75TH
EDITION

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BUILDING BACK TO THE FUTURE

SCIENCE JOURNAL 2019

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A word from the Editor

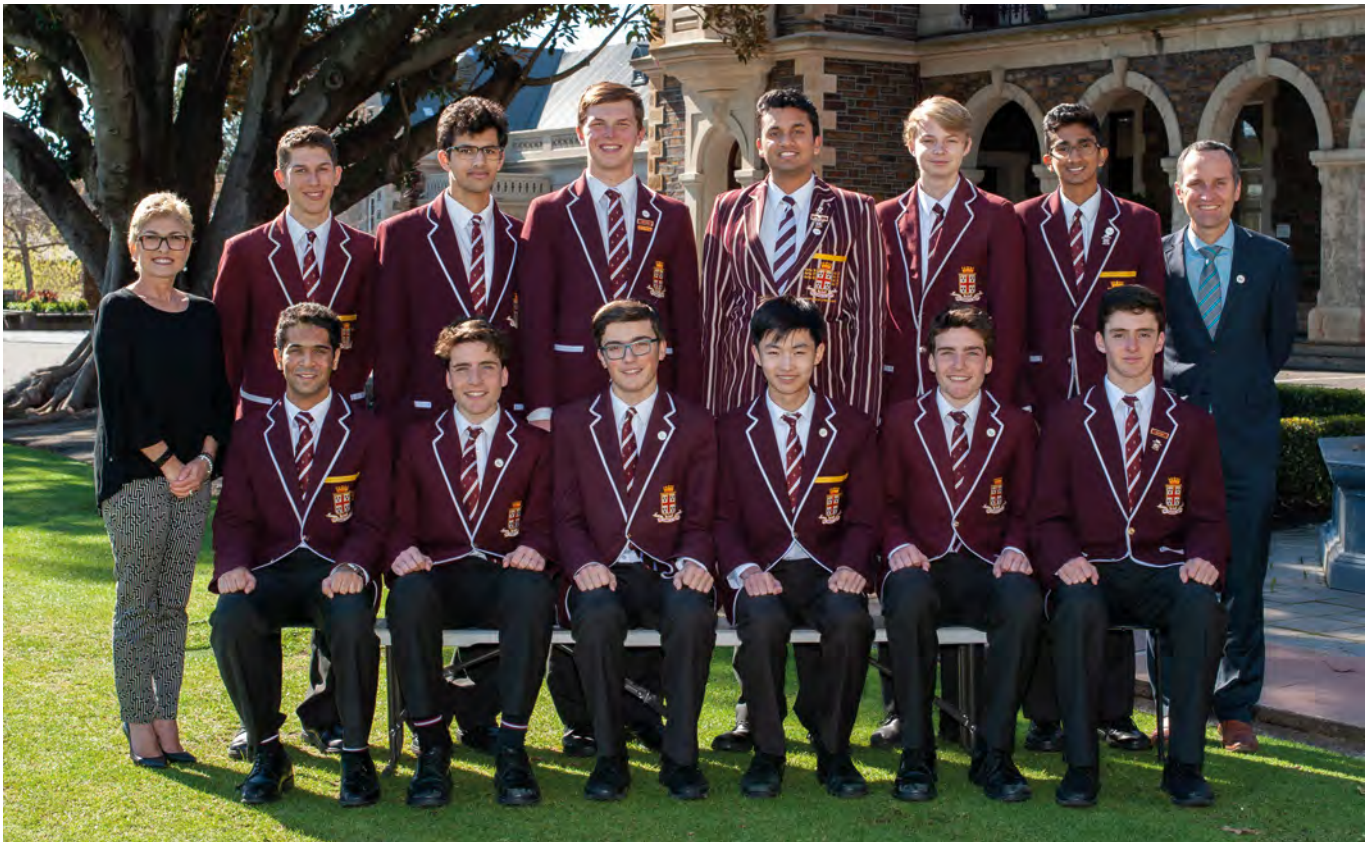
This year's Journal marks a significant milestone in the history of Prince Alfred College, mirroring the College's sesquicentenary (150th) celebrations with our 75th edition. The Journal's theme, *"Building Back to the Future",* aims to capture how the rich history of science allows current innovators to push scientific boundaries. Hinting to a famous 1985 sci-fi film, the sense of progression, development and milestones within the advancement of science is not only reflected by the theme, but in every one of the rigorously selected articles. The concept of *'building back'* seems contradictory, yet intentionally points to the necessity for researchers to learn and adapt from the mistakes and innovations of previous scientists, akin to looking towards the past to seek guidance for the future. With issues such as climate change, the Anthropocene era, and the finite nature of Earth's resources, it is pertinent that our oversights from the past require significant amendment. Hence, we can only act to preserve the world as we know it, if we accept and understand the downfalls of our past and current practices. Nevertheless, the excitement of a future with profound improvements in healthcare, ease of living and environmental sustainability drive scientists to work harder and smarter.

The Journal is a celebration of the diverse scientific knowledge we gain from our education at Princes, with elements of philosophy, culture and medicine within the articles highlights science's integral part within our everyday lives. No matter your level of engagement or understanding of the many scientific concepts that are examined, everyone can appreciate the profound impact science has in our lives, in shaping the way we live. In a break from recent tradition, in line with the historical theme of the 75th edition of the Journal, the articles have been presented in chronological order this year to acknowledge what has transpired in the past and where we may be headed in the future.

I would like to thank our two co-ordinating teachers of the Journal – Mr Peter Hopkins and Ms Christine Papanicolas – for their tireless effort and guidance with every step of the Journal's development. From helping choose the journal theme to reminding us of the approaching deadlines faced by the Committee, your dedication to this publication was admired by all Committee members, and for this we cannot thank you enough. I would also like to thank Elias Raptis for his assiduous commitment in designing the promotional posters and front cover, the latter melding the 'building' theme of the Journal with the 150 year history of the College. Finally, the Science Journal Committee and the article writers must both be thanked for their contribution to this significant Journal in the history of the College, through either composing or editing of articles.

I am very grateful for continuing the tradition from the many successful and amazing past Chief Editors and hope both myself and the rest of the Science Journal Committee have lived up to the expectations of this illustrious Journal!

Seran Perera
Chief Editor 2019



Science Journal Committee 2019
Back Row: Ms Christine Papanicolas, Joshua Lesicar, Alexander Titus, Hugo Jordan, Seran Perera (Chief Editor), Harry Benn, Dinan Perera, Mr Peter Hopkins
Front Row: Yash Giri, Harry Russell, James Newman, Ryan Li, Angus Russell, Nicholas Devlin **Absent:** Blake Lindner, Elias Raptis

Front cover artwork: Elias Raptis

Past editors

John West, 1945

John has gone on to great heights in the scientific field of physiology. He completed a degree in Medicine at University of Adelaide before moving to Hammersmith Hospital in England. A fascination in respiratory physiology led to his involvement in Sir Edmund Hillary's Himalayan and Scientific Mountaineering Expedition in 1960-61, and the American Medical Research Expedition to Mt. Everest in 1981. Presently he is the Professor of Medicine and Physiology at the University of California, San Diego, and is actively involved with NASA in research into astronauts' physiology in space. In 2001 John was awarded membership of the American Academy of Arts and Science and he was inducted into the Princes Men Gallery. He is also a member of the Institute of Medicine of the National Academy of Sciences.

Bruce Chartres, 1946

Bruce gained top position in Leaving Honours examinations, overall and in all five subjects and followed that with a Master of Science and PhD in quick succession. He has had a distinguished academic career and his last position before retiring was as Professor of Computer Science and Applied Mathematics at the University of Virginia, USA. Sadly Bruce passed away in 2003.

Geoff Ward, 1947

Geoff graduated in Medicine from University of Adelaide in 1955. He studied Surgery and Radiotherapy at the Royal Adelaide Hospital and the Peter MacCallum Clinic in Melbourne, gaining Fellowships of both Royal Colleges. He gained further experience in Radiotherapy at the Royal Marsden Hospital in London and the Princes Margaret Hospital in Toronto. In 1970 he returned to Adelaide, where he held a visiting post in Radiotherapy at the Royal Adelaide Hospital and worked in private practice. In 1985 he was instrumental in the opening of the Adelaide Radiotherapy Centre, where he continued in private practice until his retirement at the end of 1997. Geoff passed away in 2016.

Alan McFarlane, Co-Editor 1948

After gaining a B.E. in 1952, he won a scholarship to the United Kingdom to continue his study. Alan moved to Perth and he worked as the senior process design engineer on an Australian project to provide a large natural gas plant for Indonesia. He continued working in the area of safe chemical engineering design and operation of high pressure natural gas plants. In his retirement, Alan began testing his physical capabilities on a bicycle, culminating in 2007, when he completed the Otago Rail Trail, New Zealand. Alan passed away in 2012.

Colin Schwartz, Co-Editor 1948

Colin achieved top place in examinations for the degrees of M.B., B.S. in 1954. He has since worked at the Institute of Medical and Veterinary Science in Adelaide, as the Professor of Pathology at McMaster University Ontario, and is currently Head of the Cardiovascular Department, Texas University, San Antonio.

David Prest AM, 1949

After leaving PAC, David was educated at the Universities of Adelaide, Southampton (UK), Birmingham (UK) and Oregon (USA). He holds Masters Degrees in Physics and Education. David was Principal of four independent schools including 20 years at Wesley College, Melbourne, and finished his career as Director of Foundation Studies at the University of Melbourne. In 2002 he was inducted into the Princes Men Gallery and passed away in 2018.

Bob Hale, 1950

Bob Hale graduated from Adelaide University with a First Class Honours degree in Physics in 1954. This was followed with a M.A. from Cambridge in Pure Mathematics (1958) and a Graduate Diploma in Computing Studies from Melbourne (1982). Bob taught at King's College and lectured at the Gordon Institute of Technology and the Universities of Adelaide, Deakin and Papua New Guinea. Bob is now a computer consultant.

Sandford Skinner, 1951

After leaving PAC, Sandford obtained M.B., B.Sc. and M.D. then worked in hospitals in the U.S.A. and England. Since then he concentrated on Physiology and became the Reader and Chairman of the Department of Physiology, University of Melbourne. Sadly he passed away in May 2005.

Barry Smith, 1952

Barry had an interesting, varied and exciting career. He said that this "chequered" career included teaching Mathematics and Physics at PAC, having senior positions in computing in the public service, academia and private enterprise, twice being a free-lance consultant, Assistant Secretary in the former Schools Commission, Director of a unit advising the NSW Government on technological change, heading the NSW Computer Education Unit, doing policy-oriented research in education at the ANU, statistical analysis in two government agencies, and finally being the Research Analyst at the Family Court. Barry passed away in 2018.

Michael Smyth, 1953

Michael went on to secure a First Class Honours degree in Zoology, swiftly followed by a Rhodes scholarship in 1959. Upon the awarding of his Oxford doctorate, he lectured for two years at the University of California before returning to Adelaide as Senior Lecturer in Zoology. He was the guest writer in 1966 and passed away in 1974.

Fred Symons, 1954

Dux of School, Fred went on to gain First Class Honours in Electrical Engineering and was awarded a fellowship by the General Electric Company. While studying at the University of London, he gained the Duddell Scholarship from the Institution of Electrical Engineers, London. Returning to Australia in 1964, he joined the Telecom Research Laboratories (TRL) working on a range of projects in digital networks and systems. In 1975 he was granted a Telecom postgraduate scholarship to study at the University of Essex, England for which he was awarded a PhD.

In 1979 he returned to TRL as Assistant Director, Head of the Switching and Signalling Branch. Fred was a member of many Australian IT research Boards and Committees. From 1988 to 1996, when he retired, he was the Foundation Telstra Professor of Telecommunications at Monash University. Fred passed away in 2007.

Geoff Symons, 1955

In 1960 Geoff gained a B.A. in Mathematics as well as a science degree with First Class Honours in Physics. He was awarded a PhD in 1963, and a fellowship in Physics at the Kellogg Radiation Laboratories. He later spent time at New Jersey State University, the Niels Bohr Institute in Copenhagen, the Atomic Weapons Research Establishment, Harwell U.K., and Oxford University. He is currently lecturing at the Open University, U.K.

John Lawton, 1956

John gained third place in the General Honours list then graduated MBBS (1962) and M.D. (1968) for research into lymphocyte metabolism. He then held positions at the Royal Adelaide Hospital, the University of Michigan and the Royal Infirmary of Edinburgh. In 1975 he joined the Department of Pathology University of Hong Kong where he attained the grade of Professor. His research in Hong Kong included immuno-deficiency in children, immunology of breast milk and autoimmunity. He retired in 1999.

Greg Bennett, 1957

Greg gained sixth place in Leaving Honours examinations followed by degrees of B.A. and B.Sc with honours in Mathematics. Post-graduate studies with the CSIRO resulted in the award of PhD in mathematical statistics. He retired from the Faculty of Mathematics at the University of Waterloo, Ontario, Canada after 31 years. Greg is still actively involved in the development of tools for data analysis using LISP as the base language.

Colin Luke, 1958

Colin was Dux of School and gained second place on the general honours list. Following on from graduating in Medicine and Surgery, he was awarded a National Heart Foundation Research Scholarship, and held positions of Senior Medical Research Officer at the University of Adelaide, Mortlock Medical Research Fellow and Honorary Virologist at the Royal Adelaide Hospital and then 15 years of private practice. Colin was engaged by Government to investigate the problem of lead exposure in young children at Port Pirie which formed the basis of a Masters Degree in Public Health. This was followed by a career as a Public Health Physician applying epidemiological principless to cancerresearch and in which discipline he was awarded a Doctor of Medicine. He iscurrently Senior Specialist Medical Consultantand Director of Clinical Epidemiology in the South Australian Department of Health.

Garry Brown, 1959

Garry was Dux of School and graduated from the University of Adelaide with First Class Honours in Mechanical Engineering. In 1964 he was awarded the coveted Rhodes Scholarship anwent on to gain a PhD from Oxford University for research into fluid mechanics. Positions at the University of Adelaide, Aeronautical Research Laboratories in Melbourne, and the Department of Mechanical and Aerospace Engineering, Princeton University have since followed.

Robert Smith, 1960

Robert graduated with a B.E. in Chemical Engineering in 1965, followed by three years with ICI in Melbourne. He is now the Eastern Marketing Manager for Exxon Chemical's Additive Division in Singapore.

Geoff Trott, 1961

Geoff graduated from the University of Adelaide with a BSc, BE (Hons 1) and then from the University of Alberta with a PhD. He then spent 35 years as an academic in the University of Wollongong, finishing his working career as Sub-Dean of the Faculty of Informatics and Senior Lecturer in the School of Electrical, Computer and Telecommunications Engineering. He is currently retired and enjoying playing tennis and volunteering for Tennis Wollongong as well as travelling.

Geoff Williamson, 1962

Geoff was also Captain of the School. After Matriculation, he secured an excellent academic record while completing a M.B., B.S. A period in general practice in Whyalla followed, leading him to be Head of the Accident and Emergency Department at the Modbury Hospital. After serving as Director of Medical Services at Maroondah Hospital in Ringwood, Victoria, Geoff is currently Director Clinical Services atRockingham General Hospital, in W. Australia.

Richard Nicholls, 1963

Richard passed away during his third year of a Chemistry degree at Adelaide University.

Adrian Wilson, 1964

In 1965 Adrian gained the Elder prize for first year medicine and completed the degree in 1968, with Honours in Psychology. The years since have been spent studying and teaching history in the United Kingdom.

