

Dedication and prominence: 31 years in 'Biosensors and bioelectronics'

Dedicated to Professor Anthony P.F. Turner's 61st birthday

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ABSTRACT

The name Anthony P. F. Turner, biosensor pioneer, is often considered synonymous with his chosen field. This 5th June will be his 61st birthday. We track here his professional footprint, in order to celebrate his upcoming birthday and to commemorate his 31-years of dedication to biosensors. Commemorating this pioneer's achievements is a multidisciplinary celebration of his prominent contribution to biotechnology, chemistry, biomaterials and nanotechnology. Copyright © 2011 VBRI press.

Keywords: Biosensors and bioelectronics; Anthony P.F. Turner; pioneer; contribution in science.



Songjun Li is the first-ever Marie Curie Incoming International Fellow (IIF) granted by EU in Cranfield Health, UK. His research interest has been focusing on molecularly imprinted polymers, smart materials and catalysis. He is a professor of chemistry and currently serves as president of the International Association of Advanced Materials, and Editor-in-Chief of the international Journal *Advanced Materials Letters*. He is also Chair of the 1st International Congress on Advanced Materials, 13-16 May 2011,

Jinan, Shandong, China. Dr. Li, as the PI and first author (excluding non-PI and co-authors) has published about 60 papers in peer-reviewed journals and as the leading editor edited four books in prestigious Wiley-VCH (Germany), Nova Science (USA), Bentham Science (USA) and Research Signpost (India), respectively. He currently also serves as the editorial member for/or in the editorial boards of "American Journal of Environmental Sciences", "Journal of Public Health and Epidemiology", "the Open Electrochemistry Journal", and "Journal of Computational Biology and Bioinformatics Research". He has been invited more than 200 times to be the reviewer for various grants and international journals, and PhD and M.Sc. thesis as well.



Ashutosh Tiwari is a Marie Curie Fellow of European Commission. His current research interest is focus on designing and development of the smart materials for biomedical and engineering appliances. He is an invited professor of Materials Science and Engineering at the University of Jinan, adjunct professor of Materials Chemistry in the Jiangsu University, China and assistant professor of Nanobioelectronics at the Biosensors and bioelectronics Centre, Department of

Physics, Chemistry and Biology, Linköping University, Sweden. He also works as foreign researcher at the National Institute of Materials Science, Japan. He did PhD in Chemistry from the University of Allahabad, India, later joined National Physical Laboratory, India as a young scientist. After that he moved to the University of Wisconsin, USA as a post-doctoral researcher. Also, he obtained many international fellowships including JSPS in Japan, SI in Sweden and Marie Curie in England. In his academic carrier, he has published over 125-plus publications and patents in the field of materials science and technology. He has also edited/authored more than 7 books on the advanced state-of-the-art of materials science for prestigious publishers including WILEY-Scrivener Publishing, USA, Bentham Science, USA, Nova Science, USA, and VBRI Press, India. He currently serves as secretary general of the International Association of Advanced Materials, and Editor-in-Chief of the *Advanced Materials Letters*. He is also secretary general of the 1st International Congress on Advanced Materials, 13-16 May 2011, Jinan, Shandong, China and International conference on nanostructured materials and composites for medical technology, 5-8 December 2011, Lucknow, India.

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Professor Anthony P.F. Turner

