DETAILED CURRICULUM VITAE

Name : **Anil K. Tyagi**

Designations : Former Vice Chancellor
Guru Gobind Singh Indraprastha University
Dwarka, New Delhi-110078
Mob. 9312266218

- Former Professor and Head
  Department of Biochemistry, University of Delhi South Campus
- Former J.C. Bose National Fellow
  Department of Biochemistry, University of Delhi South Campus
- Adjunct Professor
  Translational Health Science and Technology Institute,
  Faridabad, Haryana

Experience : 35 years experience of teaching, research andadministration at University of Delhi and GGS Indraprastha University:

- Professor of Biochemistry, Head of the Department,
- Co-ordinator of UGC-SAP Programme,
- Chairman of Advisory Committee of WUS Health Centre, University of Delhi South Campus,
- Member of Governing Body of a number of Delhi University Colleges.
- Member Scientific Advisory Committee of a number of national institutions
- Member of National/International Committees for evaluation/funding/review of scientific projects

Electronic Mail : akt1003@rediffmail.com
Website : www.aniltyagi.org
Date of Birth : 2nd April 1951, Sex: Male

Honours/ Awards

- **Shanti Swarup Bhatnagar Prize by CSIR (1995)**
- **J.C. Bose National Fellow, Department of Science and Technology, GOI (2010)**
- **Vigyan Gaurav Samman Award by UP Government. (2010)**
- **Vice President, Society of Biological Chemists (India) from 2004-2006**
- **Ranbaxy Research Award by Ranbaxy Science Foundation (1999)**
- **P.S. Sarma memorial award by the Society of Biological Chemists (India) (1993)**
- **Dr. Nitya Anand Endowment Lecture Award by INSA (1999)**
- **C.R. Krishnamurthy Memorial Oration Award by CDRI, Lucknow (2007)**
- **Prof. S.H. Zaidi Oration Award by ITRC, Lucknow (2005)**
- **Dr. Kona Sampath Kumar prize by the University of Delhi (1983)**
- **Distinguished service award by Delhi University (2019)**
- **Om Prakash Bhasin Award for Biotechnology (2019)**
- **Fellow of the National Academy of Sciences, India**
- **Fellow of the Indian Academy of Sciences, India**
- **Fellow of the Indian National Science Academy, India**

Membership to professional associations/societies

- Member of Guha Research Conference
- Life Member of the Society of Biological Chemists (India)
- Life Member of Indian Society of Cell Biology
- Life Member of Association of Microbiologists of India

Education

Degree	University	Subject	Division	Year
Ph.D.	University of Delhi	Medical Biochemistry	-	1977
M.Sc.	University of Allahabad	Biochemistry	First	1972
B.Sc.	University of Meerut	Zoology, Botany, Chemistry	First	1970

Positions

Duration	Designation	Institution
May 2014 – May 2019	**Vice Chancellor**	Guru Gobind Singh Indraprastha University, Sector 16C, Dwarka, New Delhi-110078
August 2011–May 2014	**Professor**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
August 2008 - August 2011	**Professor & Head**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
August 1999 - August 2008	**Professor**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
August 1996 - August 1999	**Professor and Head of the Department**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
August 1993 - August 1996	**Professor of Biochemistry**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
May 1993 – August 1993	**Professor and Head of the Department**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
August 1990 - May 1993	**Reader and Head of the Department**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
June 1986 - August 1990	**Reader**	Department of Biochemistry, University of Delhi, South Campus, New Delhi-110021
June 1983 - June 1986	**Lecturer**	Department of Biochemistry, V.P. Chest Institute, Delhi-110007
May 1980 - June 1983	**International Visiting Associate**	National Institutes of Health, Bethesda, MD USA
May 1978 - April 1980	**International Visiting Fellow**	National Cancer Institute, NIH, Bethesda, MD USA

January 1973 - April 1978	**CSIR – JRF SRF, PDF**	Department of Biochemistry, V.P. Chest Institute, Delhi-110007

Administrative Experience / Public Service / Consulting Activity

Achievements of the GGS Indraprastha University during the Vice Chancellorship since May 2014 – May 2019:

Academic Reforms and Achievements:

- Promoted scientific research in the University by taking initiatives such as University sponsored visits of faculty members abroad to attend scientific meetings; by providing University grants for publication charges and by enhancing University research scholarships. Besides, the perpetual delay in Ph.D. thesis adjudication was removed by taking care of anomalies.
- New Ph.D. Ordinance has been revised and implemented twice. First in February, 2015 and second in July, 2017 on the basis of UGC Regulations to enhance research quality.
- Choice based credit system and Grading system of evaluation has been implemented from the academic session 2015-2016 on the basis of UGC Regulations.
- Guidelines for grant of financial assistance for attending conference were revised.
- Development of faculty feedback system by students from conceptualization to creating and successful implement.
- The University formulated Regulations governing the grant of equated teaching designation to Medical Doctors.

Infrastructure:

- Safety measures and other facilities have been improved in the University hostels. Installation of CCTV Cameras have already been done in the campus.
- The process of construction of East Delhi Campus in Surajmal Vihar has been initiated and an amount of Rs.90 crores has already been released.
- The facilities at University Canteen, Day Care Centre, and Children's Park in Dwarka Campus have been enhanced.
- Safety measures and other facilities have been improved in the University hostels.
- University Schools of Studies have raised state of art laboratory and other infrastructure facilities. A number of high end equipments have been procured for various university schools.
- Doctors for Medicine, Gynecologist, Psychiatrist& Psychologist have been engaged on visit basis for University Employees/students and establishment of a Physiotherapy Centre.

Faculty (Promotion & Recruitment):

- The faculty promotions in the University were not carried out for the last more than seven years. During the last four years, 3 rounds of CAS based promotions were completed for all levels of faculty.

- The University reviewed all pending case(s) of equated teaching designation pending from 2006. The process of equated teaching designation was completed in the year of 2016.
- The University has also started the process for recognition of teachers of affiliated institutions which was not conducted by the University in the last five years.

Research & Grants:

- The University awards Indraprastha Research Fellowship (IPRF) to research scholars of different Schools of Studies. The fellowship and contingency amount has been made at par with the national research fellowships.
- The University started Short Term Research Fellowship (STRF) to research scholars of University School of Studies who are not getting any other scholarship. The amount of fellowship is Rs. 10,000/ per month consolidated. Initially the term of fellowship was one year, which has now been extended to two years.
- The University has started Faculty Research Grant Scheme (FRGS) in 2015-16. Under this scheme a faculty is eligible for an annual grant to carry out a research project. The maximum grant permissible under this scheme is Rs. 2.0 lakhs for Science and Technology disciplines and Rs. 1.0 lakh for Social Sciences, Humanities and Law disciplines. For every year, ~70 projects were approved.

New academic programmes started :

- M. Tech. (Robotics & Automation) - On Campus
- M.Phil (English) - On Campus
- M.A. (Economics) - On Campus
- B.A.(H) (Economics) - Affiliated Institution
- B.A.(H)(English) - Affiliated Institution
- M.Phil (Clinical Psychology) - Affiliated Institution
- B. Voc. (Software Development, Mobile Communication, Automobile, Construction Technology, Refrigeration and Air Conditioning, Consumer Electronics, Applied Arts, Interior Design) - Affiliated Institutions
- B.Ed. Spl. Education (LD) - Affiliated Institutions
- B.Sc. – Post Basic Nursing - Affiliated Institutions
- M.Sc. (Forensic Science) - Affiliated Institutions
- M.A. (Criminology) - Affiliated Institutions
- M.D. (Anatomy, Biochemistry, Community Medicine, Pharmacology, Physiology, Psychiatry) - Affiliated Institutions
- MS (General Surgery, Ophthalmology, Orthopedics, ENT) - Affiliated Institutions
- M.Sc.(Plastic surgery, Pediatric surgery) - Affiliated Institutions

Technology And Administrative Updates :

- Submission of applications forms for admissions is being done in online mode. Counseling for admissions in major programmes is being executed in online mode.
- Increase in number of online counseling for various programmes in comparison to previous year.
- Several administrative branches were strengthened and recuperated in order to perform better. Special attention was provided to admission branch and affiliation branch of the University resulting in their smooth and far superior functioning.

System Reforms:

- **Medical Scheme:** The University holistically reviewed the Medical Regulations of the University aiming for welfare of the University Employees.
- **Merger of USICT & USET:** In order to streamline academic programmes the University has done away with the virtual school of USET and merged it with USICT to align the academic activities to avoid overlapping.

Affiliation:

New Institutions

- Eight new institutions have been affliated.

Past Experience

Member Scientific Advisory Committees of following National Institutions:

1. Member, Scientific Advisory Group, Translational Health Science and Technology Institute (THSTI), Udyog Vihar, Gurgaon.
2. Member Expert, Research Council of Institute of Genomics and Integrative Biology, Delhi.
3. Member, Research Advisory Committee, Central Institute of Fisheries Technology (CIFT), Cochin.
4. Member of Scientific Advisory Committee, National Centre for Cell Sciences (NCCS), Pune.
5. Member, Apex Committee of the Department of Biotechnology, Government of India on "New Programme Support in High Priority Area of Biology" at Indian Institute of Science, Bangalore.
6. Member of Scientific Advisory Committee, National Institute of Nutrition, Indian Council of Medical Research, Hyderabad.
7. Member of the Research Area Panels and Scientific Advisory Committee, Centre for DNA Finger Printing and Diagnosis (CDFD), Hyderabad.
8. Member of Scientific Advisory Committee, Institute of Pathology, Indian Council of Medical Research, Safdarjung Hospital, New Delhi.
9. Member of Scientific Advisory Committee, Tuberculosis Research Centre, Indian Council of Medical Research, Chennai.
10. Member of the Project Advisory Committee on "Biochemistry, Biophysics and Molecular Biology", Department of Science and Technology, Government of India.
11. Member of the Research Committee on "Animal Science and Biotechnology" Council of Scientific and Industrial Research, New Delhi.
12. Member of the Research Council of Centre for Biochemical Technology, New Delhi.
13. Member, Research Area Panels and Scientific Advisory Committee, National Institute of Immunology, New Delhi.
14. External expert on the Board of Studies for Biotechnology, Banaras Hindu University, Varanasi.
15. Expert Consultant to the Tuberculosis Research Programme (TBRU) of the National Institutes of Health, USA.
16. Member Board of Studies for Biochemistry, Aligarh Muslim University, Aligarh.
17. External expert on the Board of Research Studies in Science, The University of Kashmir, Srinagar.
18. Member, Board of Research Studies, Faculty of Inter Disciplinary and Applied Sciences, University of Delhi.

Member of National / International Committees for evaluation / funding / review of scientific research

19. Member, APEX Committee, Vaccine Grant Challenge Programme, Department of Biotechnology, Government of India, New Delhi.
20. Member of Expert Committee for North Eastern Region Biotechnology Programmes, Department of Biotechnology, Government of India.

21. Member, Technical Advisory Committee (TAC) for advising, evaluating, reviewing and monitoring activities of National Research Development Corporation (NRDC), New Delhi for activities funded by DSIR.
22. Member, Task Force for Vaccines and Diagnostics in the areas of health care, Department of Biotechnology, Government of India, New Delhi.
23. Member, Task Force for Infectious Disease Biology, Department of Biotechnology, Government of India, New Delhi.
24. Member, Expert Committee, University Grants Commission (UGC), New Delhi for evaluation of major research projects.
25. Member, Task Force on International Collaborations, Department of Science and Technology, Government of India.
26. Member of the Task Force on Basic Research in Modern Biology, Department of Biotechnology, Government of India.
27. Member of the International Programme Approval Committee (IPAC), Department of Biotechnology, Ministry of Science and Technology, New Delhi.
28. Member of Research Council of Human Research Development Group, Council of Scientific and Industrial Research, New Delhi.
29. Member, Project Review Committee on “Leprosy and Tuberculosis and Other Chest Diseases”, Indian Council of Medical Research.
30. Member of the Project Advisory Committee on "Biochemistry, Biophysics and Molecular Biology”, Department of Science and Technology, Government of India.

Member Governing Bodies of Institutions

31. Chairman, Governing Body, Miranda House, University of Delhi.
32. Member, Governing Body, Moti Lal Nehru College, University of Delhi.
33. Member, Governing Body, Shivaji College, University of Delhi.
34. Member, Governing Body, Ram Lal Anand College, University of Delhi.
35. Member, Governing Body, University College of Medical Sciences (UCMS), University of Delhi.
36. Member of Academic Council of University of Delhi.
37. Member, Governing Body, Acharya Narendra Dev College, New Delhi.
38. Member, Governing Body, V.P. Chest Institute, University of Delhi, Delhi.
39. Member, Governing Body, ARSD College, University of Delhi, Dhaula Kuan, New Delhi.
40. Member, Governing Body, Dayal Singh College, New Delhi.
41. Member, Governing Body, Maulana Azad Medical College, New Delhi.
42. Member, Governing Body, Sri Venkateswara College, New Delhi.
43. Member, Governing Body, Rajkumari Amrit Kaur College of Nursing, New Delhi.
44. Member, Governing Body, Lady Harding Medical College, New Delhi.
45. Member, Governing Body, Acharya Narendra Dev College, New Delhi.
46. Member, Governing Body of Sri Venkateswara College, University of Delhi, New Delhi.

47. Member, Governing Body of Moti Lal Nehru College, University of Delhi.
48. Member, Governing Body of Maitreyi College, University of Delhi, New Delhi.

Member of Academic Committees of Scientific Institutions

49. Member, Academic Committee, Translational Health Science and Technology Institute, Gurgaon.
50. Member, Academic Committee, National Institute of Immunology, New Delhi.
51. Member, Academic Committee, International Centre for Genetic Engineering and Biotechnology, New Delhi.
52. Member, Advisory Committee of DRS Programme, Interdisciplinary Biotechnology Unit, Aligarh Muslim University, Aligarh.
53. Member of Special Committee of the Special Centre of Molecular Medicine, Jawahar Lal Nehru University, New Delhi.
54. Member of Special Committee, School of Life Sciences, Jawaharlal Nehru University, New Delhi.
55. Member of the Academic Committee, Central Drug Research Institute, Lucknow.
56. Member of Academic Committee, Centre for Biotechnology, Banaras Hindu University, Varanasi.
57. Member of the Academic Committee of the International Centre for Genetic Engineering and Biotechnology, New Delhi.
58. Member of the Academic Committee, Institute of Microbial Technology, Chandigarh.
59. Member of the Academic Committee, National Institute of Immunology, New Delhi.
60. Member of Special committee for Centre of Biotechnology, Jawaharlal Nehru University, New Delhi.
61. Member of academic committee for Biochemistry - Kurukshetra University.

Other services

62. Member Committee of Courses for M.Phil. Biotechnology for designing, reviewing and running of various courses concerning M.Phil Biotechnology at University of Delhi.
63. Member, Institutional Biosafety Committee, National Institute of Immunology, New Delhi.
64. Member, Management Committee of Bakson Homoeopathic Medical College, Greater NOIDA, Gautam Budh Nagar, U.P.
65. Member Committee of Courses for Biochemistry for designing, reviewing and modification of various curriculum of the University of Delhi pertaining to Biochemistry.
66. Member, Sectional Committee IX (General Biology), Indian National Science Academy, New Delhi.
67. Member, Sectional Committee X (General Biology), Indian National Science Academy, New Delhi.
68. Member, Sectional Committee M-2 (Multidisciplinary Committee for Engineering and Applied Sciences), Indian National Science Academy, New Delhi.

