Institution: University College London/Birkbeck

Unit of Assessment: 5 - Biological Sciences

Title of case study: Enhancing public awareness and engagement with evolutionary cell biology

1. Summary of the impact (indicative maximum 100 words)

Through the publication of three books based on his original research, written for a non-specialist audience, and through an extensive schedule of public engagement work, Dr Nick Lane (UCL Department of Genetics, Evolution and Environment) has enhanced public awareness of relatively little known areas of science (evolutionary biochemistry and cell biology), stimulating discussion and debate in a wide range of media. His books have been translated into 20 languages and have sold around 100,000 copies since 2008. They have had significant societal impacts, such as inspiring young people to study biological sciences, raising public awareness of research being undertaken in this field and stimulating debate and interest in the subject area.

2. Underpinning research (indicative maximum 500 words)

Lane's research is on the role of bioenergetics in cell evolution, especially the origin of life and the evolution of complex cells. These ideas, while seemingly remote in terms of deep time, have striking implications for the physiology and health of humans, which Lane has brought to the fore in research terms through his research. All of this work was performed while at UCL, from around 2000 as an Honorary Reader, and more recently (2009) as Provost's Venture Research Fellow and, since 2012, as a member of Faculty.

Lane has published three books that lay out his original, testable framework for understanding the four billion year-sweep of evolution – a grand interpretation of evidence in the tradition of Darwin's *Origin of Species* and more recent books such as Maynard Smith and Szathmary's *Major Transitions of Evolution*. Lane's books themselves are recognised internationally as original contributions to research, and have received hundreds of academic citations.

In 2002, he published *Oxygen: The Molecule that Made the World*, an account of the strange effects of oxygen on the evolution process, particularly concepts of mortality and our place in nature **[1]**. The Sunday Times (Books of the Year, 2002) described this book as "an extraordinary orchestration of disparate scientific disciplines, connecting the origins of life on earth with disease, age and death in human beings."

In 2005, this was followed by *Power, Sex, Suicide: Mitochondria and the Meaning of Life*, a book which set out many of Lane's original ideas on the role of mitochondria in the evolution of complex cells, and how that affects our health today **[2]**. A review in Nature described this book as "audacious… parts of it qualify as primary literature, by announcing at least two major, original and testable hypotheses." The Economist (Books of the Year 2005) described it as "full of startling insights into the nature and evolution of life as we know it". It was shortlisted for the Times Higher Education's Young Academic Author of the Year in 2005 and the Royal Society Prize for Science Books in 2006.

Then in 2009, *Life Ascending: The Ten Great Inventions of Evolution* was published **[3]**. This covered evolution more broadly, from a biochemical point of view, and won the Royal Society Prize for Science Books in 2010. The journal Science commented that "Lane is that particularly rare breed: a scientist who can not only offer a birds-eye view of an entire field but also tell you about his own very interesting ideas."

In the years following publication of the books, Lane has formally tested their hypotheses through a serious of theoretical papers, along with mathematical modelling of population genetic traits, and experimental work on the role of energy at the origin of life, currently funded by the Leverhulme Trust **[4-7]**. He has taken a sweeping bioenergetic view of evolution, which places the interactions

between genes and energy at the heart of natural selection, postulating in testable terms why the complex eukaryotic cell arose only once in four billion years of evolution; and why all eukaryotic organisms (plants, animals, fungi, algae, etc.) share numerous counter-intuitive traits that are not seen in simpler cells such as bacteria, notably sex, two sexes, speciation and senescence. These ideas have potentially critical implications for human health issues, including infertility and age-related diseases **[6]**, which form the basis for future experimental and genetic work. A remarkable aspect of the bioenergetic focus of Lane's work is that a central set of ideas gives insights ranging from the origin of life to ageing and death.

3. References to the research (indicative maximum of six references)

[1] Lane N. ***Oxygen: The Molecule that made the World***. Oxford: OUP; 2002. Copy available on request.

[2] Lane N. ***Power, Sex, Suicide: Mitochondria and the Meaning of Life***. Oxford: OUP; 2005. Copy available on request.

[3] Lane N. ***Life Ascending: The Ten Great Inventions of Evolution***. London: Profile Books; 2009. Copy available on request.

[4] Lane N, Martin W. **The energetics of genome complexity**. Nature. 2010 Oct 21; 467(7318):929-34. http://dx.doi.org/10.1038/nature09486

A hypothesis paper, based on original data analysis (such hypothesis papers are published just once a year in all subjects in Nature). It has had 150 citations in 3 years. Selected by F1000 as a 'must-read' paper. Altmetric: 53 (in the top 1% of all articles ranked by attention this year).

