Jian Liu, Ph.D.
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SUMMARY

Dr. Jian Liu has been working with heparin for more than 20 years. His expertise is in structural characterization of heparin and heparan sulfate, biosynthetic mechanism of heparin and enzymatic synthesis of heparin. He has invented an enzyme-based method to prepare heparin and heparan sulfate from bacteria polysaccharides. His method could potentially manufacture heparin in a confined facility to improve the safety of heparin drug.

APPOINTMENT

2011-present	**Professor** (with tenure) of Chemical Biology and Medicinal Chemistry, Eshelman School of Pharmacy, University of North Carolina at Chapel Hill, NC
2006-2011	**Associate Professor** (with tenure) of Medicinal Chemistry and Natural Products, Eshelman School of Pharmacy, University of North Carolina at Chapel Hill, Chapel Hill, NC
2009-present	**Visiting Associate Professor**, Department of Chemistry and Chemical Biology, Rensselaer Polytechnic Institute, Troy, NY
2000-2006	**Assistant Professor** of Medicinal Chemistry and Natural Products, School of Pharmacy, University of North Carolina at Chapel Hill, Chapel Hill, NC
1999-2000	**Research Scientist**, Biology Department, Massachusetts Institute of Technology, Cambridge, MA
1998-2000	**Research Fellow**, Molecular Medicine Unit, Beth Israel Hospital, Boston, MA

TRAINING

1993-1999	**Postdoctoral Research Associate** Department of Biology, Massachusetts Institute of Technology Cambridge, MA 02139
Mentor:	Professor Robert D. Rosenberg
1989-1993	**Ph.D. in Medicinal Chemistry and Natural Products** College of Pharmacy, The University of Iowa, Iowa City, Iowa.
Thesis Advisor:	Professor Robert J. Linhardt

1984-1987 **M.S. in Biochemistry**, Nankai University, Tianjin, China.
1980-1984 **B.S. in Chemistry**, Nankai University, Tianjin, China.

FUNDING

Active

1) National Institute of Allergy/Infectious Diseases, 2R01AI050050-05A1, February 1 of 2006 to January 31 of 2011. Project title: "Structural specificity of heparan sulfate for herpes infection" (Principal Investigator). Direct cost $226,000/yr for five years, 15% effort.

2) National Heart, Lung and Blood Institute. 1R01HL094463-01, February 13 of 2009 to January 31 of 2013. Project title: "In vitro synthesis of recombinant heparan sulfate" (Principal Investigator). Direct cost $286,000/yr for 4 years, 15% effort.

3) National Institute of Allergy/Infectious Diseases, 3R01AI050050-07S1, February 1 of 2008 to January 31 of 2011. Project title: "Structural specificity of heparan sulfate for herpes infection" (Principal Investigator). Direct cost $33,000/yr for three years. This grant is to support Ms. Courtney Jones' PhD studies.

4) National Heart, Lung, and Blood Institute, 3R01HL094463-01S1, July 1 of 2009 to January 31 of 2013. Project title: "In vitro synthesis of recombinant heparan sulfate" (Principal Investigator). Direct cost $33,961/yr. This grant is to support Ms. Priscilla Paul's PhD studies.

5) National Institute of Allergy/Infectious Diseases, 1R21AI074775-01A2, August 1 of 2009 to July 31 of 2011. Project title: "Glycomics of Heparan Sulfate in Bacterial Pathogenesis" (Principal Investigator). Direct cost, $150,000/yr1 and $125,000/yr2, 10% effort.

6) National Heart, Lung and Blood Institute. 1R01HL096972-01, August 1 of 2009 to April 30 of 2014. Project title: "Development of a Bioengineered Heparin from a Non-Animal Source" (Principal Investigator, Robert J Linhardt). Role in the project: Co-PI. Direct cost $100,000/yr for Yr 1-Yr3 and $75,000/yr for Yr4-Yr5, 5% effort.

7) National Institute of Allergy/Infectious Diseases, 3R01AI050050, September 18 of 2009 to August 31 of 2010. Project title: "Structural specificity of heparan sulfate for herpes infection" (Principal Investigator). Direct cost $99,760. This grant is to purchase a LC/MS system.

8) National Institute of General Medical Sciences, 1R01GM090257-01, September 30 of 2009 to August 31 of 2011. Project title: "An artificial Golgi: Controlled GAG synthesis and screening" (Principal Investigator, Robert J Linhardt). Role in the project: Co-PI. Direct cost $55,000/yr1 and $65,000/yr 2, 3% effort.

9) National Institute of Allergy/Infectious Diseases, 3R01AI50050-9S1, May 17 of 2009 to September 30 of 2010. Project title: "Structural specificity of heparan sulfate for herpes infection" (Principal Investigator). Direct cost $5,029. This grant is to support the summer research training for Mrinalini Ramanan.

10) National Institute of General Medical Sciences, 1R01GM072667-06, June 1 of 2010 to May 30 of 2014. Project title: "Chemoenzymatic synthesis of heparan sulfate oligosaccharides- subcontract" (Principal Investigator, Xuefei Huang). Role in the project: Co-PI. Direct cost $60,000/yr for four years, 4% effort.

11) National Institute of General Medical Sciences, 1R01GM093131-01, May 1 of 2010 to April 30 of 2014. Project title: "STRUCTURE AND FUNCTION OF 3-O-SULFATION IN HEPARAN SULFATE" (Principal Investigator, Jeff Esko). Role in the project: Co-PI. Direct cost $16,000/yr for two years, 3% effort.

12) National Science Foundation, CHE-1111550, July 1 of 2011 to June 30 of 2014. Project title: "Synthesis of homogeneous heparan sulfate proteoglycans" (Principal Investigator, Xuefei Huang). Role in the project: Co-PI. Direct cost $29,000/yr for three years, 3% effort.