1. Splendid 31 years in education and academe

Professor Turner was born on 5th June 1950 in London, UK. He graduated with Biochemistry major there in 1973 and got his post-graduate certificate in Adult Education at Christchurch University College in 1974. Following two years as a Lecturer in Anatomy, he joined in the University of Kent and completed an M.Sc. in Biochemistry by research in 1977. He received his PhD degree in Microbiology from the University of Portsmouth in 1980 with sponsorship from the Royal Navy. In 1981, he helped found the UK's first Biotechnology Centre at Cranfield University, where he established one of the most successful biosensor R&D centre in the world. During this period, he contributed pioneering work to "bioelectrochemical fuel cells" that underpinned his early innovations in electrochemical biosensor systems. Prominent among this period were 1982 and 1983, when he published three key papers entitled "Applied aspects of bioelectrochemistry: fuel cells, sensors and bioorganic synthesis" (*Biotechnol. Bioeng.*, 1982, 12: 410-412), "Bioelectrochemical fuels cell and sensor based on a quinoprotein alcohol dehydrogenase" (*Enzyme Microbial Technol.*, 1983, 5: 383-388) and "Applications of electron transfer between biological systems and electrodes" (*Biochem. Soc. Trans.*, 1983, 11: 445-448), respectively. In these papers, the concept of a simple analytical devices based on mediated electrochemistry is expounded (see **Section 3**). This was followed by his definitive paper in Analytical Chemistry (1984) which laid the foundation for the commercial success of hand-held mediated glucose sensors for people with diabetes. Professor Turner further advanced this field by leading the team that developed the first-ever mediated amperometric glucose sensors for home use, the Medisense Exactech Glucose Meter. This type of device is presently the world's best selling biosensor for diabetes healthcare.

In 1987, Professor Turner published the first-ever text book on Biosensors (*Biosensors: Fundamentals and*

Applications. ISBN: 0198547242; Oxford Univ. Press) and this book is still among the most cited works in the field. In 1985, he co-founded the principal international journal in the sensor field, *Biosensors & Bioelectronics* (IF 5.4) and is currently the Editor-in-Chief for this journal. He further founded the World Congress on Biosensors in 1990 and has been the chairman ever since. He doubled also as the programme chair for the World Congress on Synthetic Receptors during the period from 2003 to 2007. Nowadays, in a wider context, he regularly provides his expert advices on bio- and nano-technological exploitation to blue-chip companies world-wide and to governments. He was also a key player in the formulation and implementation of some important EU Framework Programs (including 3, 4, 5, 6 and 7). He has also served as expert witness in patent litigations across three continents (Europe, Asia and America) concerning biosensors and biomimetic sensors. He serves as the honorary editor or on editorial boards for a range of first-class journals, such as "Advanced Materials Letters", "Trends in Biotechnology", "International Journal of Electrochemical Sciences", "American Journal of Biomedical Sciences", "Open Nanoscience Journal" "Anaerobe" etc.

Professor Turner was made a Foreign Associate of the USA National Academy of Engineering in 2006 for his outstanding contribution to "glucose sensors, environmental monitors and synthetic recognition molecules". He was also elected Fellow of the Royal Society of Chemistry (1996), Fellow of Higher Education Academy (1997), and invited to Fellowships of the Institute of Biology (1999) and the Institute of Physics (2006). He was awarded a higher doctorate (D.Sc.) by the University of Kent in 2001 and an honorary D.Sc. by the University of Bedfordshire in 2008, for his exceptional contribution to biosensors and to higher education, respectively.



Young Dr. Turner (1981)

2. Unique ‘Distinguished Professor’ at Cranfield University

Professor Turner is not only an outstanding scientist and researcher but also a devoted educator and mentor. He has dedicated the past 38 years to life-science teaching at all levels in both the further education and higher education. He launched a new series of short courses on ‘Nanotechnology’ in 2007 in conjunction with the Institute of Nanotechnology (UK). In 2009, he launched again a unique Master’s course in Nanomedicine building on the success of these ‘Nanotechnology’ courses. Indeed, over the past 40 years, Professor Turner has made almost every venture a success. In Cranfield University, such laudits as “Professor Turner’s lectures are very attractive and interesting”, “he is really a humorous and impressive professor” or “we like him and his lectures” are common among his students and fellows. During the past 30 years, Professor Turner has directly supervised nearly 70 research students, 25 post-doctoral researchers and managed 3 Marie Curie Incoming International Fellows. Prominent among his graduate students are Dr Bill Aston, Dr Stuart Hendry, Dr Mark Downs and Dr Selly Saini who became General Manager (Medisense), Chief Executive (Sphere Medical), Scientific Attaché to the British Embassy and Vice President for Global Research (Lifescan and Johnson & Johnson), respectively. Other of his protégées went on to work with innovative companies, such as Pelikan Technologies (USA), SCA Group (Sweden), NEC Electronics (Europe), VTT Finland, Roche (Germany), Biosensia (Ireland), GSK (UK), Bayer (USA) and Akubio Ltd (UK) *etc.*