69. Member of the Biosafety Committee for the Ranbaxy Laboratories, Gurgaon, India.
70. Member of the Biosafety Committee for the Jawahar Lal Nehru University, New Delhi.
71. Member of the Biosafety Committee for the Centre for Biochemical Technology, Delhi.
72. Member of the University - Industry interaction Cell, University of Delhi.
73. Chairman, Institutional Animal Ethics Committee, University of Delhi South Campus.

Invited Lectures delivered at:

International Conferences -

1. International Symposium on "Probiotics-From Bench to Community", New Delhi, 7th& 8th March 2015. Acted as Chief Guest and delivered a talk.
2. International Conference on Plant Biotechnology, Molecular Medicine and Human Health, Department of Genetics, UDSC, New Delhi, Chaired a session and delivered a talk, 18th to 20th October 2013.
3. Indo-Swedish Conference on "Post Genomic Opportunities in Tuberculosis and Other Mycobacteria Diseases, Unchagaon Fort, Bulandshahr, 29th – 31st January 2012.
4. International Symposium on "Vaccine to Translation", Suraj Kund, Faridabad, 14th – 17th November 2011.
5. Key note Lecture delivered in the Indo-Canada symposium on "Redox Status and Control in TB: From Basic Research to Drug Development", January 30th to February 1st, 2011, Hyderabad.
6. Rama-Robbins Lecture delivered during the annual meeting of the Indo-US Vaccine Action Programme, New Delhi 17th November 2010.
7. International symposium on "Understanding and Managing the Pathogenic Microorganisms", Institute of Microbial Technology, Chandigarh, 22-24 January 2010.
8. International symposium on Trends in Drug Discovery and Development, Department of Chemistry, University of Delhi, 5th – 8th January 2010.
9. International symposium on Emerging Trends in Biotechnology, Banaras Hindu University, Varnasi, 4th – 6th December 2009.
10. Indo-US Tuberculosis Consultation Meeing, National Institute of Immunology, New Delhi, July 2009.
11. International Symposium on Emerging Trends in Tuberculosis Research: Biomarkers, Drugs and Vaccines, ICGEB, New Delhi, 1st-3rd December 2008.
12. 49th Annual Conference of Association of Microbiologists of India – International Symposium on Microbial Biotechnology: Diversity, Genomics and Metagenomics, Delhi, 18th – 20th November 2008.
13. 22nd Meeting of the Joint Working Group of INDO-US Vaccine Action Programme, New Delhi, 23rd – 24th October 2008.
14. Indo-German Workshop on infectious diseases at INSA, New Delhi, 24th November 2007.

15. International symposium on New Frontiers in Tuberculosis Research, ICGEB, New Delhi, 4th –6th December 2006.
16. Indo-UK Meeting organized by Royal Society, London, UK, 12th –14th September 2006.
17. Indo-Europe Meeting on Infectious Diseases, Bangalore, 5th –6th June 2006
18. International Conference on Opportunistic Pathogens in AIDS, New Delhi, 27th –29th March 2006.
19. Third Indo-Australian Conference on "Vaccines for Cancer, Infectious Diseases, Lifestyle and Degenerative Diseases" Hyderabad, 6th –8th March 2006.
20. INDO-Australian Symposium, "Modern Biological Approaches for the Diseases caused by Mycobacteria and Helicobacter" CDFD, Hyderabad, 5th March 2005.
21. Asian Regional Workshop on International Training and Research in Emerging Infectious Diseases, JNU, New Delhi, 8th –11th March 2005.
22. International symposium on "Emerging Trends in Tuberculosis Research", 15th –17th November 2004, New Delhi, India
23. INDO-US Workshop on "AIDS in India: A workshop-symposium on Research, Trials and Treatment", 2nd – 4th August 2004, Bangalore, India.
24. INDO-UK Tuberculosis Meeting organized by the Royal Society London and DST, India, Hyderabad, 12th –13th January 2004.
25. 10th Congress of Federation of Asian and Oceanian Biochemists and Molecular Biologists, Bangalore, India, 7th –11th December 2003.
26. Tuberculosis Discussion Meeting organized by Royal Society, London, UK, 9th -10th December 2002.
27. INDO-German Workshop on Infectious Diseases, Centre for DNA Fingerprinting and Diagnostics, Hyderabad, 11th -13th December 2002.
28. BCG Group Meeting for the development of a vaccine against AIDS, International AIDS Vaccine Initiative, New York, 19th June 2002.
29. International symposium on "Mycobacterial Diseases: Pathogenesis, Protection and Control", Calcutta, January 2001.
30. INDO-GERMAN Workshop on Tuberculosis Braunschweig, Germany, 18th –20th September 2000
31. ILTP Workshop – INDO-RUSSIAN Collaboration in Biotechnology, Moscow, Russia, 24th – 30th June 2000.
32. 5th International Conference on Emerging Infectious Diseases in the Pacific Rim, Chennai, 7th – 9th January 2000.
33. International training and research in emerging infectious diseases - Asian Regional Workshop on Intracellular Pathogens, New Delhi, 6th – 10th December 1999.
34. WHO/IUIS Refresher Course on immunology, vaccinology and biotechnology applied to infectious diseases, Pune, 24th November – 10th December1999.
35. Indo-US Vaccine Action Programme, Joint workshop on Novel Vaccine Technologies, 26th – 27th October 1999.
36. Indo-French Symposium on Multiple Drug Resistance and Emerging Diseases, New Delhi, March 1999.
37. 12th International Congress of Immunology, New Delhi, November 1998.
38. Department of Biological Sciences, Institute of Bacteriophages, University of Pittsburgh, Pittsburgh, USA, October 1998.

39. "Reemerging Infectious Diseases" - symposium held during the meeting of Indo-US Vaccine Action Programme, Washington, DC, USA, October 1998.
40. Indo-European Commission Symposium on Tuberculosis Research: Into the 21st Century, Chennai, 3rd – 5th February 1998.
41. International conference on Eukaryotic Expression Vector Systems: Biology and Applications, National Institute of Immunology, New Delhi, February 1996.
42. International Symposium on Trends in Microbiology, Bose Institute, Calcutta, December 1995.
43. Albert Einstein Medical College, New York, USA, April 1995.
44. Institute of Public Health Services, New York, USA, April 1995.
45. John L. McClellan Memorial Veteran's Hospital, Little Rock, USA, April 1995.
46. Third Asian Conference on Transcription, Bangalore, September 1994.
47. International symposium on gene expression at Indian Institute of Science, Bangalore, December 1991.
48. Laboratory of Biochemical Pharmacology, National Institute of Arthritis, Diabetes, Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland, USA, May 1990.

National Conferences –

49. Delivered Bimal K. Bachhawat lecture at the 6th Symposium on "Frontiers in Molecular Medicine", JNU, New Delhi, 13th-15th February 2015.
50. Symposium on ''Current Trends in Structural Biology in Multidrug Resistant Bacterial Therapeutics and Thrombosis'', AIIMS, New Delhi, February 27-28, 2014.
51. National Symposium on "Innovation in TB Diagnostics, Drug Targets and Biomarkers",JBTDRC, MGIMS, Sevagram, January 27 - 28, 2014.
52. Zoonotic Mycobacterial Infections and their Impact on Public Health, AIIMS, New Delhi, 25th-27th February 2013.
53. Refresher Course in Life Science, UDSC, New Delhi, 15th March 2013
54. Science, Technology and Innovation (STI) Policy – a Brainstorming conference on implementation aspects, National Institute of Plant Genome Research, New Delhi, 2nd March, 2013
55. Symposium on "Vaccines for India: Innovations and Roadmap", St. Johns Research Institute, Bangalore, 5th February 2013.
56. National Symposium on Microbes in Health and Agriculture, JNU, New Delhi, 12th and 13th March 2012.
57. "Celebration of 100 years of Chemistry", special lecture on "Development of TB Vaccines", Hans Raj College, University of Delhi, 26th March 2011.
58. UGC-SAP workshop on "Advances in Molecular Biologyand Biotechnology", Department of Plant Molecular Biology, UDSC, New Delhi, 25th March 2011.
59. National Symposium on "Emerging Trends in Biotechnology", Indian Institute of Advanced Research, Gandhinagar, Ahmedabad, Gujarat, 27th-28th April 2010.
60. Inaugural Lecture for the Annual Function of Biochemistry Society, Institute of Home Economics, Hauz Khas, New Delhi, 15th December 2009.
61. 77th Annual Meeting of the Society of Biological Chemists (India), IIT Madras, Chennai, 18th – 20th December 2008.

62. Ranbaxy Science Foundation's 22nd Round Table Conference on "Challenges of MDR/XDR Tuberculosis in India", New Delhi, 13th December 2008.
63. 32nd Annual Conference of Indian Association of Medical Microbiologists (IAMM), A CME on "Vaccinology - an update", AFMC, Pune, 22nd October 2008.
64. Symposium on Industrial application of microbial proteomics, Indian Institute of Advanced Research, Gandhi Nagar, Gujarat, 2nd-4th June 2008.
65. Symposium on Recent Trends in Biotechnology, Aligarh Muslim University, Aligarh, 16thJanuary, 2008.
66. B.R. Ambedkar Centre, University of Delhi, Delhi, 10th July 2007.
67. Dr. C.R. Krishnamurthy Memorial Oration, ITRC, Lucknow, 5th June 2007.
68. Foundation Day Lecture at JALMA National Institute of Leprosy and Other Mycobacterial Diseases, Agra, 17th April 2007
69. Department of Genetics, University of Delhi South Campus, New Delhi-110021, 4th April 2007
70. Department of Biochemistry, Faculty of Science, MS University, Baroda, 7th March 2007.
71. 24th Biennial Conference of the Indian Association of Leprologists, JALMA, Agra, 12th - 14th November 2005.
72. Annual Meeting of the Society of Biological Chemist(s) and Molecular Biologists, India, Lucknow, 7th –10th November 2005.
73. Brainstorming workshop on Tuberculosis, ICGEB, New Delhi, 19th – 21st May 2005.
74. Prof. S.H. Zaidi Oration at Industrial Toxicology Research Centre, Lucknow 3rd November 2005.
75. Symposium on Tuberculosis Research – An Indian Perspective (TRIP), AstraZeneca Bangalore, India, 20th October 2005.
76. 59th National Conference on Tuberculosis and Chest Diseases, New Delhi, 3rd-6th February 2005.
77. Ranbaxy Science Foundation's 15th Round Table Conference on "HIV and Tuberculosis: Co-Infections", New Delhi, 8th January 2005.
78. ICMR-INSERM Workshop on Tuberculosis, Agra, India, 12th – 14th December 2003.
79. Global challenges in TB: An update. V.P. Chest Institute, Delhi, 6th April 2003.
80. Symposium on "The Frontiers of Molecular Medicine", Special Centre for Molecular Medicine, Jawaharlal Nehru University, New Delhi, 2nd February 2002.
81. Refresher Course for teachers in Biochemistry, B.R. Ambedkar Centre, University of Delhi, Delhi, 6th October 2001
82. 1st Conference of Biotechnology Society of India, "Biotecon-2001", New Delhi, 4th – 6th October 2001.
83. Annual meeting of the Association of Microbiologists of India (AMI), Jaipur, November 2000.
84. ATA-Apollo Millennium Medical Conference, Hyderabad, December 2000.
85. The first Sir Dorabji Tata Symposium – Status of tuberculosis in India, March 11-12, 2000.
86. Dr. Nitya Anand Endowment Lecture 1999 (awarded by INSA), Tata Institute of Fundamental Research, Bombay, 27th December 1999.

87. Annual Meeting of the Society of Biological Chemists, India, New Delhi, December 1998.
88. HIV Vaccine Development Initiative by India - Seminar arranged by NACO and Ministry of Health, New Delhi, November 1998.
89. "Mycobacterial Genome" August - symposium arranged by : Bioinformatics Centre, JNU, August 1998.
90. Host Pathogen defences in Mycobacterium tuberculosis and HIV Infections: Emerging scenario, National Institute of Immunology, New Delhi, 1998.
91. Brain Storming Session on "Development and deployment of target molecules from New Bioactive Substances" held at CCMB, Hyderabad, 1st – 2nd August 1998.
92. ASTRA-CCMB Symposium on Molecular Aspects of Microbial Pathogenesis, Hyderabad, 11th – 13th January 1998.
93. 38th Annual Meeting of the Indian Science Congress, Hyderabad, 3rd – 6th January 1998.
94. Centre for Genetic Engineering, MK University, Madurai, March 1997.
95. Department of Biochemistry, M.S. University, Baroda, February 1997.
96. 37th Annual Meeting of the Association of Microbiologists of India, Chennai, 4th – 6th December 1996.
97. Department of Biochemistry, North-Eastern Hill University, Shillong, September 1996.
98. Institute of Nuclear Medicine and Allied Sciences, New Delhi, January 1996.
99. Workshop on Infectious diseases: diagnostics, prophylactics, and therapeutics, National Institute of Immunology, December 1995.
100. Annual meeting of the Society of Biological Chemists, India, Lucknow, October 1995.
101. Symposium on Pasteur's Heritage: from Molecular asymmetry/Industrial fermentation to causality and cure of infectious diseases, Institute of Microbial Technology, Chandigarh, September 1995.
102. XI National Symposium on Developmental Biology, Maharshi Dayanand University, Rohtak, March 1995.
103. First Congress of Federation of Indian Physiological Societies, New Delhi, March 1995
104. XVIII All India Cell Biology Conference and Symposia, National Botanical Research Institute, Lucknow, February 1995.
105. Institute of Microbial Technology, Chandigarh, August 1994.
106. Department of Biochemistry, Banaras Hindu University, Varanasi, July 1994.
107. UGC sponsored Refresher course in Biochemistry at Sri Venkateswara College, University of Delhi, April 1994.
108. Annual Meeting of the Society of Biological Chemists, India, Madurai, December 1993.
109. Department of Biochemistry, North Eastern Hill University, Shillong, December 1993.
110. UGC sponsored Refresher course in Biochemistry at Daulat Ram College, University of Delhi, July 1993.
111. Annual meeting of the Society of Biological Chemists, India, Hyderabad, December 1992.
112. National Chemical Laboratory, Pune, May 1992.
113. National Institute of Immunology, New Delhi, April 1992.
114. Department of Biochemistry, University of Allahabad - March 1992
115. Brain Storming session on Molecular Biology sponsored by TAB - CSIR Centre for Biochemicals, Delhi, March 1992.
116. Annual meeting of the Tuberculosis Association of India, New Delhi, January 1992.
117. Department of Plant Molecular Biology, University of Delhi, March 1991.

118. Symposium on Molecular Genetics, at the annual meeting of the Indian Science Congress, Indore - January 1991.
119. The annual meeting of the Society of Biological Chemists India, New Delhi, October 1984.

Editorial Work

Academic Editor, PLoS ONE from 2009 onwards, published by Public Library of Science.

Member of Editorial Advisory Board for the journal Tuberculosis from 2012-2015.