Completed

1) National Institute of Allergy/Infectious Diseases, R01 AI50050-01, July, 2001 to May, 2006. Project title: "Specificity of Heparan Sulfate for Herpes Infection". (Principal Investigator) direct cost $625,000 for five years, 40% effort.
2) American Heart Association Mid-Atlantic Affiliate, grant-in-aid 0355800U, July 1 of 2003 to June 30 of 2005. Project title: "Understanding the biosynthesis of anticoagulant heparan sulfate". (Principal Investigator) direct cost $120,000 for two years, 10% effort.
3) Pharmacy Foundation of North Carolina, seed grant, Feb. 1 to Dec. 31, 2004. Project title: "Investigation of the Molecular Mechanism of the Biosynthesis of Anticoagulant Heparan Sulfate". (Principal Investigator) direct cost $9,500.
4) American Heart Association, MidAtlantic grant-in-aid 0855424E, July 1 of 2008 to June 30 of 2010. Project title: "Investigation of the substrate specificities of heparan sulfate biosynthetic enzymes" (Principal Investigator). Direct cost $60,000/yr for two years, 5% effort.
5) Zacharon, Inc, June 1 of 2009 to May 31 of 2010. Project title: "Inhibition of heparan sulfate biosynthetic enzymes by small molecules" (Principal Investigator). Direct cost $20,000.

Serve as a sponsor for graduate student fellowship

1) National Institute of Allergy/Infectious Diseases, R01 AI50050S1, June 2004 to May 2005. Project title: "Specificity of Heparan Sulfate for Herpes Infection". A supplement fellowship to support Tanya Scarlett. Direct cost $25,048.
2) American Heart Association, MidAtlantic Affiliate, July 2005 to June 2007. Project title: "Understanding the substrate recognition mechanism of heparan sulfate 3-*O*-sulfotransferase". A predoctoral fellowship to support Ding Xu. Direct cost $40,000.
3) National Institute of General Medical Sciences, F31GM090647, Jan 1 of 2010 to Dec 31 of 2012. Project title:" Investigation of the inhibitor of heparnase" (P.I. Sherket Peterson). Direct cost $35,000/yr for three years.
4) National Institute on Aging, F31AG040927-01, September 1 of 2011 to August 31 of 2014. Project title: "Contribution of structural motifs to heparin clearance" (P.I. Elizabeth Pempe). Direct cost $29,000/yr for three years.

Pending applications

1) National Institute of Allergy/Infectious Diseases, R01AI050050-10, April 1 of 2011 to March 31 of 2016. Project title: "Structural specificity of heparan sulfate for herpes infection" (Principal Investigator). Direct cost $300,000/yr for five years, 20% effort.
2) National Heart, Lung and Blood Institute, April 1 of 2011 to March 31 of 2018. Project title: "Preparation anticoagulant without side effects" (Project 2, principal investigator). Direct cost $225,000/yr for seven years, 20% effort. This is part of program project (PI, Robert Linhardt) in response to RFA entitled "Program of Excellence in Glycosciences" issued by NIH.
3) National Heart, Lung and Blood Institute, R21XXXX, July 1 of 2011 to June 30 of 2013. Project title: "Enzymatic synthesis of structurally homogeneous low molecular weight heparins" (Principal Investigator). Direct cost $150,000/yr1 and $125,000/yr2, 7% (yr1) and 5% (yr2) effort.

HONORS AND AWARDS

2010 Distinguished Faculty Award from Chinese-American Chemistry & Chemical Biology Professor Association, presented to outstanding faculty members of Chinese ethnics in US and China. Four awards (two from US and two from China) are given each year.

1996-1998 Postdoctoral Fellowship from American Heart Association Massachusetts and Rhode Island Affiliates, presented to outstanding physicians and scientists engaging in cardiovascular research.

1991-1993 Predoctoral Fellowship from American Heart Association Iowa Affiliates, presented to outstanding M.D. and Ph.D. candidates engaging in cardiovascular research.

SERVICE

Louisiana Board of Regents' Research Competitiveness Subprogram (2007)

American Heart Association, Co-Chair and member for Region II Basic Cell Peer Review Committee 2 (2008 – 2009)
American Heart Association, Chair for Region II Basic Cell Peer Review Committee (2010-2011)
National Institutes of Health, Member for Drug Discovery and Development (DDD) study section (Nov, 2008 – 2009).
National Science Foundation of China, Biochemistry Division (May, 2009)
National Institutes of Health, Member for Shared Instrumentation study section (July, 2009)
US Pharmacopeia, Member for "Unfractionated and Low Molecular Weight Heparins Ad Hoc Advisory Panel" (November, 2009-present)
March of Dimes Foundation, *adhoc* grant reviewer (January, 2010).
National Science Foundation, neural system cluster *adhoc* grant reviewer (April, 2010)
National Institute of General Medical Sciences sponsored workshop entitled "Expanding the chemical space for carbohydrates: Road map to automated synthesis" (March 2011).
National Institute of General Medical Sciences sponsored working group entitled "10K Glycan Array Working Group" (Sept 2011).

LIST OF PUBLICATIONS

Research Articles (* denotes corresponding author)

1. Moon, A., Xu, Y., Woody, S.M., Krahn, J.M., Linhardt, R.J., **Liu*, J**. and Pedersen, L.C., (2011) Unveiling substrate recognition of 3-O-sulfotransferase for the biosynthesis of anticoagulant heparin. Submitted.

