

## REFERENCES

1. Bonnie, T., "Regulation of The Assimilation of Nitrogen Compounds," Ann.Rev.Biochem., 47:1127-62, 1978.
2. Brown, C.M., "Nitrogen Metabolism in Bacteria and Fungi," Continuous culture 6:applications and new fields. Ellis Horwood, (In Dean,A.C.R., Ellword,D.C., Evans,C.G.T., and Melling,J., eds.), p.176-183, chichester, England., 1976.
3. Kleiner, D.S.P., and Fitxke, E., "Pathway and Regulation Aspects of  $N_2$  And  $NH_4^+$  Assimilation in  $N_2$ -fixing bacteria," Inorganic nitrogen and sulfer., (in Bothe, H. and Treb,A.,eds), p.131-140, Springer-verlag, Newyork, 1981.
4. Natagani, H., Shimizu, M., and Valentine, R.C., "The Mechanism of Ammonia Assimilation in Nitrogen Fixing Bacteria," Arch.Mikro biol., 79: 164-175, 1971.
5. Stadtman, E.R., and Ginberg,A., in The Enzyme., (Boyer, P.D.ed.), Vol.10, p.755-807, Academic press, Orlando, FL., 3rd ed.,1974.
6. Chock, P.B., Rhee, H.G., and Stadtman, E.R., "Interconvertible Enzyme Cascades in Cellular

- Regulation, "Ann. Rev. Biochem.", 49:813-843, 1980.
7. Magasanik, B., "Genetic Control of Nitrogen Assimilation in Bacteria," Ann. Rev. Genet., 16:135-168, 1982.
8. Almarsi, R.J., Janson, C.A., Hamlin, R., Xuong, N.H., and Isenberg, E.D., "Novel Subunit-Subunit Interactions in The Structure of Glutamine Synthetase," Nature, 323:304-309, 1986.
9. Shapiro, B.M., and Stadtman, E.R., "5'-Adenylyl-O-Tyrosine The Novel Phosphordiester Residue of Adenylylated Glutamine Synthetase From Escherichia coli," J. Biol. Chem., 243: 3769-3771, 1968.
10. Caban, C.E., and Ginburg, A., "Glutamine Synthetase Adenylyltransferase from Escherichia coli. Purification and Physical and Chemical Properties," Biochemistry, 15:1569-1580, 1976.
11. Rhee, S.G., Park, R., Chock, P.B., and Stadtman, E.R., "Allosteric Regulation of Monocyclic Interconvertible Enzyme Cascade System: Use of Escherichia coli Glutamine Synthetase As An Experimental Model," Proc. Natl. Acad. Sci. USA., 75:3138-3142, 1978.

12. Brown, M.S., Segal, A., and Stadtman, E.R., "Modulation of Glutamine Synthetase Adenylylation and Deadenylylation is Mediated by Metabolic Transformation of The P<sub>11</sub> Regulatory Protein," Proc. Natl. Acad. Sci. USA., 68:2949-2953, 1971.
13. Alder, S.P., Purich, D., and Stadtman, E.R., "Cascade Control of Escherichia coli. Glutamine Synthetase. Properties of The P<sub>11</sub> Regulatory Protein and The Uridylyltransferase-Uridyl-Removing Enzyme," J. Biol. Chem., 250:6264-6272, 1975.
14. Garcia, E., and Rhee, S.G., "Cascade Control of Escherichia coli. Glutamine Synthetase Purification and Properties of P<sub>11</sub> Uridylyltransferase and Uridyl-Removing Enzyme," J. Biol. Chem., 258:2246-2253, 1983.
15. Ginburg, A., and Stadtman, E.R., in "The Enzyme of Glutamine Metabolism", (Prusiner, S., and Stadtman, E.R., eds.), Academic press, Newyork, pp.9-24, 1973.
16. Reitzer, L.J., and Magasanik, B., "Transcription of glnA in Escherichia coli is Stimulated by Activators Bound to Sites Far From The Promotor," Cell, 45:785-792, 1986.