John Loxton, 1965

Dux of the School, John completed a B.Sc. at Melbourne University and was awarded the Wyselaskie Scholarship, followed by a M.Sc. and PhD from Cambridge University. In 1988 he was appointed Professor of Mathematics at Macquarie University and in 1995 was inducted as Deputy Vice Chancellor (Academic). John left Macquarie University in 2007 to take up a short term role as Deputy Vice-Chancellor (Academic) at the University of Western Sydney. He has stayed on at the University of Western Sydney as Senior Academic Advisor.

Rob Hall, 1966

Rob studied Medicine at University of Adelaide and trained in Neurology at the Royal Adelaide Hospital and Flinders Medical Centre. He was Clinical Teaching and Research Fellow at the Montreal Neurological Institute in 1980. He is currently working in private practice as a Consultant Neurologist at Memorial Hospital. Rob was President of the PAOC Association in 2000.

Malcolm MacDonald, 1967

Malcolm graduated from University of Adelaide in 1973 with a degree in Computing Science and Applied Mathematics. At one stage, he was senior advisor to the Algerian Minister of Petrochemistry on computer applications for oil exploration. Five years were spent at University of Adelaide lecturing on Computer Engineering until invited to the Norwegian Institute of Technology. His time now is largely spent as a consultant in real-time monitoring and control.

Lindsay Packer, 1968

A B.A. in Pure Mathematics and Logic at Adelaide University followed Dux of School and fourth place in Leaving Examinations in 1968 for Lindsay.He completed a M. Sc. at Oxford University and then began Operations Research at Imperial College, London. In 1992 he completed his PhD at the University of Texas. Lindsay hasspent time at the D.S.I.R. in Wellington, New Zealand and has held positions at the University of Texas, University of Charleston and is currently Associate Professor at the Metropolitan State College of Denver.

Phil Thomas, 1969

Phil moved into several fields including truck contracting and plant propagation. 1978 saw him join the Supply Section of the Road Transport Agency, where he is now the Administration and Finance Officer, Supply.

James Cooper, 1970

James graduated with an MBBS and PhD in Immunology from the University of Adelaide. After a period of research overseas, which included time at Oxford and Harvard Universitiesand the Max Planck Institute, Freiburg, James returned to clinical practice in Adelaide. He retired from practice in 2010 and completed an MA in Art History at the University of Adelaide. He remains a director of Coopers Brewery.

Nick Birrell, 1971

Nick graduated from Flinders University with B.Sc. (Hons) and M.Sc. degrees and from King's College, London University with a Ph.D. in mathematical physics. Following a 30 year executive career in technology and finance, Nick now works through his private company, Kintan Pty Ltd, in the fields of venture capital and consulting. Nick is an advisor to Sydney based venture capital company, Innovation Capital, and is an associate of Quaero Investment Solutions. He is an adjunct Professor of Monash University and is involved in a number of high technology start-up companies.

William Lee, 1972

William completed Medicine at University of Adelaide. Upon returning to Australia in 1985, he trained as an anaesthetist and is now in private practice in Lismore, NSW.

Jamie Cooper AO, 1973

Jamie was in the inaugural cohort of medical students at Flinders, did postgraduate studies in medicine, anaesthesia and intensive care medicine at Royal Adelaide, and then a critical care research fellowship at University of British Columbia, Canada. He is now Professor of Intensive Care Medicine at Monash University, an NHMRC Practitioner Fellow, Director of the ANZIC Research Centre and Deputy Director of Intensive Care at the Alfred Hospital Melbourne. He enjoys building and leading large national/international clinical research trials, aiming to improve outcomes for critically ill patients, and has published seven original research papers in the New England Journal of Medicine.

Bill Griggs AM ASM, 1974

Bill completed Medicine at Adelaide and then specialist training in Intensive Care and Anaesthesia. He gained a tertiary qualification in Aerospace Medicine from Otago University in 2000 and completed an MBA from Adelaide University in 2009. He holds multiple positions including Director of Trauma Services at Royal Adelaide Hospital, State Controller (Health and Medical) for disasters, and Director Air Force Health Reserves for SA and WA. He has been deployed as both a civilian and a military officer on multiple occasions including to the Gulf War in 1991, East Timor in 1999 and 2007, both the 2002 and 2005 Bali Bombings, the 2004 Asian Tsunami and the 2009 Samoan Tsunami. In 1989 he invented a surgical instrument and technique (the "Griggs technique") to create a breathing passage through the neck. This technique was used on Pope John Paul II and is now used around the world. He was the South Australian winner of the Australian of the Year award in 2006 and the South Australian of the Year in 2009. He is a member of the Princes Men Gallery.

Dr Alan Branford, Co-Editor 1975

Dr Alan Branford was born at Henley Beach near Adelaide, South Australia, in 1958. He was educated at Prince Alfred College and the University of Adelaide, graduating Bachelor of Science (Honours) and Master of Science in Mathematics. Alan was awarded a PhD from the University of Cambridge, U.K., in Applied Probability in 1983. From 1984, he lectured Mathematics and Statistics at Flinders University in Adelaide, retiring as an Associate Professor in 2016.

David Hone, Co-Editor 1975

David graduated from University of Adelaide in 1979 with Honours in Chemical Engineering. He worked as a refinery engineer in Australia, then spent a time in the Netherlands until he based himself in the UK working for Shell Trading. He is now Chief Climate Change Adviser for Shell, with a focus on carbon capture and storage and the use of carbon pricing policies globally.

David Weller, 1976

David Weller completed Medicine at University of Adelaide in 1982 and undertook his PhD at Adelaide and Nottingham. From 1995-2000 he was senior lecturer, Department of GeneralPractice, Flinders University. In 2000 David was appointed Professor and Head of the Department of General Practice at the University of Edinburgh.

Randell Brown, 1977

After completing Medicine at Adelaide in 1983, Randell began specialist training in Radiology, with his final year at Hammersmith Hospital, London. He is now in general practice in Adelaide, and visiting specialist in Radiology at the Queen Elizabeth Hospital.

Michael Coats, 1978

Michael commenced a Law degree before he completed a Bachelor of Arts in English Literature and then undertook post-graduate study.

Graham Slaney, 1979

Following completion of Medicine at Adelaide University, Graham worked in the UK andNewfoundland, Canada, for several years. He was searching for 'real' winters, and the opportunity to pursue further medical trainingin Anaesthetics and Obstetrics. He has now settled in Mansfield, Victoria, as a country GP. He works at Mount Buller during the winter which enables him to perform some emergency medicine (and ski).

Nick Low, 1980

Nick completed Chemical Engineering with first class Honours in 1986. He was awarded the Institute of Engineers Australia Award for Engineering and the Lokan Prize for ChemicalEngineering, and after his first year he won the Shell Scholarship in Chemical Engineering. After his third year, he was awarded the Petroleum Australia and Western Mining Corporation Prizes for Chemical Engineering. He works with the Field Support group, Research and Engineering Centre, Dowel Schlumberger, France.

Christopher Miller, 1981

Chris studied medicine at the University of Adelaide and since graduation has worked in various medical specialisations including general practice, sexual health, health informatics and travel medicine. He developed an interest in the use of computers and the internet in medicine and gained additional qualifications in health informatics and the internet in health care and has worked in medical software and web development and consulting. Since 2010, Chris has refocussed on clinical medicine, with particular interest in skin cancer screening, diagnosis and management.

Wesley Phoa, 1982

Wesley graduated with Honours in Mathematics from ANU and then took up a scholarship to Trinity College, Cambridge, where he studied category theory and the mathematics of computing. After several years as a lecturer in the Department of Computer Science, University of NSW, Wesley worked for the Deutsche Bank in Australia in their fixed income division. He now lives in the USA where he works as a consultant to the finance sector.

Richard Moore, 1983

Richard graduated from ANU in Science with Honours in Pure Mathematics and majors in Applied Mathematics and Computer Science. In 1989, he joined the Bankers Trust in the funds Management Department. Richard moved to Salomon Smith Barney in 1996 and was Co Head of the Equity Capital Markets. After 12 years in finance in Sydney, he moved to Brisbane. Since 2001, he has been the Chief Executive Officer of Dark Blue Sea, an internet company specialising in domain names.

Andrew Moore, 1984

Andrew completed a B.Sc. and B.Ec. at ANU in Canberra. He went on to pursue a career in business and banking working in Sydney for six years with Price Waterhouse Coopers and Bankers Trust (gaining professional qualifications in Chartered Accounting and Finance & Investment). In 1997, Andrew spent a year in France doing an MBA at INSEAD. He then joined General Electric in London as a Business Development executive, working on corporate acquisitions for GE throughout Europe. In 2004, Andrew returned to Australia with GE as Managing Director of their Home Lending business in Australia and NZ, including the well-known Wizard Home Loans brand. In 2008, Andrew joined St.George Bank as General Manager of Retail Banking. He recently took up the position as Chief Operating Officer of St.George Bank. St.George bank is perhaps best known in SA through its ownership of BankSA.

Nick Falkner, 1985

After completing a PhD in 2007, Nick is currently a Senior Lecturer in the School of Computer Science at the University of Adelaide and is also an Associate Dean for the Faculty of Engineering, Computer and Mathematical Science. He has been involved in a number of educational projects involving puzzle-based learning and flipping the classroom. The Computer Science Education Research group at Adelaide is currently developing resources to support the Digital Technologies component of the new National Curriculum, in conjunction with Google.

David Fotheringham, 1986

David completed a M.Sc. in Laser Physics at ANU in 1995 and undertook a Masters degree in Theology at the Melbourne College of Divinity.

David Silver, 1987

David completed a degree in Computer Systems Engineering at Adelaide University in 1991. He then worked as a Research Engineer in the field of avionics with the Department of Science and Technology Organisation (DSTO), Salisbury, and now works as Systems Engineer for Integra Australia at Technology Park.

Chor Chen Goh, 1988

Chor completed Law at University of Adelaide.

Adam Hanieh, 1989

After studying engineering, Adam devoted himself to human rights. Since 1997 he has worked for several human right organizations, including the United Nations in Palestine. He is now the Research Coordinator of Defence for Children International/ Palestine Section. This role includes documenting cases of human rights violations against Palestinian children and providing legal services to children who are held as political prisoners.

Samuel Whittle, 1990

Sam was awarded the Adelaide University Medal in the Health Science division on completion of his M.B., B.S. (Hons) degree. After completing his medical degree he undertook specialist training in rheumatology in Adelaide and the UK. He is now a senior staff specialist rheumatologist at the Queen Elizabeth Hospital and aimed to have completed a masters degree in clinical epidemiology in 2010.

Kingsley Storer, 1991

Kingsley completed his B Med Sc (Hons) in 1997 and MB BS in 1998. After an internship at the Royal Adelaide Hospital he moved to Royal North Shore Hospital, Sydney. In 2007, he was awarded a PhD in Neurosurgery from the University of New South Wales for an investigation of the effects of high dose radiation on arteriovenous malformations within the brain. Since June 2007, he has lived in New York City where he is currently Assistant Professor in Anesthesiology at New York's Weill Cornell Medical College with a clinical anaesthetic practice and a research focus on how general anaesthetics cause unconsciousness.

Ben Gooden, 1992

Ben was awarded a B.Sc. (Honours) in physiology from the University of Adelaide in 1998. He then studied Medicine at the University of Sydney and completed his M.B., B.S. (Honours) degree in 2001. He researched the cause of spontaneous tendon rupture at the Raymond Purves Bone and Joint Research Laboratories and was awarded a Ph.D. from the University of Sydney in 2009. He resumed his clinical work and in 2010 became a Fellow of the Royal Australasian College of Surgeons. His post-fellowship training was at the Klinikum Emil von Behring in Berlin. He completed a Fellowship in Orthopaedic trauma, hip and knee arthroplasty at Royal Prince Alfred Hospital, Sydney. He now practices as an orthopaedic specialist at the Mater Private, Adventist and Hornsby Ku-ring-gai Hospitals in Sydney and Tamworth Rural Referral Hospital.

Andrew Newman, 1993

Andrew graduated with Honours in Mathematical and Computer Science from the University of Adelaide in 1996 focusing on game theory. After graduating Andrew worked as a management consultant at PA Consulting in Melbourne and completed a Graduate Diploma in Applied Finance and Investment from FINSIA. In 1999, Andrew joined what is now Macquarie Capital, the investment banking division of Macquarie Group. Andrew then returned to Adelaide and focuses on the infrastructure sector, and lead the Macquarie team on the successful bid for the New Royal Adelaide Hospital PPP in 2011.

Matthew McConnell, 1994

Matthew graduated in 2000 from the University of Adelaide with a M.B.,B.S. He went on to further his post-graduate studies and was awarded with a Masters in Public Health. He was a part-time Lecturer at the University of Adelaide's Medical School for six years before commencing advanced training in public health medicine with the Royal Australasian College of Physicians. Matthew became a Public Health Physician in early 2014 and is working in South Australia.

Shom Goel, 1995

Shom Goel graduated MBBS in 2003 from the University of Adelaide. He was awarded the prestigious Alumni University Medal for being ranked the most outstanding honours graduate of his year. Shom was ranked the top M.B.,B.S. student each year of his course and along the way he received 19 prizes and scholarships.

Ross Mullner, 1996

Having completed a Chemical Engineering Degree (Honours) at Adelaide University, Rossworked as a Process Technician at the Mobil Adelaide Refinery until its closure. He then joined Santos as a Senior Process Engineer, supporting various Gas Plant operations and projects around Australia.

Gwyn Morfey, 1997

Gwyn undertook a double degree in Law and Commerce, with a major in Computer Science, at Flinders University.

Tom Newman, 1998

Tom graduated in Commerce, University of Adelaide.

Mitchell Raeside, 1999

Dux of School, Mitchell began an accelerated science degree at Flinders University which he completed in 2001, winning the Bragg Medal for best Physics student. Mitchell completed missionary work for his church in 2003 and then undertook an M.B.,B.S. at Flinders University. In 2008, he was an intern at the Lyell-McEwin Hospital.

Iain Murchland, 2000

Iain completed a Bachelor of Biotechnology (Hons) at the University of Adelaide, and commenced a PhD in the field of structure-based drug design in the Discipline of Biochemistry at the University of Adelaide.

Peter Mathews, 2001

Peter completed a degree in Engineering (IT and Telecommunications) with Mathematical and Computer Sciences at University of Adelaide.

Edward Heddle, 2002

Edward completed Science at University of Adelaide.

Mark Hosking, 2003

Mark holds a Bachelor of Laws and a Bachelor of Commerce from the University of Adelaide, and a Master of Law from the University of Cambridge. Since graduating from the University of Adelaide, Mark has worked at the International Criminal Tribunal for the former Yugoslavia, at the law firm Allens Arthur Robinson, and as an Associate to the Hon Justice Susan Crennan AC at the High Court of Australia. Mark currently practises as a lawyer in Melbourne.

Chris Davies, 2004

Chris completed a Bachelor of Mathematical and Computer Sciences at the University of Adelaide, and Honours in Statistics for which he was awarded the Adelaide University Medal. After working at the Australian Bureau of Statistics and in the

University of Adelaide School of Public Health, he completed a PhD in Statistics at the University of Adelaide. He is now a Senior Biostatistician at the Australia and New Zealand Dialysis and Transplant Registry based at the South Australian Health and Medical Research Institute.

George Evans, 2005

George enrolled in Medicine, University of Adelaide.

Paul Hosking, 2006

Paul completed his Bachelor of Medicine and Bachelor of Surgery degrees at the University of Adelaide and will commence specialist training in Psychiatry in 2015.

Sam Lehman, 2007

Sam enrolled for a double degree in Health Sciences and Law, University of Adelaide.

