

Chi-Ching Hwang, Ph.D.

Name : Hwang, Chi-Ching

Address : Department of Biochemistry, Faculty of Medicine, College of Medicine, Kaohsiung Medical University, 100, Shih-Chuan 1st RD., Kaohsiung 80731, Taiwan

Phone : 886-7-3121101 ext. 2305-14

Fax : 886-7-3218309

E-MAIL:cchwang@kmu.edu.tw

Education

Ph.D. Degree, March 1995

University of Utah, Department of Chemistry
Salt Lake City, Utah

B.S Degree, June 1986

National Cheng Kung University
Tainan, Taiwan, R.O.C.

Professional Experience

Associate Professor, Dept. of Biochemistry, Kaohsiung Medical University, Aug., 2010- present

Assistant Professor, Dept. of Biochemistry, Kaohsiung Medical University, Aug., 2001- July,2010

Research Chemist, ScinoPharm Taiwan, LTD, Jan, 2000- July, 2001

Postdoctoral Science Associate, February, 1999-November, 1999

University of Oklahoma Health Sciences Center, Dept. of Biochemistry and Molecular Biology

Postdoctoral Science Associate, August,1996-January,1999

University of Oklahoma, Department of Chemistry and Biochemistry

Postdoctoral Science Associate, January, 1995- July, 1996

University of North Texas Health Science Center at Fort Worth

Awards

2005 The Best Impact Factor Award

2007 The Best Impact Factor Award

Editor

Editorial Board, Global Journal of Biochemistry (2010~present)

Area of Research Interests

Enzyme mechanism, Enzymology, Protein Chemistry, Isotope Effect Study

Invited Speech

Date	Meeting /Place	Title
2002/4/11	國防醫學院生物化學科	Mechanism of <i>O</i> -acetylserine Sulfhydrase Catalyzed Reaction
2006/12	正修科技大學	3 α -羥基類固醇脫氫酶/還原酶之催化機制
2008/7	Trends in Enzymology/ St. Malo, France	Characterization of the proton relay system in the 3 α -hydroxysteroid dehydrogenase/carbonyl reductase from <i>Comamonas testosteroni</i> : the function of Lys 159 and Asn 86 in proton transfer
2009/05/01	陽明大學生命科學系暨 基因體研究所	The catalytic mechanism of 3 α -hydroxysteroid dehydrogenase/carbonyl reductase from <i>Comamonas testosteroni</i>
2009/12/5	2009 年中國化學年會/ 義守大學	Mechanism of 3 α -Hydroxysteroid Dehydrogenase/ Carbonyl Reductase: Insight into the Roles of N86, S114, Y155 and K159 in Cofactor Binding, Conformational Change, and Catalysis
2009/12/15	2009 Taiwan enzyme mechanism conference/ <i>Academia Sinica</i>	Mechanistic roles of the catalytic tetrad N86, S114, Y155 and K159 in 3 α -hydroxysteroid dehydrogenase/ carbonyl reductase

Research

Research in this laboratory studies the mechanism of enzyme-catalyzed reaction, enzyme kinetics, protein stability and oligomerization. The enzymes have been studied in the lab include (1) hydroxysteroid dehydrogenase, an oxidoreductase, (2) nattokinase, a serine protease, and (3) the enzymes involves the salvage pathways of NAD⁺ biosynthesis.

3 α -Hydroxysteroid dehydrogenase belongs to the family of short-chain dehydrogenases/reductases (SDR). One of the physiological functions of SDR enzymes is to regulate the cellular availability of a hormone receptor ligand by controlling the amount of active hormone. Hence, it is a target for drug design, especially in breast and prostate cancer treatment.

Short-chain dehydrogenases/reductases (SDR) are either homodimers or tetramers, constitute a large protein family with highly diverse functions in pro- and eukaryotes. Protein dimerization and oligomerization can confer several different structural and functional advantages to proteins, including the improved stability, the accessibility and specificity of active sites, and the increased

complexity or the formation of pathogenic structures. We are interesting in the interrelationship between subunit assembly, substrate specificity and enzyme function within SDR family to shed more light on the protein oligomerization and their function.