[5] Lane N, Martin W. **The origin of membrane bioenergetics**. Cell. 2012 Dec 21;151(7):1406-16 http://dx.doi.org/10.1016/j.cell.2012.11.050

A detailed theoretical biochemistry paper which lays out a testable hypothesis for how geochemical proton gradients in alkaline hydrothermal vents could have given rise to abiotic carbon assimilation and energy transduction at the origin of life. Altmetric 57 (in the top 1% of articles ranked by attention).

[6] Lane N. **The costs of breathing**. Science. 2011 Oct 14;334(6053):184-5. http://dx.doi.org/10.1126/science.1214012

A short Perspective article presenting an original hypothesis on the basis of respiratory tradeoffs entailed by two genomes in eukaryotic cells, the mitochondrial and the nuclear. A more detailed exposition was published in BioEssays. Altmetric: 25 (in the top 5% of all articles ranked by attention this year).

[7] Lane N. **Energetics and genetics across the prokaryote-eukaryote divide**. Biol Direct. 2011 Jun 30;6:35. http://dx.doi.org/10.1186/1745-6150-6-35

A hypothesis, based on original data analysis, linking energetics and endosymbiosis to the origin of meiotic sex in eukaryotes. Winner of the 2011 BMC Genetics, Genomics, Bioinformatics and Evolution Research Award, and one of the most highly accessed papers ever published by Biology Direct.

Supporting Grant: Leverhulme Trust 'A far-from-equilibrium reactor to investigate the origin of life'. 2012-15. £248,883. http://www.leverhulme.ac.uk/news/news_item.cfm/newsid/6/newsid/168

4. Details of the impact (indicative maximum 750 words)

Through the publication of three books, written for a non-specialist audience, and through an extensive schedule of public engagement work, Lane has enhanced public awareness of relatively

little known areas of science (evolutionary biochemistry and cell biology) stimulating discussion and debate in a wide range of media.

During the period 2008-13, sales figures for these books were around 100,000 copies. Since 2008, Lane's books have been translated into 20 languages, including Japanese and Chinese. *Power, Sex and Suicide* has sold 13,200 copies in Japan alone in the five years since its launch in translation at the end of December 2007 **[a]**.

Lane's books have been reviewed in many high-circulation newspapers and magazines. For example, *Life Ascending* was selected as a book of the year by *The Times* (2010), *The Independent* (2010) and *New Scientist* (2009) and won the Royal Society Prize for Science Books in 2010 **[b]**. It has also been recommended for use in school by the website *Science in Schools* **[c]**. Lane's books have received thousands of 5-star ratings and reviews online on Amazon, GoodReads **[d]**, LibraryThing etc.; they have been recommended by book clubs (e.g. Scientific American Book Club) and on reading lists for the public (e.g. the US National Center for Science Education **[e]**).

Impact on the study of science

Admissions tutors at UCL report that 50% of students applying to read biology or biochemistry at UCL cite Lane's books as inspiration on their UCAS forms or at interview **[f]**. That this inspiration goes beyond UCL is supported by the fact that Lane's books are recommended on reading lists at universities including Oxford and Cambridge, and are regularly recommended in online student forums such as The Student Room **[g]**. Lane's student seminars often pack lecture theatres, and generate return invitations, a record being four invited lectures to the Oxford University Scientific Society. Lane is regularly invited to give talks in schools, including Henrietta Barnett, St Paul's, and Haberdasher's Aske's, to cafés scientifiques, and the University of the Third Age **[h]**. These talks directly present the ideas from the research to a non-specialist audience. All these activities help draw students into studying biology and biochemistry at university.

Media engagement

Lane has appeared as an expert in a number of television and radio shows, bringing the little-known world of cells and evolution to large audiences. On TV he appeared on the BBC2/Discovery documentary *Secret Universe: The Hidden Life of the Cell* (October 2012), a one hour television special for BBC 2 and Discovery US that uniquely explored the latest understanding of human cellular biology through the dramatic arc of an adenovirus invasion. The film (initially aired in the UK, America and France) has been watched by about four million people worldwide, was received to great critical acclaim, and is now routinely viewed as part of A-level biology courses **[i]**. Lane also acted as scientific adviser to the major BBC series *Wonders of Life* (2013), with Brian Cox. The producers have stated "*Without doubt, Nick's input and influence on the series had a significant impact. Each episode drew an audience reach of well over 3.5 million people on television. Hundreds of thousands more watched on iPlayer…Some of the topics that we discussed have also influenced thinking in the wider Science Department of the BBC*" **[j]**.