Harry Crawford, 2008

Harry completed a Bachelor of Arts, majoring in Chinese Language, from the University of Adelaide, and worked for six months in Beijing.

Jerome Squires, 2009

Jerome is studying Law and Arts at the University of Adelaide.

Nicholas Burton, 2010

Nicholas took a gap year and travelled to Cambodia as a volunteer with New Hope for Cambodia Children, working with those affected by HIV/AIDS. He is now studying Civil and Structural Engineering at Adelaide University.

Tien Chen 2011

Tien is currently undertaking the Doctor of Medicine (MD) degree at Griffith University, and hopes to become an internal medicine physician. In 2012 he graduated from PAC as joint Dux of the College, and in 2014 graduated from Griffith University with a Bachelor of Medical Science (BMedSc). Tien also holds an Associate Diploma in Music, Australia (AMusA) and over the summer, was the inaugural Summer Scholarship holder at the South Australian Health and Medical Research Institute (SAHMRI).

Henry Bui, Co-Editor 2012

Henry is studying Medicine at University of New South Wales, in Sydney.

Theo Squires, Co-Editor 2012

Theo is studying a double degree in Finance and Mathematics with Computer Science at the University of Adelaide.

Isuru Dissanyake, 2013

Isuru studied Bachelor of Science (Advanced) at University of Adelaide, recently completing it with a major in Chemistry. He has recently completed First Class Honours in Chemistry and in 2019, embarked on what was a long term goal of his of studying a PhD in orgainc synthetic chemistry. Isuru was acknowledged in an Australia Day ceremony as a "Young Citizen of Australia 2015."

Timothy Hobbs, 2014

Timothy Hobbs started at Prince Alfred College in 2001 at the age of four and completed his International Baccalaureate Diploma 14 years later as the 2015 College Captain. He is now studying a double degree of Law and International Security at ANU. He has recently been awarded the prestigious Charles Hawker Scholarship to help support his studies. He has a goal of obtaining a position with DFAT and ultimately a dream job of Minister for Foreign Affairs and Trade.

Yu Le Kong-Lim, 2015

Yu Le Kong-Lim is currently completing his IB Diploma and is a College Prefect this year. He is heavily involved in the School music program and a keen debater. He hopes to study Law and International Studies at University.

Eddie Han, 2016-17

Eddie graduated from the IB Diploma Program in 2017 and was the Chief Editor of the Science Journal in his last two years of senior schooling. He is currently studying Computer Engineering at New York University – Abu Dhabi.

Denny Han, 2018

Denny studied the IB Diploma in 2017-18 and after contributing to the Journal Committee over several years was Chief Editor in 2018. He is currently studying at New York University - Abu Dahbi.

Contents

From Princes to Everest and astronauts, and other adventures in between

Words by John B. West

Guest article Journal editor 1945; the first edition of the journal

I can still clearly remember working on the first issue of the Journal in 1945. The project was only made possible by the great enthusiasm of our science master, Raymond Smith, who had a clarity of teaching that still influences me. I wonder how many other high schools/colleges can boast of such a long-lived, impressive publication. This says something about the strength of science teaching at PAC. My coeditor was Bruce Chartres who was a talented mathematician, and who went on to make a career in this discipline. The crude arrangements we had for making copies of the Journal would appall students today. Word processers and computers were far off, and everything was done by a medieval process known as cyclostyling.

For this article I plan to say something about my career because I have been fortunate to be involved in several unusual opportunities. Many students in their last year of school are unaware of the variety of avenues that a university degree, opens up. My main interest in my final school year was high energy physics, particularly the cyclotron, and this was the topic of my Science Journal contribution. In the event, I did medicine at Adelaide University, but my career has been very much in research.

Very soon after I graduated, I moved to London partly because I have always been an anglophile, and also I wanted to see the world. An extraordinary opportunity opened up a few years after I arrived when I was told that Sir Edmund Hillary was arranging a medical research expedition in the Himalayas. Of course, Hillary was the first man to reach the summit of Mount Everest, with his partner Tensing Norgay, some six years before. In 1960 he was collaborating with an English group of physiologists headed by Griffith Pugh to obtain more information on how people from sea level can tolerate very high altitudes over a long period. The upshot was what was known as the Silver Hut expedition because we lived in a wooden structure painted silver for several months at an altitude of 5800 m (19,000 ft). Coming from Australia, I had never been to high altitude before, and when Hillary asked me about my previous experience, I felt very defensive. However, he then asked me to climb a flight of stairs, and when I accomplished this, he said join the team!

The expedition was extremely productive and resulted in many publications. I was one of a group of about seven physiologists who spent the winter at the very high altitude. It was not a pleasant experience because we were always extremely short of breath, and there was a relentless loss of weight. The conclusion was that probably no one could spend much longer at that altitude. However, we had a laboratory in the hut with extensive equipment, and made a series of important discoveries on how the body responds to the very low oxygen environment.

In the spring, the climbers attempted to reach the summit of Mount Makalu (8481m, 27838 ft) but they were not successful because one of them became acutely ill near the summit. However, before that, another climbers and myself assembled a stationary bicycle on the Makalu Col (7440m, 24410 ft) (Figure 1), and made the highest measurements of maximal oxygen consumption that have been reported to date. A fascinating feature of these measurements was that they suggested that it would be impossible for a climber to reach the summit of Mount Everest without supplementary oxygen.

Because of the great success of the Silver Hut expedition, I subsequently wondered whether it would be possible to make physiological measurements at even higher altitudes, possibly at the highest point of the world on Mount Everest. The opportunity came some 20 years later. By this time, I had moved to the University of California San Diego where the opportunities for large projects were better than in the UK. The upshot was that with two collaborators, I organized the American Medical Research Expedition to Everest with the primary aim of getting the first physiological measurements at the highest point in the world. The expedition was very successful in that five climbers reached the summit, and a number of measurements were made there, mainly by Christopher Pizzo. One of the most important findings was that it would be impossible to reach these extreme altitudes without an enormous degree of hyperventilation, that is increased breathing. In fact, Pizzo collected samples of gas from the depths of his lung using the special equipment shown in figure 2, and the partial pressure of carbon dioxide in these was only 7-8 mm Hg. Since the normal value is 40, and there is an inverse relationship between the carbon dioxide level and the ventilation, this indicated that he had increased his breathing about fivefold. Pizzo also recorded some data on a hand-held device and it was striking that he needed to take another breath after every 2 or 3 words. He also many other measurements in this unique environment.

I have continued to work on the physiology of high altitude. Some people think this is a rather arcane topic, but in fact millions of people live at very high altitude, and many unanswered questions remain. One of my present interests is the possibility of reducing the equivalent altitude of various institutions that are located very high. This can be done by what we call oxygen conditioning. This is similar to air conditioning except that rather than changing the temperature of the air, the concentration of oxygen is raised by adding this gas. It turns out that there are now many areas of industry that use very large amounts of oxygen, and the addition can be made at a reasonable cost. Institutions that would benefit include hospitals, schools, and indeed anywhere where important decisions are being made. The basic principle here is that the hypoxia of high altitude impairs many physiological functions such as healing of wounds. In addition, there is evidence that neuropsychological function is impaired at high altitude and, for example, children learn better if the equivalent altitude is reduced.

Figure 1 Stationary bicycle being assembled (See references)

High altitude physiology is just one of my interests, although certainly a colorful one. In addition, I have also been heavily involved in the NASA space program, and have had the opportunity to make measurements on a number of the astronauts during flight. The story of how this developed is interesting.

After I moved to London in 1953, I eventually obtained a position in the Postgraduate Medical School at Hammersmith Hospital which is well known for its research productivity. Fortunately, the School was developing a new research program in lung disease, and I was offered a position in this. A very lucky opportunity developed in the late 1950s. The Medical Research Council had previously arranged for a cyclotron to be built at Hammersmith Hospital. This was the first cyclotron ever to be set up in a hospital environment, and I was one of the first people to be able take advantage of this. Is it not a strange coincidence that the article that I wrote for the first issue of the PAC Science Journal was on the cyclotron, and here I am some 15 years later being able to use it in research.

There were two reasons for locating a cyclotron in a hospital. One was to investigate the potential of neutron therapy for cancer. The other was to produce short-lived isotopes. One of these was oxygen 15 which is obtained by bombarding nitrogen with deuterons from the cyclotron. However, the isotope has a half-life of only two minutes, which means that half of it disintegrates during that short time. Consequently, the isotope has to be continuously prepared to work with it.

With colleagues, I arranged for oxygen 15 labeled carbon dioxide to be produced. This was then inhaled, and with external counters, we looked at the rate at which the radioactive material was removed from different regions of the lung by the blood flow. To our astonishment, the rate was much higher at the bottom of the upright lung than the top. This was the first clear demonstration of the uneven distribution of blood flow in the human lung. The finding created great interest, and we extended the study to a variety of disease conditions.

The uneven distribution of blood flow in the lung results from the fact that the blood pressure in the pulmonary circulation is very low and therefore gravitation plays a major role in the distribution. In the mid-1960s I wondered whether it might be possible to look at the situation in astronauts during space flight when gravitational factors were abolished. I therefore arranged to spend a year at the NASA Ames Research Center south of San Francisco. While I was there I wrote a proposal to measure pulmonary function in the astronauts during space flight, although I did not expect any immediate response because at the time, NASA was heavily involved with the Apollo program to put a man on the moon and return him safely to earth. However, amazingly my proposal was accepted and funded, and eventually we mounted an extensive program to study pulmonary function in astronauts during flight.

In the meantime, I had moved to the University of California San Diego. Although we were able to make preliminary measurements during short periods of microgravity in high performance aircraft, most of our studies on astronauts were carried out in the 1990s using Spacelab. This was a cylindrical laboratory taken up in the bay of the Shuttle, and it supported a number of very sophisticated experiments. We found, as expected, that the effects of gravity that we had seen on earth were essentially abolished during spaceflight. We also conducted a few experiments in the International Space Station. The upshot of all this work was that lung function is certainly altered during spaceflight, but the essential gas exchange function of lung remains intact. Furthermore, when astronauts return to earth after up to six months in the Space Station, pulmonary function returns to its pre-flight status within a few

Figure 2 Dr Christopher Pizzo sitting on the summit of Mt Everest (See references)

days. The overall message is that while pulmonary function is altered in space, it is unlikely to be a problem during long-term spaceflight. This of course is one of the questions that NASA was anxious to have answered.

This short account has concentrated on some of the unusual opportunities that I have had for studies at very high altitude and in space. However, my main function at the University of California San Diego, in addition to research, has been teaching medical students, and I have enjoyed this very much. I have written a book “Respiratory Physiology: the essentials” which has been translated into 15 languages and is used by medical students throughout the world. This has been complemented by a series of YouTube lectures on respiratory physiology and pathophysiology that are freely accessible to everybody at https://meded.ucsd.edu/ifp/jwest/index.html. These lectures have been popular with some receiving over 300,000 visits. I like to think that my teaching continues the tradition that I inherited from Ray Smith over 70 years ago.

I am now 90 years old but fortunately in good health, and I continue to teach and do research. In fact, at the moment we are working on a new device that enables us to determine whether pulmonary function is normal or not by having the patient simply breathe through a tube, with an oximeter on a finger. I have hopes that this will greatly simplify testing lung function.

References

West, J.B. *Human physiology at extreme altitudes on Mount Everest.* Science 223: 784-788, 1984.

West, J.B., A.R. Elliott, H.J.B. Guy and G.K. Prisk. *Pulmonary function in space*. JAMA 277: 1957-1961, 1997.

West, J.B. *The Silver Hut expedition, high-altitude field expeditions, and low-pressure chamber simulations*. In: Hypoxia and Molecular Medicine, edited by J.R. Sutton, C.S. Houston and G. Coates. Burlington, VT: Queen City Printers, 1993.

Figure full captions:

Figure 1. Stationary bicycle being assembled by Dr Michael Ward and myself on the Makalu Col, altitude 7440m,(24410 ft). We pedaled this at maximum speed to measure the maximal oxygen consumptions at the highest altitude that have ever been reported. In the background, the summit of M Everest can be seen on the right, (obscured by a small cloud). The summit of Lhotse is on the left. It is unusual to see photos of these mountains from the East.

Figure 2. Dr Christopher Pizzo sitting on the summit of Mt Everest while collecting alveolar gas samples from his lung. To do this he exhales maximally, and then pulls a lever which opens the valve of a pre-evacuated ampoule. These were later analyzed at the University of California San Diego. The results showed an extremely low level of carbon dioxide indicating a very high level of ventilation.

Cyanobacteria, the hidden killer of Australian waterways

Words by Alexander Titus

3.5 billion years ago – Cyanobacteria, one of the earliest life forms, is theorised to first exist.

Considering that environmental conservation is ingrained into public mentality, it is surprising that river health has yet to see widespread attention. To accommodate the increasing Australian population, gross agricultural worth has grown 34% over the last twenty years. This has increased the strain on all of our river systems. Due to its richness, waterways have always been considered the lifeblood of Australia. Their importance in recreation, drinking and agriculture makes their continued health integral to the nation. The Murray-Darling Basin alone contributes over $24 billion to the economy – one-third of agricultural revenue. One of the many issues facing Australian rivers is increased salinity and erosion, resulting from water mismanagement. The decline in water quality has been exacerbated by invasive species that have diminished native flora and fauna. This in conjunction with the increased prevalence of nitrogen-based fertilisers has led to disastrous algal blooms. In the face of this growing issue, many wonder how best we can control cyanobacterial populations. While currently there are many options that range from newer ultrasound-based methods, to the more traditional chemical and aeration-based methods, they all have their limitations.

The phenomena known as eutrophication is the origin of Australian Algal blooms. When a location is nutrient rich and temperatures are favourable, blue-green algae grows uncontrollably. This results in water surfaces being covered in cyanobacteria, preventing light from reaching submerged producers. The death of the producers causes substantial disruption in food webs, affecting both consumers and decomposers. The rise in the number of dead organisms results in the exponential growth of bacterial populations responsible for decomposition. Some of these bacteria are aerobic, hence as they decompose dead organisms, they absorb oxygen. Consequently, oxygen levels in the water fall, causing the death of many aquatic animal species, as they do not receive enough oxygen to survive. Furthermore, blue-green algal blooms produce arsenic, which is toxic for aquatic species. In Australia, cyanobacterial blooms are most likely to occur during summer as the bacteria lie dormant during the colder winter temperatures.

Traditionally, cyanobacterial blooms are controlled with algaecides. While economical and efficient, when employed carelessly they can cause environmental damage. Currently there are three main algaecides: chlorine, hydrogen peroxide and copper-based compounds. Chemical treatment can be explained by redox reactions. The chemical oxidises cyanobacterial cellulose, hence rupturing the bacteria's cell wall. Typically, chlorine treatment causes more environmental damage than hydrogen peroxide. Also, hydrogen peroxide, a newer treatment, has the added effect of reacting with micro-molecules such as fluorine. As blue green algae require these micro-molecules to survive, hydrogen peroxide often starve the area's algal population without significant environmental damage. Unfortunately, chemical treatment releases extracellular toxins into river systems that can cause the death of other organisms. Hence, employing widespread chemical treatment to decrease cyanobacterial concentrations has a side-effect of increasing toxicity to aquatic life.

In contrast, the aeration of river systems is an environmentally friendly method of controlling rampant algal populations. The main principal behind aeration is that by increasing the level of oxygen within the water, the decomposing of dead vegetation can be accelerated. This occurs because increasing oxygen content increases the frequency of collisions between it and the enzymes involved in aerobic respiration in decomposers, hence increasing the rate and efficiency of aerobic respiration – and consequently decomposition. This lowers the water's toxicity and nutrient content, hence limiting a rivers' capacity to support abnormal populations of cyanobacteria. Hence, aeration is superior to traditional chemical methods in terms of impacts on water toxicity. However, aeration can be ineffective and have a significant impact lag. Hence the method has greater utility as a preventative measure ensuring river health, rather than as a band-aid solution.