Member of the Editorial Board for the Journal "Indian Journal of Medical Research" published by ICMR, New Delhi, 2003 onwards.

Member of Editorial Board for the journal "Tuberculosis" published by Elsevier Press, 2003-2007.

TEACHING EXPERIENCE AT UNIVERSITY OF DELHI

M.Sc., BIOCHEMISTRY	:	Molecular biology, Molecular genetics, Recombinant DNA technology, enzymes, carbohydrate metabolism
M.Sc., GENETICS	:	Molecular biology
M.Sc., MICROBIOLOGY	:	Molecular biology
M.Phil., BIOTECHNOLOGY	:	Molecular genetics and Molecular biology

DETAILS OF TEACHING EXPERIENCE

Total teaching experience = 31 years

M.Phil. Biotechnology	1988-2014	Molecular Biology
M.Sc. Microbiology	1994-2009	Molecular Biology
M.Sc. Genetics	1986-1989	Recombinant DNA Technology
M.Sc. Genetics	1986-2009	Molecular Biology
M.Sc. Biochemistry	1985-1989	Recombinant DNA Technology
M.Sc. Biochemistry	1985-2014	Molecular Biology
M.Sc. Biochemistry	1985-1987	Molecular genetics
M.Sc. Biochemistry	1983-1987	Enzymes, Carbohydrate metabolism

Development of curriculum for various courses

Major contribution in developing the curriculum for the following courses

- Development of new revised syllabus for B.Sc. (Hons) Biochemistry, University of Delhi, 2010.
- Development of new/revised curriculum for M.Sc. Biochemistry, University of Delhi, 2009.
- Development of revised curriculum for B.Sc. (Hons) Biochemistry for Delhi University, 1998.
- Development of revised curriculum for post-graduate diploma in Molecular and Biochemical Technology, University of Delhi, 1998.
- Development of Curriculum for M.Sc. Biochemistry, Kurukshetra University, 1991.
- Development of curriculum for postgraduate diploma course in Biochemical Technology, University of Delhi, 1990.
- Development of revised/advanced curriculum for M.Sc. Biochemistry, University of Delhi, 1989.
- Development of Curriculum for M.Phil Biotechnology, University of Delhi, 1988.
- Development of curriculum for B.Sc.(Hons) Biochemistry Course for Delhi University, 1987.
- Development of new/revised curriculum for M.Sc. Biochemistry, University of Delhi, 1985.

Meetings / Symposia / Refresher courses organized

- Co-Convenor of the National Symposium on "Ramachandran Manifestation: Peptide to Proteome", UDSC, New Delhi, 14th-15th March 2013.
- Co-Convenor of the symposium on "Systems Biology" held at the Department of Biochemistry, University of Delhi South Campus, New Delhi, 26th March 2012.
- Co-Convenor of the symposium-cum-workshop on "Next Generation Sequencing Data Analysis" held at the Department of Biochemistry, University of Delhi South Campus and JNU, New Delhi, 28th – 29th January 2011.
- Co-Convenor of the national conference on "Drug Discovery and Development" held at the University of Delhi South Campus, New Delhi, organized by Bioinformatics Centre, Sri Venkateswara College in association with Bioinformatics Centre, DISC, University of Delhi South Campus, 21st – 23rd January 2009.
- Co-Convenor of the symposium-cum-workshop on "Computational Biology – Construction of databases" held at the Department of Biochemistry, University of Delhi South Campus and JNU, New Delhi, 14th - 15th March 2008.

- Co-Convenor of the symposium on "Systems Biology" held at the Department of Biochemistry, University of Delhi South Campus and JNU, New Delhi, 12th - 13th March 2006.
- Chairman, Organizing Committee for Brain Storming Session on Tuberculosis held at ICGEB, New Delhi, 19th - 21st May 2005.
- Co-Convenor of the workshop entitled, "Machine Learning Techniques in Bioinformatics" held at the Department of Biochemistry, University of Delhi South Campus and JNU, New Delhi, 28th - 29th March 2005.
- Co-Convenor of the Workshop entitled, "Biological databases – Mining of Information" held at the Department of Biochemistry, University of Delhi South Campus and JNU, New Delhi, 28th - 29th March 2003.
- Co-Convenor of the Workshop entitled, "Applications of Genomics and Proteomics" held at the Department of Biochemistry, University of Delhi South Campus and JNU, New Delhi, 1st - 3rd February 2002.
- Convenor of the Workshop entitled, "Bioinformatics and its Application to Biology" held at the Department of Biochemistry, University of Delhi South Campus, New Delhi, 22nd - 23rd March 2000.
- Joint-convenor of the meeting - TRendys in Biochemistry, held at the University of Delhi South Campus, New Delhi, 23rd – 24th November 1999.
- Convener of the symposium on "Microbial Infections: Diagnostics, Prevention and Cure" during the 38th Annual Meeting of the Association of Microbiologists of India held at New Delhi, 12th – 14th December 1997.
- Joint-Convener of "Diversity in Modern Biology - an Interdisciplinary Symposium" held at University of Delhi South Campus, 21st – 22nd September 1997
- Course in charge for the refresher course in biochemistry sponsored by the University Grants Commission, 28th June – 17th July 1993.
- Co-convener of the Guha Research Conference held at Dalhousie, 17th – 20th May 1993.
- Course Incharge for the refresher course in Immunology sponsored by the University Grants Commission, 28th September - 17th October 1992.
- Course in charge for the refresher course in Biochemistry sponsored by the University Grants Commission, 31st March – 19th April 1991.
- Course-Incharge for the workshop on Nucleic Acid Probes held on the auspices of annual meeting of the Clinical Biochemists of India, at G.T.B. Medical College, New Delhi, February 1991.
- Convener of the Annual meeting of the Society of Biological Chemists (India), New Delhi, 1984.

LIST OF COMPLETED PROJECTS

S.No.	Title of the project	Funding Agency	Status	Funding (in lacs)	Duration
Completed Projects					
1.	A Virtual Centre of Excellence for Co-ordinated Research on Tuberculosis :Development of Alternate Strategies (Phase II)	DBT (Department of Biotechnology, GOI)	Completed	Rs.484.77 lacs	September 2011 to September 2016
2.	Development and evaluation of an alpha-crystallin based prime boost vaccination strategy against TB by employing MVA	DBT	Completed	Rs.80.89 lacs	May 2012 to November 2014
3.	A Virtual Centre of Excellence for Co-ordinated Research on Tuberculosis: Development of Alternate Strategies (Phase I)	DBT	Completed	Rs.424.51 lacs	August 2006 to August 2011
4.	rBCG85C – a candidate TB vaccine: Removal of antibiotic resistance marker, modifications for stabilization of antigen expression and efficacy studies	DBT	Completed	Rs.193.90 lacs	Sept. 2009 to August 2013
5.	Development of a mice model of latent tuberculosis and evaluation of immune-therapeutic potential of DNA vaccines as an adjunct to chemotherapy against tuberculosis	DBT	Completed	Rs.220-.51 lacs	September 2006 – September 2011
6.	The *Mycobacterium w.* Genome Program: Complete Genome Sequencing, Comparative Genomics and Functional Analysis	DBT	Completed	Rs.51 lacs	January 2004 – December 2006
7.	Studies on the role of *virS* gene in the pathogenesis	ICMR	Completed	Rs.28 lacs	February 2003-

	of *Mycobacterium tuberculosis*				January 2006
8.	Development of a heterologous prime boost immunization approach for an effective TB vaccine	DBT	Completed	Rs.44 lacs	August 2002 – July 2005
9.	Protein tyrosine phosphatases from *Mycobacterium tuberculosis* and their role in pathogenesis	ICMR	Completed	Rs. 31 lacs	February 2002 – January 2005
10.	Evaluation of protective efficacy of recombinant BCG constructs as candidate vaccines against tuberculosis and hepatitis	DBT	Completed	Rs.7 lacs	October 2000 – Sept. 2001
11.	Development and evaluation of candidate DNA vaccines for protection against tuberculosis	DBT	Completed	Rs.47 lacs	January 2000 – December 2002
12.	Analysis and characterization of monooxygenase gene of *Mycobacterium tuberculosis*	CSIR	Completed	Rs.8.5 lacs	May 1998 – April 2001
13.	Development of a detection system for rapid screening of compounds for anti-mycobacterial activity	CSIR	Completed	Rs.9.5 lacs	May 1998 – April 1999
14.	Development of a recombinant BCG based multipurpose vaccine vehicle and its application.	DBT	Completed	Rs.43 lacs	September 1996 – September 1999
15.	Molecular strategies for prevention and control of tuberculosis	DBT	Completed	Rs.45 lacs	July 1991 – July 1997
16.	Polyamine biosynthesis as a target for arresting mycobacterial growth	ICMR	Completed	Rs.1.5 lacs	Sept 1990 – Sept 1993
17.	Studies on the mechanism(s) of pathogenesis of *M.tuberculosis*	CSIR	Completed	Rs.8 lacs	March 1994 – February 1997
18.	Regulation of ornithine decarboxylase and its RNA	CSIR	Completed	Rs.8.5 lacs	September 1990 –

	inhibitor from *M. tuberculosis* $H_{37}Rv$				September 1993
19.	Role of polyamine in transcription in mycobacteria	CSIR	Completed	Rs.6 lacs	October 1987 – October 1990

Total Research Grants Received = Rs.1742.58 lacs

DETAILS OF RESEARCH EXPERIENCE

Research Activities

The research activities were focused on understanding the molecular biology of mycobacteria and developing strategies for prevention and control of tuberculosis. Techniques of molecular biology, structural biology, immunology, purification and characterization of proteins, DNA protein interactions, gene knock-outs, vaccine development strategies and animal experiments were the main tools employed. Various aspects of current research activities were:

- Vaccine development programme - Development of new vaccines against tuberculosis and evaluation of their efficacy in animal models.
- Drug discovery programme - Characterization and validation of potential drug targets of *Mycobacterium tuberculosis* and identification of new inhibitors for treatment of tuberculosis.
- Study of genes involved in the pathogenesis of *Mycobacterium tuberculosis*

Supervision of Research Work

Ph.D. awarded	:	31
M.Phil. (Biotechnology) awarded	:	2
M.D. (Medical Biochemistry) awarded	:	1

Publications

Total	:	135
Published Research papers	:	115
Book chapters	:	17
Published Scientific Reviews	:	3

Name of the important periodicals/books in which research papers/book chapters have been published

Journal of Bacteriology
Journal of Biological Chemistry
Biochemistry
Proceeding of National Academy of Sciences (USA)
Gene
Molecular Microbiology
Methods in Enzymology
Journal of Infectious Diseases
Nucleic Acid Research
Nature Chemical Biology
Microbiology (U.K.)
European Journal of Biochemistry
Cancer Research
PLoS One

Biochemical Biophysical Research Communications
Achieves of Biochemistry and Biophysics
Biochemical Pharmacology
Physiology and genomics
Molecular Genetics for Mycobacteria, ASM Press, Washington DC
Advances in Polyamine Research, Raven Press, New York
Advances in Pharmacology and Chemotherapy, Academic Press, New York
The Mycobacteria Cell Envelope, ASM Press, Washington DC
Trends in Pharmacological Sciences
Journal of Applied Bacteriology
Federation Proceedings

Details of patents taken, if any.

Sr. No.	Title of the patent	Authors	Patent No.	National / International	Applied / Granted	Year Applied / Granted	If commercialized, name of industry partner; Value; Year
1	Mutants of mycobacteria and process thereof	Anil K. Tyagi, Ramandeep Singh, Vivek Rao, Vadakkuppattu Devasenapathi Ramanathan, Chinnambedu Nainarappan Paramasivan, Paranji Ramaiyengar Narayanan, Yogendra Singh	Patent No.259 594	National	Granted	Indian Patent Application No. 882/DEL/2003 dated 09.07.2003 Patent granted on 19th March 2014	Not yet, efforts are in progress.
2.	Mutants of mycobacteria and process thereof	Anil K. Tyagi, Ramandeep Singh, Vivek Rao, Vadakkuppattu Devasenapathi Ramanathan, Chinnambedu Nainarappan Paramasivan, Paranji Ramaiyengar Narayanan, Yogendra Singh	Patent No. 7,943, 361	International (USA)	Granted	Application No.10/560,605 Date of Application: July 9, 2004 Date of grant : May 17, 2011	Not yet
3.	Recombinant BCG-Ag85C based immunization against tuberculosis	Anil K. Tyagi, Ruchi Jain, Bappaditya Dey, Neeraj Dhar, Vivek Rao, Ramandeep Singh, Vadakkuppattu Devasenapathi	Under consideration	National	Applied	Application No. 2639/DEL/2008 dated November 21, 2008	Yet to be granted

		Ramanathan, Umesh Datta Gupta, Vishwamohan Katoch					
4.	Alpha-crystallin based immunization against *Mycobacterium* and methods thereof	Anil K. Tyagi, Bappaditya Dey, Ruchi Jain, Aparna Khera, Vadakkuppattu Devasenapathi Ramanathan, Umesh Datta Gupta, Vishwamohan Katoch	Under consideration	National	Applied	Application No.473/DEL/2009 dated March 9, 2009	Yet to be granted
5.	A simple and fast process for evaluating *Mycobacterium tuberculosis* promoters and the effect of candidate antimycobacterial compounds on promoter activity and bacterial viablility under hypoxic and aerobic conditions using *M. smegmatis* as a surrogate host	Jaya Sivaswami Tyagi, Gargi Bagchi, Mayuri, Neetu Kumra, Kohinoor Kaur, Deepak Kumar Saini, Anil Kumar Tyagi	Patent No. 211217	National	Granted	Application No. 981/DEL/2003	Not yet

Important Research Contributions

Summary of Important Research Contributions

Broadly, Dr. Tyagi's laboratory, for the last 20 years, has focused on the following two important areas related to tuberculosis

(1) Vaccine development
(2) Novel targets in *M. tuberculosis* and drug discovery.

The research efforts of his group have been focused on developing the strategies, tools and knowledge related to these two aspects for the control and amelioration of tuberculosis.

In addition, Dr. Tyagi and colleagues have also carried out studies on *mycobacterium indicus pranii*. The collaborative work on this mycobacterial species, with Dr. Tyagi as the Principal Investigator, was responsible for the publication of the first completed genome of a new bacterial species from India.

The summary of the important research contributions is given below:

1. Work on the development of TB vaccines and related aspects

Dr. Tyagi and colleagues have worked in this area for the last twenty years. For this, they first studied the expression signals especially the promoters of mycobacteria and then employed them for the development of expression vectors which they later used for the expression of mycobacterial genes and development of candidate TB vaccines. The brief summary of these efforts is as follows:

A. Studies on the transcriptional signals of mycobacteria

Dr. Tyagi's group has contributed significantly to the understanding of transcriptional machinery and gene expression in mycobacteria. By isolating and characterizing, a large number of transcriptional signals from the slow growing *Mycobacterium tuberculosis* and the fast growing *Mycobacterium smegmatis*, it was demonstrated that most of the mycobacterial promoter elements function poorly in *E.coli.* His work has also provided evidence that RNA polymerases of *M.smegmatis, M.tuberculosis* and *M.bovis* BCG recognize mycobacterial promoter elements with comparable efficiencies and that mycobacterial transcriptional signals differ from their counterparts in *E.coli* with respect to their -35 regions and the corresponding recognition domain of sigma factor of RNA polymerase. These studies have shed significant light on the divergence of mycobacterial transcriptional machinery from those of other bacteria. Also, these studies have provided a better understanding of the molecular basis of slow growth rate of *M.tuberculosis* and an explanation for the poor expression of mycobacterial genes in *E.coli*.