3 α -Hydroxysteroid dehydrogenase/carbonyl reductase (3 α -HSD/CR, E.C. 1.1.1.50) from *Comamonas testosteroni* reversibly catalyses the oxidation of 3 α -hydroxysteroids with nucleotide NAD⁺. It is one of the enzymes involved in the initial stage of the steroid catabolic pathway and, therefore, plays a central role in steroid metabolism. Structurally, the SDR enzymes have a Rossmann-fold consisting of $\beta\alpha\beta$ -units forming a central six-stranded parallel β -sheet sandwiched between two arrays of α -helices. Sequence alignment of SDR family typically exhibits residue identities only at the 15-30% level. Only one residue is strictly conserved (Tyr 155 in 3 α -HSD/CR) with largely conserved residue of Lys159 and Ser114. The 3 α -HSD/CR primary structure shows two sequence motifs which are common to the members of the SDR family. These are the amino terminal Gly⁸-X-X-X-Gly¹²-X-Gly¹⁴ cofactor binding motif and the Tyr¹⁵⁵-X-X-X-Lys¹⁵⁹ motif which is located in the active site and forms with the conserved Ser¹¹⁴ a catalytic triad.

Research will focus on the enzyme mechanism including the role of the functional groups involved in substrate binding, catalysis, structure-functional relationship, and protein oligomerization in the short-chain dehydrogenases/reductases. Technique including steady-state rate measurements, spectroscopic studies, recombinant enzyme, site-directed mutagenesis, isotope effect studies, mass spectrometric analysis for noncovalent complex, protein purification and characterization, synthesis of substrate and analogs, and data analysis will be utilized for the studies.

Grant Support

1. Proton relay system in short chain dehydrogenase/reductase: the study of the role of Lys, Asn, and NAD in proton transfer in enzyme catalysis (NSC 97-2320-B-037 -019 -MY3) (PI)
2. The mechanisms of the flexible substrate binding loop in 3 α -hydroxysteroid dehydrogenase/carbonyl reductase-catalyzed reaction (NSC100-2320-B-037-014) (PI)

Publications

1. Chen, S.-C., Guh, J.-Y., Lin, T.-D., Chiou, S.-J., **Hwang, C.-C.**, Ko, Y.-M., and Chuang, L.-Y.* (2011) "Gefitinib attenuates transforming growth factor- β 1-activated mitogen-activated protein kinases and mitogenesis in NRK-49F cells" *Translational Research* **158**, 214–224.