In response to the ecological threat, various laboratories have pioneered methods of controlling algal populations. Currently two other technologies could provide alternative means of lowering cyanobacterial populations. One example is ultrasonic treatment, which utilises high frequency waves to interrupt the cyanobacteria's buoyancy and depth regulation. Specific waves stimulate the algae to prematurely empty their gas filled vacuoles to sink to the bottom of the river. This inhibits photosynthesis, resulting in their death. In some trials, the method has killed up to 90% of cyanobacteria in an area. This method has the lowest detrimental impact on the environment. However, due to ability of cyanobacteria to adapt to the frequencies, the frequencies need to be regularly changed – which is costly.

The other experimental method for algal control is the use of reservoir mixers to de-stratify water by mechanically simulating currents. This induces less favourable conditions for algal growth by reducing nutrient concentration in the water. Mixing treatment targets, the Epilimnion, Metalimnion and Hypolimnion layers of stratified river systems to reduce the concentration of iron, manganese, and anoxic odours at surface level. This improves the health of river systems as high concentrations are toxic to other organisms. Unfortunately, it has the highest maintenance and least consistent results. While the mixing treating could have preventative applications, the ultrasonic method is more viable for general use.

Burdekin River Bridge, Home Hill, Australia. Photo by Jared Bell

Despite nationwide research, algal blooms are an ever-increasing Australian problem. Growing in frequency and magnitude and accentuated by declining river quality, cyanobacterial blooms will be problematic well into the future. While improvements in methods of control can mitigate the damage, they are currently inadequate. Even though a 'cure' for river health would be great, it is more likely that better management of the environment will be the only reasonable solution. With careful monitoring of fertilisers and water-use, it is possible that water quality could return to a more desirable equilibrium devoid of algal blooms. As they say prevention is the best cure.

References

pubchem.ncbi.nlm.nih.gov. 2016. COMPOUND SUMMARY Hydrogen peroxide. [ONLINE] Available at: https://pubchem.ncbi.nlm.nih.gov/compound/Hydrogen-peroxide. [Accessed 26 August 2]

ucmp.berkeley.edu. 2018. Introduction to the Cyanobacteria. [ONLINE] Available at: https://ucmp.berkeley.edu/bacteria/cyanointro.html. [Accessed 26 August 2019].

ucmp.berkeley.edu. 2018. Cyanobacteria: Life History and Ecology. [ONLINE] Available at: https://ucmp.berkeley.edu/bacteria/cyanolh.html. [Accessed 26 August 2019].

www.lgsonic.com. 2018. algae-control. [ONLINE] Available at: https://www.lgsonic.com/blogs/algae-control/. [Accessed 26 August 2019].

www.worldatlas.com. 2018. what-are-the-biggest-industries-in-Australia. [ONLINE] Available at: https://www.worldatlas.com/articles/what-are-the-biggest-industries-in-australia.html. [Accessed 26 August 2019].

www.lgsonic.com. 2018. algal-bloom-causes-prevention. [ONLINE] Available at: https://www.lgsonic.com/blogs/algal-bloom-causes-prevention/. [Accessed 26 August 2019].

www.lgsonic.com. 2018. economic-impact-algae-blooms. [ONLINE] Available at: https://www.lgsonic.com/blogs/economic-impact-algae-blooms/. [Accessed 26 August 2019].

www.waterquality.gov.au. 2019. Cyanobacteria (blue-green algae) and water quality. [ONLINE] Available at: https://www.waterquality.gov.au/issues/blue-green-algae. [Accessed 26 August 2019].

www.landcareresearch.co.nz. 1996. CYANOBACTERIA. [ONLINE] Available at: https://www.landcareresearch.co.nz/resources/identification/algae/identification-guide/identify/guide/descriptions/cyanobacteria. [Accessed 26 August 2019].

www.business.gov.au. 2018. Agriculture industry fact sheet. [ONLINE] Available at: https://www.business.gov.au/planning/templates-and-tools/industry-factsheets/agriculture-industry-fact-sheet. [Accessed 26 August 2019].

Neighbour-Slime-Series-Saint

Words by Anthony Pham

999 BC – The first development of the concept of determinism by Eastern cultures.

Author's Disclaimer: *Note, the above title was derived from the use of a random word generator, which gave out the above string of words.*

For a long time, humans have been obsessed with the idea of choice. A recent example would be *The Matrix*'s messages on this theme, as a recurring idea throughout all three movies. In the first, Neo is given the "choice" to pick between ignorance and truth, in the second, love or destruction and in the last, death or peace. In all three movies, the trilogy has toyed with the illusion of free will, and the inevitability of certain events, regardless of the actions that humans have exerted. Certainly, *The Matrix* is a fantastic work of science-fiction, but it will be science's place to judge the fiction, and the science, through its usual, gradual construction of concepts from pre-existing ideas.

The idea that free will is an illusion, and that all events in the universe are pre-determined, is termed *determinism*. This is the belief that events are the products of highly complex causal chains, one action causing the next, that causes events to occur. A causal chain is best described as a sequence of events: A→B→C and so on. An analogy for what a determinist may believe to represent all the processes in a human, is the arc reflex in the body, for example, the patella knee-jerk reaction:

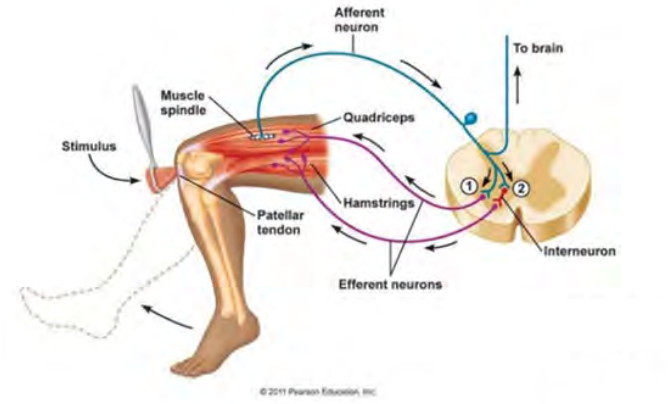


Figure 1: Neural Pathway of Patella Knee-Jerk Reaction

This neural pathway can be perfectly mapped by humans. This reflex involves the input of a stimulus, specifically the tapping of the patellar tendon below the knee, and nerve impulses causes your leg muscles to active, and you kick your leg forward. The effect or response, of the knee jerking forwards, is perfectly predictable in humans. We know that, if the patellar tendon is tapped, the stimulus, then the knee *will* jerk forward, given a lack of impairment.

This simple arc reflex of five stages, is a good analogy for determinism, which believes that every event can be mapped into a causal chain similar to this. Determinism argues that these chains (ie. Stimulus to "processing" to output) lead to events occurring in a perfectly predictable way- everything that we humans do, is a product of the stimulus we receive, and the perfectly predictable processing that we undergo. Say when responding to conversation, similar to the above arc reflex, your response is argued to be perfectly predictable, as a product of millions of steps. On the other hand, free will argues that it is possible for the formation of new casual chains, that the next event is not perfectly predictable, as new causal chains are formed by humans. As such, it becomes impossible for every event to become predictable. Imagine that the body can create its own "stimuli", instead of reacting to externally provided stimuli. Such is the argument of free will.

To examine the stance of science, and whether we'll be able to predict the future perfectly, start with the the quarks that compose the matter that we have around us. If we are able to have the exact momentum and position of these quarks, it logically follows that we are able to predict the exact way that these quarks and particles will end up in the future, which proves determinism. Unfortunately, if it was that straightforward.

Werner Heisenberg was a German theoretical physicist. He won the 1932 Nobel Prize for Physics, as credited with creating quantum mechanics. Among his variety of revolutionary concepts, one is particularly relevant for this topic, and that is the Heisenberg uncertainty principle, which he published in 1927. The principle discusses how there is a strict limit for how accurate two properties of a particle can be determined: the position of this particle, and its momentum. One is able to determine the position highly accurately, but in doing so, is less able to determine momentum to an accurate degree, and vice versa. In brief, one cannot have the cake, and eat it too. You cannot accurately know both the position and momentum of a small particle simultaneously, even in theory. The above concept can be expressed, mathematically, as:

$$\Delta q \times \Delta v > \hbar/m$$

Where Δq is uncertainity of position, and Δv is uncertainity in speed.

$$\hbar \approx \frac{6.62607015 \times 10^{-34}}{2\pi}$$ *and m is the mass of the object*

The above equation has <u>two conclusions:</u>

1. **Firstly,** it demonstrates how the uncertainty in speed and position cannot be determined to an *exact* degree- there is a clear threshold for how small both and can be. While you can make either as small as you want, the other must become larger, to compensate, and to satisfy the inequality. As such, one cannot determine position and momentum *exactly*.

2. **Secondly,** that while for much smaller objects (e.g. electrons), the principle becomes highly relevant, however for much larger objects, (e.g. a bouncing basketball), the principle becomes irrelevant, when compared to the size and speeds of these objects. Although the principle still occurs, the effect it has is exceptionally minor, enough to be disregarded.

It is this second conclusion that opens a new doorway. Clearly, investigating and predicting the future through subatomic particles, is not possible, from the first conclusion, due to this principle. Our hope of being able to perfectly predict the future, through having exact values of the position and momentum of an object, has been crushed. What might still be possible is the prediction of larger objects- objects that are no longer severely affected by the principle. Take, for example… a human being.

Humans are different from electrons in more than a few ways. Aside from not being heavily burdened by the Heisenberg Uncertainty principle, humans possess electrical consciousness, the ability to make decisions- an awareness of one's surroundings. Although we are not limited by the principle, to perfectly predict the future actions of every human, there may still be other limitations in place, to prevent a choice-less dystopia from arising. Perhaps, to begin to unravel the deterministic or free-will nature of humans, start with a prokaryotic cell.

It seems that, after extensive testing by humans, the actions of prokaryotes perfectly mirror our predictions of their responses. We expect that, due to binary fission, there will be amount of cells after minutes, we expect that prokaryotes will maximise absorption of iron, when these levels dwindle. In brief, humans are able to predict the actions of prokaryotes, after extensive testing and knowledge of their processes. So, we have to ask, why is this the case? Why is it that we are able to predict the actions of prokaryotes, given stimuli, so well?

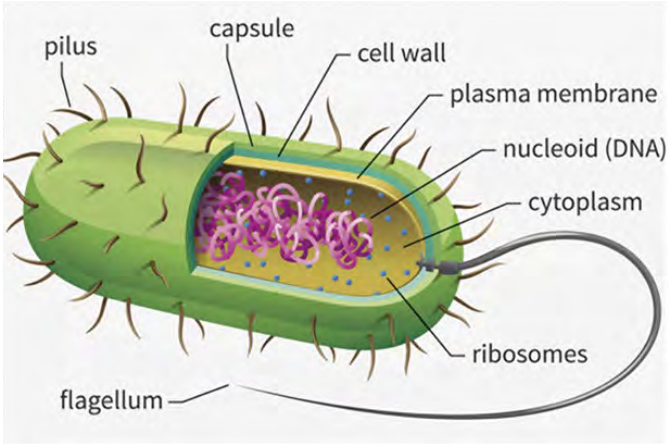


Figure 2: Generalised Prokaryotic Cell

The answer lies in the abilities of a prokaryote cell. Although the cell is able to provide a variety of responses to the stimuli that it receives, these responses have been *hardwired* into the organism itself, to execute the same response, every, single, time. You can think about these cells as having only arc reflexes, everything in their function is geared towards homeostasis-survival, and reproduction. These cells lack the complex, electrical consciousness of the Central Nervous System (CNS) in humans- they lack a brain! Even with humans possessing an electrical consciousness- the ability to make decisions, is it still possible to predict reactions, perfectly? Are humans nothing more than prokaryotic cells, to a higher species? Simply organisms with the ability to receive information, have some somewhat more complex processing, and deliver a response, that is predictable? Are our outputs, of expression, art and higher orders, mere "arc reflexes" to a different viewpoint?

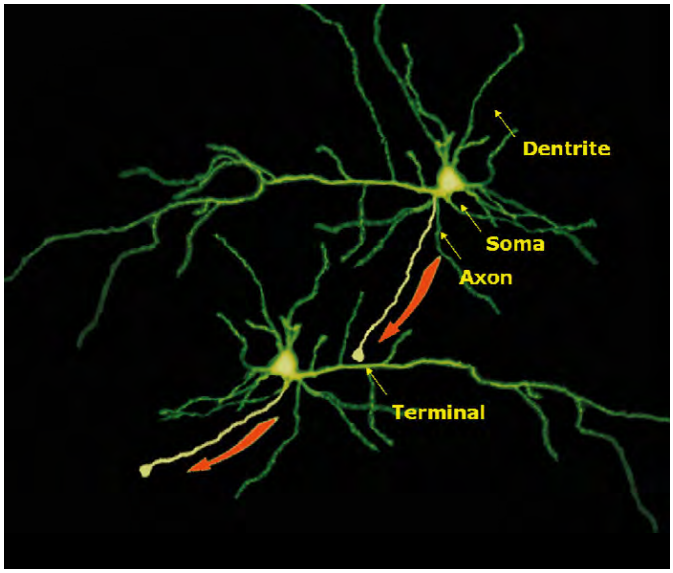


Figure 3: A Human Neuron from the Brain (Dyed and Under Microscope). A few billion of these compose the brain

To answer these questions, enter an American physiologist, Benjamin Libet, who wanted to test the evidence of determinism and free will in humans. Libet devised an experiment where participants performed simple actions, such as pressing buttons, in which they recorded the time when they consciously chose to perform this action. Through the use of an electroencephalogram (EEG), attached to subjects' scalps, Libet demonstrated that a build-up of subconscious activity occurred, before conscious action occurred to perform the task. Specifically, participants subconsciously chose to perform the task, 300 milliseconds before conscious thought.

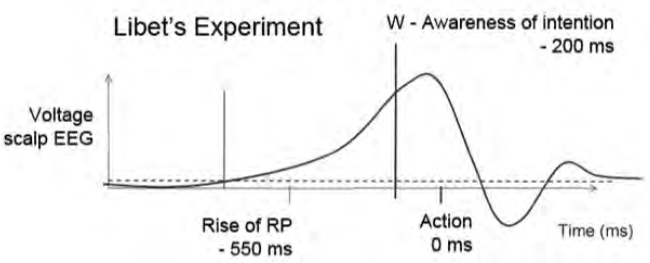


Figure 4: Build-up of Subconscious Brain Activity, Preceding Conscious Choice

These results were replicated in Vsauce (Michael Stevens') Mindfield episode with a similar setup, where he was to press a button before a computer-triggered light appeared. Stevens was able to press this button before the light appeared with ease, in the first few minutes. However, afterwards, the predictions of the computer in reading his subconscious signals, made it impossible for any later success.

Figure 5: Michael, in an EEG, attempting to trick a machine that can literally read his mind

These experiments, by Libet, and emphasised by Stevens, demonstrates the lack of conscious choice that humans exert on the actions that we make. If the "choice" occurred in our subconscious, moments before when we were aware, this directly demonstrates how we really don't have any conscious choice on the actions that we make. That we are reacting to the input of stimuli, subconsciously making a decision, then experiencing an illusion, a scam. It seems that science sides with determinism. However, the research in this area is limited. Humans simply still cannot comprehend consciousness, nor explain the origins of these subconscious brain signals. Simply, there's every possibility for free will, and every possibility for inevitability.