2. Tiwari, V., **Liu, J.**, Valyi-Nagy, T., and Shukla*, D. (2011) Anti-heparan sulfate peptides that block herpes simplex virus infection *in vivo*. *J. Biol. Chem.* 286: 25406-25415.

3. Wang, Z., Yang, B., Zhang, Z., Ly, M., Takeiddin, M., Mousa, S., **Liu, J**., Dordick, J.S., Linhardt*, R.J. (2011) Control of the heparosan *N*-deacetylation leads to an improved bioengineered heparin. *Appl. Microbiol. Biotechnol*. In press.

4. Sheng, J., Liu, R., Xu, Y. and **Liu*, J.** (2011) The dominating role of *N*-deacetylase/*N*-sulfotransferase 1 in forming domain structures in heparan sulfate. *J Biol. Chem*. 286: 19768-19776.

5. Xu, Y., Masuko, S., Takieddin, M., Xu, E., Liu, R., Jing, J., Mousa, S., Linhardt*, R.J. and **Liu*, J.** (2011) Chemoenzymatic synthesis of structurally homogeneous ultra-low molecular weight heparins. *Science* in press.

6. Liu, R. and **Liu*, J.** (2011) Enzymatic placement of 6-*O*-sulfo groups in heparan sulfate. *Biochemistry* 50:4382-4391.

7. Zhou, X., Chandarajoti, K., Phar, T.Q., Liu, R. and **Liu, J.*** (2011) Expression of secreted forms of sulfotransferases in *Kluyveromyces lactisto* to synthesize heparin and heparan sulfate. *Glycobiology* 21: 771-780.

8. Xu, Y., Wang, Z., Liu, R., Arlene Bridges, Huang*, X., and **Liu, J.*** (2011) Directing the biological activities of heparan sulfate oligosaccharides using a chemoenzymatic approach. *Glycobiology* in press.

9. Wang Z, Xu, Y, Yang, G, Tiruchinapally, B. Sun, R. Liu, S. Dulaney, **J. Liu**, and X. Huang* (2010) Preactivation-based One-pot Combinatorial Synthesis of Heparin-like Hexasaccharides for the Analysis of Heparin-Protein Interactions *Chemistry* 16:8365-8375

10. Sherket Peterson and **Jian Liu*** (2010) Unraveling the specificity of heparanase utilizing synthetic substrates *J. Biol. Chem.* 285: 14504-14513.

11. Renpeng Liu, Yongmei Xu, Miao Chen, Michel Weïwer, Xianxuan Zhou, Arlene S. Bridges, Paul L. DeAngelis, Qisheng Zhang, Robert J. Linhardt and **Jian Liu*** (2010) Chemoenzymatic design of heparan sulfate oligosaccharides *J. Biol. Chem.*285:34240-34249.

12. Li, K., Bethea, HN, and **Liu, J.** (2010) Determining the activity of heparan sulfate C5-epimerase using engineered 2-*O*-sulfotransferase *J. Biol. Chem.* 285: 11106-11113.

13. Martin JG, Gupta M, Xu Y, Akella S, **Liu J**, Dordick JS, Linhardt RJ* (2009) Toward an artificial Golgi: Redesigning the biological activities of heparan sulfate on a digital microfluidic chip *J. Am. Chem. Soc.* 131: 11041-11048.

14. Zhang Z, Xie J, Liu H, **Liu J**, Linhardt RJ.* (2009) Quantification of heparan sulfate disaccharides using ion-pairing reversed-phase microflow high-performance liquid chromatography with electrospray ionization trap mass spectrometry *Anal. Chem.* 81: 4349-4355

15. Heather N. Bethea, Ding Xu, **Jian Liu***, and Lars Pedersen (2008) Redirecting the substrate specificity of heparan sulfate 2-*O*-sulfotransferase by structurally guided mutagenesis. *Proc. Natl. Acad. Sci. USA* 105: 18724-18729.

16. Michel Weïwer, Trevor Sherwood, Dixy E. Green, Paul L. DeAngelis, **Jian Liu**, Robert J. Linhardt* (2008) Synthesis of uridine 5'-diphosphoiduronic acid (UDP-IdoA) as a potential unnatural substrate of glucuronosyltransferases for the chemoenzymatic synthesis of heparin *J. Org. Chem.* 73: 7631-7637.

17. Zhenqing Zhang, Scott A. McCallum, Jin Xie, Lidia Nieto, Francisco Corzana, Jesús Jiménez-Barbero, Miao Chen, **Jian Liu**, Robert J. Linhardt* (2008) Solution structures of chemoenzymatically synthesized heparin and its precursors *J. Am. Chem. Soc.* 130: 12998-13007.

18. Ronald Copeland, Arun Balasubramaniam, Vaibhav Tiwari, Arleen Bridges, Robert J Linhardt, Deepak Shukla, and **Jian Liu*** (2008) Using a 3-*O*-sulfated heparin octasaccharide to inhibit the entry of herpes simplex virus 1 *Biochemistry* 47: 5774-5783.

19. Xu, D., Moon, A.F., Song, D., Pedersen, L.C. and **Liu*, J.** (2008) Engineering the sulfotransferases to modify heparan sulfate *Nat. Chem. Biol*. 4: 200-202.

20. Zhenqing Zhang. Jin Xie, **Jian Liu** and Robert Linhardt* (2008) Tandem MS can distinguish hyaluronic acid from *N*-acetylheparosan *J. Am. Soc Mass Spect*. 19: 82-90

21. Chen, J., Jones, C.L., and **Liu*, J.** (2007) An enzymatic combinatorial approach to identify novel anticoagulant heparan sulfate structures *Chemistry & Biology* 14: 986-993 (Commentary by Linhardt, R.J. and Kim, J.-H. (2007) *Chemistry & Biology* 14: 972-973)

22. Lu, D., Garcia-Contreras, L., Xu, D., Kurtz, S.L., **Liu, J**., Braunstein, M., McMurray, D. and Hickey*, A.J. (2007) Poly (Lactide-co-Glycolide) Microspheres Can Enhance a T Cell Response to Recombinant Mycobacterium tuberculosis Antigen 85B. *Pharm Res.* 24: 1834-1843.