2. Hung, T.-C., Huang, L.-W., Su, S.-J., Hsieh, B.-S., Cheng, H.-L., Hu, Y.-C., Chen, Y.-H., **Hwang, C.-C.**, Chang, K.-L.* (2011) "Hemeoxygenase-1 expression in response to arecoline-induced oxidative stress in human umbilical vein endothelial cells" *Int J Cardiol.* **151**,187-94.
3. **Hwang, C.-C.**¹, Chai, H.-T.¹, Chen, H.-W., Tsai, H.-L., Lu, C.-Y., Yu, F.-J., Huang, M.-Y., Wang, J.-Y. (2011) "S100B Protein Expressions as an Independent Predictor of Early Relapse in UICC Stages II and III Colon Cancer Patients after Curative Resection" *Ann. Surg. Oncol.* **18**,139-45 (¹equal contribution).
4. Chang, Y.-H., Wang, Y.-L., Lin, J.-Y., Chuang, L.-Y., and **Hwang, C.-C.*** (2010) "Expression, purification, and characterization of a human recombinant 17 β -hydroxysteroid dehydrogenase type 1 in *E. coli*" *Mol. Biotechnol.* **44**, 133-139.
5. Huang, C.Y., Chen, J.Y., Wu, J.E., Pu, Y.S., Liu, G.Y., Pan, M.H., Huang, Y.T., Huang, A.M., **Hwang, C.-C.**, Chung, S.J., Hour, T.C. (2010) "Ling-Zhi polysaccharides potentiate cytotoxic effects of anticancer drugs against drug-resistant urothelial carcinoma cells" *J Agric Food Chem.* **58(15)**, 8798-805.
6. Chen, J.-Y.¹, **Hwang, C.-C.**¹, Chen, W.-Y., Lee, J.-C., Fu, T.-F., Huang, Y.-L., Chen, B.-H., Chiu, C.-C. (2010) "C(2)-ceramide sensitized Paclitaxel-induced premature senescence of human lung cancer cells" *Life Sci.* **87(11-12)**:350-7. (¹equal contribution).
7. Yen, C.-Y., Chiu, C.-C., Chang, F.-R., Chen, J.-Y., **Hwang, C.-C.**, Hseu, Y.-C., Yang, H.-L., Lee, A.-Y., Tsai, M.-T., Guo, Z.-L., Cheng, Y.-S., Liu, Y.-C., Lan, Y.-H., Chang, Y.-C., Ko, Y.-C., Chang, H.-W., Wu, Y.-C. (2010) "4beta-Hydroxywithanolide E from *Physalis peruviana* (golden berry) inhibits growth of human lung cancer cells through DNA damage, apoptosis and G2/M arrest" *BMC Cancer* **10**, 46.
8. Howng, S.-L.¹, **Hwang, C.-C.**¹, Hsu, C.-Y.¹, Hsu, M.-Y., Teng, C.-Y., Chou, C.-H., Lee, M.-F., Wu, C.-H., Chiou, S.-J., Lieu, A.-S., Loh, J.-K., Yang, C.-N., Lin, C.-S., Hong, Y.-R.. (2010) "Involvement of the residues of GSKIP, AxinGID, and FRATtide in their binding with GSK3beta to unravel a novel C-terminal scaffold-binding region" *Mol. Cell Biochem.* **339(1-2)**:23-33. (¹equal contribution)
9. Chang, Y.-H., Wang, C.-Z., Chiu, C.-C., Chuang, L.-Y., and **Hwang, C.-C.*** (2010) "Contributions of Active Site Residues to Cofactor Binding and Catalysis of 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase" *Biochim. Biophys. Acta.* **1804**, 235-241.
10. **Hwang, C.-C.***, Hsu, C.-N., Huang, T.-J., Chiou, S.-J., and Hong, Y.-R. (2009) "Interactions across the interface contribute the stability of homodimeric 3 α -hydroxysteroid

dehydrogenase/carbonyl reductase" *Arch. Biochem. Biophys.* **480**, 36-41.