To finish with an analogy by the famous philosopher John Locke, on the idea of determinism and free will, Locke envisions a sleeping man, in a locked, dark room. Upon waking up, the man decides to stay in the room, believing that he could open the door, and leave, although the door is actually locked. Locke suggests that the ignorance of this man provides the illusion of his free will. And to protest this, I generated a title through a random word generator, in the hopes of demonstrating my power of free will, to generate a totally unpredictable title. And yet, I may simply be presented with the illusion of free will, of randomness. And it will be humans through science, as the sleeping man, to get up, to walk to the door, and to pull the handle.

References

Cave, S., 2016. There's No Such Thing as Free Will. The Atlantic.

Chivers, T., 2010. Neuroscience, free will and determinism: "I'm just a machine."

Egnor, M., 2014. Do Benjamin Libet's Experiments Show that Free Will Is an Illusion? [WWW Document]. Evolution News. URL https://evolutionnews.org/2014/01/do_benjamin_lib/ (accessed 9.23.19).

Hoefer, C., 2016. Causal Determinism, in: Zalta, E.N. (Ed.), The Stanford Encyclopedia of Philosophy. Metaphysics Research Lab, Stanford University.

Jha, A., 2013. What is Heisenberg's Uncertainty Principle? The Guardian.

Libet Experiments. Retrieved September 23, 2019, from Information Philosopher. Web site: http://www.informationphilosopher.com/freedom/libet_experiments.htm

Newman, T., 2017. Central nervous system: Structure, function, and diseases [WWW Document]. URL https://www.medicalnewstoday.com/articles/307076.php (accessed 9.23.19).

O'Connor, W., n.d. Figure 1. Image showing real neurons from the human brain. They have... [WWW Document]. ResearchGate. URL https://www.researchgate.net/figure/Image-showing-real-neurons-from-the-human-brain-They-have-been-filled-with-a-fluorescent_fig1_271556079 (accessed 9.23.19).

Riley, J., 2019. Free Will and Determinism [WWW Document]. tutor2u. URL https://www.tutor2u.net/religious-studies/blog/free-will-and-determinism (accessed 9.23.19).

Stevens, Michael. YouTube. https://www.youtube.com/watch?v=lml7NnMqwLQ&vl=en. Accessed 23 Sept. 2019.

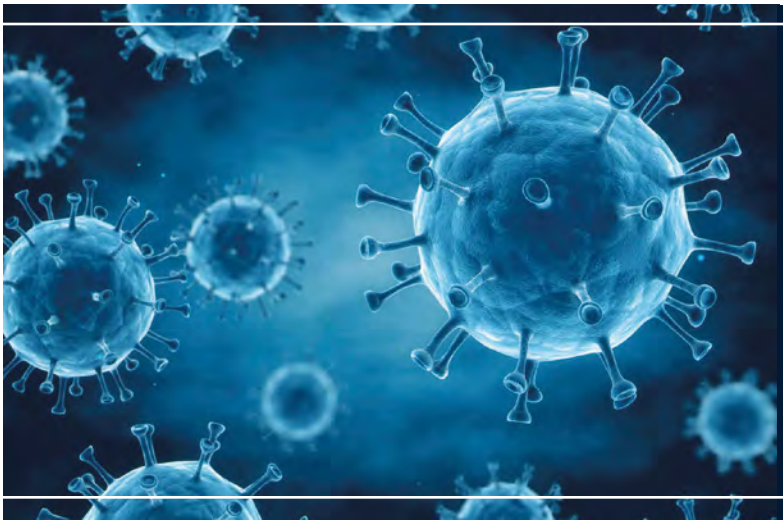
The Editors of Encyclopaedia Britannica, 2019. uncertainty principle | Definition & Equation [WWW Document]. Encyclopedia Britannica. URL https://www.britannica.com/science/uncertainty-principle (accessed 9.23.19).

tlohman2, 2015. The Reflex Arc and Selected Reflexes. AandPonline.com. URL http://aandponline.com/?p=140 (accessed 9.23.19).

Wikipedia, 2019. Benjamin Libet. Wikipedia.

Wiseman, H., n.d. Explainer: Heisenberg's Uncertainty Principle [WWW Document]. The Conversation. URL http://theconversation.com/explainer-heisenbergs-uncertainty-principle-7512 (accessed 9.23.19).

Zinni, Y., 2017. What Is Bacteria Homeostasis? [WWW Document]. Sciencing. URL https://sciencing.com/bacteria-homeostasis-8706627.html (accessed 9.23.19).



Researchers believe the first human case of HIV was in Kinshasa, Congo, around 1920.

New HIV infections rising dramatically in Philippines 2018

http://www.bssnews.net/?p=95458

The theory of Earth

Words by Ryan Li

600 BC – The first development of the concept of determinism by Western Cultures.

Butterfly effect

If we lose a nail, there goes a hoof
Lose a hoof there goes a horse
Lose a horse there goes a knight
Lose a knight there goes one victory
Lose a victory there goes a whole country

Butterfly effect is the sensitive dependence of initial conditions, as a small change in a deterministic nonlinear system can result in a large difference during later states. For example, a butterfly flapping its wings in Brazil can cause a hurricane in Texas, through a complex set of chain reactions.

Butterfly effect shows how you could not remove a single grain of sand from its place without changing something throughout all parts of the immeasurable whole.

Consider the scenario

A person is currently in a war situation, and bombers are sent to his country, which has the potential to destroy everything.

So, to save his country, in your perspective, what should he do?

Here are three options.

A, try to communicate to the Prime minister in the opposition to discharge the attack.

B, try to calculate the initial position of weather for his country.

C, try to activate the anti-aircraft defense.

Story from A: his position is too low even for a direct communication to the prime minister, therefore, your country is destroyed. The end.

Story from C: he discovered how his country does not have anti-aircraft guns, therefore, the bombers arrive, and his disintegrate with his country. The end.

Story from B: Luckily, he has a friend which specialises in computers, the friend gave him a machine which can calculate the initial spot of weather patterns.

Therefore, he went on to calculate the initial point of clouds and mists, and discovered how, if he disturbs the sea water at one particular spot on the Pacific Ocean, great mists will fall to his country. So, the bombers will not be able to carry-out their mission.

The person tells himself, I just need to, at one particular place, at one particular moment, perform one particular action.

So, he went to the spot, and dropped a bomb into the water, and outgoes a boom.

The next day, his country is covered by intense mist, and the bombers are forced to return.

However, in prediction, the mist will only last for two days, so he operated the machine again to discover another initial point, where he is required to quickly lower the temperature of the spot.

The point is within the desert, and he took a piece of ice with him, and carried it to the spot. Then, he smashes the ice with a hammer.

The mist continued for another two days. The bombers still cannot launch their attack.

However, when the person tries to do it for the third time, he failed.

Then the sky turns clear in his country.

The bombers arrive and destroys everything. The end.

So, why did the story end in such tragedy, and why did the person fail.

Because, even though one may discover a single initial point of butterfly effect, however, being so indulged in the consequences of his one single action, he seems to disregard the impacts of his other performances which are also “butterflies”. During his last action, the ice he carried, melted on his way, and disturbed three other weather initial points, which caused the sky to become clear.

Therefore, the world is extremely complex with endless chains of butterfly effect, which cannot always be controlled by human technology.

This raises another point.

Luck.

Is our concept of “luck” simply the product of endless butterflies which we are unaware of? And if so, can we learn to predict every possible consequence of our actions.

The answer is most likely no, because the system is overly complex for any system of human invention.

However, if we most likely cannot produce luck intentionally, then is there another way to increase our luck?

Therefore, how important is luck, to our existence as humans?

Here is another scenario.

Imagine the sun, it is on the rim of explosion, about to take away everything of the solar system, humanity cannot forlornly wait for the impending extinction, therefore they have discovered a method to run away, safe and sound.

They took the earth with them.

They added ten thousand repulsion systems on the surface of the planet, delivering 15 billion tonnes of energy in total. This therefore allows the earth to travel at one eighth the speed of light. Humanity will be seeking another resting place in the far universe. The whole campaign, known as the wandering

Photo by Greg Rakozy

earth, will last for 2500 years, furrowing its way through many generations of people.

By means of physics, it is ridiculous.

However, look closely, not at the progress of charging the earth through universe, yet at the decision itself.

For the escape, people did not choose to create any spectacular space air crafts to carry the whole of humanity, instead, they took the whole bulky planet with them, causing a lot more systemic difficulties when it comes to changing directions and controlling the population. So, given humanity had the option of building a space aircraft, which will be a lot more nimble and easier to control, why did they come this idea of taking the entire planet? Firstly, a space aircraft is fragile, even though it may be the crystallisation of the most advanced and powerful human technology. A space aircraft is still fragile, because, it comes from everything that is known to human, not the unknown.

Even though a space aircraft can encounter and withstand everything possibility conceived by human, however it is incredibly vulnerable to the unknown, and space travel is full of the unknown. A space aircraft will therefore not be a sustainable plan in a course of 2500 years. However, the earth instead is imbued with many uncertainties within it, much more than a space aircraft, as humans have not truly understood their planet. The earth's increased level of uncertainty will therefore allow humans with a greater capacity to withstand against the unknown. In particular, the increased level of uncertainty will simultaneously increase the level of luck, and luck is determined by a very sophisticated system which humanity cannot fully grasp. This will, therefore, increase the chances of our survival. Therefore, luck is essential to our very existence.

Then, we might position our lens into the universe, specifically, the system of doubt.

If we discover another civilization which is far away from our earth, and we cannot have active communication, it is impossible for us to determine whether the other has good or bad intentions. The same applies for the others as well. Furthermore, even if we may have good intentions to the other civilization at the start, our fundamental system of self-protection will force us to assume how the distant population has evil purposes. Therefore, we are compelled to either fight or eliminate them

This is the theory to survival in the universe, if we detect another civilization, there are only two options, fight or hide. If we are more superior, than we will strike, however, if the opposition is stronger, it is best to hide our own existence.

References

Farnam Street. 2019. The Butterfly Effect: Everything You Need to Know About This Powerful Mental Model. Available at: https://fs.blog/2017/08/the-butterfly-effect/. Accessed 27 August 2019.

Liu ci xin 2019. *The Three-Body Problem* (novel) - Accessed 27 August 2019.

Wikipedia. 2019. The Wandering Earth - Wikipedia. Available at: https://en.wikipedia.org/wiki/The_Wandering_Earth. Accessed 27 August 2019.

What is the evidence supporting the use of gut microbiota in the treatment of obesity in humans?

Words by Alexander Nind

1869 – Gut microbiota are discovered and changes the way we view our bodies.

Obesity and its common associations such as diabetes and cardiovascular disease are reaching epidemic levels. Increased food intake and lack of exercise are two factors which have contributed to the rise of obesity. Obesity refers to excessive fat accumulation that presents a large risk to health. A person with BMI of greater than 30kg/m^2 is considered obese. Current scientific studies have led to the identification of the role of gut microbiota in the development of metabolic disorders but have also highlighted that more evidence is needed to support this. Gut microbiota refers to all the microorganisms which inhabit the digestive tract of animals, which assist in food digestion and absorption. This report explores the connection between the gut microbiota and obesity. It will also look at the epidemiology of obesity, its current management and how the gut microbiota could be used as a treatment for this.

Since 1975, the number of obese people in the world has tripled. In 2016 over 1.9 billion adults were overweight and 650 million of these were obese. This has mainly been caused by people having an excess of calorie intake over energy expenditure, resulting in the development of more adipose tissue. This can lead to many health consequences. These include:

Type 2 diabetes is strongly connected with obesity. Over 80% of cases can be attributed to obesity. It is a progressive condition that causes the body to become resistant to the effects of insulin, causing blood glucose levels to increase. This can result in excessive thirst, lethargy, weight gain and headaches. Currently there is no cure for Type 2 diabetes, but it is treated with medication and the modification of lifestyle. Without proper management, Type 2 diabetes can lead to macro and microvascular complications, which increase the risk of dying prematurely.

Metabolic syndrome is linked closely to obesity and inactivity. This is a cluster of conditions which can occur together increasing the risk of developing heart disease, cerebrovascular and peripheral vascular disease. The features of this syndrome are: central obesity, hypertension, high blood triglycerides, low levels of high-density lipoproteins, obstructive sleep apnoea and Type 2 diabetes. Treatments for the metabolic syndrome include losing weight, and medications to reduce blood pressure, cholesterol and blood sugar levels. Without treatment Metabolic syndrome may lead to atherosclerosis and an increased risk of developing coronary heart disease, kidney disease and cerebrovascular disease. These may lead to morbidity in affected patients and premature death.

Obesity has long been correlated with cardiovascular disease, a collective term for diseases relating to the heart and blood vessels, but most specifically as an independent risk factor for the development of coronary heart disease (CHD). CHD is caused when the coronary arteries are blocked through atherosclerosis. This can lead to a serious reduction in blood flow to the heart, leading to a heart attack or angina. Obesity can also lead to coronary diseases such as high blood pressure and stroke. Currently, CHD and cardiovascular diseases are treated with aspirin or by surgical means through coronary artery bypass graft.

The treatment of obesity and its related conditions comes at a high economic cost. This, in addition to other costs, such as lost work productivity, insurance and lower household income cost the United States approximately $1.4 trillion in 2017. It has been estimated that if obesity rates continue to grow unchecked, medical costs related to obesity could rise by $48 to $66 billion per year in the U.S. by 2030.

Current treatments for obesity depend on the causes and severity of the condition. Presently, treatments are limited, and include exercise and diet modification, drugs/medications and surgery.

Exercise and diet play a vital role in treating obesity. Combining increased exercise and improving one's diet can be used to reduce caloric intake below caloric expenditure, resulting in weight loss related to an energy deficit.

Increased physical activity is useful for obesity management but doesn't normally increase caloric expenditure enough to cause significant weight loss by itself. For maximal results, a multicomponent exercise program should be implemented. A meta-analysis of trials ranging from 12 weeks to 12 months revealed that exercise resulted in modest reductions in weight loss compared to no treatment (mean difference -1.6kg). The goal of dietary therapy is to reduce the intake of calories so that the energy expenditure is greater. There are many different types of diets to choose from and consultation with experts is advised. An initial goal of 5-7% loss of body weight should be set as it has been found to lower the rates of many chronic diseases. When used in combination with behavioural modification, the treatment tends to be more effective as this helps the patients make long-term changes in their eating behaviour and physical activity.

Drug therapy may assist in obesity treatment in conjunction with diet, exercise and behavioural changes. Concerns have risen about its efficacy, safety and the durability of its effect when

drugs are stopped. Most of these agents cause up to a 10% loss of body weight, but this weight is usually regained upon cessation. A commonly prescribed drug is Orlistat which limits fat digestion by inhibiting pancreatic lipases. In a meta-analysis of trials looking at the efficacy of Orlistat, it was found that over a 12-month period, patients randomly assigned to this drug and a behavioural intervention lost 5 to 10kg compared with 3 to 6kg in the control group (placebo plus behavioural intervention). Other drugs used to treat obesity include Liraglutide and Phentermine, however their side effects limit their use.