Professor Turner’s pioneering paper published in Analytical Chemistry (1984)

Indeed, as an educator, Professor Turner has devoted much of his energy to his students and fellows during the past 37 years. For his former students, he has been more like a father than an educator, demonstrating affinity and patience. For his former fellows, he has been a kind mentor and contributed much of his time to help and pilot them. For his colleagues, he has been and is always a model gentleman. His charismatic personality always inspires them to go forward and helps to activate their morale. Because of his extraordinary success in teaching and

research, Professor Turner is also frequently invited to give his expert advice to other universities and organisations. He was a visiting professor at Tokyo Institute of Technology (1987), University of Florence (2004 onwards) and Linköping University (2010). He has served as a member of the International Advisory Board for Tokyo University of Technology since 2002, the National Science and Technology Development Agency of Thailand from 2005-2010 and was a Governor of the University of Bedfordshire from 2002 to 2008.



Professor Turner was admitted to the USA National Academy of Engineering (2006)

Professor Turner is also an excellent administrator and manager both within Cranfield University and in connection with his various spinouts and international initiatives. The biosensor group founded by him in 1981, is widely recognised as one of the most successful biosensors R & D centres around the world. His group pioneered the world’s most successful type of biosensor, the mediated amperometric glucose sensor for diabetes, typified by Medisense’s ExacTech™. Medisense was sold to Abbott Diagnostics for \$867 million in 1996. In 1989, he was awarded a personal Chair in Biosensor Technology. He also doubled as the Business Manager for Cranfield Biotechnology Ltd during the period 1989 to 1991. In 1992, he founded the Institute of BioScience & Technology, which he headed until 1999. He further founded the Cranfield Post-Graduate Medical School in 1999, shortly after he became Principal of Cranfield University at Silsoe. Following the merger of the Silsoe campus and the Cranfield campus in 2006, he returned to full-time research. On completing his term as the Principal, Cranfield University created the unique position of ‘Distinguished Professor’ for him in recognition of his outstanding contribution. In response to the latest financial crisis, he acted as a ‘fireman’ and was pushed centre stage of this university again in 2007. He was appointed Commercial Director for Cranfield Health and Director, Cranfield Ventures, with responsibility for leveraging the University’s intellectual property by licensing and creating spinouts. In November 2010, he moved his research activities to Sweden to head the Biosensors and Bioelectronics centre in the IFM, Linköping University,

while continuing to advise Cranfield University on innovation.



Professor Turner was received by the Crown Prince Charles (1984)

As the pioneer of the rising biosensors discipline, as well as a talented administrator, Professor Turner has demonstrated much wisdom and capability during the past 30 years. He was one of those who were received by the Crown Prince Charles (in person) because of his outstanding contribution to UK research (1984). As his admirers and followers, we have tried our best to document his adventures over the past 40 years. It is apparent that the title ‘Distinguished Professor’ is too weak to summarise his entire 40 years’ contribution. The value of his presence, as well as his continuing legend, in itself, is far beyond any linguistic symbol. Thus, we only regard ‘Distinguished Professor’ as a minor episode in his 40 years’ dedication to science and education during his 61 year life.