11. Chen, S.-C., Guh, J.-Y., **Hwang, C.-C.**, Chiou, S.-J., Lin, T.-D., Ko, Y.-M., Huang, J.-S., Yang, Y.-L., Chuang, L.-Y. (2009) "Advanced glycation end-products activate extracellular signal-regulated kinase via the oxidative stress-EGF receptor pathway in renal fibroblasts" *J. Cell. Biochem.* 109(1):38-48.
12. Lin, C.-C., Chou, C.-H., Howng, S.-L., Hsu, C.-Y., **Hwang, C.-C.**, Wang, C., Hsu, C.-M., Hong, Y.-R. (2009)"GSKIP, an inhibitor of GSK3beta, mediates the N-cadherin/beta-catenin pool in the differentiation of SH-SY5Y cells" *J. Cell. Biochem.* **108**, 1325-1336.
13. Chang, Y.-H., Huang, T.-J., Chuang, L.-Y., and **Hwang, C.-C.*** (2009) "Role of S114 in the NADH-induced conformational change and catalysis of 3 α -hydroxysteroid dehydrogenase/carbonyl reductase from *Comamonas testosteroni*" *Biochim. Biophys. Acta* **1794**, 1459–1466.
14. Chou, W.-W., Guh, J.-Y., Tsai, J.-F., **Hwang, C.-C.**, Chiou, S.-J., and Chuang, L.-Y. (2009) Arecoline-induced phosphorylated p53 and p21(WAF1) protein expression is dependent on ATM/ATR and phosphatidylinositol-3-kinase in clone-9 cells. *J. Cell. Biochem.* 107, 408-17.
15. Lin, K.-H., Guh, J.-Y., Mo, J.-F., Chiou, S.-J., **Hwang, C.-C.**, and Chuang, L.-Y. (2008) "Advanced glycation end-product-inhibited cell proliferation and protein expression of beta-catenin and cyclin D1 are dependent on glycogen synthase kinase 3beta in LLC-PK1 cells" *Arch. Biochem. Biophys.* **477**, 27-32.
16. Chou, W.-W., Guh, J.-Y., Tsai, J.-F., **Hwang, C.-C.**, Chen, H.-C., Huang, J.-S., Yang, Y.-L., Hung, W.-C., and Chuang, L.-Y. (2008) "Arecoline-induced growth arrest and p21WAF1 expression are dependent on p53 in rat hepatocytes" *Toxicology* **243**, 1-10.
17. Chang, Y.-H., Chuang, L.-Y., and **Hwang, C.-C.*** (2007) "Mechanism of Proton Transfer in the 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase from *Comamonas testosteroni*" *J. Biol. Chem.* **282**, 34306-34314.
18. **Hwang, C.-C.***, Chang, Y.-H., Hsu, C.-N., Hsu, H.-H., Li, C.-W., & Pon, H.-I. (2005) "Mechanistic Roles of Ser114, Tyr155 and Lys159 in 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase from *Comamonas testosterone*" *J. Biol. Chem.* **280**, 3522-3528.
19. Gulati, U., **Hwang, C.-C.**, Venkatramani, L., Gulati, S., Stray, S. J., Lee, J. T., Laver, W. G., Bochkarev, A., Zlotnick, A., & Air, G. M. (2002) "Antibody Epitopes on the Neuraminidase of a Recent H3N2 Influenza Virus (A/Memphis/31/98)" *J. Virol.* **76**, 12274-12280.
20. Liu, D., **Hwang, C.-C.**, & Cook, P. F. (2002) "Alternative Substrates for Malic Enzyme:

Oxidative Decarboxylation of L-Aspartate" *Biochemistry* **41**, 12200-12203.

21. Stanley, T. M., Johnson, W. H., Jr., Burks, E. A., Whitman, C. P., **Hwang, C.-C.**, & Cook, P. F. (2000) "Expression and Stereochemical and Isotope Effect Studies of Active 4-Oxalocrotonate Decarboxylase" *Biochemistry* **39**, 718-726.
22. Karsten, W. E., Chooback, L., Liu, D., **Hwang, C.-C.**, Lynch, C., & Cook, P. F. (1999) "Mapping the Active Site Topography of the NAD-Malic Enzyme via Alanine-Scanning Site-Directed Mutagenesis" *Biochemistry* **38**, 10527-10532.
23. Ehrlich, J. I., **Hwang, C.-C.**, Cook, P. F., & Blanchard, J. S. (1999) "Evidence for a Stepwise Mechanism of OMP Decarboxylase" *J. Am. Chem. Soc.* **121**, 6966-6967.
24. Karsten, W. E., **Hwang, C.-C.**, & Cook, P. F. (1999) " α -Secondary Tritium Kinetic Isotope Effects Indicate Hydrogen Tunneling and Coupled Motion in the Oxidation of L-Malate by NAD-Malic Enzyme" *Biochemistry* **38**, 4398-4402.
25. **Hwang, C.-C.**, & Cook, P. F. (1998) "Multiple Isotope Effects as a Probe of Proton and Hydride Transfer in the 6-Phosphogluconate Dehydrogenase Reaction" *Biochemistry* **37**, 15698-15702.
26. **Hwang, C.-C.**, Berdis, A., Karsten, W. E., Cleland, W. W., & Cook, P.F. (1998) "Oxidative Decarboxylation of 6-Phosphogluconate Dehydrogenase Proceeds by a Stepwise Mechanism with NADP and APADP as Oxidants" *Biochemistry* **37**, 12596-12602.
27. Cook, P. F., Tai, C. -H., **Hwang, C.-C.**, Woehl, E. U., Dunn, M. F., & Schnackerz, K. D. (1996) "Substitution of Pyridoxal 5'-Phosphate in the *O*-Acetylserine Sulphydrylase from *Salmonella typhimurium* by Cofactor Analogs Provides a Test of the Mechanism Proposed for Formation of the α -Aminoacrylate Intermediate" *J. Biol. Chem.* **271**, 25842-25849.
28. **Hwang, C.-C.**, Woehl, E. U., Minter, D. E., Dunn, M. F., & Cook, P. F. (1996) "Kinetic Isotope Effects as a Probe of the β -Elimination Reaction Catalyzed by *O*-Acetylserine Sulphydrylase" *Biochemistry* **35**, 6358-6365.
29. **Hwang, C. -C.** and Grissom, C. B. (1994) "Unusually Large Isotope Effects in Soybean Lipoxygenase Are Not Caused by a Magnetic Isotope Effect" *J. Am. Chem. Soc.* **116**, 795-796.
30. Yeh, M. Y., Tien, H. J., Tung, C. H., & **Hwang, C. -C.** (1988) "A Convenient Method for the Preparation of Nitriles from Aldehydes and Aldoximes" *J. Chinese Chem. Soc.* **35**, 459-462.