Bariatric surgery is an option for people dealing with severe obesity, particularly when they suffer from Type 2 diabetes mellitus. It is generally considered after lifestyle and behavioural treatments have failed. Bariatric surgery can limit the amount of food a patient can comfortably eat, decrease the absorption of food or both. It doesn't guarantee sustained weight loss unless lifestyle changes are also undertaken. Common bariatric surgical procedures include gastric bypass surgery, laparoscopic gastric banding and gastric sleeve surgery. A study conducted by Natalie Lukas and others found the 65 participants in the study lost a mean weight of 22.6 kg by 3 months, 34.2kg by 12 months and 39.9 kg by 24 months and concluded that bariatric surgery is an efficacious treatment for those who have morbid obesity. These surgical procedures provides the best chance for a very obese patient to lose and maintain weight loss but can lead to nutritional deficiencies and new gut symptoms, such as gastroesophageal reflux.

The gut microbiota has a large impact on our health, the extent of which has only started to be realised. Current studies show the gut microbiota plays a significant role in an individual's response to a meal. Currently few human trials have been conducted, however, it is postulated that gut microbiota will have an effect on the risk of developing obesity.

The human gut contains trillions of microorganisms which colonise our body from birth. The gut microbiota is made of up of a few main phyla: Actinobacteria, Bacteroidetes, Firmicutes, Proteobacteria, and Verrucomicrobia, each of which serve multiple functions within the gut including exogenous and endogenous metabolism, immune regulation and generation of energy through the production of short chain fatty acids. The composition of an individual's gut microbiota is partially determined by genetics but can also be altered by gut infections, medications (particularly antibiotics) and by diet. The evidence for genetics has been shown from twin studies as monozygotic twins have more similar gut microbiomes than dizygotic twins. With gut infections, the overgrowth of the infecting organism may alter the composition and diversity of the gut microbiota in the short term and sometimes long term and this may alter the effects of the gut microbiota on metabolism. The use of broad-spectrum antibiotics may kill sensitive bacteria at least in the short term, again, leading to a decrease in bacterial diversity in the gut, which also may have effects on metabolism. Low microbial diversity is typical of obese people; hence, these conditions could lead to obesity. This was confirmed by a Danish study which concluded that individuals with a more diverse gut microbiome had a lower prevalence of metabolic disorders and obesity.

The gut microbiota is involved in nutrient metabolism. It ferments carbohydrates that have escaped proximal gut digestion and this leads to the synthesis of short chain fatty acids (SCFA) such as butyrate, propionate and acetate. Butyrate is synthesised from the bacterial metabolism of fibre in the colon and provides energy for enterocytes to maintain enterocyte health. It also promotes intestinal gluconeogenesis which has beneficial effects on energy homeostasis in the body. There is evidence supporting that butyrate can both alleviate and induce obesity. Mice studies have shown that butyrate alleviates diet induced obesity and insulin resistance by stimulating the release of certain gut hormones, which have effects on glucose and lipid metabolism and also inhibit food intake. However, obese humans have increased SCFA levels compared to lean and obese humans who have lost weight have a decrease in their caecal SCFA levels. It has been suggested that SCFAs may be assimilated into host carbohydrate and lipids providing excess energy.

Currently, the most commonly used method to alter an individual's gut microbiota is faecal microbial transplantation (FMT). This involves the transfer of faecal matter, and thus gut microbiota, from a healthy, screened person to a patient with a gut infection or inflammatory bowel disease. It is not entirely understood how FMT works, but it is postulated that the effect is mediated either directly by the transplanted microbiota or by the products they produce. FMT is currently approved for the treatment of the Clostridium difficile infection of the gut which develops in 10-25% of people who receive a course of antibiotics. If a patient with this infection has recurrent infections after treatment with courses of metronidazole and vancomycin or they have a severe infection, in many countries they are now offered a FMT. This will cure the infection in 70-90% of cases and over 50,000 cases of this treatment have now been performed with few safety issues. However, there was recently a death due to the transfer of multidrug resistant bacteria.

The first double blind placebo-controlled trial on the effect of faecal microbiota transplant in obese patients yielded a negative result. This study of 22 obese patients who had Metabolic Syndrome, found no significant difference between the BMI of the placebo and FMT capsule groups after 12 weeks. However, this study may have been underpowered to show that FMT was of benefit in treating obesity.

Currently, there is insufficient evidence to support using FMT as a treatment for obesity. However, there is some evidence to suggest that modifying an individual's gut microbiota may be a future treatment for this. In the meantime, diet and exercise in combination with behavioural therapy and bariatric surgery are the only proven treatments for this major health problem.

Grasshoppers have ears in their bellies

Elegance Thika

https://unsplash.com/photos/Ja_FldTNJaQ

References

Alegretti, J. et al. (2019). Effects of Fecal Microbiota Transplantation With Oral Capsules in Obese Patients. Clinical Gastroenterology and Hepatology. Available at: https://www.cghjournal.org/article/S1542-3565(19)30739-6/pdf [Accessed 8 Aug. 2019].

Baothman, O. et al. (2016). *The role of Gut Microbiota in the development of obesity and Diabetes*. NCBI. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4912704/ [Accessed 30 Jun. 2019].

Better Health Channel. (2018). *Diabetes - long-term effects*. Available at: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/diabetes-long-term-effects [Accessed 2 Aug. 2019].

Better Health Channel. (2018). *Metabolic syndrome*. Available at: https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/metabolic-syndrome [Accessed 2 Aug. 2019].

Bryant, R, 2019, Gut Microbiota Specialist, interview conducted by 495439X, 1 July.

Costello, S, 2019, Gut Microbiota Specialist, interview conducted by 459439X, 2 July.

Department of Health. (2016). *Cardiovascular disease*. Available at: https://www1.health.gov.au/internet/main/publishing.nsf/Content/chronic-cardio#wha [Accessed 6 Aug. 2019].

Diabetes Australia. (2019). *Type 2 Diabetes*. Available at: https://www.diabetesaustralia.com.au/type-2-diabetes [Accessed 3 Aug. 2019].

Harris, M. (2013). *The metabolic syndrome*. RACGP. Available at: https://www.racgp.org.au/afp/2013/august/the-metabolic-syndrome/ [Accessed 3 Aug. 2019].

Harvard T.H. Chan. (2019). *Economic Costs*. Available at: https://www.hsph.harvard.edu/obesity-prevention-source/obesity-consequences/economic/ [Accessed 5 Aug. 2019].

Health Direct. (2019). *Guide to bariatric surgery*. Available at: https://www.healthdirect.gov.au/guide-to-bariatric-surgery [Accessed 27 Jul. 2019].

Jackson, E. and Barnes, G. (2018). *Obesity, weight reduction, and cardiovascular disease*. UpToDate. Available at: https://www.uptodate.com/contents/obesity-weight-reduction-and-cardiovascular-disease?search=treatment%20of%20obesity&topicRef=5370&source=see_link#H4 [Accessed 3 Aug. 2019].

Jandhyala, S. et al. (2015). *Role of the normal gut microbiota*. NCBI. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4528021/ [Accessed 1 Aug. 2019].

Kelly, C., Lamont, J. and Bakken, J. (2019). *Clostridioides (formerly Clostridium) difficile infection in adults: Treatment and prevention*. UpToDate. Available at: https://www.uptodate.com/contents/clostridioides-formerly-clostridium-difficile-infection-in-adults-treatment-and-prevention?sectionName=Third%20or%20subsequent%20recurrence&search=FMT%20for%20Clostridium%20difficile%20colitis&topicRef=2604&anchor=H3167428316&source=see_link#H3167428316 [Accessed 6 Aug. 2019].

Liu, H. et al. (2018). Butyrate: A Double-Edged Sword for Health?. *Advances in Nutrition*, 9(1), pp.21–29. Available at: https://academic.oup.com/advances/article/9/1/21/4849000 [Accessed 30 Aug. 2019].

Lukas, N., Franklin, J., Lee, C. and Taylor, C. (2014). The efficacy of bariatric surgery performed in the public sector for obese patients with comorbid conditions. MJA. Available at: https://www.mja.com.au/journal/2014/201/4/efficacy-bariatric-surgery-performed-public-sector-obese-patients-comorbid [Accessed 28 Jun. 2019].

Mayo Clinic. (2019). *Metabolic syndrome - Symptoms and causes*. Available at: https://www.mayoclinic.org/diseases-conditions/metabolic-syndrome/symptoms-causes/syc-20351916 [Accessed 27 Jul. 2019].

Mayo Clinic. (2019). *Obesity - Diagnosis and treatment*. Available at: https://www.mayoclinic.org/diseases-conditions/obesity/diagnosis-treatment/drc-20375749 [Accessed 26 Jul. 2019].

NHLBI. (n.d.). *Overweight and Obesity*. [online] Available at: https://www.nhlbi.nih.gov/health-topics/overweight-and-obesity [Accessed 25 Apr. 2019].

Perreault, L. (2019). *Overweight and obesity in adults: Health consequences*. Available at: https://www.uptodate.com/contents/overweight-and-obesity-in-adults-health-consequences?search=treatment%20of%20obesity&topicRef=5375&source=see_link#H36 [Accessed 1 May. 2019].

Perrault, L. (2019). *Obesity in Adults: Behavioural Therapy*. UpToDate. Available at: https://www.uptodate.com/contents/obesity-in-adults-behavioraltherapy?sectionName=Efficacy&search=treatment%20of%20obesity&topicRef=5375&anchor=H386459340&source=see_link#H386459340 [Accessed 28 Jun. 2019].

Perreault, L. (2019). *Obesity in adults: Dietary therapy*. UpToDate. Available at: https://www.uptodate.com/contents/obesity-in-adults-dietary-therapy?search=treatment%20of%20obesity&topicRef=5376&source=related_link#H6 [Accessed 1 May 2019].

Perrault, L. (2019). Obesity in adults: Drug therapy. UpToDate. Available at: https://www.uptodate.com/contents/obesity-in-adults-drugtherapy?search=treatment%20of%20obesity&source=search_result&selectedTitle=2~150&usage_type=default&display_ran=2 [Accessed 28 Jun. 2019].

Perreault, L. (2019). *Obesity in adults: Role of physical activity and exercise*. Available at: https://www.uptodate.com/contents/obesity-in-adults-role-of-physical-activity-and-exercise?sectionName=Health%20benefits%20associated%20with%20exercise&search=undefined&topicRef=5370&anchor=H4054096330&source=see_link#H4054096330 [Accessed 1 May. 2019].

The Heart Foundation. (2019). *What is coronary heart disease?*. Available at: https://www.heartfoundation.org.au/your-heart/heart-conditions/what-is-coronary-heart-disease [Accessed 4 Aug. 2019].

Valdes, A., Walter, J., Segal, E. and Spector, T. (2018). *Role of the gut microbiota in nutrition and health*. Available at: https://www.bmj.com/content/361/bmj.k2179 [Accessed 24 Apr. 2019].

Wen, L. and Duffy, A. (2017). Factors Influencing the Gut Microbiota, Inflammation, and Type 2 Diabetes. NCBI. Available at: https://www.ncbi.nlm.nih.gov/ pmc/articles/PMC5483960/ [Accessed 29 Apr. 2019].

World Health Organisation. (2019). *Diet, nutrition and the prevention of chronic diseases Report of the joint WHO/FAO expert consultation*. Available at: https://www.who.int/dietphysicalactivity/publications/trs916/summary/en/ [Accessed 1 Aug. 2019].

World Health Organisation. (2019). *Obesity and overwight.* Available at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight [Accessed 1 Aug. 2019].

World Health Organisation. (2019). *Obesity*. Available at: https://www.who.int/topics/obesity/en/ [Accessed 1 Aug. 2019].

Are artificial sweeteners a healthier alternative to sugar?

Words by Joshua Lesicar

1879 – The first artificial sweetener is discovered and the stats are huge.

Diet related diseases are on the rise in Australia and it is a problem needing resolution. In 2011-12 alone, Australians consumed an average of 60 grams of free sugars per day. With more sugar (sucrose) being consumed and the percentage of obesity and other diseases increasing, it is clear Australian people need to limit their sugar intake. An alternative, artificial sweeteners, may pose as a solution as they can be used to lose weight, manage diabetes and prevent dental cavities without introducing energy content, a solution to this very problem. However, their usage can promote cancer, stroke, decline in diet and all its health effects are currently unidentified.

Australian Dietary Guidelines suggest that sugar consumption should be limited, as it can lead to many health risks. Hence, the invention of artificial sweeteners which are made to offer the same sweet satisfaction as sugar is crucial. They are not digested the same way as sucrose and hence have little to no kilojoule effect, making them an attractive alternate as they can achieve great taste without introducing additional energy.

Artificial sweeteners don't introduce kilojoules which is crucial, as less consumed energy promotes increased levels of weight loss and a lower risk of heart disease. According to expert Christopher Gardner, "Smart use of non-nutritive sweeteners could help you reduce added sugars in your diet, therefore lowering the number of calories you eat. Reducing calories could help you attain and maintain a healthy body weight, and thereby lower your risk of heart disease and diabetes". A case study also found a decrease in weight when 81 rats that were consuming high levels of sucrose began to consume artificial sweeteners instead. The use of such sweeteners can therefore allow for a negative energy balance encouraging better health.

Artificial sweeteners are an excellent way to control blood glucose levels, crucial for diabetics to prevent further related health problems if blood glucose isn't managed. Expert Diane Reader states "The use of non-nutritive sweeteners may be used in a carbohydrate-controlled food plan, to potentially reduce carbohydrate intake which may aid in weight management and diabetes control." Artificial sweeteners were also shown to promote excellent oral health, contrasting with sugar which can create dental cavities. An extensive study found its use decreased the incidence of dental cavities by increasing salivary flow and pH.

However, artificial sweeteners have some major flaws which may not make them any healthier than sugar. It was found in a study of 2888 participants, that artificially sweetened soft drink was associated with a higher chance of stroke and dementia. Furthermore another study found a link between high consumptions of artificial sweeteners and an elevated risk of bladder cancer in humans. Links between leukaemia and artificial sweeteners were also made when rats underwent an experiment using artificial sweeteners. Moreover, both studies concluded that there is a lack of research to actually be sure of sweeteners additional affects, a large concern as sweeteners could pose more unknown threats.

FDA– Approved Artificial Sweeteners

ARTIFICIAL SWEETENER	BRAND NAME	SWEETNESS COMPARED TO SUGAR
Aspartame	Equal®, NutraSweet®, others	**180** times sweeter than sugar
Acesulfame-K	Sunett®, Sweet One®	**200** times sweeter than sugar
Saccharin	Sweet'N Low®, Necta Sweet®, others	**300** times sweeter than sugar
Sucralose	Splenda®	**600** times sweeter than sugar
Neotame	No brand names	**7,000 to 13,000** times sweeter than sugar
Advantame	No brand names	**20,000** times sweeter than sugar

Figure 1: Comparison between the sweetness of sugar and common artificial sweeteners

Another detrimental issue with artificial sweeteners is the fact they are many times sweeter than sugar, (as seen in figure one) an issue as if sweeteners are habitually consumed it may desensitize someone to its sweetness, potentially result in in the overall diet declining with healthy foods like fruit and vegetables becoming undesirable, and simple carbohydrates and lipids being consumed instead. Furthermore, the lack of energy provided by artificial sweeteners can lead to a lack of satiety, allowing for additional consumption of kilojoules and potentially promoting weight gain.

The lack of knowledge about artificial sweeteners and its effect on health is of major concern, as potentially only a small number of its health consequences are known. A major analysis which reviewed 372 studies concluded that there are numerous evidence gaps related to the health effects of artificial sweeteners.

Artificial sweeteners can serve many purposes and are known to manage weight, blood glucose levels and oral health. However, the potential risks of artificial sweeteners include the risk of cancer, strokes, a decline in diet and all the unknown health effects pose dangerous health threats. It is therefore recommended that the consumption of artificial sweeteners is avoided as sugar, is a much healthier option. However, the consumption of sugar should be limited, promoting better nutrition which could fix many health issues in Australia.