3. Contribution to the biosensor field

During the past 30 years, Professor Turner has focused most of his time on inventing, designing, creating and developing, sensors. His Biosensors Group developed the first-ever mediated amperometric glucose sensor and is internationally recognised as the most successful and productive group across the world in the area of biosensors. Nowadays, he and his team continue to be committed to the biosensor field and are working on both *in vitro* and *in vivo* devices for diabetes monitoring and a wide range of other applications. From his personal database, we can see that he has contributed nearly 700 publications over the past 31 years, which include 157 full research papers, 154 peer-reviewed reviews, 302 proceedings, 21 books and 58 published patents [1]. He has also presented well over 400 keynote and plenary lectures at a broad range of international meetings and honorary ceremonies. These publications and lectures are virtually all in the field of biosensors. In summary, his multidisciplinary contribution has been in five main categories : (1) introducing, creating and developing biosensing principles and mechanisms [2,3], (2) designing and developing the world’s most

successful commercial biosensors, (3) inventing biosensor-based disease diagnostic systems [4], (4) biomimetic sensors using molecular imprinting [5, 6], and (5) synthetic receptors capable of highly specific molecular recognition [7, 8]. In almost every category, Professor Turner has made impressive progress and led to significant advances to the field of biosensors. His book “*Biosensors: Fundamentals and Applications*”, as previously mentioned, is still among the most cited works in the biosensor field [9]. His three articles dedicated to “*bio-electrochemical fuel cells*” published in 1982 and 1983 are generally regarded as laying the foundations for ‘mediated amperometric biosensors’ [10-12]. His definitive paper that led to a plethora of publications involving the use of ferrocene and its derivatives in mediated amperometric biosensors was published by *Analytical Chemistry* in 1984 [13] and has been cited nearly 1,000 times. The reversible electrochemistry of ferrocene and its derivatives at modest potentials, coupled with their stability and flexible chemistry, has made them the first widely adopted choice for mediated electrochemistry [14-16].

Professor Turner’s earliest research interests was biocatalysis, which largely involved hydrocarbon metabolism and supplying reducing equivalents to monooxygenases using electrochemistry. Prominent among his early studies was the finding that electron transfer between the quinoprotein methanol dehydrogenase and electrodes was proportional to the “fuel” added. The use of low molecular weight redox compounds as the mediator of electron transfer provided a powerful expedient to effect the fast coupling between catalytic activity and current flow [10-12]. These findings led to the essential conversion of a fuel cell to an alcohol sensor, which thereby acted as, an important milestone in the development of biosensors.

The definitive contribution by Professor Turner, was the introduction of ferrocene and its derivatives in mediated amperometric biosensors [13], which directly led to the launch of the “Medisense” glucose sensor. This type of device has proven a remarkable success and mediated biosensors are now the world’s best selling home blood-glucose meters. In the early devices, insoluble ferrocenes were deposited as immobilised mediators at a carbon electrode and coated with glucose oxidase. The reversible electrochemistry of these mediators enabled a sensitive and efficient blood-glucose biosensor.

Another important contribution made by Professor Turner was the solution to the leaching problem of redox mediators in both biosensors for environmental monitoring and for fermentation monitoring [17]. The benefits of mediated amperometry are most pronounced in single use and disposable sensors, but the continuous slow leaching of the soluble form of redox mediators (*e.g.* the ferricinium ion) can make sensor designs unduly complex and hence uncompetitive in commercial terms. Thus, it was of great interest to explore both alternative mediators and solution to the leaching problem. Based on a series of studies [18-20], Professor Turner found that TCNQ and TTF (tetrathiafulvalene) both acted as excellent mediators for amperometric biosensors and reduced the leaching problem of redox mediators within biosensors.

Professor Turner has also published one of the earliest DNA biosensor papers and anticipated the incredible boom

in the area that is now known as DNA chip technology [21]. He explored both electrochemical and optical detections for biological hybridisation, though at that time he was inhibited by the absence of PCR technology and microfabrication facilities. The alternative, but related concept of using double-stranded DNA as a sensing element was also discussed in his work [22], where the liquid crystal properties of DNA were exploited to detect biologically active compounds. This technique showed great promise for the detection at a very low level of endogenous heparin, indicative of preeclampsia in women.