Lane has appeared on many radio shows, again with audiences numbering millions, including the Today Programme (February 2010), *The World Tonight* (October 2010) and *The Infinite Monkey Cage* (December 2011, June 2013) **[k]**, as well as popular radio shows in the US, such as NPR's *All Things Considered* (Feb 2010). He featured on the BBC Radio 4 programme *In Our Time* (on cells, September 2012), with an audience of over two million in the UK, and downloads in 40 countries, about which the producer said "*The programme…is used widely as a teaching aid in schools and universities in both the UK and abroad…each episode is a permanent – and free – learning resource. …Nick's contribution was crucial in ensuring that…complex ideas were communicated clearly while retaining full scientific rigour, and his specialist knowledge in the field ensured that our account of the subject was both approachable and authoritative*". **[l]**

Public engagement.

Lane is regularly invited to give public talks at literature and science festivals, museums, schools and universities, frequently attracting capacity audiences. These include talks and debates at the Edinburgh Festival (August 2009), British Science Festival (September 2010), Wellcome Trust (September 2010, April 2011) and Natural History Museum (November 2011) **[h]**. His lectures on YouTube have attracted tens of thousands of views (his mini lecture 'The Origins of Complex Life' on the UCLTV channel is the second most popular lecture of 29 with over 16,000 views) **[m]**. His feature articles for *New Scientist* and occasional guest blogs for newspapers such as *The Times* attract hundreds of comments per article **[n]**; features on the origin of life and the evolution of complexity were among the most commented pieces for *New Scientist*. Blogs and tweets about Lane's academic and media work have also attracted significant attention and wider debate, notably the blogs *Panda's Thumb* **[o]**, *Not Exactly Rocket Science*, *The Loom* and *Pharyngula*. He has also taken part in debates and discussions on podcasts such as *The Guardian Science Weekly* (January 2010).

5. Sources to corroborate the impact (indicative maximum of 10 references)

[a] *Oxygen* and *Power, Sex, Suicide* sales figures: report of sales from Oxford University Press available on request. *Life Ascending* sales figures: reports of sales from Profile Books (UK) and WW Norton available on request.

[b] New Scientist Best Books of 2009. http://www.newscientist.com/article/mg20727751.600#.UmT0OhbIYyE; Press Coverage relating to Royal Society Prize for Science Books 2010: http://www.guardian.co.uk/science/2010/oct/21/nick-lane-royal-society-life-ascending?intcmp=239

[c] http://www.scienceinschool.org/2010/issue16/ascending

[d] http://www.amazon.com/Nick-Lane/e/B001IXSEJ2/ref=ntt_athr_dp_pel_1 http://www.goodreads.com/author/show/21987.Nick_Lane

[e] Reports of the National Center for Science Education, Vol 32, no 5, 2012 http://reports.ncse.com./index.php/rncse/issue/view/11/showToc

[f] Corroboration available from the UCL admissions tutors for Biology and Biochemistry.

[g] Discussion and recommendations of Lane's books among students applying for university and already at university: http://www.thestudentroom.co.uk/search.php?query=%22nick+lane%22&filter[type]=post

[h] Full list available at http://www.nick-lane.net/Nick%20Lane%20Talks.htm

[i] http://www.secret-universe.co.uk Statement from the programme Producer, *Secret Universe: The Hidden Life of the Cell*, Wide-eyed Entertainment, available on request.

[j] Statement from the series Producer, *Wonders of Life,* BBC, available on request

[k] The Infinite Monkey Cage on the origin of life: http://www.bbc.co.uk/programmes/b017vsj9

[l] Statement from the series Producer, *in Our Time,* BBC, available on request. *In Our Time* on the cell: http://www.bbc.co.uk/programmes/b01mk8vh

[m] UCL Mini-lecture with 15,000 hits on YouTube: http://youtu.be/ZJ3x4Iq91Sw

[n] New Scientist articles and discussions of Lane's work: http://www.newscientist.com/search?doSearch=true&query=%22nick+lane%22

[o] Blog discussing Lane's academic work: http://pandasthumb.org/archives/2010/12/how-to-afford-a.html