References

Australian Institute of Health and Welfare. (2019). Overweight & obesity. [online] Available at: https://www.aihw.gov.au/reports-data/behaviours-risk-factors/overweight-obesity/overview [Accessed 22 May 2019].

Australian Bureau of Statistics. (2016). Australian Health Survey: Consumption of added sugars, 2011-12. [online] Available at: https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4364.0.55.011main+features12011-12 [Accessed 22 May 2019].

American Diabetes Association. (2012). American Heart Association/American Diabetes Association Scientific Statement: Non-nutritive sweeteners: A potentially useful option – with caveats. [online] Available at: http://www.diabetes.org/newsroom/press-releases/2012/ada-aha-sweetener-statement.html [Accessed 22 May 2019].

Dr. Mercola (2019). ARTIFICIAL SWEETENERS CAUSE CANCER. [online] Hart Family Chiropractic. Available at: https://www.hartfamilychiro.com/artificial-sweeteners-cause-cancer/ [Accessed 22 May 2019].

Gardner, C. (2012). Non-nutritive Sweeteners: Current Use and Health Perspectives. [ebook] AHA/ADA Scientific Statement. Available at: https://www.ahajournals.org/doi/pdf/10.1161/CIR.0b013e31825c42ee [Accessed 22 May 2019].

Ludwig, D. (2011). Ask the doctor: Are artificial sweeteners a good alternative to sugar?. [online] Harvard Health Publishing. Available at: https://www.health.harvard.edu/staying-healthy/are-artificial-sweeteners-a-good-alternative-to-sugar [Accessed 22 May 2019].

Mendoza, J., Drewnowski, A. and Christakis, D. (2007). Dietary Energy Density Is Associated with Obesity and the Metabolic Syndrome in U.S. Adults. [ebook] Cardiovascular and Metabolic Risk. Available at: http://care.diabetesjournals.org/content/diacare/30/4/974.full.pdf [Accessed 22 May 2019].

Mowll, B. (2018). Artificial Sweeteners Are Not So Sweet. [online] Dr. Mowll. Available at: https://drmowll.com/artificial-sweeteners-are-not-so-sweet/ [Accessed 22 May 2019].

Nutrition Australia. (2013). Australian Dietary Guidelines 2013. [online] Available at: http://www.nutritionaustralia.org/national/resource/australian-dietary-guidelines-2013 [Accessed 22 May 2019].

Park, A. (2019). The Problem With Sugar Free Kids. [online] Time Parents. Available at: http://time.com/the-trouble-with-sugar-free-kids/ [Accessed 22 May 2019].

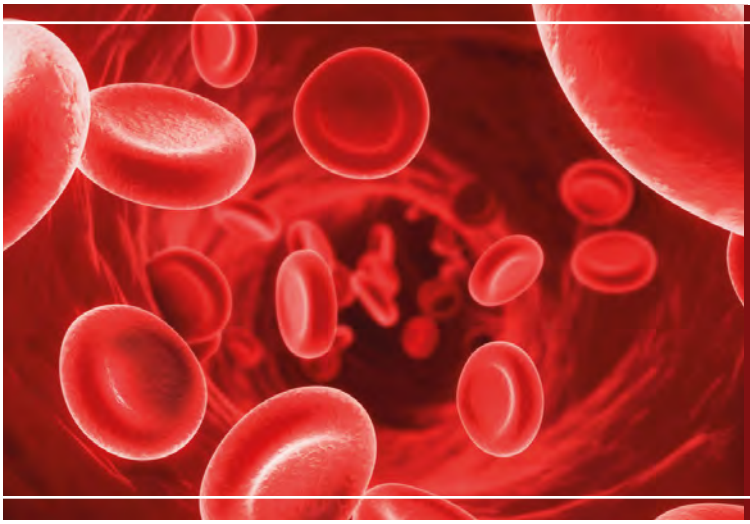
Pase, M., Himali, J. and Beiser, A. (2017). Sugar- and Artificially Sweetened Beverages and the Risks of Incident Stroke and Dementia. [ebook] Clinical Sciences. Available at: https://www.ahajournals.org/doi/pdf/10.1161/STROKEAHA.116.016027 [Accessed 22 May 2019].

Porikos, K. (1998). The effect of non-nutritive sweeteners on body weight in rats. [ebook] Direct Science. Available at: https://www.sciencedirect.com/science/article/pii/S0195666388800400 [Accessed 22 May 2019].

Prathibha, N. (2014). The effect of xylitol on dental caries and oral flora. [ebook] NCBI. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4232036/pdf/ccide-6-089.pdf [Accessed 22 May 2019].

Szimonetta, L. (2017). Health outcomes of non-nutritive sweeteners: analysis of the research landscape. Nutrition Journal.

Weihrauch, M. and Diehl, V. (2004). Artificial sweeteners—do they bear a carcinogenic risk? [ebook] Cologne: Department of Internal Medicine I of the University of Cologne, Cologne, Germany. Available at: https://academic.oup.com/annonc/article/15/10/1460/170200 [Accessed 22 May 2019].



An individual blood cell takes about 60 seconds to make a complete circuit of the body

Posts, The Circulatory System, Leslie Samuel

http://www.interactive-biology.com/3945/production-and-regulation-of-rbcs/Interactive Biology, Production and Regulation of Red Blood Cells

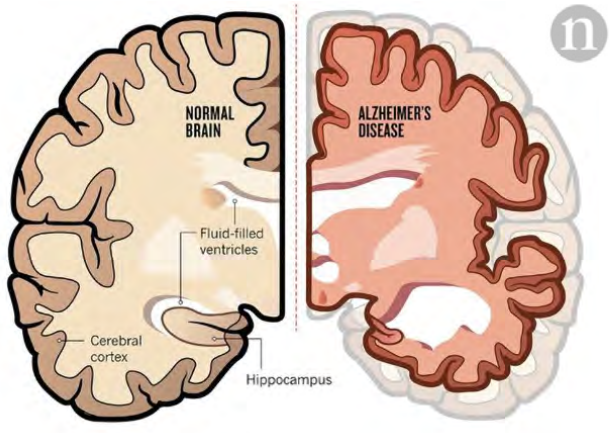
A step in the right direction for Alzheimer's

Words by Hugo Jordan

1906 – The passing of the first patient diagnosed with Alzheimer's disease.

Losing our memory, one of many people's greatest fears. Losing the treasured memories of loved ones, of childhood, of significant lifetime achievements, the day of your wedding among a range of treasured memories. For many, this is a reality when suffering from the increasingly common neurodegenerative form of dementia, Alzheimer's Disease. The disease causes incremental memory loss and reduced cognitive and motor skills in over 332 000 Australians. Meanwhile, the number expected to pass away from this disease is estimated at 400 000 in the next 10 years. This report will investigate the research conducted by the University of Southern California (USC) in 2018, which created an artificial compound that may inhibit the effects of Alzheimer's Disease.

A healthy functioning brain consists of an interconnected web of neurons that transmit chemical and electrical signals across the brain through synapses. The signal is then carried to the body for carrying out bodily functions. An individual suffering from Alzheimer's undergoes a significant decrease in the number of neurons and mass of the brain (brain atrophy) which can be seen in Figure 1. In addition to neuron degeneration, Alzheimer's is also characterised by numerous chemical changes in the brain. These include abnormally folded Beta-Amyloid proteins in between neurons, especially the toxic beta-amyloid 42 protein, which together with the accumulation of tau proteins, block synaptic communication between neurons. The specific chemical changes which causes the excessive build-up of proteins are yet to be discovered, which is one of the reasons that make it difficult to study the causes of Alzheimer's Disease.



Adapted from illustration by Stacy Jannis/Alzheimer's Association

Figure 1: Structural difference between Healthy and Alzheimer's effected Brain

Furthermore, these changes first occur in the hippocampus and the entorhinal cortex, both incredibly important to memory and in later stages attacking the cerebral cortex responsible for behaviour and language. This decay causes less and less brain activity (shown in figure 2) until the individual suffering will be unable to maintain the ability to function, resulting in death.

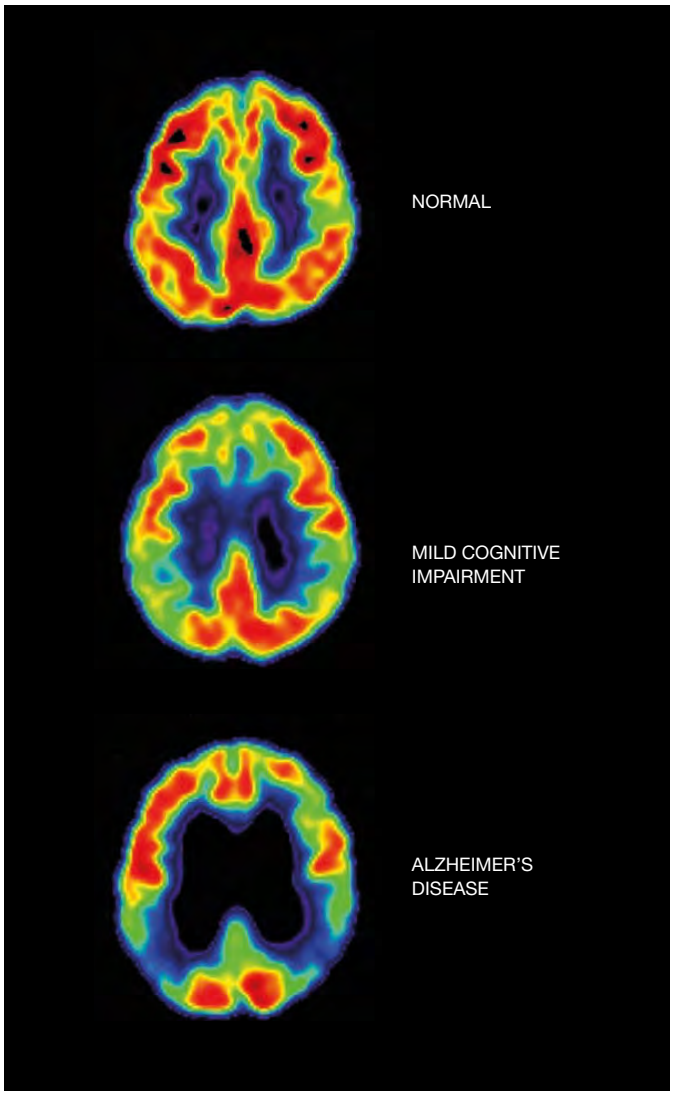


Figure 2: PET scans displaying the effect that Alzheimer's has on human brain activity

The USC have formed a new altered version of the C-reactive Protein, the coagulant protein that prevents damage to brain cells and blood vessels during inflammation called 3K3A-APC (3PC). This new protein is similar to CRP in its protective abilities yet with 90% less capacity for coagulation. To test its effectiveness, they injected 3PC proteins in mice that exhibited cognitive decline, neuroinflammation and high levels of Beta-amyloid much like humans. Their key findings revealed that

3PC did reduce the toxic build-up of protein in the brain. The 3PC was found to inhibit the secretion of the beta-secretase 1 enzyme by nerve cells. These enzymes were instrumental in the formation of the BA plaques that restrict communication between neurons. Despite the benefit of this information, the researchers stated that it will only be of use in “early stage Alzheimer’s disease in humans”, before any “widespread [beta-amyloid] plaque formation occurs”.

This new information is even more valuable and critical to the development of a cure when considering how there is currently no effective treatment that can delay the effects of this life-shattering disease, effecting the lives of many people.

References

Association, A. (2019). *Alzheimer’s & Dementia Help | Australia | Alzheimer’s Association*. [online] Alzheimer’s Association. Available at: https://www.alz.org/au/dementia-alzheimers-australia.asp#targetText=Alzheimer's%20and%20Dementia%20in%20Australia,crisis%20that%20must%20be%20addressed. [Accessed 1 Sep. 2019].

EverydayHealth.com. (2019). *Alzheimer’s Progression: Mild, Moderate, and Severe Stages | Everyday Health*. [online] Available at: https://www.everydayhealth.com/alzheimers-disease/progression-mild-moderate-severe-stages/ [Accessed 2 Sep. 2019].

EverydayHealth.com. (2019). *Amyloid PET Scans May Drastically Change Alzheimer’s Diagnosis and Care, Study Finds*. [online] Available at: https://www.everydayhealth.com/alzheimers-disease/amyloid-pet-scans-may-drastically-change-alzheimers-diagnosis-care-study-finds/ [Accessed 2 Sep. 2019].

National Institute on Aging. (2019). *What Happens to the Brain in Alzheimer’s Disease?* [online] Available at: https://www.nia.nih.gov/health/what-happens-brain-alzheimers-disease [Accessed 1 Sep. 2019].

Newman, T. (2019). *Experimental drug may prevent Alzheimer’s disease*. [online] Medical News Today. Available at: https://www.medicalnewstoday.com/articles/324172.php#targetText=A%20drug%20that%20scientists%20are,most%20common%20form%20of%20dementia. [Accessed 2 Sep. 2019].

It would take light 100,000 years to travel from one end of the Milky Way galaxy to the other

Denis Degioanni

https://unsplash.com/s/photos/milky-way

What effect does nitrogen have on the growth rate of vines?

Words by Patrick Liebich

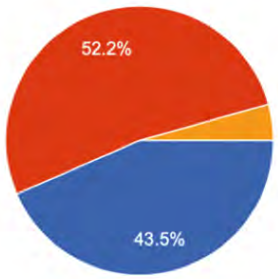
1909 – German Chemist Fritz Haber invented the Haber process, which is used to produce nitrogen fertilizers.

Nitrogen is an element found in nature and one of the basic tools used in an agricultural setting all around the world. Nitrogen is often applied in vineyards by viticulturists to increase the growth of their vines. The question of many grape growers is what effects nitrogen can have on the growth rate of vines? The average viticulturist will consider what the nitrogen does to the vine to help the vine grow. and what there is in the way of cheaper alternatives that could use the naturally occurring nitrogen cycle as well as applying other helpful, important macro-nutrients. As the climate changes in the near future the way that nitrogen is used will change and how can the new information can be used to make changes for the best use in applying nitrogen. A survey of 23 grape growers from the Riverland area was undertaken to gain knowledge on how nitrogen can affect grape vines.

Nitrogen

Nitrogen is commonly found in the atmosphere and it is a very small amount that is found in the ground. The survey conducted, seen on the right, found that 43.5% of respondents reported that soluble Nitrogen applied by the grower, causes vines to grow vigorously for short spans of time. This is because it is absorbed by the vine as it does not require time to release the nitrogen into the soil, this is not seen when nitrogen is applied as biodegradable matter as it releases the nitrogen into the soil slowly as it breaks down. Nitrogen is often used just after/ during bud burst or post-harvest. The reason nitrogen is applied during or after bud burst is to increase the foliage that the vine has so it will be able to protect the flowering grapes from the harsh sunlight. Post-harvest application of nitrogen is not to give vines new growth, but rather to save energy for next season's budburst. The vine's abortion of nitrogen goes directly into new shoot growth if it is applied before harvest, as the vine grows a canopy less nitrogen is needed to be applied. The nitrogen that is absorbed is used predominantly for creating new foliage growth and so less fruit growth this is why as the grapes start to ripen less nitrogen is applied.

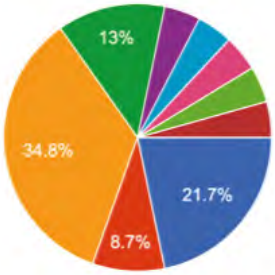
Nitrogen is not the only nutrient that the vine uses to help grow. Farmers often apply phosphorus with nitrogen. They do this because the root activity is increased to absorb the nitrogen and so the phosphorus is absorbed as well. Phosphorus helps the vine form new roots, flowers, make new seed and fruit. For these reasons, growers often like to apply it, just as nitrogen is applied after bud burst. The additional effects of applying phosphorus with nitrogen is it enhances its solubility, which is helpful for growers to apply.