Professor Turner, Chair of the Scientific Advisory Board of Pelikan Technologies Inc. (2004)

Professor Turner's present research is focused on the use of biomimetic receptors in biosensors and molecularly imprinted polymers (MIPs). For the former, his prominent work has been published by *Biosensors & Bioelectronics* [23], where he described the use of combinatorial chemistry, guided by computational design, to generate synthetic ligands for sensors and assays. The use of synthetic glycosylated-haemoglobin receptor essentially led to the selectivity and specificity of biological recognition. When the work began in 1994, it was believed to be the first program of its kind dedicated to disease diagnostics. The complementary program is currently under way to produce synthetic ligands for pesticide metabolites basing on the use of multi-channel optical affinity sensors. These works have won several national and international prizes, such as the ATB Milano Award (Italy) for "Outstanding Contribution to Diagnostic Technology" (1995), DTI SMART Award for Technology (1995) and Mid Beds Innovation Award for "Contribution to the Quality of Life" (1998), etc.

Professor Turner and his group have also developed the first-ever biomimetic electrochemical sensor by molecular imprinting [24]. This sensor system was based on molecular recognition by a MIP that coupled with an electrochemical detector. 2,4-Dichlorophenol and homogentisic acid were used as the electro-active probes. It was found that the former showed very high nonspecific binding to the prepared polymer. However, the latter (*i.e.*, homogentisic acid) demonstrated highly specific binding to the imprinted sites and thus allowed calibration curves for the analyte in the micro-molar range to be recorded. In this way, an integrated sensor was developed by coating the imprinted

polymer particles directly onto the working electrode. As a result, this system provided a cheap, disposable sensor for rapid determination of environmentally relevant and other analytes. Currently, further work from him is underway, which includes combining computational design and molecular imprinting and generating powerful arrays of ligands for diagnostics, separations, simulations, remediation and therapy.

4. Peaceful life and happy family

Despite being an outstanding scientist, Professor Turner is also a good father and husband. His well-educated personality and smooth temper endow him with a peaceful, quiet and happy life. He deeply loves each member in his family, including his sons, daughter and wife. For his children, he is a kind father and has demonstrated patience to guide their growth. His charming character results not only from his paternity, but also (probably more) from the edification of his high-level ideology. His charismatic personality and character have set a good example for their growth, inspiring them to go forward. For his wife, Dr Alice Tang, the Managing Editor of the international principal journal of *Biosensors and Bioelectronics*, he is not only a kind husband, a life friend and a respect-deserving gentleman; but also a good work partner with a broad mind and a merciful heart. We are indeed jealous of his wife's pet phrase - "he is indeed a good husband and father, and we love him so much".



Professor Turner and his wife Dr. Alice Tang (2007)

In fact, we have been trying hard to understand and learn from Professor Turner's 61-years' of active life. We are greatly impressed by his selfless and devoted character, which has steered the balance between his work and his family. The imagery depicted in Professor Turner's 61-years' life legend is poet and beautiful. It is as harmonious as the couple of earth and moon. It is also as natural as peaceful oceans. His 61-years, in itself, is perfect and beyond our understanding. We feel so fortunate and honored to be able to work with him under his inspiration and encouragement.