B. Development of tools for genetic manipulations in mycobacteria

Dr. Tyagi's laboratory has developed a repertoire of vectors, which have proved to be extremely useful to several investigators in genetic manipulations of mycobacteria for the basic understanding of these organisms at a molecular level. Besides developing several vectors, for the isolation of promoters, for construction of expression libraries and for trapping the promoters of structural genes under the control of a transcriptional regulator, Dr. Tyagi and colleagues have also developed an integration-proficient vector system for stable expression of genes in mycobacteria. This recombinant BCG system has been very useful for a large number of investigators for expression of mycobacterial genes as well as antigen genes from several other pathogens for the development of BCG into a multipurpose vaccine vehicle.

C. Development of candidate vaccines against tuberculosis

With the aim of modifying BCG into a more potent vaccine against TB, a generic approach was developed by Dr. Tyagi's laboratory for expression of genes in mycobacteria which provides a desired level of expression of an antigen based upon the choice of mycobacterial promoter. Dr. Tyagi's group has expressed several antigens of *M. tuberculosis* by using this expression system to develop a number of candidate vaccines against TB. The evaluation of these candidate vaccines for immune responses in mice and for protective efficacy in guinea pigs has shown that two of the recombinant BCG vaccines provide more efficient protection than BCG itself against a sub-cutaneous challenge of *M. tuberculosis* in guinea pigs. In a parallel approach, Dr. Tyagi and colleagues have also developed several candidate DNA vaccines. Based on reduction in the bacillary load in lung and spleen of guinea pigs as well as associated histopathological changes, some of these candidate DNA vaccines imparted significant protection against the subcutaneous challenge of *M. tuberculosis*.

Till this point of time, no aerosol challenge facility was available in India. Hence, evaluation of the candidate vaccines was carried out by using subcutaneous infection of guinea pigs. However, as the aerosol infection facility at the National JALMA Institute of Leprosy and Other Mycobacterial Diseases, Agra became available, the promising candidate vaccines were evaluated against the aerosol challenge of *M. tuberculosis* in guinea pigs by using heterologous prime boost approach. In this study, three regimens comprising of (i) recombinant BCG overexpressing 85C, (ii) recombinant BCG overexpressing α–crystallin as the priming agent followed by boosting with a DNA vaccine expressing the same antigen and (iii) BCG as priming agent followed by boosting with DNA vaccine expressing α–crystallin showed extremely good results and proved their superiority in comparison to the present BCG vaccine both on the basis of reduction in the bacillary load in lung and spleen as well as histopathological changes. The Tuberculosis Vaccine Clinical Trial Expert Group (TVCTEG) of the Department of Biotechnology, Government of India, has approved these vaccine regimens for human clinical trials. Currently, pre-clinical work on these candidate vaccines is in progress so that the human clinical trials can be initiated.

By employing modified Cornell model, Dr. Tyagi and colleagues have also evaluated the potential of adjunctive immunotherapy with DNA vaccines to shorten the tuberculosis

chemotherapy period and reduce disease reactivation and demonstrated that α-crystallin based DNA vaccine (DNAacr) significantly reduced the chemotherapy period from 12 weeks to 8 weeks when compared with the chemotherapy alone. Hence, α-crystallin based DNA vaccine holds a significant promise for its use both as a prophylactic vaccine as well as in the therapeutic approach.

D. Development of first oligonucleotidew microarray for global gene expression profiling in guinea pigs: defining the transcription signature of infectious diseases

The Guinea pig (Cavia porcellus) is one of the most extensively used animal models to study infectious diseases. However, despite its tremendous contribution towards understanding the establishment, progression and control of a number of diseases in general and tuberculosis in particular, the lack of fully annotated guinea pig genome sequence as well as appropriate molecular reagents has severely hampered detailed genetic and immunological analysis in this animal model. Dr. Tyagi and colleagues developed the first comprehensive microarray (44K) for studying the global gene expression profile in guinea pigs and validation of its usefulness with tuberculosis as a case study. This study by Dr. Tyagi and colleagues addressed an important gap in the area of infectious diseases and vaccine development and provided a valuable molecular tool to optimally harness the potential of guinea pig model to develop better vaccines and therapies against human diseases.

Since, fully annotated guinea pig genome sequence was not available, Dr. Tyagi and colleagues employed cross-species hybridization technology to develop a 44 K microarray platform to study gene expression profile in guinea pigs. In their study, the pulmonary transcriptional profiling of M. tuberculosis infected guinea pigs revealed a significant regulation of 3200 unique targets. While, 1344 unique genes exhibited a marked up regulation, 1856 genes were significantly down regulated. Differentially regulated genes were further classified into different categories based on their direct or indirect involvement in various biological processes or pathways. A massive re-alignment of metabolic pathways, mostly associated with catabolism, emerged as one of the interesting themes from their analysis. The most prominent observation related to the repression of numerous genes related to MAPK, Wnt and calcium signaling pathways. MAPK signaling is known to be crucial for the anti-bacterial response of the host and it also represents a strategic target for bacterial subversion tactics. Thus, dampening of the MAPK signaling has emerged as a key to achieve alteration in the antibacterial phenotype of macrophages. Recently, Wnt signaling pathway has been implicated in the generation of long-lived multi-potent memory T cells and in the modulation of inflammatory response of macrophages to M. tuberculosis infection, thus repression of Wnt signaling pathway observed by Dr. Tyagi and colleagues suggested a possible mechanism by which, M. tuberculosis inhibits effective Tcell memory response.

The transcriptional profiling of M. tuberculosis infected guinea pig lungs developed by Dr. Tyagi and colleagues not only revealed modulation of key immunologically relevant genes but also demonstrated involvement of novel metabolic and signaling pathways in TB pathogenesis. Moreover, their analysis revealed a higher resemblance of guinea pigs to humans in terms of transcriptional response to M. tuberculosis infection when compared to

mouse and non-human primates. Development of the 44 K GPOM thus has been a critical step towards characterization of the guinea pig model, which will greatly aid in improving our understanding of host responses to a number of infectious diseases.

2. Novel targets in *M. tuberculosis* and drug discovery

In a comprehensive approach, Dr. Tyagi and colleagues have worked on several aspects related to this broad area of drug discovery which include study of *M. tuberculosis* genes essential for the pathogenesis of *M. tuberculosis* andvalidation of their essentiality in animal models, crystallization and structure determination of important *M. tuberculosis* proteins, characterization of important *M. tuberculosis* targets and finally use these targets for the identification of mycobacterial inhibitors by target based virtual screening in addition to whole cell based screens. The summary of these efforts is provided below:

A. Study of genes that are essential for the pathogenesis of *M. tuberculosis* – identification of new drug targets

(i) mymA operon

Dr. Tyagi's laboratory identified a new gene (*virS*) from *M .tuberculosis*. The 7 genes (*Rv3083-Rv3089*), which were present divergently to *virS (Rv3082c)* constitute an operon designated as the *mymA* operon. Dr. Tyagi's group showed that transcription of the *mymA* operon is dependent on the presence of VirS protein. A 4-fold induction of the *mymA* operon promoter occurs specifically in the wild type *M. tuberculosis* and not in the *virS* mutant of *M. tuberculosis* (Mtb∆*virS*) when exposed to acidic pH. Dr. Tyagi's group showed that the expression of the *mymA* operon was also induced by 10-folds in infected macrophages. Based on further studies, his group proposed the involvement of these proteins in the modification of fatty acids required for cell envelope under acetic environment. This was supported by altered colony morphology and cell envelope ultra structure displayed by the *virS* mutant of *M. tuberculosis* (Mtb∆*virS*). Dr. Tyagi and colleagues showed that disruption of *virS* and *mymA* genes impairs the ability of *M. tuberculosis* to survive in the activated macrophages, but not in resting macrophages, suggesting the importance of *mymA* operon in protecting the bacterium against harsher conditions. Infection of guinea pigs with Mtb∆*virS*, Mtb*mym:hyg* and the parental strain resulted in ~800-fold reduced bacillary load of the mutant strains as compared with the parental strain in the spleens of animals at 20 weeks post infection. These observations by Dr. Tyagi's laboratory demonstrated important role of *mymA* operon in the pathogenesis of *M. tuberculosis* at later stages of progression of the disease.

(ii) Tyrosine phosphatases of *M. tuberculosis*

Two tyrosine phosphatases namely MptpA and MptpB have been identified and characterized from *Mycobacterium tuberculosis*. To determine the role of MptpB in the pathogenesis of *M. tuberculosis* Dr. Tyagi and colleagues constructed an *mptpB* mutant strain and showed that disruption of the *mptpB* gene specifically impairs the ability of the mutant strain to survive in guinea pigs but not *in vitro* or in a macrophage cell line suggesting the importance of its role in the host-pathogen interaction. Infection of guinea

pigs with the mutant strain resulted in a 70-fold reduction in the bacillary load of spleens in infected animals as compared to the bacillary load in the animals infected with the parental strain along with the commensurate pathological damage in the organs.

Dr. Tyagi and colleagues also showed that disruption of *mptpA* gene impairs the ability of *M. tuberculosis* to survive in IFN-γ activated macrophages as well as in guinea pigs. Infection of activated macrophages with *M. tuberculosis*, or *mptipA* mutant resulted in an approximately 14-fold reduction in the survival of intracellular *mptpA* mutant in comparison to the intracellular parental strain. Dr. Tyagi and colleagues also demonstrated that on infection of guinea pigs the bacillary load in guinea pigs infected with the *mptpA* mutant strain was reduced by 80 and 90 folds in spleens and lungs, respectively, in comparison to bacillary load in guinea pigs infected with the parental strain. Commensurate with these observations, infection of animals with the *mptpA* mutant strain showed a significantly reduced histopathological damage to lungs in comparison to infection with the parental strain. These studies by Dr. Tyagi and colleagues established the importance of *mptpB* and *mptpA* operon in the intracellular survival of *M. tuberculosis*. These studies have provided a better understanding of the importance of tyrosine phosphatases in the survival of *M. tuberculosis* in the host tissue and led to the identification of these two tyrosine phosphatases as attractive targets for the development of new anti-tubercular drugs.

(iii) Iron storage proteins and their importance in the pathogenesis and survival of *Mycobacterium tuberculosis* in the host

Iron is an essential nutrient for almost all microbes, including pathogens such as *Mycobacterium tuberculosis*. It is an indispensable cofactor for proteins involved in critical cellular processes, such as electron transfer, oxygen transport, DNA synthesis, etc. Although iron is essential, excess free iron is potentially toxic for the cells because it catalyzes the production of reactive oxygen radicals by a Fenton reaction, leading to oxidative damage. Thus, all living organisms tightly regulate the cellular levels of iron by employing efficient iron acquisition and storage mechanisms. The sequencing of the *M. tuberculosis* H37Rv genome revealed the presence of two putative iron storage proteins, namely, BfrA (Rv1876), a bacterioferritin, and BfrB (Rv3841), a ferritin-like protein.

However, the biological significance of these iron-storing proteins for *M. tuberculosis* has not been genetically proven. Hence, Dr. Tyagi and colleagues generated mutants of *M. tuberculosis* lacking *bfrA* (Rv1876) and *bfrB* (Rv3841) that encode the iron storage proteins and showed that the mutant of *M. tuberculosis*, H37Rv Δ*bfrA*, Δ*bfrB*, which lacks the function of both *bfrA* and *bfrB*, has significantly reduced growth under iron-deprived conditions, is markedly vulnerable to oxidative stress, and exhibits the attenuation of growth in human macrophages. Moreover, reduced bacillary load in lung and spleen of H37Rv Δ*bfrA* Δ*bfrB*-infected guinea pigs, resulting in a significant reduction in pathology, clearly implied that these proteins play a crucial role in the pathogenesis of *M.tuberculosis.* Mycobacteria are continuously exposed to oxidative stressgenerated by the activated macrophages that they inhabit. Dr. Tyagi and colleagues evaluated the ability of *M. tuberculosis* mutants lacking the function of *bfrA* and *bfrB* to resist oxidative stress and observed that simultaneous mutations in *bfrA* and *bfrB* in *M. tuberculosis* (H37Rv Δ*bfrA* Δ*bfrB*) tremendously reduced its ability to withstand oxidative stress, implying the role of

these iron storage proteins in restricting oxidative damage. These observations by Dr. Tyagi's laboratory clearly demonstrated the importance of these iron storage proteins in the mycobacterial response to oxidative stress.

Thus, Dr. Tyagi and colleagues demonstrated that BfrA and BfrB proteins play a crucial role in protecting the pathogen against oxidative stress encountered during infection. In addition, they showed that BfrA and BfrB proteins are important for the survival and hematogenous spread of the pathogen. Their studies established these proteins as attractive drug targets for the development of new therapeutic molecules against mycobacterial infections.

(iv) Importance of mycobactin biosynthesis in the physiology, growth and pathogenesis of *M. tuberculosis*

M.tuberculosis has developed an efficient mechanism to sequester iron from the host by secreting siderophores known as mycobactins. Mycobactins bind to iron more strongly than the iron storage proteins of the host and play a crucial role of scavenging iron from the iron limiting host environment. *M.tuberculosis*, *mbt* cluster is induced under low iron conditions. No studies have been carried out to evaluate the importance of mycobactin biosynthesis during the survival of *M.tuberculosis* in the host.

Dr. Tyagi and colleagues disrupted the *mbtE* gene (Rv2380c) of *M.tuberculosis* that encodes a non ribosomal peptide synthetase in the *mbt* cluster. Disruption of this gene renders *M.tuberculosis* incapable of synthesizing mycobactins. The Mtb*ΔmbtE* mutant displayed an altered colony morphology and was drastically affected in its ability to grow on agar medium and in broth culture as compared to the parental strain. Supplementation of agar and broth medium with Fe3+CMBT or Fe3+MBT restored the growth of Mtb*ΔmbtE* to levels similar to that of the parental strain. Genetic complementation of Mtb*ΔmbtE* with *mbtE* gene restored the in vitro growth phenotype of the mutant similar to that of the parental strain. From these observations by Dr. Tyagi and colleagues, it was evident that mycobactin mediated iron acquisition is important for the normal growth of the pathogen. Transmission electron microscopy studies demonstrated an altered cell wall permeability of Mtb*ΔmbtE*. Supplementation of growth medium with Fe3+CMBT restored the staining of Mtb*ΔmbtE* similar to that of the parental strain. The altered colony morphology, cell wall permeability and growth characteristics of Mtb*ΔmbtE* suggested that in the absence of mycobactins, several iron requiring systems of Mtb*ΔmbtE* might have been affected (emanating as a consequence of inability of the mutant to synthesize mycobactins). The restoration of normal growth, cell wall permeability as well as colony morphology resulting from the addition of mycobactins in the media suggested that due to its essential role in procuring iron, mycobactin biosynthesis plays an important role in the biology of the pathogen.

