test results and explain the mathematical origins in different cases.

**Grader/TA for Chem/Biochem 565/665 Biophysical Chemistry**

University of Wisconsin-Madison

2015 Fall & 2016 Fall

**Grader/TA for Math 341 Linear Algebra (Honor) and Math 561 Differential Geometry**

University of Wisconsin-Madison

2016 Spring

## VOLUNTEERING AND INTERNSHIP EXPERIENCES

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**Tencent Quantum Lab, Tencent**

July 2021–September 2021

*Research Intern*

- Work on the interface between machine learning and physical problems, including molecular modeling, drug design and material design.
- Develop, implement and test Bayesian learning algorithm in real world problems in the fields of biology, chemistry and material sciences.

**Department of Mathematics, University of Wisconsin–Madison**

*Administrative Office and Front Desk Student Help*

August 2015–May 2016

**Sonoco Products Co., 455 Science Drive, Madison, WI**

*Research Project Assistant*

September 2014–January 2015

- Measure geometries and properties of different materials and perform mathematical modeling of products.
- Analyzing data using various software, for example, Excel, Auto CAD, FEA.
- Develop test devices and search the literature to support our own research projects.

**Department of Chemistry and Mathematics, University of Wisconsin–Madison**

*Private Tutor*

August 2014–May 2017

**College Library, University of Wisconsin–Madison**

*Circulation Student Assistant*

August 2013–May 2015

**Greater University Tutoring Service (GUTS), University of Wisconsin–Madison**

*Academic Tutor (Chemistry and Mathematics)*

September 2012–August 2013

## PATENTS, PUBLICATIONS AND THESES

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### Post-Caltech work

- **Cheng, L.**; Yang, Z.; Liao, B.; Hsieh, C.; Zhang, S. ODBO: Bayesian Optimization with prescreening for directed protein evolution. arXiv:2205.09548 (2022). [\[Link\]](#)[\[Repo\]](#)
- Li, W.; Allcock, J.; **Cheng, L.**; Zhang, S.X.; Chen, Y.Q.; Mailoa, J.P.; Zhang, S. TenCirChem: An efficient quantum computational chemistry package for the NISQ era. arXiv:2303.10825 (2023). [\[Link\]](#)[\[Repo\]](#)
- **Cheng, L.**\*; Chen, Y.Q.\*; Zhang, S.X.; Zhang, S. Error-mitigated quantum approximate optimization via learning-based adaptive optimization. arXiv:2303.14877 (2023) (\*co-first author) [\[Link\]](#) [\[Repo\]](#)
- Sun, J.; **Cheng, L.**; Li, W. Towards chemical accuracy with shallow quantum circuits: A Clifford-based Hamiltonian engineering approach. arXiv:2306.12053 (2023).[\[Link\]](#)[\[Repo\]](#)
- **Cheng, L.** et al. Operator-based machine learning for molecular modelling (in preparation)