17. Hirschman, J., Wong, P.K., Sei, K., Keeher, J., and Kustu, S., "Products of Nitrogen Regulatory Genes ntrA and ntrC of Enteric Bacteria Activated glnA Transcription in Vitro:Evident That The ntrA Product is A Factor" Proc.Natl.Acad.Sci. USA., 82:7525-7529, 1985.
18. Ninfa, A.J., and Magasanik, B., "Covalent Modification of The glnG Product, NR<sub>1</sub>, by The glnL Product, NR<sub>11</sub>, Regulates The Transcription of The glnALG Operon in Escherichia coli" Proc.Natl.Acad.Sci. USA., 83:5909-5913, 1986.
19. Kanamori, K., Robert, L.W., and John, D.R., "Ammonia Assimilation in Bacillus polymyxa: <sup>15</sup>N NMR and Enzymatic Studies.," J.Biol.Chem., 262: 11038-11045, 1987.
20. Kanamori, K., Richard, L.W., and John, D.R., "Role of Glutamate Dehydrogenase in Ammonia Assimilation in Nitrogen-Fixing Bacillus maceran " J.Bacteriol., 169(10):4692-2695, 1987.
21. Brown, C.M., and Herbert, R.A., "Ammonia Assimilation in Members of The Rhodospirillaceae" FEMS Lett., 1:39-42, 1977.
22. Drozd, J.W., Tubb, R.S., and Postgate, J.R., "A Chemostat Study of The Effect of Fixed

- Nitrogen Sources on Nitrogen Fixation,  
Membranes and Free Amino Acids in Azotobacter chroococcum," J.Gen.Microbiol., 73:221-232, 1973.
23. Stewart, W.D.P., "Prerequisites for Biological Nitrogen Fixation in Blue Green Algae," in The biology of nitrogen fixation., (A.Quispel ed.), pp.696-718, Amsterdam:North Holland, 1974.
24. Sprent, J.L., The biology of nitrogen fixing organisms. london:Mcgraw-Hill, 1979.
25. Posgate, J.R., FRS., The fundamental of nitrogen fixation., Cambridge ,University press p.90-91, 1982
26. Harinsut, P., "Isolation and Characterization of Some Nitrogen Fixing Aerobic Diazotrophic Bacteria From Rice Rhizosphere" Thesis, Department of Biochemistry, Chulalongkorn University, 1981
27. Limpananont, J., "Role of Lectin From Rice (Oryza sativa L.) in The Association Between Klebsiella spp.and Root Epidermal Cells," Thesis, Department of Biochemistry, Chulalongkorn University, 1987.
28. Siedel,J., and Shelton,E., "Purification and Properties of Azotobacter vinelandii

- Glutamine Synthetase," Arch.Biochem.Biophys.,  
192:214-224, 1979.
29. Wedler, F., Hoftman, F.M., "Glutamine Synthetase of Bacillus stearothermophilus. Purification and Basic Properties," Biochemistry, 13:3207-3221, 1974.
30. Janet,E., Nancy,A.N., and David,R.B., "The Actinorhizal Root-Nodule Symbiont Frankia spp. strain CpII Has Two Glutamine Synthetase," Proc.Natl.Acad.Sci.U.S.A., 84:6126-6130, 1987.
31. Robert, G.K.D.,and Robert,A.L., "Rhizobium sp.Strain ORS571 Ammonium Assimilation and Nitrogen Fixation," J.Bacteriol., 158(3):1144-1151, 1984.
32. Palaclos, R., "Neurospora crassa Glutamine Synthetase. Purification by Affinity Chromatography and Characterization of Subunit Structure," J.Biol.Chem., 251:1789-1791, 1975
33. Bertrand, H., and pierre, G., "Glutamine Synthetase in Rice:A Comparative Study of The Enzymes from Root and Leaves," Plant Physiol., 66:619-623, 1980.
34. Michael, R.M., Harold, B.P., and Ann.G., "ADP, Chloride, Ion, and Metal Ion Binding to Bovine Brain Glutamine Synthetase," Biochemistry,

26:5023-5031, 1987.

35. Kleiner, D., and Kleinschmidt, J.A., "Selective Inactivation of Nitrogenase in Azotobacter vinelandii Batch Cultures," J.Bacteriol., 128:117-122, 1976.
36. Tempest, D.W., Meers, J.L., and Brown, C.M., "Short Communications Synthesis of Glutamate in Aerobacter aerogene by a Hitherto Unknown Route," Biochem.J., 117:405-407, 1970.
37. Tronick, S.R., Ciardi, J.E., and Stadtman, E.R., "Comparative Biochemical and Immunological of Bacterial Glutamine Synthetase," J.Bacteriol., 115:858-868, 1973.
38. Darrow, R.A., and Knotts, R.R., "Two Forms of Glutamine Synthetase in Free-Living Root-Nodule Bacteria," Biochem.Biophys.Res.Commun., 78: 554-559, 1977.
39. Fuchs, R.L., and Keister, D.L., "Comparative Properties of Glutamine Synthetase I and II in Rhizobium and Agrobacterium spp.," J.Bacteriol., 144: 641-648, 1980.
40. Darrow, R.A., Crist, D., Evan, W.R., Jane, D.L., Keister, D.L., and Knott, R.R. in Current Perspectives in Nitrogen Fixation, (Gibson, A.H., and Newton, W.E.) Australian Academy of