Dr. Tyagi and colleagues also demonstrated that Mtb*ΔmbtE* mutant displayed a significantly reduced ability to infect and grow inside the human THP-1 macrophages in comparison to the parental strain, emphasizing that mycobactins are vital for mycobacterial growth. Their studies in guinea pigs provided further evidence that Mtb*ΔmbtE* is highly attenuated for its growth and ability to cause pathology. In the case of infection with the

parental strain, a substantial number of CFU was recovered from the lungs and spleen of animals, at 4 as well as 10 weeks post infection, while no CFU was obtained from the animals infected with Mtb∆*mbtE* at both the time points. These observations demonstrated that the mutant strain could survive in the host only for a limited period of time. These observations demonstrated a severe attenuation in the ability of the mutant to grow in the host and cause disease. Thus, this study Dr. Tyagi and colleagues highlighted the importance of mycobactins for the normal physiology of *M.tuberculosis*, in vitro as well as in the host.

(v) Secreted acid phosphatase (SapM) of *Mycobacterium tuberculosis*

Phagosomal maturation arrest is an important strategy employed by *Mycobacterium tuberculosis* to evade the host immune system. Secretory acid phosphatase (SapM) of *M.tuberculosis* is known to dephosphorylate phosphotidylinositol 3-phosphate (PI3P) present on phagosomes. However, there have been divergent reports on the involvement of SapM in phagosomal maturation arrest in mycobacteria. Dr Tyagi and colleagues conducted a study to reascertain the involvement of SapM in phagosomal maturation arrest in *M.tuberculosis*. Further, for the first time, they also studied whether SapM is essential for the pathogenesis of *M.tuberculosis*. By deleting the *sapM* gene of *M.tuberculosis*, Dr Tyagi and colleagues demonstrated that SapM mediates an important role in the protection of *M.tuberculosis* against the host defense by subverting the phagosomal maturation pathway. Moreover, the disruption of *sapM* in *M.tuberculosis* resulted in a highly attenuated strain with an impaired ability to grow in the THP-1 macrophages. Dr Tyagi et al further showed that Mtb∆*sapM* is severely attenuated for growth in the lungs and spleen of guinea pigs and has a significantly reduced ability to cause pathological damage in the host when compared with the parental strain. Also, the guinea pigs infected with Mtb∆*sapM* exhibited a significantly enhanced survival when compared with *M.tuberculosis* infected animals. The importance of SapM in phagosomal maturation arrest as well as in the pathogenesis of *M.tuberculosis* established it as an important target for the designing of anti-tubercular molecules.The fact that there are no known human analogues of SapM makes it even more important target for the development of new therapeutic molecules against TB. In addition, the secretory nature of SapM presents a unique opportunity in order to avoid the drug permeability issue due to thick hydrophobic cell envelopeof *M.tuberculosis*.

(vi) Apurinic/Apyrimidinic endonucleases of *Mycobacterium tuberculosis*

In host cells, *Mycobacterium tuberculosis* encounters an array of reactive molecules capable of damaging its genome. Non-bulky DNA lesions are the most common damages produced on exposure to reactive species and base excision repair (BER) pathway is involved in the removal of such damage. During BER, apurinic/apyrimidinic (AP) endonuclease enzymes repair the abasic sites that are generated after spontaneous DNA base loss or by the action of DNA glycosylases, which if left unrepaired lead to inhibition of replication and transcription. However, the role of AP endonucleases in the growth and pathogenesis of *M.tuberculosis* has not yet been elucidated. To demonstrate the biological significance of these enzymes in *M.tuberculosis*, Dr Tyagi and colleagues generated *M.tuberculosis* mutants of the base excision repair (BER) system, disrupted in either one (Mtb∆*end* or Mtb∆*xthA*) or both (Mtb∆*end*∆*xthA*) the AP endonucleases and demonstrate that these genes are crucial

for bacteria to withstand alkylation and oxidative stress *in vitro*. In addition, the mutant disrupted in both the AP endonucleases (Mtb∆*end*∆*xthA*) was shown to exhibit a significant reduction in its ability to survive inside human macrophages. However, infection of guinea pigs with either Mtb∆*end* or Mtb∆*xthA* or Mtb∆*end*∆*xthA* resulted in the similar bacillary load and pathological damage in the organs as observed in the case of infection with *M.tuberculosis*indicating that the pathogen must have alternate repair machinery for the repair of the damaged DNA to safeguard its genome during its survival in the host.

B. Crystallization of *M. tuberculosis* proteins and structure determination

Dr. Tyagi and colleagues determined the crystal structure of several important *M. tuberculosis* proteins such as BfrA, BfrB and BirA.

(i) BfrA

Dr. Tyagi et al. determined the crystal structure of the selenomethionyl analog of bacterioferritin A (SeMet-BfrA) from *Mycobacterium tuberculosis* (*Mtb*) at 2.5 A^{o}resolution. Unexpectedly, electron density observed in the crystals of SeMet-BfrA analogous to haem location in bacterioferritins, showed a demetallated and degraded product of haem. They showed that this unanticipated observation was a consequence of the altered spatial electronic environment around the axial ligands of haem (in lieu of Met52 modification to SeMet52). Furthermore, the structure of *Mtb* SeMet-BfrA displayed a possible lost protein interaction with haem propionates due to formation of a salt bridge between Arg53-Glu57, which appeared to be unique to *Mtb* BfrA, resulting in slight modulation of haem binding pocket in this organism. Determination of the crystal structure of *Mtb* SeMet-BfrA by Dr. Tyagi and colleagues provided novel leads to the physiological function of haem in Bfrs. It may also serve as a scaffold for designing specific inhibitors. In addition, this study provided evidence against the general belief that a selenium derivative of a protein represents its true physiological native structure.

(ii) BfrB

Dr. Tyagi and colleagues also determined a 3.0 A° crystal structure of BfrB from *Mycobacterium tuberculosis* (Mtb). The Mtb BfrB subunit exhibited the characteristic fold of a four-helical bundle that possesses the ferroxidase catalytic centre. Dr. Tyagi et al. compared the structure of Mtb BfrB with representatives of the ferritin family belonging to the archaea, eubacteria and eukarya. Unlike most other ferritins, Mtb BfrB has an extended C-terminus. To dissect the role of this extended C-terminus, truncated Mtb BfrB was purified and biochemical studies carried out by Dr. Tyagi and colleagues implicate this region in ferroxidase activity and iron release in addition to providing stability to the protein.

(iii) BirA

The first committed step in lipid biosynthesis is the biotinylation of Acetyl Coenzyme A Carboxylase (ACC) mediated by biotin acetyl-CoA carboxylase ligase/biotin protein ligase (BirA). BirA appears to be an attractive target for the development of broad spectrum therapeutic agents against multiple infections. The apo BirA crystal structure developed by

Dr. Tyagi et al. (at 2.69 A^{o} resolution) revealed the presence of disordered flexible loops, which undergo a conformational transition upon biotin and biotinyl-59-AMP binding. These loops are known to participate in either dimer interface or ligandbinding or both. Dr. Tyagi and colleagues showed that dehydration of *Mtb*-BirA crystals traps both the apo and active conformations in its asymmetric unit, and for the first time provided structural evidence of such transformation. In addition, crystal dehydration resulted in a shift of 3.5 A° in the flexible loop L6, a proline-rich loop unique to *Mtb* complex as well as around the L11 region. The shift in loop L11 in the C-terminal domain on dehydration emulates the action responsible for the complex formation with its protein ligand biotin carboxyl carrier protein (BCCP) domain of ACCA3. This is contrary to the involvement of loop L14 observed in Pyrococcus horikoshii BirA-BCCP complex. This dehydrated crystal structure not only provided key leads to the understanding of the structure/function relationships in the protein in the absence of any ligand-bound structure, but also demonstrated the merit of dehydration of crystals as an inimitable technique to have a glance at proteins in action.

C. Characterization of Drug Target Proteins

(i) Characterization of FaD13 and identification of important residues

To gain further insight into the functioning of *mymA* operon, a potential target for developing antitubercular drugs, Dr. Tyagi's laboratory characterized its gene products. *fadD13*, the last gene of the *mymA* operon, encodes a Fatty Acyl-CoA Synthetase. Dr. Tyagi and colleagues developed several site-directed mutants of FadD13 and analyzed them for the structural-functional integrity of the enzyme. This study revealed that mutation of Lys487 resulted in 95% loss of the activity thus demonstrating its crucial requirement for the enzymatic activity. Comparison of the kinetic parameters by Dr. Tyagi et al. showed the residues Lys172 and Ala302 to be involved in the binding of ATP and Ser404 in the binding of CoenzymeA. The influence of mutations of the residues Val209 and Trp377 emphasized their importance in maintaining the structural integrity of FadD13. Besides, Dr. Tyagi and colleagues showed a synergistic influence of fatty acid and ATP binding on the conformation and rigidity of FadD13. FadD13 represents the first Fatty Acyl-CoA Synthetase to display biphasic kinetics for fatty acids. The studies by Dr. Tyagi and colleagues provided a significant understanding of the FadD13 protein including the identification of residues important for its activity as well for the maintenance of structural integrity.

(ii) Identification of "switch residues" or "interface hot spots" involved in the self assembly and function of bacterioferritin B of *M. tuberculosis*

By employing site-directed mutagenesis Dr. Tyagi and colleagues identified important residues for interactions between subunits of this ferritin that are required for molecular assembly, structural integrity, thermodynamic stability, and ferroxidase activity to provide an improved understanding of the determinants of self-assembly and the structure–function relationship.

To identify the crucial residues involved in the self assembly and function of BfrB, Dr. Tyagi and colleagues constructed various mutants by employing site-directed mutagenesis. The analysis of mutants led to the identification of "interface hot-spot residues" that act as

"switch points" for BfrB oligomerization. These studies demonstrated the importance of 4-fold axis residues in assembly formation. Moreover, it was demonstrated that single-point mutations can enhance the thermal stability of the protein without affecting its assembly. Importantly, a comparative analysis of various mutations by Dr. Tyagi and colleagues revealed that the function of various homologous positions in different ferritins could be at variance; hence, predicting the function of a residue just based on sequence−structure comparisons may not be appropriate. Thus, these studies showed that single-point mutations have a remarkable potential for alteration of multiple properties of ferritins. Besides, "switch residues" or "interface hot spots" identified in this study could also prove to be helpful for the rational design of interfacial inhibitors.

(D) Identification of inhibitors against *M. tuberculosis*

(i). Identification of inhibitors against Fatty Acyl-CoA Synthetase (FadD13, Rv3089) of *M.tuberculosis*

Dr. Tyagi et al. earlier demonstrated that exposure to acidic pH results in the upregulation of the *mymA* operon of *M.tuberculosis* (Rv3083 -Rv3089). The functional loss of the *mymA* operon leads to alterations in the colony morphology, cell wall structure, mycolic acid composition and drug sensitivity and results in markedly reduced intracellular survival of *M.tb* in macrophages. Besides, the *mymA* mutant of *M.tb* shows a drastic reduction (800fold) in its ability to survive in the spleen of guinea pigs as compared to the parental strain and hence, represents an important drug target for *M.tuberculosis*. *fadD13*, the last gene of the *mymA* operon, encodes a Fatty Acyl-CoA Synthetase (FACS), which catalyzes the activation of various fatty acids by converting them into fatty acyl-CoA thioesters.

Dr. Tyagi and colleagues generated the three–dimensional structure of FadD13 by comparative homology modeling. The predicted active site covered parts of both the N- and C-terminal domains along with the cleft region placed between both the domains. Moreover, the active site was similar to that seen in other homologous proteins.

Dr. Tyagi and colleagues employed the NCI Open Database comprising of 2,60,071 compounds for virtual screening against the FadD13 model with the ATP binding site as the target for docking by using AutoDock4. Based on the results, the top 40 compounds were requested from National Cancer Institute - Developmental Therapeutics Program (NCI-DTP). The compounds were experimentally evaluated for their potential to inhibit the activity of FadD13. Among the compounds evaluated, 13 exhibited inhibition of the activity. Seven compounds were selected for further studies based on their ability to inhibit FadD13 activity by more than 20%.

For further assessment, Dr. Tyagi and colleagues first examined the effect of various compounds on the growth of *M.smegmatis* (a fast grower) by using the alamar blue dye method. It was observed that two compounds exhibited a marked inhibition of *M.smegmatis* growth with MIC_{99} value of 6.25 µg/ml. Besides, one more compound also exhibited a significant inhibition of *M.smegmatis* growth with MIC_{99} value of 12.5 µg/ml. The compounds were simultaneously also evaluated for their ability to inhibit the growth of

M.tuberculosis by broth macrodilution as well as microplate alamar blue method. The results revealed that one of the compounds exhibited the highest inhibition with an MIC_{99} value of 6.25 μg/ml. Optimization of lead obtained in this study would provide valuable inputs towards the development of inhibitors against *mymA* operon, an important target for the development of antitubercular drugs.

(ii). Identification of Inhibitors against *Mycobacterium tuberculosis* Thiamin Phosphate Synthase

In spite of the availability of drugs for the treatment of TB, the non-compliance to long chemotherapeutic regimens often results in the emergence of multidrug resistant strains of *Mycobacterium tuberculosis* adding to the precariousness of the situation. This has necessitated the development of more effective drugs. Thiamin biosynthesis, an important metabolic pathway of *M. tuberculosis*, is shown to be essential for the intracellular growth of this pathogen. Dr. Tyagi and colleagues constructed a three–dimensional homology model of *M. tuberculosis* thiamin phosphate synthase by using the X-ray crystal structure of thiamin phosphate synthase from *Pyrococcus furiosus.*

Dr. Tyagi and colleagues employed computational screening approach to identify potential small-molecule inhibitors of MtTPS from the NCI diversity set II comprising of 1541 compounds. Compound A, (4-{[(2-hydroxy-5-nitrophenyl) methylidene]amino}-5-methyl-2-(propan-2-yl)phenol), B, (3-benzylsulfanyl-phenanthro [9,10-e][1,2,4]triazine) and C, (Coumarin, 7-[[4-chloro-6-(diethylamino)-s-triazin-2-yl]amino]-3-phenyl-) were identified as potential inhibitors of *M. tuberculosis* growth. All these compounds exhibited inhibition of MtTPS enzymatic activity as well as the growth of *M. tuberculosis* in broth culture. However, one of the compounds A exhibited the highest efficacy with an MIC99 value of 6 μg/ml. In addition, it did not exhibit any significant toxicity in various cell lines till a concentration of 25 μg/ml and also adhered to the Lipinsky rules for drug-likeness. The binding mode of compound A provided key insights into the likely binding sites. The compound A is docked at the large hydrophobic pocket at the active site of MtTPS. The aromatic ring A is placed in a hydrophobic environment surrounded by Ile173, Val193 and Phe171 while the two oxygen atoms of the nitro group appear to be making hydrogen bonds with the hydrogen atoms of the adjacent Cys136 and Cys11 both present within 2.5A° distance from the oxygen atoms. Moreover, the hydroxyl group of the aromatic ring B can form hydrogen bond with the carboxyl group of Asp98 present at a distance of 1.78A°. Inhibition of MtTPS by compound A in the presence of varying concentrations of the substrate HMPPP showed that an enhancement in the concentration of the substrate causes a decline in the inhibition and vice versa, which clearly indicated that it inhibits MtTPS by competing with HMP-PP for binding at the active site thus substantiating the docking results. In conclusion, Dr. Tyagi and colleagues have identified a promising lead molecule (compound A) for the development of sterilizing agents against *M. tuberculosis* and further efforts are in progress to optimize and enhance the inhibitory potency of this lead compound.