23. Lawrence, R., Yabe, T., HajMohammadi, S., Rhodes, J., McNeely, M., **Liu, J.**, Lamperti, E.D., Toselli, P.A., Lech, M., Spear, P.G., Rosenberg, R.D., and Shworak*, N.W. (2007) The principal neuronal gD-type 3-*O*-sulfotrnsferases and their products in central and peripheral nervous system tissues *Matrix Biology* 26: 442-455.

24. Xu, D., Song, D., Pedersen, L. and **Liu*, J.** (2007) Mutational study of heparan sulfate and chondroitin sulfate 2-*O*-sulfotransferases *J. Biol. Chem.* 282: 8356-8367.

25. Tiwari, V., O'Donnell, C., Copeland, R.J., Scarlett, T., **Liu, J.** and Shukla* D. (2007) Soluble 3-O-sulfated heparan sulfate can trigger herpes simplex virus type 1 entry into resistant Chinese hamster ovary (CHO-K1) cells *J. Gen Virol.* 88: 1075-1079.

26. Chen, M., Bridges, A. and **Liu*, J.** (2006) Determination of the substrate specificities of *N*-acetyl-D-glucosaminyl transferase *Biochemistry* 45: 12358-12365.

27. Vaibhav Tiwari, Christian Clement, Ding Xu, Perry M. Scanlan, Veeral Seth, Gary Chung, Devanand Kowlessur, Tibor Valyi-Nagy, Beatrice Y.J.T. Yue, **Jian Liu**, and Deepak Shukla* (2006) Entry of HSV-1 into primary cultures of corneal fibroblasts is mediated by HVEM and 3-*O*-S HS but not nectin-1. *J. Virol.* 80: 8970-8980.

28. Muñoz, E., Xu, D., Kemp, M., Zhang, F., **Liu, J.**, Linhardt*, R.J. (2006) Affinity, kinetic and structural study of the interaction of 3-*O*-sulfotransferase isoform 1 with heparan sulfate *Biochemistry* 45: 5122-5128.

29. McDowell, L.M., Frazier, B., Studelska, D.R., Giljum, K., Chen, J., **Liu, J**., Yu, K., Ornitz, D.M., and Zhang, L.* (2006) Inhibition or activation of Apert syndrome FGFRs (S252W) signaling by specific glycosaminoglycans *J. Biol. Chem.* 281: 6924-6930.

30. Duncan, M., Liu, M., Fox, C. and **Liu, J.*** (2006) Characterization of the *N*-Deacetylase Domain from the Heparan Sulfate *N*-Deacetylase/*N*-Sulfotransferase 2 *Biochem. Biophys. Res. Commun*. 339: 1232-1237.

31. Eva Muñoz, Ding Xu, Fikri Avci, Melissa Kemp, **Jian Liu**, Robert J. Linhardt* (2006) Enzymatic synthesis of heparin related polysaccharide on sensor chips: Rapid screening of heparin-protein interactions *Biochem. Biophys. Res. Commun.* 339:597-602.

32. Jinghua Chen, Fikri Y. Avci, Eva M. Muñoz, Lynda M. McDowel, Miao Chen, Lars C. Pedersen, Lijuan Zhang, Robert J. Linhardt, and **Jian Liu*** (2005) Enzymatic redesigning of biologically active heparan sulfate *J. Biol. Chem.* 280: 42817-42825.

33. Gong, Y., Duvvuri, M., Duncan, M., **Liu, J.** and Krise, J.P.* (2006) Niemann-pick C1 protein facilitates the efflux of the anticancer drug duanorubicin from cells according to a novel vesicle-mediated pathway *J. Pharmacol. Exp. Ther.* 316: 242-247.

34. Jinghua Chen and **Jian Liu*** (2005) Characterization of the Structure of Antithrombin-binding Heparan Sulfate Generated by Heparan Sulfate 3-*O*-Sulfotransferase 5 *Biochim. Biophys. Acta* 1725:190-200.

35. Ding Xu, Vaibhav Tiwari, Guoqing Xia, Christian Clement, Deepak Shukla and **Jian Liu*** (2005) Characterization of heparan sulphate 3-*O*-sulphotransferase isoform 6 and the role in assisting the entry of herpes simplex virus, type 1. *Biochem. J*.385: 451-459.

36. Andrea Moon, Suzanne C. Edavettal, Joe M. Krahn, Eva M. Munoz, Masahiko Negishi, Robert J. Linhardt, **Jian Liu***, and Lars C. Pedersen (2004) Structural analysis of the sulfotransferase (3-OST-3) involved in the biosynthesis of an entry receptor of herpes simplex virus 1. *J. Biol. Chem*. 279: 45185-45193 (Cover of October 22 issue).

37. Atsuko Negishi, Jinghua Chen, Douglas McCarty, Jude Samulski, **Jian Liu***, and Richard Superfine* (2004) Analysis of the interaction of heparan sulfate and adeno-associated virus by atomic force microscopy. *Glycobiology* 14: 969-977.

38. Suzanne C. Edavettal, Karen A. Lee, Masahiko Negishi, Robert J. Linhardt, **Jian Liu***, and Lars C. Pedersen (2004) Crystal structure and mutational analysis of heparan sulfate 3-*O*-sulfotransferase isoform 1. *J. Biol. Chem*. 279: 25789-25797.