- science, canberra, pp.182-185, 1981.
41. Carlson, T.A., and Chelm, B.K., "Apparent Eucaryotic Origin of Glutamine Synthetase II From The Bacterium Bradyrhizobium japonicum, " Nature (London), 322:568-570, 1986.
42. Farden, K.J.F., and Bergersen, F.J., "Methods for Studying Enzymes Involved in Metabolism Related to Nitrogenase," in Methods For Evaluating Biological Nitrogen Fixation., (Bergersen, F.J., ed.), p.265-314, John Wiley & Sons, Ltd., Chichester, Newyork, 1980.
43. Stadtman, E. R., Ginsburge, A., Ciardi, J.E., Yeh, J., Hunning, S.B., and Shapiro, B.M., "Multiple Molecular Forms of Glutamine Synthetase Produced by Enzyme Catalyzed Adenylylation and Deadenylylation Reaction," Adv. Enz. Regul 8:99-118, 1970.
44. Robert, A.B., Karren, A.J., Arther, D.R., Miroslarv, B., Forrest, F., and Baris, M., "Biochemical Parameters of Glutamine Synthetase from Klebsiella aerogene," J. Bacteriol., 129: 1001-1009, 1977.
45. Sabina, R., Bruno, C., Giuliana, Z., and Enrica, G., "Purification and Characterization of Glutamate Synthetase from Azospillum brasiliense,"

- J.Bacteriol., 103(2):724-729, 1985.
46. Sharad, K., and Nicholas, D.J.D., "Purification, Properties and Regulation of Glutamine Synthetase from Nitrobacter agilis," General Microbiology, 130:959-966, 1984.
47. David, B.J., "Disc Electrophoresis. II. Method and Application to Human Serum Protein," Ann.N.Y.Acad.Sci., 121:404-427, 1964.
48. O'Farrel, P.H., "High Resolution Two-Dimensional Electrophoresis of Protein," J.Biol.Chem., 250:4007, 1975.
49. Bradford, M.M., "A Rapid and Sensitive Method for Quantitation of Microgram quantities of Protein Utilizing The Principle of Protein Dye Binding," Anal.Biochem., 72:248-254, 1976.
50. Rebello, J.L., and Norman, S., "Regulation of Synthesis of Glutamine Synthetase in Bacillus subtilis," J.American Society for Microbiology, 98(2):683-688, 1969.
51. Stadtman, E.R., Shapiro, B.M., Kingdon, H.S., Wollfolk, C.A., and Hubbard, J.S., "Cellular Regulation of Glutamine Synthetase Activity in Escherichia coli," in Adv.Enz.Regul., 6:257-289, 1968.

52. Haff, L., Easterday, R.L., "Cibacron Blue-Sepharose:A  
Tool for Genaral Ligand Affinity  
Chromatography," in Theory and Practice in  
Affinity Chromatography, (Eukstein, F., and  
Sundarum, P.V. eds), Academic Press, to be  
published.

**APPENDIX**

Calculation of % feedback inhibition with  
cumulative or additive mode.

Example: A inhibits transferase activity by 20%

B inhibits transferase activity by 50%

If A+B inhibit transferase activity by  
cumulative mode, the inhibition will be  
 $20 + (100 - 20) \cdot .5 = 60\%$

If A+B inhibit transferase activity by  
additive mode, the inhibition will be  
 $20 + 50 = 70\%$

## BIOGRAPHY

Miss Boontariga Wongwaitayakul was born on June 18, 1960 in Bangkok, Thailand. She graduated with the Bachelor degree of Science in Medical Technology from the Faculty of Medicine, Chulalongkorn University in 1982. She has been working in the Obstetrics and Gynaecology Department, Faculty of Medicine, Chulalongkorn University since 1983.