3. The first completed genome of a new bacterial species (*Mycobacterium indicus pranii*) from India

This work on *Mycobacterium indicus pranii* (MIP) was responsible for the publication of the first completed genome of a new bacterial species from India and was covered in Nature as "Science News" item in September 2012.

MIP is a saprophytic mycobacterial species that is known for its immunomodulatory properties. MIP, which shares antigens with both *M. leprae* and *M. tuberculosis*, provides protection against *M. tuberculosis* infection in mice and accelerates sputum conversion in both type I and type II category of tuberculosis (TB) patients when used as an adjunct to chemotherapy. In HIV/TB co-infections, a single dose of MIP converted tuberculin -ve patients into tuberculin +ve in >95% of the cases. This attribute is unique to MIP because similar application of other saprophytic mycobacteria such as *M. vaccae* does not provide commensurate protection. Based on its demonstrated immunomodulatory action in various human diseases, MIP has been the focus of several clinical trials and successful completion of one such trial has led to its use as an immunotherapeutic vaccine 'Immuvac' against leprosy. However, very little information was available about MIP's molecular, biochemical, genetic and phylogenomic features. Thus, in a collaborative effort, Dr. Tyagi and colleagues in a molecular phylogenetic study by using candidate marker genes and FAFLP (fluorescent-amplified fragment length polymorphism techniques) fingerprinting assay showed that MIP belongs to a group of opportunistic mycobacteria and is a predecessor of *M. avium* complex (MAC). A comprehensive analysis of cellular and biochemical features of MIP along with chemotaxonomic markers such as FAME (fatty acid methyl ester) analysis and comparison with other mycobacterial species established that MIP is endowed with specific attributes.

In a collaborative effort with Dr. Tyagi being the Principal Investigator, the complete MIP genome was sequenced to gain an insight into its unique life style and molecular basis of immunomodulation. In addition, they employed comparative genomics to understand the habitat diversification and bases and means of functional genetic correlates responsible for evolution of pathogenicity in ancestral mycobacterial lineages.

Different analyses performed in an earlier study established that MIP represents an organism at a unique phylogenetic point as the immediate predecessor of opportunistic mycobacterial species of MAC. It also became evident that natural selection in MAC has acted in a preferential manner on specific categories of genes leading to reduced habitat diversity of pathogenic bacteria, and thus facilitating host tropism. The genome of MIP was ~5.6Mb in size and was found to be shaped by a large number of lateralgene acquisitions thus revealing, for the first time,mosaic architecture of a mycobacterial genome. Thus,this study by Dr. Tyagi and colleagues offered a paradigm shift in our understandingof evolutionary divergence, habitat diversification andadvent of pathogenic attributes in mycobacteria. Ascenario for mycobacterial evolution was envisagedwherein the earliest evolving soil derived mycobacterialspecies like MIP underwent massive gene acquisitions toattain a unique soil–water interface habitat beforeadapting to an aquatic and parasitic lifestyle. Theselateral acquisition events were selective and possiblyfacilitated by the presence of specific genetic factors(i.e. ComEC) that induce competence to acquire largechunks of DNA to confer immediate survival advantageto the recipient organism.

Subsequently,mycobacterial species tuned their genetic repertoires torespective host adapted forms with a high degree ofgenomic fluidity aided by selective lateral gene acquisitionsand gene loss by deletion or pesudogenization.Importantly, a significant increase in transposonelements in the pathogenic mycobacteria as comparedwith MIP, for the first time, suggested their possiblerole toward mycobacterial virulence.In addition, comparative genomic analysis revealed ahigher antigenic potential of MIP subscribing to itsunique ability for immunomodulation against varioustypes of infections and presented a template to developreverse genetics based approaches to design betterstrategies against mycobacterial infections.

PUBLICATIONS

1. Garima Khare, Prachi Nangpal and **Anil K. Tyagi** (2019). Challenges and Advances in TB Drug Discovery. In: Hasnain S., Ehtesham N., Grover S. (eds) Mycobacterium Tuberculosis: Molecular Infection Biology, Pathogenesis, Diagnostics and New Interventions, Springer, Singapore, (pp 463-495).

2. **Anil K. Tyagi**, Bappaditya Dey and Ruchi Jain (2019). Tuberculosis vaccine development: A current perspective. In: Sharma SK. (ed) Tuberculosis & Nontuberculosis mycobacterial diseases. 3rd ed., New Delhi: Jaypee Brothers, Medical Publishers (pp 727-745).

3. Swati Singh, Nikita Goswami, **Anil K. Tyagi** and Garima Khare (2019) Unraveling the role of the transcriptional regulator VirS in low pH-induced responses of *Mycobacterium tuberculosis* and identification of VirS inhibitors. *Journal of Biological Chemistry*. 294(26) 10055-10075.

4. Neetika Jaisinghania, Stanzin Dawa, Kaurab Singh, Ananya Nandy, Dilip Menon, Purva D. Bhandari, Garima Khare, **Anil K. Tyagi** and Sheetal Gandotra (2018). Necrosis driven triglyceride synthesis primes macrophages for inflammation during Mycobacterium tuberculosis infection. *Frontiers in Immunology*. 9, 1490. doi: 10.3389/fimmu.2018.01490.

5. Swati Singh, Garima Khare, Ritika Kar Bahal, Prahlad C. Ghosh, **Anil K. Tyagi** (2018). Identification of *Mycobacterium tuberculosis* BioA inhibitors by using structure based virtual screening. *Drug Des Devel Ther. 12: 12 1065*.

6. Akshay Rohilla, Garima Khare, **Anil K. Tyagi**. (2018) A combination of docking and cheminformatics approaches for the identification of inhibitors against 4' phosphopantetheinyl transferase of *Mycobacterium tuberculosis*. *RSC Advances. 8 (1): 328-341*.

7. Ahmad, J.; Farhana, A.; Pancsa, R.; Arora, S.; Srinivasan, A., **Tyagi, A. K**., Babu, M., Ehtesham, N., and Hasnain, S. (2018) Contrasting function of structured N-terminal and unstructured C-terminal segments of *Mycobacterium tuberculosis* PPE37 protein. *mbio. 9(1), e01712-17*.

8. Ritka Kar Bahal, Shubhita Mathur, Priyanka Chauhan, **Anil K. Tyagi**. (2018) An attenuated quadruple gene mutant of *Mycobacterium tuberculosis* imparts protection against tuberculosis in guinea pigs. *Biol Open. Jan 5;7(1). pii: bio029546*

9. Prachi Nangpal, Ritka Kar Bahal, **Anil K. Tyagi**. (2017) Boosting with recombinant MVA expressing *M. tuberculosis* α-crystallin antigen augments the protection imparted by BCG against tuberculosis in guinea pigs. *Sci Rep. 7(1): 17286*.

10. Akshay Rohilla, Garima Khare, **Anil K. Tyagi**. (2017) Virtual Screening, pharmacophore development and structure based similarity search to identify

inhibitors against IdeR, a transcription factor of *Mycobacterium tuberculosis*. *Sci Rep. 7(1):4653*.

11. Ritika Kar, Prachi Nangpal, Shubhita Mathur, SwatiSingh, **Anil K. Tyagi**. (2017) *bioA* mutant of *Mycobacterium tuberculosis* shows severe growth defect and imparts protection against tuberculosis in guinea pigs. *PLoS One*. *12(6):e0179513. doi: 10.1371/journal.pone.0179513.*

12. Garima Khare, Prachi Nangpal, **Anil K. Tyagi**. (2017) Differential roles of two bacterioferritins in maintaining the iron homeostasis in *Mycobacterium tuberculosis*. *PLoS One*., 12(1):e0169545. doi: 10.1371/journal.pone.0169545.

13. Garima Khare, Priyanka Chauhan, Prachi Nangpal, Ritika Kar and **Anil K. Tyagi**. (2016). Tuberculosis : Current situation, challenges and intervention strategies. In A. Datta and V.P. Sharma (Eds.), Recent advances in communicable and non-communicable diseases, Capital Publshing Company, New Delhi, India, (pp.77-109).

14. Rahman, S. A.;Singh, Y.; Kohli, S.; Ahmad, J.; Ehtesham, N. Z.;**Tyagi A. K.**; Hasnain. S. E.; (2015) *Mycobacterium indicus pranii* is a distinct genus, not derived from *M. intracellulare*, and is an organism at an evolutionary transition point between a fast grower and slow grower. *mBio. 6(2):e00352-15.DOI:10.1128/Mbio.00352-15.*

15. Sharma, S., Rajmani, R. S., Kumar, A., Bhaskar, A., Singh, A., Manivel, V., **Tyagi, A.K**., & Rao, K.V. (2015). Differential proteomics approach to identify putative protective antigens of mycobacterium tuberculosis presented during early stages of macrophage infection and their evaluation as DNA vaccines. *Indian Journal of Experimental Biology*,*53*, 429-439.

16. DeepakKumar,Khare, G., Beena, Kidwai, S, **Tyagi. A.K.,** Singh, R. & Rawat, D.S. (2015). Novel isoniazid–amidoether derivatives: synthesis, characterization and antimycobacterial activity evaluation. *Med. Chem. Commun.*, **6**, 131-137.

17. S. A. Rahman, Singh, Y., Kohli, S., Ahmad, J., Ehtesham, N. Z., **Tyagi, A. K.**, & Hasnain, S. E. (2014). Comparative Analyses of Nonpathogenic, Opportunistic, and Totally Pathogenic Mycobacteria Reveal Genomic and Biochemical Variabilities and Highlight the Survival Attributes of *Mycobacterium tuberculosis*. *mBio, 5(6),* e02020-14.

18. Deepal Kumar, Beena, Khare, G., Kidwai, S., **Tyagi, A. K.**, Singh, R., & Rawat, D. S. (2014). Synthesis of novel 1, 2, 3-triazole derivatives of isoniazid and their *in vitro* and *in vivo* antimycobacterial activity evaluation. *European Journal of Medicinal Chemistry*, *81*, 301-313.

19. Y. Singh, Kohli, S., Sowpati, D. T., Rahman, S. A., **Tyagi, A. K.**, & Hasnain, S.E. (2014). Gene cooption in Mycobacteria and search for virulence attributes: comparative proteomic analyses of *Mycobacterium tuberculosis*, *Mycobacterium indicus pranii*

and other mycobacteria*. International Journal of Medical Microbiology. 304(5-6)*:742-8.

20. Rupangi Verma Puri, Reddy, P. V., &**Tyagi, A. K.** (2014). Apurinic/Apyrimidinic Endonucleases of *Mycobacterium tuberculosis* Protect against DNA Damage but Are Dispensable for the Growth of the Pathogen in Guinea Pigs. *PloS ONE, 9(5),* e92035.

21. Garima Khare, Praveen Kumar, **Anil K Tyagi**. (2013). Whole-Cell Screening-Based Identification of Inhibitors against the Intraphagosomal Survival of*Mycobacterium tuberculosis.* Antimicrobial Agents and Chemotherapy.doi:10.1128/AAC.01444-13.

22. Garima Khare, P. Vineel Reddy, Pragya Sidhwani &**Anil K. Tyagi** (2013). KefB inhibits phagosomal acidification but its role is unrelated to *M. tuberculosis* survival in host. Scientific Reports. 3 : 3527 | DOI: 10.1038/srep03527.

23. Priyanka Chauhan, P. Vineel Reddy, Ramandeep Singh, Neetika Jaisinghani, Sheetal Gandotra and **Anil K. Tyagi**. (2013). Secretory phosphatases deficient mutant of *Mycobacterium tuberculosis* imparts protection at the primary site of infection in guinea pigs. PloS ONE.8(10): e77930. doi:10.1371.

24. Rupangi Verma Puri, Nisha Singh, Rakesh K. Gupta, **Anil K. Tyagi**. (2013). Endonuclease IV Is the Major Apurinic/ApyrimidinicEndonuclease in *Mycobacterium tuberculosis* and IsImportant for Protection against Oxidative Damage. PLoS ONE 8(8): e71535. doi:10.1371/journal.pone.0071535.

25. Rupangi Verma Puri, P. Vineel Reddy, **Anil K. Tyagi**. (2013). Secreted Acid Phosphatase (SapM) of *Mycobacterium tuberculosis* Is Indispensable for Arresting Phagosomal Maturation and Growth of the Pathogen in Guinea Pig Tissues. PLoS ONE 8(7): e70514. doi:10.1371/journal.pone.0070514.

26. P. Vineel Reddy, Rupangi Verma Puri, Priyanka Chauhan, Ritika Kar, Akshay Rohilla, Aparna Khera and **Anil K. Tyagi**. (2013). Disruption of mycobactin biosynthesis leads to attenuation of *Mycobacterium tuberculosis* for growth and virulence. Journal of Infectious Diseases. DOI: 10.1093/infdis/jit250.

27. Priyanka Chauhan, Ruchi Jain, Bappaditya Dey and **Anil K. Tyagi.** (2013). Adjunctive immunotherapy with α–crystallin based DNA vaccination reduces tuberculosis chemotherapy period in chronically infected mice. Scientific Reports. 3: 1821, DOI: 10.1038.

28. Garima Khare, Prachi Nangpal and **Anil K. Tyagi**. (2013). Unique residues at the 3-fold and 4-fold axis of mycobacterial ferritin are involved in oligomer switching. Biochemistry**,** 52(10) : 1694-1704.

29. Ruchi Jain, Bappaditya Dey and **Anil K. Tyagi**. (2012). Development of the first oligonucleotide microarray for global gene expression profiling in guinea pigs:

defining the transcription signature of infectious diseases. BMC Genomics, 13: 520-530.

30. Vikram Saini, Saurabh Raghuvanshi, Jitendra P. Khurana, Niyaz Ahmed, Seyed E. Hasnain, Akhilesh K. Tyagi and **Anil K. Tyagi**. (2012). Massive gene acquisitions in *Mycobacterium indicus pranii* provide a perspective on mycobacterial evolution. Nucleic Acids Research. 1-19, doi:10.1093/nar/gks793.

31. P. Vineel Reddy, Rupangi Verma Puri, Aparna Khera and **Anil K. Tyagi**. (2012). Iron Storage Proteins Are Essential for the Survival and Pathogenesis of *Mycobacterium tuberculosis* in THP-1 Macrophages and the Guinea Pig Model of Infection. *J. Bacteriol.* 194(3):567. DOI: 10.1128/JB.05553-11.

32. Ruchi Jain, Bappaditya Dey, Aparna Khera, Priyadarshani Srivastava, Umesh D. Gupta, V.M. Katoch, V.D. Ramanathan, **Anil K. Tyagi.** (2011). Over-expression of superoxide dismutase obliterates the protective effect of BCG against tuberculosis by modulating innate and adaptive immune responses. Vaccine. 29: 8118– 8125.

33. Bappaditya Dey, Ruchi Jain, Umesh D. Gupta, V. M. Katoch, V. D. Ramanathan, **Anil K. Tyagi.** (2011). A Booster Vaccine Expressing a Latency-Associated Antigen Augments BCG Induced Immunity and Confers Enhanced Protection against Tuberculosis. PLoS ONE 6(8): e23360.