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References

1. www.ifm.liu.se/biosensors
2. Turner, A.P.F. <http://www.cranfield.ac.uk/biotech/chinap.htm>, 1997.
3. Turner, A.P.F. Biosensors, McGraw-Hill, Year book of Science and Technology, New York, USA, 2000.
4. Turner, A.P.F.; Magan, N. *Nature Microbiol. Rev.* **2004**, 2, 161.
DOI: [10.1038/nrmicro823](https://doi.org/10.1038/nrmicro823)
5. Piletsky, S.A.; Susan, A. Turner, A.P.F. *Trends Biotechnol.* **2001**, 19, 9.
DOI: [10.1016/S0167-7799\(00\)01523-7](https://doi.org/10.1016/S0167-7799(00)01523-7)
6. Ge, Y.; Turner, A.P.F. *Chem. Euro. J.* **2009**, 33, 8100.
7. Zourob, M.; Elwary, S.; Turner, A.P.F. Principles of bacterial detection: biosensors, recognition receptors and microsystems, Springer, New York, 2008.
8. Piletska, E.; Piletsky, S.; Karim, K.; Terpetschnig, E.; Turner, A.P.F. *Anal. Chim. Acta* **2004**, 504, 179.
DOI: [10.1016/S0003-2670\(03\)00813-4](https://doi.org/10.1016/S0003-2670(03)00813-4)
9. Turner, A.P.F.; Karube, I.; Wilson, G.S. Biosensors: Fundamentals and Applications. Oxford University Press, Oxford, UK, 1987.
10. Turner, A.P.F.; Aston, W.J.; Higgins, I.J.; Davis, G.; Hill, H.A.O. *Biotechnol. Bioeng.* **1982**, 12, 410.
11. Davis, G.; Hill, H.A.O.; Aston, W.J.; Higgins, I.J.; Turner, A.P.F. *Enzyme Microbial Technol.* **1983**, 5, 383.
12. Turner, A.P.F.; Ramsay, G.; Higgins, I.J. *Biochem. Soc. Trans.* **1983**, 11, 445.
13. Cass, A.E.G.; Davis, G.; Francis, G.D.; Hill, H.A.O.; Aston, W.J.; Higgins, I.J.; Plotkin, E.V.; Scott, L.D.L.; Turner, A.P.F. *Anal. Chem.* **1984**, 56, 667.
DOI: [10.1021/ac00268a018](https://doi.org/10.1021/ac00268a018)
14. Gorton, L. *Electroanalysis* **2005**, 7, 23.
15. Bartlett, P.N.; Whitaker, R.G. *J. Electroanal. Chem.* **1987**, 224, 37.
16. Bourbonnais, R.; Leech, D.; Paicea, M.R. *Biochim. Biophys. Acta* **1998**, 1379, 381.
17. Loughran, M.G.; Hall, J.M.; Turner, A.P.F. *Electroanalysis* **2005**, 8, 870.
18. Turner, A.P.F.; Hendry, S.P.; Cardosi, M.F. Tetrathiafulvalene: a new mediator for amperometric biosensors. In: Biosensors, Instrumentation and Processing, *The World Biotech Report Online*, London, 1987, 1(3), pp.125-137.
19. Palleschi, G.; Turner, A.P.F. *Anal. Chim. Acta* **1990**, 234, 459.
DOI: [10.1016/S0003-2670\(00\)83591-6](https://doi.org/10.1016/S0003-2670(00)83591-6)
20. Bifulco, L.; Cammaroto, C.; Newman, J.D.; Turner, A.P.F. *Anal. Lett.* **1994**, 27, 1443.
21. Downs, M.E.A.; Warner, P.J.; Fothergill, J.C.; Turner, A.P.F. *Biomaterials* **1988**, 9, 66.
DOI: [10.1016/0142-9612\(88\)90072-5](https://doi.org/10.1016/0142-9612(88)90072-5)
22. Skuridin, S.G.; Hall, J.M.; Turner, A.P.F.; Yevdokimov, Y.M. *Liquid Crystals.* **1995**, 19, 595.
23. Chen, B.; Bestetti, G.; Day, R.M.; Turner, A.P.F. *Biosens. Bioelectr.* **1998**, 13, 779.
DOI: [10.1016/S0956-5663\(98\)00042-6](https://doi.org/10.1016/S0956-5663(98)00042-6)
24. Kröger, S.; Turner, A.P.F.; Mosbach, K.; Haupt, K. *Anal. Chem.* **1999**, 71, 3698.
DOI: [10.1021/ac9811827](https://doi.org/10.1021/ac9811827)

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