39. Suzanne C. Edavettal, Kevin Carrick, Ruchir Shah, Lars C. Pedersen, Alex Tropsha, R. Marshall Pope, and **Jian Liu*** (2004) A conformational change of heparan sulfate 3-*O*-sulfotransferase induced by binding to heparan sulfate. *Biochemistry* 43: 4680 - 4688.

40. Vaibhav Tiwari, Christain Clement, Michael B. Duncan, Jinghua Chen, **Jian Liu**, and Deepak Shukla* (2004) A role of 3-*O*-sulfated heparan sulfate in cell fusion induced by herpes simplex virus type-1. *J. Gen. Virol*. 85: 805-809.

41. Michael B. Duncan, Jinghua Chen, Jeffrey Krise and **Jian Liu*** (2004) The contribution of heparan sulfate 3-*O*-sulfotransferase isoform 5 to the biosynthesis of anticoagulant heparan sulfate. *Biochim. Biophys. Acta* 1671: 34-43.

42. Jinghua Chen, Michael B. Duncan, Kevin Carrick, R. Marshall Pope, and **Jian Liu*** (2003) Biosynthesis of 3-*O*-sulfated heparan sulfate: unique substrate specificity of heparan sulfate 3-*O*-sulfotransferase isoform 5. *Glycobiology* 13: 785-794.

43. Guoqing Xia, Jinghua Chen, Vaibhav Tiwari, Wujian Ju, Jing-pin Li, Anders Malmström, Deepak Shukla, **Jian Liu*** (2002) Heparan sulfate 3-*O*-sulfotransferase isoform 5 generates both an antithrombin-binding site and an entry receptor for herpes simplex virus-1. *J. Biol. Chem*. 277: 37912-37919.

44. **Jian Liu***, Zach Shriver, R. Marshall Pope, Suzanne C. Thorp, Michael B. Duncan, Ronald J. Copeland, Christina S. Raska, Keiichi Yoshida, Roselyn J. Eisenberg, Gary Cohen, Robert J. Linhardt, and Ram Sasisekharan (2002) Characterization of a heparan sulfate octasaccharide that binds to herpes simplex viral type 1 glycoprotein D. *J. Biol. Chem.* 277: 33456-3346.

45. Myette JR, Shriver Z, **Liu J**, Venkataraman G, Rosenberg R, Sasisekharan R* (2002) Expression in *Escherichia coli*, purification and kinetic characterization of human heparan sulfate 3-*O*-sulfotransferase-1. *Biochem. Biophys. Res. Commun.* 290: 1206-1213.

46. Marshall Pope, Christina S. Raska, Suzanne C. Thorp and **Jian Liu*** (2001) Analysis of heparan sulfate oligosaccharides by nanoelectrospray ionization mass spectrometry. *Glycobiology* 11: 505-513.

47. Maria Hernaiz, **Jian Liu**, Robert D. Rosenberg, and Robert J. Linhardt (2000) Enzymatic modification of heparan sulfate on a biochip promotes its interaction with antithrombin III. *Biochem. Biophys. Res. Commun.* 276: 292-297.

48. Lijuan Zhang, David L. Beeler, Roger Lawrence, Miroslaw Lech, **Jian Liu**, Joseph C. Davis, Zachary Shriver, Ram Sasisekharan, and Robert D. Rosenberg (2001) 6-O-Sulfotransferase-1 represents a critical enzyme in the anticoagulant heparan sulfate biosynthetic pathway. *J. Biol. Chem.* 276: 42311-42321.

49. Deepak Shukla¶, **Jian Liu¶**, Peter Blaiklock, Nicholas W. Shworak, Xiaomei Bai, Jeffrey D. Esko, Gary H. Cohen, Roselyn J. Eisenberg, Robert D. Rosenberg and Patricia G. Spear (1999) A novel role for 3-*O*-sulfated heparan sulfate in herpes simplex virus 1 entry. *Cell* 99: 13-22.(¶Both authors contributed equally to this work.)

50. **Jian Liu**, Zach Shriver, Peter Blaiklock, Keiichi Yoshida, Ram Sasisekharan, and Robert D. Rosenberg (1999) Heparan sulfate D-glucosaminyl 3-*O*-sulfotransferase 3A sulfates *N*-unsubstituted glucosamine. *J. Biol. Chem.* 274: 38155-38162.

51. **Jian Liu**, Nicholas W. Shworak, Pierre Sinaÿ, John J. Schwartz, Lijuan Zhang, Linda M.S. Fritze and Robert D. Rosenberg (1999) Expression of heparan sulfate D-glucosaminyl 3-*O*-sulfotransferase isoforms reveals novel substrate specificities. *J. Biol. Chem.* 274: 5185-5192.

52. Nicholas W. Shworak, **Jian Liu**, Lorin M. Petros, Neal G. Copeland, Nancy A. Jenkins and Robert D. Rosenberg (1999) Diversity of the extensive heparan sulfate D-glucosaminyl 3-*O*-sulfotransferase (3-OST) multigene family. *J. Biol. Chem.* 274: 5170-5184.

53. Lijuan Zhang, Keiichi Yoshida, **Jian Liu** and Robert D. Rosenberg (1999) Anticoagulant heparan sulfate precursor structures in F9 embryonic carcinoma cells. *J. Biol. Chem.* 274: 5681-5691.

54. Masashi Kobayashi, Geetha Sugumaran, **Jian Liu**, Nicholas W. Shworak, Jeremiah E. Silbert, and Robert D. Rosenberg (1999) Molecular cloning and characterization of a human uronyl 2-sulfotransferase that sulfates iduronyl and glucuronyl residues in dermatan/chondroitin sulfate. *J. Biol. Chem.* 274: 10474-10480.