Book Chapter

Hwang, C. -C. and Grissom, C. B. (1996) "Large Deuterium Kinetic Isotope Effects in Soybean

Lipoxygenase" in Lipoxygenase and Lipoxygenase pathway enzyme, Chapter 7, Piazza, G. J., Ed., AOCS Press, Champaign, Illinois, pp116-137.

Poster Abstracts

1. Su, Y.-M., Chang, Y.-H. and **Hwang, C.-C.*** "The Role of Thr188 and Pro185 in Substrate Binding Loop of 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase" The 26th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2011.
2. Hsu, C.-H., Wang, Y.-L. and **Hwang, C.-C.*** "Characteristics of Conserved Residues Asp in the Phosphoribosylpyrophosphate Synthetase from *Bacillus subtilis*" The 26th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2011.
3. **Hwang, C.-C.***, Su, Y.-M., and Chen, H.-W. "Characterization of substrate binding loop of 3 α -hydroxysteroid dehydrogenase/carbonyl reductase" 22nd Enzyme Mechanisms Conference, St. Pete Beach, Florida, USA, Jan 2-6, 2011.
4. **Hwang, C.-C.***, Huang, T.-J., Hsu, C.-N. and Wang, Y.-L. "Roles of interfacial interactions of D249 and R167 in the oligomerization of 3 α -hydroxysteroid dehydrogenase/carbonyl reductase" Experimental Biology 2010 Annual Meeting (ASBMB), Anaheim, California, USA, April 24 – 28, 2010.
5. Wang, Y.-L. and **Hwang, C.-C.** "Cloning, Overexpression and Purification of Enzymes Related NAD⁺ Biosynthesis in Salvage Pathway from *Bacillus subtilis*" The 25th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2010.
6. Chen, H.-W., Chang, Y.-H., Wang, Y.-L. and **Hwang, C.-C.** "Role of Pro185 and Thr188 in Substrate Binding Loop of 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase" The 25th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2010.
7. Li, C.-Y., Huang, P.-Y., and **Hwang, C.-C.** "Substrate Specificity in Subtilisin NAT-Catalyzed Reaction: Roles of Ala85 and Ser221" The 24th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2009.
8. **Hwang, C.-C.** and Chang, Y.-H. "Characterization of the proton relay system in the 3 α -hydroxysteroid dehydrogenase/carbonyl reductase from *Comamonas testosteroni*: the function of Lys 159 and Asn 86 in proton transfer" Trends in Enzymology, St. Malo, France, July 2-5, 2008. *Selected for an oral presentation in one of the « Contributed Lecture » sessions.*
9. Chang, Y.-H. and **Hwang, C.-C.** "The Role of the Conserved Asn86 in the Reaction Catalyzed by 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase from *Comamonas testosteroni*" The 23th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2008.