### Caltech work

- Patent: Miller III, T.F.; Welborn, M.; **Cheng, L.**; Husch, T.; Song, J.; Kovachiki, N.; Burov, D.; Teh, Y.S.; Anandkumar, A.; Ding, F.; Lee, S.J.R.; Qiao, Z.; Lale, A.S. Systems and methods for determining molecular structures with molecular-orbital-based features. U.S. Patent 16817489, 2020 [\[Link\]](#)
- **Cheng, L.**; Sun, J.; Deustua, J. E.; Bhethanabotla, V.C.; Miller III, T.F. Molecular-orbital-based machine learning for open-shell and multi-reference systems with kernel addition Gaussian process regression. arXiv:2207.08317 (2022). [\[Link\]](#)
- Sun, J.; **Cheng, L.**; Miller III, T. F. Molecular dipole moment learning via rotationally equivariant Gaussian process regression with derivatives in molecular-orbital-based machine learning. *J. Chem. Phys.*, (in press) **2022**. [\[Link\]](#)
- **Cheng, L.**; Sun, J.; Miller III, T.F. Accurate molecular-orbital-based machine learning energies via unsupervised clustering of chemical space. *J. Chem. Theory Comput.*, **2022**. [\[Link\]](#)
- Sun, J.; **Cheng, L.**; Miller III, T.F. Molecular energy learning using alternative blackbox matrix-matrix multiplication algorithm for exact Gaussian process. arXiv: 2109.09817 (2022). [\[Link\]](#).
- Lu, F.\*; **Cheng, L.**\*; DiRisio, R. J.\*; Finney, J. M.; Boyer, M. A.; Sun, J.; Lee, S. J. R.; Deustua, J. E.; Miller III, T. F.; McCoy, A. B. Fast near *ab initio* potential energy surfaces using machine learning. *J. Phys. Chem. A*, **2022**. (\*co-first author) [\[Link\]](#)
- Husch, T.; Sun, J.; **Cheng, L.**; Lee, S. J. R.; Miller III, T.F. Improved accuracy and transferability of molecular- orbital-based machine learning: Organics, transition-metal complexes, non-covalent interactions, and transition states. *J. Chem. Phys.*, **2021**. [\[Link\]](#)
- **Cheng, L.**; Kovachki, N.; Welborn, M.; Miller III, T. F. Regression clustering for improved accuracy and training costs with molecular-orbital-based machine learning. *J. Chem. Theory Comput.*, **2019**. [\[Link\]](#)
- **Cheng, L.**; Welborn, M.; Miller III, T. F. A universal density matrix functional from molecular orbital-based machine learning: Transferability across organic molecules. *J. Chem. Phys.*, **2019**. [\[Link\]](#)
- Welborn, M.; **Cheng, L.**; Miller III, T. F. Transferability in machine learning for electronic structure via the molecular orbital basis. *J. Chem. Theory Comput.* **2018**.[\[Link\]](#) (Highlighted with commentary in [C&EN](#) and [Caltech News](#))

### UW-Madison work

- Knowles, D. B.; Shkel, I. A.; Phan, N. M.; Sternke, M.; Lingeman, E.; Cheng, X.; **Cheng, L.**; O'Connor, K.; Record, M. T. Chemical interactions of polyethylene glycols (PEGs) and glycerol with protein functional groups: Applications to effects of PEG and glycerol on protein processes. *Biochemistry* **2015**, 54 (22), 3528–3542. [\[Link\]](#)
- Undergraduate Senior Honor Thesis for Chemistry with Prof. M. Thomas Record: *Interactions of polyols with aromatics and nucleobases: Large opposing contributions from interactions of nonpolar and polar groups*

- Undergraduate Senior Honor Thesis for Mathematics with Prof. Qin Li: *Randomized singular value decomposition (RSVD) algorithm for low rank matrices and its numerical applications*

## HONORS AND AWARDS

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- 2017 Caltech General Fellowship, Division of Chemistry and Chemical Engineering, Caltech
- 2016 Mary Ellen Rudin Foundation Scholarship Award, Department of Mathematics, UW-Madison
- 2015 David H. Durra Scholarship, College of Letters & Sciences, UW-Madison
- 2015 Eugene and Patricia Kreger Herscher Undergraduate Scholarship for the 2015–16 Academic Year, Department of Chemistry, UW-Madison
- 2015 Walter W. & Young-Ja C. Toy Summer Research Fellowship, Department of Chemistry, UW-Madison
- 2014 Biochemistry Undergraduate Summer Research Scholarship, Department of Biochemistry, UW-Madison
- 2014 Gerald W. and Tui G. Hedstrom Scholarship, College of Letters & Science, UW-Madison
- 2014 Martha Gunhild Weeks Undergraduate Scholarship for the 2014-15 Academic Year, Department of Chemistry, UW-Madison
- 2014 The Honor Society of Phi Kappa Phi Member, University of Wisconsin-Madison Chapter
- 2014 Trewartha Senior Thesis Grant, Letters & Science Honors Program, UW-Madison
- 2014 Wisconsin Hilldale Undergraduate/Faculty Research Fellowship, UW-Madison
- 2013 John & Elizabeth Moore Awards for Excellence, Department of Chemistry, UW-Madison: Excellence for Chem109 Advanced General Chemistry, 1/350