55. Lijuan Zhang, John J. Schwartz, Joseph Miller, **Jian Liu**, Linda M.S.Fritze, Nicholas W. Shworak, Robert D. Rosenberg (1998) The retinoic acid and cAMP-dependent up-regulation of 3-*O*-sulfotransferase-1 leads to a dramatic augmentation of anticoagulantly active heparan sulfate biosynthesis in F9 embryonal carcinoma cells. *J. Biol. Chem.* 273: 27998-28003.

56. Nicholas W. Shworak, **Jian Liu**, Linda M.S. Fritze, John J. Schwartz, Lijuan Zhang, Logear, D. and Robert D. Rosenberg (1997) Molecular cloning and expression of mouse and human cDNAs encoding heparan sulfate D-glucosaminyl 3-*O*-sulfotransferase. *J. Biol. Chem.* 272: 28008-28019.

57. **Jian Liu**, Nicholas W. Shworak, Linda M.S. Fritze, Jay M. Edelberg and Robert D. Rosenberg (1996) Purification of heparan sulfate D-glucosaminyl 3-*O*-sulfotransferase. *J. Biol. Chem.* 271: 27072-27082.

58. Nicholas W. Shworak, Linda M.S. Fritze, **Jian Liu**, Lynne D. Butler and Robert D. Rosenberg (1996) Cell-free synthesis of anticoagulant heparan sulfate reveals a limiting converting activity that modifies an excess precursor pool. *J. Biol. Chem.* 271: 27063-27071.

59. Ghamartaj Hossein, **Jian Liu** and Ariane I. De Agostini (1996) Characterization and hormonal modulation of anticoagulant heparan sulfate proteoglycans synthesized by rat ovarian granulosa cells. *J. Biol. Chem.* 271: 22090-22099.

60. **Jian Liu**, Umesh R. Desai, Xue-Jun Han, Toshihiko Toida and Robert J. Linhardt (1995) Strategy for the sequence analysis of heparin. *Glycobiology* 5: 765-774.

61. Sylvia Colliec-Jouault, Nicholas W. Shworak, **Jian Liu**, Ariane I. De Agostini and Robert D. Rosenberg (1994) Characterization of a cell mutant specifically defective in the synthesis of anticoagulantly active heparan sulfate. *J. Biol. Chem.* 271: 24953-24958.

62. Nicholas W. Shworak, Motoaki Shirakawa, Sylvia Colliec-Jouault, **Jian Liu**, Richard C. Mulligan, Louis K. Birinyi and Robert D. Rosenberg (1994) Pathway-specific regulation of the biosynthesis of anticoagulantly active heparan sulfate. *J. Biol. Chem.* 269: 24941-24952.

63. Y. S. Kim, **J. Liu**, X.J. Han, A. Pervin and R. J. Linhardt (1994) Analysis of fluorescently labeled sugars by reversed-phase ion-pairing high performance liquid chromatography. *J. Chromatogr. Sci.* 33: 162-167.

64. **Jian Liu**, Azra Pervin, Cindy M. Gallo, Umesh R. Desai, Case VanGorp and Robert J. Linhardt (1994) New approaches for the preparation of hydrophobic heparin. *J. Pharmaceut. Sci.* 83: 1034-1039.

65. Robert J. Linhardt, Umesh Desai, **Jian Liu**, Debra Hoppensteadt and Jawed Fareed (1994) Low molecular weight dermatan sulfate as an antithrombotic agent: Structure activity relationship studies. *Biochem. Pharmacol.* 47: 1241-1252.

66. Kenan Gu, **Jian Liu**, Azra Pervin and Robert J. Linhardt (1993) Comparison of the activity of two chondroitin AC lyases on dermatan sulfate. *Carbohydr. Res.* 244: 369-377.

67. Robert J. Linhardt, Ali Al-Hakim, **Jian Liu**, Debra Hoppensteadt, Jawed Fareed, Guiseppe Mascellani, and Pietro Bianchini (1991) Structure features of dermatan sulfates and their relationship to anticoagulant and antithrombotic activities. *Biochem. Pharmacol.* 42: 1609-1619.

68. Youhan Xu, **Jian Liu**, Suipo Zhang and Lisheng Liu (1987) The effect of berbamine derivatives on activated Ca^{2+}-stimulated Mg^{2+}-dependent ATPase in erythrocyte membranes. *Biochem. J.* 248: 985-988.

69. Fayi Zhang, Yibao Zhang, **Jian Liu** and Xuezhuang Zhao (1986) Ascorbic acid oxidation reaction-kinetics of oxidation by molecular oxygen. *WuliHuaxue Xuebao* 2: 335-341 (in Chinese).

Peer-reviewed review articles

1. Zhou, X., O'Leary, T., Xu, Y., Sheng, J. and **Liu*, J.** (2011) Chemoenzymatic synthesis of heparin and heparan sulfate. *Biocatalys. Biotransf.* In press.

2. Laremore TN, Zhang F, Dordick JS, **Liu J**, Linhardt RJ.* (2009) Recent progress and applications in glycosaminoglycan and heparin research *Curr Opin Chem Biol* 13:633-40

3. Sherket Peterson, Amber Frick, **Jian Liu*** (2009) Designing of biologically active heparan sulfate and heparin using an enzyme-based approach *Nat. Prod. Rep.* 26: 610-627.

4. Chen, Y., Götte, M., **Liu, J**., and Park, P.W. (2008) Microbial subversion of heparan sulfate proteoglycans *Mol Cells* 26: 415-426.