34. Garima Khare, Ritika Kar, **Anil K. Tyagi.** (2011). Identification of Inhibitors against *Mycobacterium tuberculosis* Thiamin Phosphate Synthase, an Important Target for the Development of Anti-TB Drugs. PLoS ONE 6(7): e22441.

35. Bappaditya Dey, Ruchi Jain, Aparna Khera, Umesh D. Gupta, V.M. Katoch, V.D. Ramanathan and **Anil K. Tyagi**. (2011). Latency antigen α–crystalin based vaccination imparts a robust protection against TB by modulating the dynamics of pulmonary cytokines. PLoSONE 6(4): e18773.

36. Garima Khare, Vibha Gupta, Prachi Nangpal, Rakesh K. Gupta, Nicholas K. Sauter and **Anil K. Tyagi**. (2011). Ferritin Structure from *Mycobacterium tuberculosis*: Comparative Study with Homologues identifies Extended C-terminus involved in Ferroxidase Activity. PLoSONE 6(4): e18570.

37. Purushothaman S, Annamalai K, **Tyagi AK**, Surolia A (2011). Diversity in Functional Organization of Class I and Class II Biotin Protein Ligase. PLoS ONE 6(3):e16850.

38. Nidhi Jatana, Sarvesh Jangid, Garima Khare, **Anil K. Tyagi** and Narayanan Latha. (2011). Molecular modeling studies of fatty acyl-CoA synthetase (FadD13) from *Mycobacterium tuberculosis* – a potential target for the development of antitubercular drugs. J. Mol. Model. 17(2) : 301-313.

39. Ashish Arora, Nagasuma R. Chandra, Amit Das, Balasubramanian Gopal, Shekhar C. Mande, Balaji Prakash, Ravishankar Ramachandran, Rajan Sankaranarayanan, K. Sekar, Kaza Suguna, **Anil K. Tyagi**, Mamannamana Vijayan. (2011). Structural

biology of *Mycobacterium tuberculosis* proteins: The Indian efforts, Tuberculosis, doi:10.1016/j.tube.2011.03.004

40. **Anil K. Tyagi**, Prachi Nangpal, Vijaya Satchidanandam. (2011). Development of vaccines against tuberculosis. Tuberculosis. Doi:10.1016/j.tube.2011.01.003.

41. Anuj Kumar Gutpa, Vineel P. Reddy, Mallika Lavania, D.S. Chauhan, K. Venkatesan, V.D. Sharma, **A.K. Tyagi** and V.M. Katoch. (2010). *jefA* (Rv2459), a drug efflux gene in *Mycobacteirum tuberculosis* confers resistance to isoniazid and ethambutol. Indian J. Med. Res. 132: 176-188.

42. Vibha Gupta, Rakesh K. Gupta, Garima Khare, Dinakar M. Salunke, Avadhesha Surolia and **Anil K. Tyagi**. (2010). Structural ordering of disordered ligand-binding loops of biotin protein ligase into active conformations as a consequence of dehydration. PloS ONE 5(2): e9222.

43. Bappaditya Dey, Ruchi Jain, Aparna Khera, Vivek Rao, Neeraj Dhar, Umesh D. Gupta, V.M. Katoch, V.D. Ramanathan and **Anil K. Tyagi**. (2010). Boosting with a DNA vaccine expressing ESAT-6 (DNAE6) obliterates the protection imparted by recombinant BCG (rBCGE6) against aerosol *Mycobacterium tuberculosis* infection in guinea pigs. Vaccine. 28: 63-70.

44. Khare, G., Gupta, V., Gupta, R.K., Gupta, R, Bhat, R. and **Anil K. Tyagi**. (2009). Dissecting the role of critical residues and substrate preferene of a fatty Acyl-CoA synthetase (FadD13) of *Mycobacterium tuberculosis*. PLoS ONE 4(12): e8387.

45. Vibha Gupta, Rakesh K. Gupta, Garima Khare, Dinakar M. Salunke and **Anil K. Tyagi**. (2009). Crystal structure of Bfr A from *Mycobacterium tuberculosis:* Incorporation of selenomethionine results in cleavage and demetallation of Haem. PLoS One. 4(11): e8028.

46. Preeti Sachdeva, Richa Misra, **Anil K. Tyagi** and Yogendra Singh. 2009. The sigma factors of *Mycobacterium tuberculosis:* regulation of the regulators. FEBS Journal. Doi:10.1111/j.1742-4658.2009.07479.x.

47. C.M. Santosh Kumar, Garima Khare, C.V. Srikanth, **Anil K. Tyagi**, Abhijit A. Sardesai and Shekhar C. Mande. (2009). Facilitated oligomericzation of mycobacterial GroEL: Evidence for phosphorylation-mediated oligomerization. J. Bacteriol. 191: 6525-6538.

48. Vikram Saini, S. Raghuvanshi, G.P. Talwar, N. Ahmed, J.P. Khurana, S.E. Hasnain, Akhilesh K. Tyagi, and **Anil K. Tyagi.** (2009). Polyphasic Taxonomic Analysis Establishes *Mycobacterium indicus pranii* as a Distinct Species. PLoS ONE 4(7): e6263.

49. D. Basu, Garima Khare, S. Singh, **Anil K. Tyagi,** S. Khosla, S.C. Mande. (2009). A novel nucleoid-associated protein of *Mycobacterium tuberculosis* is a sequence homolog of GrotL. Nucleic Acids Res. Doi:10.1093/nar/gkp502.

50. Pooja Arora, Aneesh Goyal, Vivek T. Natarajan, Eerappa Rajakumara, Priyanka Verma, Radhika Gupta, Malikmohamed Yousuf, Omkita A. Trivedi, Debasisa Mohanty, **Anil Tyagi**, Rajan Sankaranarayanan and Rajesh S. Gokhale. (2009). Mechanistic and functional insights into fatty acid activation in *Mycobacterium tuberculosis*. Nature Chemical Biology. 5, 166-173.

51. **Anil K. Tyagi,** Bappaditya Dey and Ruchi Jain (2009). Tuberculosis vaccine development: Current status and future expectations. In: Sharma, S.K., Mohan, A. (eds.). Tuberculosis, 2nd ed., New Delhi: Jaypee Brothers, Medical Publishers pg 918-946.

52. Ruchi Jain, Bappaditya Dey, Neeraj Dhar, Vivek Rao, Ramandeep Singh, Umesh D. Gupta, V.M. Katoch, V.D. Ramanathan and **Anil K. Tyagi**. (2008). Enhanced and Enduring Protection against Tuberculosis by Recombinant BCG-Ag85C and its Association with Modulation of Cytokine Profile in Lung. PLoS ONE. 3(12): 3869.

53. Mohd Akif, Garima Khare, **Anil K. Tyagi,** Shekhar C. Mande, and Abhijit A. Sardesai(2008). Functional Studies on Multiple Thioredoxins from *Mycobacterium tuberculosis.* J. Bacteriol. 190: 7087-7095.

54. Vibha Gupta, Rakesh K. Gupta, Garima Khare, Dinakar M. Salunke and **Anil K. Tyagi**. (2008). Cloning, expression, purification, crystallization and preliminary x-ray crystallographic analysis of bacterioferritin A from *Mycobacterium tuberculosis*. Acta Cryst. F 64: 398-401.

55. Vibha Gupta, Rakesh K. Gupta, Garima Khare, Avadhesha Surolia, Dinakar M. Salunke and **Anil K. Tyagi**. (2008). Crystallization and preliminary x-ray diffraction analhysis of biotin acetyl-CoA carboxylase ligare (BirA) from *Mycobacterium tuberculosis*. Acta Cryst. F 64: 524-527.

56. A. Farhana, S. Kumar, S.S. Rathore, P.C. Ghosh, N.Z. Ehtesham, **Anil K. Tyagi,** and S.E. Hasnain. (2008). Mechanistic insights into a novel export-import system of *Mycobacterium tuberculosis* unravel its role in trafficking of iron. PLoS ONE. 3(5): e2087.

57. Shruti Jain, Garima Khare, Pushplata Tripathi and **Anil K. Tyagi.** (2008). An inducible system for the identification of target genes for a regulator in mycobacteria. American Journal of Biochemistry and Biotechnology 4(3): 226-230.

58. Ruchi Jain, Bappaditya Dey and **Anil K. Tyagi**. (2008). Role of vaccines and immuno-modulation in tuberculosis. In: O.P. Sood and S.K. Sharma (eds.), Round Table Conference Series, Challenges of MDR/ XDR Tuberculosis in India, Ranbaxy Science Foundation, New Delhi, pg.93-102.

59. **Anil K. Tyagi,** Ramandeep Singh and Vibha Gupta. (2008). Role of Mycobacterial kinases and Phosphatases in Growth and Pathogenesis, in Reyrat, J.M. and Daffe, M. (Eds.): The Mycobacterial Cell Envelope, ASM Press, Washington DC, USA, pp.323-343.

60. Ahmed, N., Saini, V., Raghuvanshi, S., Khurana, J.P., Tyagi, Akhilesh K., **Tyagi, Anil K.** and Hasnain, S.E. (2007). Molecular analysis of a leprosy immunotherapeutic bacillus provides insights into *Mycobacterium* evolution. PLoS ONE 2(10): e968.

61. Azeet Narayan, Preeti Sachdeva, Kirti Sharma, Adesh K. Saini, **Anil K. Tyagi** and Yogendra Singh. (2007). Serine threonine protein kinases of mycobacterial genus: phylogeny to function. Physiol. Genomics 29: 66-75.

62. Nisheeth Agarwal and **Anil K. Tyagi.** (2006). Mycobacterial Transcriptional Signals: Requirements for Recognition by RNA polymerase and Optimal Transcriptional Activity. Nucleic Acid Research. 34: 4245-4257.

63. Ramandeep Singh, Amit Singh and **Anil K. Tyagi.** (2005). Deciphering the genes involved in pathogenesis of *Mycobacterium tuberculosis.* Tuberculosis 85:325-335.

64. Aparna Khera, Ramandeep Singh, H. Shakila, VivekRao, Neeraj Dhar, P.R. Narayanan, C.N. Parmasivan, V.D.Ramanathan and **Anil K.Tyagi**. (2005). Elicitation of efficient, protective immune responses by using DNA vaccines against tuberculosis. Vaccine 23:5655-5665.

65. Parampal, Deol, Reena Vohra, Adesh K. Saini, Amit Singh, Harish Chandra, Puneet Chopra, Taposh K. Das, **Anil K. Tyagi**, and Yogendra Singh. (2005). Role of *Mycobacterium tuberculosis* Ser/Thr kinase PknF: implications in glucose transport and cell division. J. Bacteriol. 187: 3415-3420.

66. Amit Singh,Radhika Gupta,R. A.Vishwakarma,P.R. Narayanan,C.N. Paramasivan,V. D. Ramanathanand **Anil K. Tyagi**. (2005). Requirement of *mymA* operon for appropriate cell wall ultrastructure and persistence of *Mycobacterium tuberculosis* in the spleens of guinea pigs. J. Bacteriol. 187: 4173-4186.

67. Vivek Rao, Neeraj Dhar, H. Shakila, Ramandeep Singh, Aparna Khera, M. Naseema, C. N. Paramasivan, P. R. Narayananan, V. D. Ramanthanand **Anil K. Tyagi.** (2005). Over-expression of the 19kDa lipoprotein of *Mycobacterium tuberculosis* obliterates the protective efficacy of BCG by polarizing the host immune responses to the Th2 phenotype. Scand. J. Immunol. 61: 410-417.

68. V.K. Chaudhary, Kulshresta Abhishek, Gupta Ghata, Verma Nitin, Sampati Kumari, S.K. Sharma, Gupta Amita, **A.K. Tyagi.** (2005). Expression and purification of 38-kDa and Mtb81 antigens of *Mycobacterium tuberculosis* for application in serodiagnosis. Protein Expr. Purif. 40: 169-176.

69. Ruchi Jain and **Anil K. Tyagi**. (2005). New technology forces microbes to reveal their secrets. In: T. Satyanarayana and B.N. Johri (eds.). Microbial Diversity: Current Perspectives and Potential Applications, I.K. International Pvt. Ltd., India, 1053-1074.

70. **Anil K. Tyagi,** Bappaditya Dey and Ruchi Jain. (2005). Development of vaccine against tuberculosis. In: N.K. Mehra and S.K. Sharma and O.P. Sood (eds.) "HIV and Tuberculosis: Co-infection" under "Round Table Conference Series", Ranbaxy Science Foundation, India, 15: 149-153.

71. Saini, A.K., Maithal, K., Chand, P., Chowdhury, S., Vohra, R., Goyal, A., Dubey, G.P., Chopra, P., Chandra, R., **Tyagi, A.K.**, Singh, Y., Tandon, V. (2004). Nuclear localization and in situ DNA damage by *Mycobacterium tuberculosis* nucleosidediphosphate kinase. J. Biol. Chem. 279: 50142-50149.

72. Chopra, P., Koduri, H., Singh, R., Koul, A., Ghildiyal, M., Sharma, K., **Tyagi, A.K.**, Singh, Y. (2004). Nucleoside diphosphate kinase of *Mycobacterium tuberculosis* acts as GTPase-activating protein for Rho-GTPases. FEBS Lett. 571: 212-216.

73. Neeraj Dhar, Vivek Rao and **Anil K. Tyagi**. (2004). Immunogenicity of recombinant BCG vaccine strains overexpressing components of the antigen 85 Complex of *M. tuberculosis*. Med Microbiol Immunol. 193: 19-25.

74. Ruchi Jain, Neeraj Dhar, Vivek Rao and **Anil K. Tyagi.** (2004). Development of candidate vaccines for protection against tuberculosis. In: Pawan Sharma (eds.). Tuberculosis: Current Research Trends, Allied Publishers Pvt. Ltd., India, 138-158.

75. **Anil K. Tyagi** and Aparna Khera. (2004). Protection against tuberculosis: How close are we to a perfect vaccine? Current Science. 86: 154-166.

76. **Anil K. Tyagi** and Neeraj Dhar. (2003). Recent Advances in Tuberculosis Research in India. In: T.K. Ghose and P. Ghosh (eds.): "Biotechnology in India" under the series "Advances in Biochemical Engineering/Biotechnology", Springer Verlag 84, 211-273.

77. Ramandeep Singh, Vivek Rao, H. Shakila, Radhika Gupta, Aparna Khera, Neeraj Dhar, Amit Singh, Anil Koul, Yogendra Singh, M. Naseema, P.R. Narayanan, C.N. Paramasivan, V.D. Ramanathanand **Anil K. Tyagi**. (2003). Disruption of *mptpB* impairs the ability of *Mycobacterium tuberculosis* to survive in guinea pigs. Molecular Microbiology 50(3): 751-762.

78. Chopra P, Singh B, Singh R, Vohra, R, Koul A, Meena LS, Koduri H, Ghildiyal M, Deol P, Das TK, **Tyagi AK**, Singh Y. (2003). Phosphoprotein phosphatase of Mycobacterium tuberculosis dephosphorylates serine-threonine kinases PknA and PknB. Biochem Biophys Res Commun. 311(1): 112-120.