10. Lin, J.-Y., Chang, Y.-H. and **Hwang, C.-C.** "Molecular Cloning, Overexpression and Characterization of the Human Recombinant 17 β -Hydroxysteroid Dehydrogenase Type 1 in E.coli." The 23th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2008.
11. **Hwang, C.-C.**, and Chang, Y.-H. "Role of Lys159 in the Proton Relay System of the 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase from *Comamonas testosteroni*" Experimental Biology 2007 Annual Meeting (ASBMB), Washington, DC. USA, April 28 – May 2, 2007.
12. **Hwang, C.-C.**, and Chang, Y.-H. "Solvent isotope effect to probe the proton transfer on the reaction catalyzed by 3 α -hydroxysteroid dehydrogenase/carbonyl reductase from *Comamonas testoteroni*" The 22th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2007
13. Chang, Y.-H., Huang, P.-Y., and **Hwang, C.-C.** "Lys159 is involved in the proton transfer of 3 α -hydroxysteroid dehydrogenase/carbonyl reductase from *Comamonas testoteroni*" The 22th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2007
14. Chang, Y.-H., Huang, T.-J., and **Hwang, C.-C.** "The mechanism of proton relay in the active site of the 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase from *Comamonas testosteroni*" Trends in Enzymology, Como city, Italy, June 7-10, 2006
15. Huang, T.-J., Hsun, C.-N., Chang, Y.-H., and **Hwang, C.-C.** "The electronic interaction of Asp249 and Arg167 contributes in the oligomerization of 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase from *Comamonas testosteroni*" The 21th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2006
16. **Hwang, C.-C.**, Chang, Y.-H., Hsu, C.-N., Hsu, H.-H., Li, C.-W., & Pon, H.-I. "Mechanistic Roles of Ser114, Tyr155 and Lys159 in 3 α -Hydroxysteroid Dehydrogenase/Carbonyl Reductase from *Comamonas testosteroni*" The 20th joint annual conference of biomedical sciences, Taipei, Taiwan, March, 2005.
17. Chang, Y.-H., and **Hwang, C.-C.** "The Catalytic Role of Conserved Y155 in 3 α -Hydroxysteroid Dehydrogenase-catalyzed Reaction" The 19th joint annual conference of biomedical sciences, Taipei, Taiwan, April, 2004.
18. **Hwang, C.-C.**, Hsu, H.-H., and Lee, J.-W. "Probing the Functional Roles of S114 and K159 on the 3 α -Hydroxysteroid Dehydrogenase-catalyzed Reaction" The 19th joint annual conference of biomedical sciences, Taipei, Taiwan, April, 2004.
19. **Hwang, C.-C.**, Jenn, T., Gani, D., & Cook, P. F. "Substrate Analogs as Structural Probes of the External Schiff Base of *O*-Acetylserine Sulfhydrylase: An Implication for the Closed Conformation" ASBMB meeting, San Francisco, CA., August 1997.

20. **Hwang, C.-C.**, Woehl, E. U., Minter, D. E., Dunn, M. F., & Cook, P. F. "Kinetic Isotope Effects as a Probe of the β -Elimination Reaction Catalyzed by *O*-Acetylserine Sulfhydrylase" *Isotopes in Biology and Chemistry*, Golden Research Conference. Ventura, CA. February 11-16, 1996.
21. Grissom, C. B., and **Hwang, C.-C.** "Solvent Enhancement of Large Deuterium Kinetic Isotope Effects in Soybean Lipoxygenase Gives $D(V_{max}/K_m) > 100$: Is This a Binding Isotope Effect?" *Isotopes in Biology and Chemistry*, Golden Research Conference. Ventura, CA. February 11-16, 1996.
22. **Hwang, C. -C.** and Grissom, C. B. "Soybean Lipoxygenase Kinetic Isotope Effects: Organic Solvent Dependence of Large Kinetic Isotope Effect" ACS-DBC/ASBMB meeting, Washington, D. C. August 21, 1994.
23. **Hwang, C. -C.** and Grissom, C. B. "Soybean Lipoxygenase Kinetic Isotope Effects: Organic Solvent Dependence of Large Isotope Effect Suggests Amplification" *Enzymes, Coenzymes, Metabolic Pathways* Golden conference. July, 1994.
24. **Hwang, C. -C.** and Grissom, C. B. "Magnetic Field Effect Studies of Lipoxygenase-Catalyzed Oxidation of Linoleic Acid" *Biochemistry* **31**, 2194 (1992).