5. Robert J Linhardt*, Jonathan S. Dordick, Paul DeAngelis, **Jian Liu** (2007) Enzymatic synthesis of glycosaminoglycan heparin *Semin. Thromb. Hemost.* 33: 453-465.

6. **Jian Liu*** and Lars C. Pedersen (2007) Anticoagulant heparan sulfate: Structural specificity and biosynthesis. *Appl. Microbiol. Biotechnol.* 74:263-272.

7. **Jian Liu*** and Suzanne C. Thorp (2001) Cell surface heparan sulfate and the roles in assisting viral infections. *Med. Res. Rev.* 22:1-25.

8. Robert D. Rosenberg*, Nicholas W. Shworak, **Jian Liu**, John J. Schwartz, and Lijuan Zhang (1997) Heparan sulfate proteoglycans of the cardiovascular system: specific structures emerge but how is synthesis regulated? *J. Clin. Invest.* 99: 2062-2070.

9. Robert J. Linhardt*, **Jian Liu** and Xue-jun Han (1993) Mapping and sequencing of oligosaccharides by electrophoresis. *Trends Glycosci. Glycotechnol.* 5: 181-192.

Refereed book chapters

1. Renpeng Liu and **Jian Liu*** (2010) Enzymatic synthesis of heparin, in *Sustainable Biotechnology-Sources of Renewable Energy* (O.V. Sigh and S.P. Harrey Eds.), in press.

2. Courtney L. Jones, Ding Xu and **Jian Liu*** (2010) Structure, Biosynthesis and Function of Glycosaminoglycans, in "Carbohydrates, Nucleosides, & Nucleic Acids" (C.H. Wong and G.P. Wang, eds), *Comprehensive Natural Products Chemistry II* series (L. Mendor and H.-W. Liu, editor in-chief) Vol 6, in press.

3. Fikri Y. Avci, Paul L. DeAngelis, **Jian Liu**, and Robert J. Linhardt* (2007) Enzymatic synthesis of glycosaminoglycans: improving on nature, in *Frontiers in Carbohydrate Chemistry*, pp 253-284.

4. **Jian Liu*** and Robert D. Rosenberg (2001) Heparan sulfate D-glucosaminyl 3-*O*-sulfotransferase, in *Handbook of Glycosyltransferases and Their Related Genes* (N. Taniguchi and M. Fukuda Eds.) Springer-Verlag, Tokyo pp 475-483. (Book Chapter)

5. Robert J. Linhardt*, Ali Al-Hakim and **Jian Liu** (1991) Acidic polysaccharides: Their modification and potential uses, in *Biotechnology and Polymers* (C. G. Gebelein Ed.) Plenum Press, New York, 155-165. (Book Chapter)

INVITED LECTURES

1. Georgia State University, Atlanta, GA, November 2011. Title: “An enzymatic approach to synthesize heparan sulfate glycome”.

2. 19th Symposium on Glycosaminoglycans, Loveno, Lake Como, Italy, September 2011. Title: "Enzymatic synthesis of heparin and heparan sulfate".
3. 7th Canadian National Carbohydrate Symposium, Banff, Canada, May 2011. Title: "Enzymatic synthesis of heparin and ultra-low molecular weight heparins".
4. 9th Carbohydrate Bioengineering Meeting (Keynote speaker), Lisbon, Portugal, May, 2011. "Enzymatic synthesis of heparin and ultra-low molecular weight heparins".
5. University of Alabama, Birmingham, AL, January 2011. Title: "Developing a chemoenzymatic approach to synthesize heparan sulfate".
6. Academia Sinica, Taiwan, December 2010. Title: "Enzymatic synthesis of heparin and heparan sulfate".
7. American Chemical Society/Carbohydrate Chemistry Division annual meeting, Boston, MA, August 2010. Title: "Developing an enzymatic approach to synthesize heparan sulfate".
8. International Carbohydrate Symposium Satellite meeti1ng, Taipei, Taiwan, July 2010. Title: "Developing an enzymatic approach to synthesize heparan sulfate oligosaccharides".
9. Shangdon University, Jinan, China, September, 2009. Title: "An enzymatic approach to synthesize heparin".
10. Jiangnan University, Wuxi, China, April 2009. Title: "Developing an enzymatic approach to synthesize polysaccharide-based therapeutics".
11. University of Georgia, Athens, GA, September, 2008. Title: "Enzymatic synthesis of heparan sulfate".
12. Chinese Glycobiology conference, Jinan, China, July, 2008. Title: "Developing an enzymatic approach to synthesize heparin-based drugs". (Keynote speaker)
13. University of California at Davis, Davis, CA, April, 2008. Title: "An enzymatic approach to design polysaccharides drugs".
14. University of Toledo, Toledo, OH, March, 2008. Title: " Using a glycomics approach to develop polysaccharide-based drugs".
15. National Institute of Environmental Health Sciences, LSB retreat, September, 2007. Title: " Using a glycomics approach to develop polysaccharide-based drugs".
16. Tsin Hua University, Taiwan, April, 2007. Title: "An enzymatic approach to synthesize heparan sulfate with specific functions".
17. Ohio State University, Columbus, Ohio, October 2006. Title: "Enzymatic synthesis of anticoagulant heparan sulfate".
18. University of Illinois at Chicago, Chicago, Illinois, September 2006. Title: "Heparan sulfate: The roles in regulating blood coagulation and assisting viral infections".
19. University of Iowa, Iowa City, IA, February 2006. Title: "Enzymatic synthesis of anticoagulant drugs".
20. University of Illinois at Chicago, Chicago, Illinois, September 2004. Title: "Investigation of the structural and functional relationship of heparan sulfate".
21. University of Arkansas, Little Rock, Arkansas, April 2004. Title: "The biological functions and the fine structures of heparan sulfate".
22. Rensselaer Polytechnic Institute, Troy, New York, October 2003. Title: "Heparan sulfate: from an anticoagulant to a viral receptor".
23. Georgia State University, Atlanta, Georgia, October 2003. Title: "Cell surface heparan sulfate: from an anticoagulant to a viral receptor."
24. Virginia Commonwealth University, Richmond, Virginia, May 2002. Title "Specificity of heparan sulfate in assisting herpes simplex viral infection".