79. Vivek Rao, Neeraj Dhar and **Anil K. Tyagi**. (2003). Modulation of host immune responses by over-expression of immunodominant antigens of *M. tuberculosis* in BCG. Scand J Immunol. 58(4): 449-461.

80. Amit Singh, Shruti Jain, Seema Gupta, Taposh Dasand **Anil K. Tyagi.** (2003). *mymA* operon of *Mycobacterium tuberculosis* : its regulation and importance in the cell envelope. FEMS Microbiol. Lett. 227(1): 53-63.

81. Nisheeth Agarwal and **Anil K. Tyagi.** (2003).Role of 5`TGN3` Motif in the Interaction of Mycobacterial RNA Polymerase with a Promoter of "Extended –10" class. FEMS Microbiol. Lett. 225: 75-83.

82. Neeraj Dhar, Vivek Rao and **Anil K. Tyagi.** (2003). Skewing of the Th1/Th2 responses in mice due to variation in the level of expression of an antigen in a recombinant BCG system. Immunol Lett. 88(3): 175-184.

83. Puneet Chopra, Anubha Singh, Anil Koul, S. Ramachandran, Karl Drilica, **Anil K. Tyagi** and Yogendra Singh. (2003). Cytotoxic activity of nucleoside diphosphate kinase secreted from *Mycobacterium tuberculosis*. Eur. J. Biochem. 270, 625-634.

84. Koul, A., Choidas, A., **Tyagi, A.K.,** Drilca, K., Singh, Y. and Ullrich, A. 2001. Serine/threonine protein kinases PknF and PknG of *Mycobacterium tuberculosis*: Characterization and Localization. Microbiology (U.K.). 147, 2307-2314.

85. Dhar Neeraj, Rao, Vivek and **Tyagi, A.K.** 2000. Recombinant BCG approach for development of vaccines: cloning and expression of immunodominant antigens of *M.*tuberculosis. FEMS Microbiol. Lett., 190(2), 309-316.

86. Koul, Anil, Choidas, Axel, Treder, Martin, **Tyagi, A.K.**, Drlica, Karl, Singh, Y. and Ullrich, Axel. 2000. Cloning and characterization of secretory tyrosine phosphatases of *Mycobacterium tuberculosis*. J. Bacteriol. 182(19), 5425-5432.

87. **Anil K. Tyagi** (2000). A Perfect Vaccine Against Tuberculosis: Premises and Promises. In: Sushma Gupta and O.P. Sood (eds.) "Tuberculosis" under "Round Table Conference Series", Ranbaxy Science Foundation, India, 7: 135-139.

88. **Tyagi, A.K.**, Das Gupta, S.K. and Jain, S. 2000. Gene Expression: Reporter Technologies. In: Graham F. Hatfull and William R. Jacobs Jr. (eds.) : Molecular Genetics of Mycobacteria, ASM Press, pp.131-147.

89. **Tyagi, A.K.** and Jain, S. 1999. *Mycobacterium tuberculosis*: Studies on Gene Regulation, Pathogenesis and Development of Recombinant BCG Vaccines. In : R.C. Mahajan and Amu Therwath (eds.), Multidrug Resistance in Emerging and Re-emerging diseases. Narosa Press, pp.109-124.

90. Gupta, S., Jain, S. and **Tyagi, A.K**. 1999. Analysis, expression and prevalence of the *M.tuberculosis* homolog of bacterial virulence regulating proteins. FEMS. Microbiol. Lett. 172, 137-143.

91. Bashyam, M.D., and **Tyagi, A.K.** 1998. Identification and analysis of "Extended-10" promoters from Mycobacteria. J. Bacteriol. 180, 2568-2573.

92. DasGupta, S.K., Jain, S., Kaushal, D., and **Tyagi, A.K.** 1998. Expression systems for study of mycobacterial gene regulation and development of recombinant BCG vaccines. Biochem. Biophys. Res. Commun. 246, 797-804.

93. **Tyagi, A.K.** 1998. *Mycobacterium tuberculosis*: Studies on gene regulation, pathogenesis and development of recombinant BCG vaccines. In: Tuberculosis Research: Into the 21st Century, pp.29-42.

94. Jain, S., Kaushal, D., Dasgupta, S.K., and **Tyagi, A.K.** 1997. Construction of shuttle vectors for genetic manipulation and molecular analysis of mycobacteria. Gene 190, 37-44.

95. Bashyam, M.D., Kaushal, D., Dasgupta, S.K., and **Tyagi, A.K.** 1996. A study of the Mycobacterial transcriptional apparatus: Identification of novel features in promoter elements. J. Bacteriol. 178, 4847-4853.

96. Sarkar, N.K., Shankar, S., and **Tyagi, A.K.** 1995. Polyamines exert regulatory control on mycobacterial transcription - A study using RNA polymerase form *Mycobacterium phlei*. Biochemistry and Molecular Biology International 35, 1189-1198.

97. Bashyam, M.D. and **Tyagi, A.K.** 1994. An efficient and high-yielding method for isolation of RNA from mycobacteria. Biotechniques 17 : 834-836.

98. DasGupta, S.K., Bashyam, M.D., and **Tyagi, A.K.** 1993. Cloning and assessment of mycobacterial promoters by using a plasmid shuttle vector. J. Bacteriol. 175, 5186-5192.

99. Gupta, S., and **Tyagi, A.K.** 1993. Sequence of a newly identified *Mycobacterium tuberculosis* gene encoding a protein with sequence homology to virulence regulating proteins. Gene 126, 157-158.

100. Shankar, S., and **Tyagi, A.K.** 1993. Purification and Characterization of restriction endonuclease *Mgo*I from *Mycobacterium gordonae*, Gene 131, 153-154.

101. Shankar, S., and **Tyagi, A.K.** 1993. *Mch*AI and *Mch*AII, two class-II restriction endonucleases from *Mycobacterium chelonei*. Gene 132, 119-123.

102. Shankar, S., and **Tyagi, A.K.** 1992. *Mha*AI, a novel isoschizomer of *Pst*I from *Mycobacterium habana* recognizing 5'-CTGCA/G-3'. Nucleic Acids Res. 20, 2891.

103. Shankar, S.,and**Tyagi, A.K.** 1992. *Mfo*AI a novel isoschizomer of *Hae*III from *Mycobacterium fortuitum* recognizing 5'-GG/CC-3'. Nucleic Acids Res. 20, 2890.

104. Balasundaram, D. and **Tyagi, A.K.** 1991. Polyamine - DNA Nexus: Structural Ramifications and Biological Implications. Mol. Cell. Biochem. 100, 129-140.

105. Tyagi, J.S., **Tyagi, A.K.**and Bhargava, S. 1990. Transfer RNA genes in mycobacteria : organization and molecular cloning. Trop Med. Parasitol 41, 294-296.

106. Bhargava, S., **Tyagi, A.K.** and Tyagi, J.S. 1990. tRNA genes in mycobacteria: organization and molecular cloning. J. Bacteriol. 172, 2930-2934.

107. Balasundaram, D. and **Tyagi, A.K.**, 1989. Modulation of Arginine decarboxylase activity from *Mycobacterium smegmatis*: Evidence for pyridoxal -5'- phosphate mediated conformational changes in the enzyme. Eur. J. Biochem. 183, 339-345.

108. Balasundaram, D., and **Tyagi, A.K.** 1988. Regulation of ornithine decarboxylase from*Mycobacterium smegmatis.* Arch. Biochem. Biophys. 264, 288-294.

109. Jain, A., and **Tyagi, A.K.** 1987. Role of polyamines in the synthesis of RNA in mycobacteria. Mol. Cell. Biochem. 78, 3-8.

110. Bhutani, V., Kumar, V., **Tyagi, A.K.** and Misra, U.K. 1987. Changes of fatty acid composition in pancreas of rats fed inadequate dietary protein. Nutrition Research 7, 763-770.

111. **Tyagi, A.K.**, Wickner, R.B., Tabor, C.W. and Tabor, H. 1984. Specificity of polyamine requirements for the replication and maintenance of different double-stranded RNA plasmids in *Saccharomyces cerevisiae*. Proc. Natl. Acad. Sci. USA. 81, 1149-1153.

112. **Tyagi, A.K.**and Cooney, D.A. 1984. Biochemical pharmacology, metabolism, and mechanism of action of L-alanosine, a novel natural antitumor agent, in Caratini, S., Goldin, A., Howking, F., and Kopin, I.J. (Eds.): *Advances in Pharmacology and Chemotherapy* Vol. 20, Academic Press, New York, pp.69-121.

113. Tabor, C.W., Tabor, H. and**Tyagi, A.K.** 1983. Biochemical and genetic studies of polyamines in *Saccharomyces cerevisiae*. In Bachrach, U., Kaye. A. and Chayen, R. (Eds.) : Advances in Polyamine Research Vol. 4, Raven Press, New York, pp. 467-478.

114. **Tyagi A.K.**, Tabor, C.W. and Tabor, H. 1983. Ornithine decarboxylase (*Saccharomyces cerevisiae*), Tabor, H. and Tabor C.W. (eds.). Methods in Enzymology, Vol. 94, Academic Press, New York. pp. 135-139.

115. **Tyagi, A.K.**and Cooney, D.A. 1983. Prospects for the chemotherapy of cancer using analogs of L-aspartic acid. Trends Pharmacol Sci., 4, 299-304.

116. **Tyagi, A.K.**, Tabor, H. and Tabor, C.W. 1982. Inactivation of yeast ornithine decarboxylase by polyamines *in vivo* does not result from the incorporation of polyaminesinto enzyme protein. Biochem. Biophys. Res. Commun. 109, 533-540.

117. Tabor, C.W., Tabor, H., **Tyagi, A.K.** and Cohn, M.S. 1982. The biochemistry, genetics, and regulation of polyamine biosynthesis in *Saccharomyces cerevisiae*. Fed. Proc. 41 (review article), pp.3084-3088.

118. **Tyagi, A.K.**, Tabor, C.W. and Tabor, H. 1981. Ornithine decarboxylase from *Saccharomyces cerevisiae*: Purification, properties and regulation of activity. J. Biol. Chem. 256, 12156-12163.

119. **Tyagi, A.K.**, Thake, D.C., Mcgee, E. and Cooney, D.A. 1981. Determinants of the toxicity of L-alanosine to various organs of the mouse. Toxicology 21, 59-69.

120. Tyagi, J.S., **Tyagi, A.K.** and Venkitasubramanian, T.A. 1981. Some factors regulating [1-^{14}C] acetate incorporation into aflatoxins by spheroplast and spheroplasts lysates from *Aspergillusparasiticus*. Toxicon 19, 445-454.

121. Tyagi, J.S.,**Tyagi, A.K.** and Venkitasubramanian, T.A. 1981. Preparation and properties of spheroplasts from *Aspergillus* parasiticus with special reference to the *denovo* synthesis of Aflatoxins. J. Appl. Bacteriol. 50, 481-491.

122. **Tyagi, A.K.**, Cooney, D.A., Jayaram, H.N., Swiniarski, N.K. and Johnson R.K. 1981. Studies on the mechanism of resistance of selected murine tumors to L-alanosine. Biochem. Pharmacol. 30, 915-924.

123. **Tyagi, A.K.**and Cooney, D.A. 1980. Identification of the antimetabolite of L-Alanosine, L-alanosyl-5-Amino-4-imidazolecarboxylic acid ribonucleotide in tumors and assessment of its inhibition of adenylosuccinate synthetase. Cancer Res. 40, 4390-4397.

124. Kensler, T.W., Erlichman, C., Jayaram, H.N., **Tyagi, A.K.**, Ardalan, B. and Cooney, D.A. 1980. Peripheral leukocytes as indicators of the enzymatic effects of N-(phosphonoacetyl)-L-aspartic acid (PALA) on human L-aspartate transcarbamoylase (ATCase) activity. Cancer Treatment Reports 64, 967-973.

125. Park, K.W., Tyagi **A.K.**, and Cooney, D.A. 1980. A radiometric technique for the measurement of adenylosuccinate lyase. J. Biochem. Biophys. Methods 2, 291-297.

126. Anandaraj, S.A., Jayaram, H.N., Cooney, D.A.; **Tyagi, A.K.** Han, N., Thomas, J.H., Chitnis, M., and Montgomery, J.A. 1980. Interaction of L-alanosine (NSC-153353) with enzymes metabolizing L-aspartic acid, L-glutamic acid and their amides. Biochem. Pharmacol. 29, 227-245.

127. **Tyagi, A.K.**, Cooney, D.A., Bledsoe, M. and Jayaram, H.N. 1980. Two complementary radiometric methods for the measurement of 5-amino-4-imidazole-N-succino-carboxamide ribonucleotide synthetase (SAICAR synthetase). J. Biochem. Biophys. Methods 2, 123-132.

128. Jayaram, H.N., **Tyagi, A.K.**, Anandaraj, S., Montgomery, J.A., Kelley, J.A., Kelley, J., Adamson, R.H. and Cooney, D.A. 1979. Metabolites of alanosine, an antitumor antibiotic. Biochem. Pharmacol. 28, 3551-3566.

129. **Tyagi, A.K.**, Jayaram, H.N., Anandaraj, S., Taylor, B. and Cooney D.A. 1979. Use of Automated chromatography on the amino acid analyzer with lithium citrate buffers to separate nucleic acid bases, nucleosides, nucleotides and their precursors. J. Biochem. Biophys. Methods. 1, 221-226.

130. Nizamuddin, A., **Tyagi, A.K.**, Padh, H. and Venkitasubramanian, T.A. 1978. Alkaline phosphatase activity in *Mycobacterium smegmatis*. Ind. J. Chest. Dis. 20, 11-20.

131. **Tyagi, A.K.**, Siddiqui, F.A. and Venkitasubramanian, T.A. 1977. Studies on the purification and characterization of malate dehydrogenase from *Mycobacterium phlei*. Biochem. Biophys. Acta 485, 255-267.

132. **Tyagi, A.K.** 1976. Sources of energy production in *Mycobacterium tuberculosis*. Ind. J. Chest Dis. 18, 250-255.

133. **Tyagi, A.K.**, Reddy, T.L.P. and Venkitasubramanian, T.A. 1976. Effect of oxygen tension on oxidative phosphorylation in *Mycobacterium phlei*. Ind. J. Biochem. Biophys. 13, 93-95.

134. **Tyagi, A.K.**, Reddy, T.L.P. and Venkitasubramanian, T.A. 1976. Oxidative phosphorylation in *Mycobacterium tuberculosis* BCG. Ind. J. Biochem. Biophys. 13, 43-45.

135. **Tyagi, A.K.** Reddy, T.L.P. and Venkitasubramanian, T.A. 1976. Site of action of nonheme iron in the malate (flavine adenine dinucleotide) pathway of *Mycobacterium phlei*. Can. J. Microb. 22, 1054-1057.

CITATION ANALYSIS OF RESEARCH PAPERS
SEARCH PERIOD: 1976-2019

(According to Google Scholar on 11th December 2019)

PROF. ANIL K TYAGI

TOTAL NO. OF PAPERS ANALYSED	135
TOTAL CITATIONS	4559
PAPERS WITH ≥ 10 CITATIONS	95
MAX. CIT. RECEIVED BY A PAPER	183
h-INDEX	**40**