25. American Association for Pharmaceutical Sciences, Denver, Colorado, October 2001. Title " Heparan sulfate: a potential new receptor for gene delivery".
26. National Institute of Environmental Health Science, Research Triangle Park, April 2001. Title " The role of heparan sulfate in assisting viral infections".

Oral Presentations at Professional Meetings

1. 2nd International Conference on Drug Discovery & Therapy, Dubai, UAE, February, 2010. Title: "An enzymatic approach to synthesize heparin".
2. Carbohydrates Gordon Conference, Tilton, NH, June, 2009. Title: "Enzymatic synthesis of heparan sulfate and heparin".
3. 67th Harden Conference, Cambridge, UK, March, 2009. Title: "Developing an enzymatic approach to synthesize heparan sulfate".
4. Glycobiology Gordon Conference, Ventura, CA, January, 2009. Title: "Engineering sulfotransferases to modify heparan sulfate".
5. Ehrlich II International Conference, Nurenberg, Germany, October, 2008. Title: An enzymatic approach for developing heparan sulfate-based drugs".
6. Rensselaer Nanotechnology in Glycomics Symposium, Troy, NY, July, 2008. Title: "Enzymatic synthesis of heparan sulfate and heparin".
7. Carbohydrate Gordon Conference, Tilton, NH, July 2007. Title: "Engineering the specificity of sulfotransferases to synthesize specific heparan sulfate structures".
8. Rensselaer Glycomics Symposium, Albany, NY, July 2006. Title: "Enzymatic synthesis of heparan sulfate."
9. International Carbohydrate Symposium, Whistler, BC, July 2006. Title: "Enzymatically redesigning of biologically active heparan sulfate."
10. Proteoglycan Gordon Conference, Andover, NH, July 2004. Title: "Crystal structure and mutational analysis of heparan sulfate 3-*O*-sulfotransferase isoform 1".
11. Proteoglycan Gordon Conference, Andover, NH, July 2002. Title: "Heparan sulfate 3-*O*-sulfotransferase isoform 5 generates both an antithrombin-binding site and an entry receptor for herpes simplex virus-1".

Previous and Current Fellows/Trainees

Total number of pre-doctoral and post-doctoral individuals sponsored *in the past* = **9**

1. **J. Chen, PhD** (postdoctoral fellow, 2001-2005) is now a professor at Jiangnan University, China.
2. **S. C. Edavettal, PhD** (PhD graduate student, 2000-2004) is now a senior scientist at Merck Inc., West Point, PA.
3. **M.B. Duncan, PhD** (PhD graduate student, 2001-2006) is now an assistant professor of medicine at the Medical College of Georgia, Augusta, GA.
4. **R. Copeland, PhD** (PhD graduate student, 2001-2006) is now a postdoc at Johns Hopkins University, Baltimore, MD.
5. **D. Xu, PhD** (PhD graduate student, 2002– 2006) is now a postdoc at University of California at San Diego, San Diego, CA.
6. **M. Chen**, **PhD** (PhD graduate student, 2003-2008) is now a graduate student in biostatistics program at Harvard University, Boston, MA.

7. **T. Burch, PhD** (PhD graduate student, 2002-2008).
8. **Renpeng Liu**, PhD (PhD graduate student, 2004 -2010) is now a postdoctoral fellow at Emory University, Atlanta, GA.
9. **Heather Bethea**, PhD (PhD graduate student, 2004-2010) is now a postdoctoral at the University of North Carolina.
10. **Courtney Jones** (PhD graduate student, 2004 to 2011).
11. **Kai Li**, PhD (postdoctoral fellow, 2008-2010) is now a research scientist at Harvard University.

Total number lab members *currently* supported = **10**

1. **Ryan Bullis** (PhD student, 2008 to present) is supported by a NIH minority supplement (1R01HL096972-01S1, PI Robert Linhardt) predoctoral fellowship till Aug of 2013.
2. **Sherket Peterson** (PhD student, 2007 to present) is supported by a NIH predoctoral fellowship F31GM090647 till Dec of 2012.
3. **Kasemsiri Chandarajoti** (PhD student, 2009 to present) is supported by a predoctoral fellowship from Thailand government till 2014.
4. **Elizabeth Pempe** (PhD student, 2009 to present) is supported by a NIH predoctoral fellowship (F31AG040927-01).
5. **Tim O'Leary** (PhD student, 2011 to present) is supported by a predoctoral fellowship from National Institutes of Health-funded program for initiative for maximizing student diversity (5R25GM055336)
6. **Susan Woody** (PhD student, 2011 to present) is supported by teaching assistantship from Eshelman School of Pharmacy.
7. **Yongmei Xu** (Post-doctoral fellow, 2007 to present) is supported by NIH grant (1R01GM072667-06 ; PI, Xuefei Huang).
8. **Xianxuan Zhou** (Post-doctoral fellow, 2009 to present) is supported by NIH grant (R01HL096972).
9. **Juzheng Sheng** (Post-doctoral fellow, 2009 to present) is supported by NIH grant 1R21AI074775.
10. **Truong Quang Pham** (Technician, 2009 to present) is supported by a NIH grant (1R01GM090257).