What effects on the vine do you see after you apply the nitrogen?

(23 responses)

- a. Vigorous growth for a short time
- b. Average continuous growth
- c. Little growth but over long periods of time
- d. Little to no growth over time

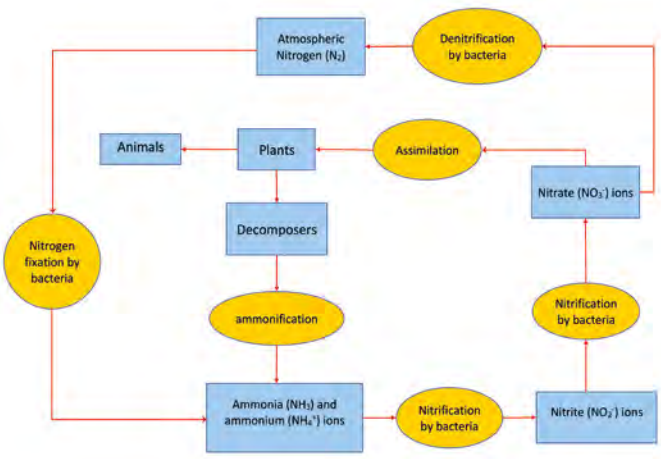


What type of nitrogen application do you apply?

(23 responses)

- a. Urea
- b. Ammonium compounds
- c. Nitrate compounds
- d. Complex organic molecules
- Liquid N as a formulation of a b and c.
- None
- Organic Nitrogen in Mulch, man...
- All of the above
- A combination of all 4 of the above

Season	Grapevine growth stage	Sensitivity to smoke uptake
Early spring	 Shoots are 10 cm in length	Low
Spring	 Vine is flowering	Low
Late spring	 Berries are pea size	Low to medium
Late spring/ early summer	 Berry bunches begin to close	Low to medium
Summer	 Berries begin to ripen	Medium
Late summer/ early autumn	 Berries have ripened (through to harvest)	High



The farmer needs to know how the different types of usable nitrogen to make an informed decision when to utilize the correct nitrogen at the right time for the vine to grow and produce the best desired grapes. The timing of nitrogen is valuable, but it is also the concentration of the nitrogen compound that can affect the vine as well as the soil around it. The nitrogen element by itself is very hard to apply to the vine to see the desired result. Because of this, it is predominantly a nitrogen compound that is used as according to the survey. The next best nitrogen fixation process that is used in the grape industry is urea, this is used mainly because of its solubility in water and so it can be applied straight to the base of the vine when watered. Both Urea and Nitrogen compounds are absorbed quickly and used in a short amount of time. The vigorous growth is why it's use is widely spread; but it does have some drawbacks, specifically it has as it breaks down into nitrite it has an acidifying effect on the soil. There are other alternatives to boost the nitrogen in the soil, like using complex organic molecules, examples of this would be to use compost. The compost has larger molecules in the green matter, the nitrogen is in it but is held up in larger molecules that the plant can't access. As the compost breaks down, it releases the nutrients molecules which are taken up by the vine. This process takes time and so the effect of nitrogen is slowly observed. This method greatly helps the soil and has no other harmful side effects.

The Nitrogen cycles

The decomposition of nitrogen into the soil follows a cycle and much like the water cycle it follows the same rules that but instead of water nitrogen is released into the atmosphere and is recycled back into plant and then into the soil.

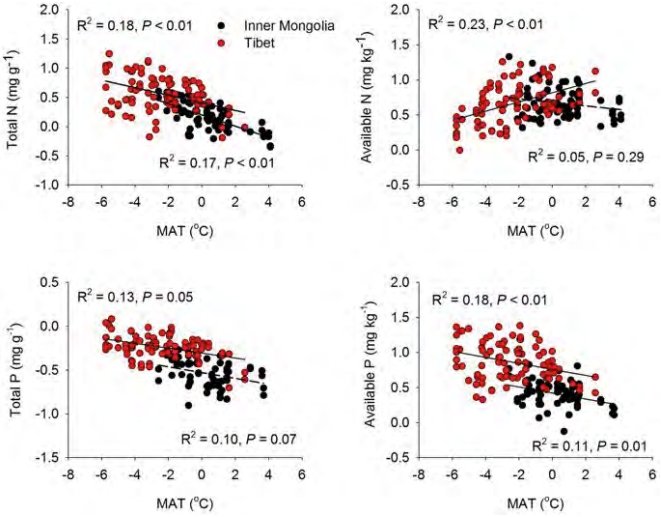
Nitrogen is found mainly in the troposphere where it makes up almost 80% of all the nitrogen found on Earth. Unfortunately, nitrogen can't be accessed by plants while it is in gas form. The nitrogen undergoes certain processes to be able to be taken up by plants. The nitrogen fixation process is when the nitrogen is converted into ammonia by cyano bacteria. It follows this reaction: $N_2 + 3\ H_2$ -> $2\ NH_3$.

After this process the ammonia is further converted into nitrite (NO_2^-) and subsequently into nitrate (NO_3^-). Nitrate is able to be absorbed by the plant, it is converted from ammonia due to aerobic bacteria that uses the oxygen around it. The chemical process that take place is: $2NH_3 + 3O_2 \rightarrow 2NO_2 + 2H + H_2O$, $2NO_3 + 3O_2$ ® $2NO_3$.

The plant absorbs the nitrogen during the assimilation process and is reformed into molecules like amino acids and DNA. The plant in this case is the grapevine; it will use the nitrogen to help its growth of foliage. The next step in the nitrogen cycle is when the plant is finished using the nitrogen it is decomposed and breaks down back into ammonium, which is then converted back to nitrogen gas in a process called denitrification;

$NO_3 + CH_2O + H \rightarrow ½\ N_2O + CO_2 + 1½\ H_2O$.

As the plant breaks down, it also releases other nutrients as well, which is why organic molecules is so helpful in many ways. The nitrogen is then released back into the atmosphere and the process continues. Because of the way that the vine takes up nitrogen, it is obvious why it is nitrates that are used predominantly over other types of nitrogen fertilizers. The process of the nitrogen cycle occurs often in large quantities, but because of the soluble nature of ammonium and urea it is washed away by water. This is why farmers also have to judge when to apply the nitrogen, so it is not washed away right after it is applied. The washed away nitrogen is dangerous to the local ecosystem if it is washed away into local waterways as it increases the risks of algae blooms. The use of nitrogen in the vineyard is all dependent on how effective the nitrogen cycle is, it is impossible not to have any nitrogen in the soil around the vine because of the nitrogen cycle.



Nitrogen for commercial uses

The commercial uses of nitrogen in arid vineyards compared to wet and colder vineyards is drastically different. The uses of nitrogen are the same in the vineyard with the type of nitrogen that is used predominantly being nitrate compounds. The uses of nitrate compounds are also related to the cost of production for the nitrogen. The cost of different nitrogen types can influence which types are used across the viticulture industry. In general, urea is more costly, this is because when it is applied it is taken up very easily and quickly but is harder to create in large amounts and so this inflates this price. This being said, this is only for nitrogen and as a farmer, time is money, so it is often found that a mix of NPK (nitrogen-phosphorus-potassium) is applied, the nitrates are able to bond with the phosphorus

or potassium ions which is why the nitrate compounds are used in conjunction with the other macro nutrients. The Nitrate compounds are bought as a solid that when it is mixed with water becomes and aqueous solution. This is almost the same for urea, but it is already in liquid form, both are applied during irrigation. This is largely different to the less costly but time inefficient organic molecules. Organic molecules are things like manures or compost. As discussed, compost takes time to break down, so the results may not be seen for a couple weeks. Although this method takes time, it greatly improves the biodiversity in the soil. The ways that farmers may apply this can include overturning organic matter (like weeds) in the soil to integrate the nitrogen as it breaks down. This method of applying nitrogen is cost effective as well as more environmentally friendly. This is not used very much in arid areas the soil is not very moist, so the organic matter takes longer to biodegrade which may lead to the grapes without protection under heatwaves.

	Inner Mongolia	Tibet	Overall
Total N (mg g^{-1})	1.72 ± 0.15 (39) a	4.40 ± 0.57 (43) b	3.13 ± 0.34
Avalable N (mg kg^{-1})	6.39 ± 1.19 (39) a	6.48 ± 0.87 (41) a	6.42 ± 0.71
Total P (mg g^{-1})	0.34 ± 0.02 (31) a	0.57 ± 0.02 (46) b	0.47 ± 0.02
Avalable P (mg kg^{-1})	2.91 ± 0.19 (33) a	8.23 ± 0.72 (46) b	5.91 ± 0.57
Total N:P ratio	5.2 ± 0.3 (32) a	6.9 ± 0.7 (42) b	6.3 ± 0.5
Available N:P ratio	2.3 ± 0.2 (32) b	0.8 ± 0.1 (40) a	1.5 ± 0.2

The effects of climate change

The Earth is changing constantly, but with the increased change of global warming this can affect how much nitrogen is applied. As temperature increases, the amount of denitrification may also increase which means that greater quantities of nitrogen would have to be applied. The trend of increasing temperatures globally can also have a significant effect on the nitrogen found in unused soils. This, in vineyards, can affect the entire sub-ecosystem which will be detrimental to the vine and as it may cause smaller harvests. The table below displays the denitrification of nitrogen in relation to the rising temperature on unused land. The graph references the nitrogen to phosphorus ratio as that is needed to be kept similar as to not damage the soil. Although the data is from Tibet and inner Mongolia and therefore isn't near the South Australian Riverland region, it does show an alarming trend where, as the temperature increases the total amount of nitrogen in the soil decreases while the available nitrogen stays similar. This can be related into the vineyard to calculate the amount of lost nitrogen or phosphorus that is needed to be accounted for when applying it. The measurements are all changed if the amount of nitrogen is lost due to denitrification.

Conclusion

In conclusion, the effects of nitrogen on the growth rate of grape vines is proportionate to the amount of nitrogen that is applied and is all due to the form of nitrate applied or the nitrogen cycle and the everchanging climate cycle. The impact on the vine that nitrogen is used for is the foliage is increased so that greater amounts of chlorophyll is available to the vine to use during photosynthesis. The use of nitrogen is also dependant on the type of nitrogen that is used on the vine as some work quicker and some deliver other macro-nutrients at the same time, this is all what the viticulturist needs to take into account as well as the price. The effects of climate change can also factor into how well the vine uses the nitrogen and what ways is best to combat these effects.

References

AWRI. 2010. Nitrogen fertilisation. [ONLINE] Available at: https://www.awri.com.au/wp-content/uploads/1_nutrition_nitrogen_fertilisation.pdf [Accessed 20 August 2019]

Crierie, A., Greig, D. and Ruthven, S., 2016. Biology. 1st ed. Adelaide Tuition Centre, 21 Fourth Street, Bowden: Adelaide Tuition Centre.

Handelsblad, 2003, Nitrogen Cycle, [ONLINE] Available at: https://www.lenntech.com/nitrogen-cycle.htm [Accessed June 2019]

Mardi L. Longbottom. 2010. phosphorus fertilisation. [ONLINE] Available at: https://www.awri.com.au/wp-content/uploads/2_nutrition_phosphorus_fertilisation.pdf [Accessed 22 July 2019].

Rhonda Dybiec. 2019. Nutrient Type - Nitrogen Overview | Agriculture Solutions. [ONLINE] Available at:

https://www.agsolcanada.com/nitrogen-summary [Accessed 27 August 2019].

Ron Hutton, Bruno Holzapfel, Jason Smith, Paul Hutchinson, Kirsten Barlow, Warren Bond. 2006. Influence of irrigation and fertiliser management on the movement of water and nutrients within and below the rootzone of vines for sustainable grape production. [ONLINE] available at: https://www.csu.edu.au/__data/assets/pdf_file/0007/453319/KBRHJSBHReport-170907.pdf

SACE 265516W. 2019. Research Project on the effect of nitrogen on vines. [ONLINE] Available at:

https://docs.google.com/forms/d/11a7YBjQ6QNP0bAGt5bauYaisqvVYlg1WDwjn45MyaTk/edit#responses [Accessed 27 August 2019].

Winetitles. 2019. The Grapegrower & Winemaker Publication - Winetitles Media. [ONLINE] Available at: https://winetitles.com.au/gwm/ [Accessed 27 August 2019].

DNA origami

Words by Sparsh Tiwari

1953 – the discovery of the structure of DNA

Amongst the host of Deoxyribonucleic Acid (DNA) applications developed since the mid-20th century, the folding of DNA into complex three-dimensional nanostructures - DNA origami - has arisen as a new paradigm for nanotechnology. This report will examine the development of DNA origami and its interactions with society.

Contemporary 'bottom-up fabrication' DNA origami relies on the following properties of DNA molecules to direct the self-assembly of nanostructures.

The two deoxyribonucleotides strands composing a DNA double helix are held together by the 'complementary' pairing of four nitrogenous bases: Adenine (A) with Thymine (T), and Guanine (G) with Cytosine (C).

Two non-complementary, single strands of DNA may be linked indirectly and made into a rigid, parallel arrangement of helices by another single strand which is complementary to both independent strands.

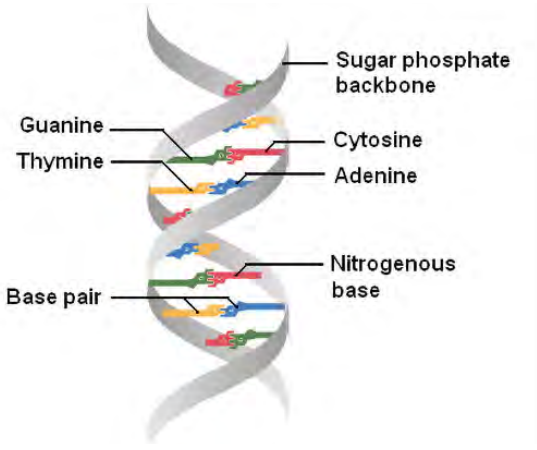


Figure 1:A DNA double helix formed from two complementary strands

DNA origami utilises Computer-Aided Design (CAD) software to generate geometrical models of desired nanostructure shapes. Raster-filling algorithms are subsequently applied to lay-out the folding path of a long DNA 'scaffold' strand with a known sequence – typically the single-stranded viral genome of the bacteriophage M13 (~ 7.2 kilo-nucleotide bases in length).

Simultaneously, CAD is used to determine the placement and base sequence of oligonucleotides (denoted 'staple strands') which cross-link portions of the 'scaffold' strand and form rigid, double-helices at these particular locations. These 'staple strands', thus, bend the 'scaffold' into place and force its precise folding.

Excess 'staple strands' are mixed with a 'scaffold' strand in a buffer solution of magnesium counterions responsible for neutralising DNA's negative charge and ensuring structural stability. The mixture undergoes a series of annealing procedures whereby the heating and cooling of DNA facilitates the breaking and formation of hydrogen bonds between complementary nitrogenous bases; thereby, promoting the internal cross-linking of complementary sections of the 'scaffold' strand. The resulting arrangement of DNA duplexes and DNA junctures across the 'scaffold' leads to the self-assembly of the pre-designed nanostructure. As approximately 10.5 bases exist per 360° DNA helix, three-dimensionality may be further adjusted by adding or removing complementary bases to the 'staples' and the 'scaffold'.

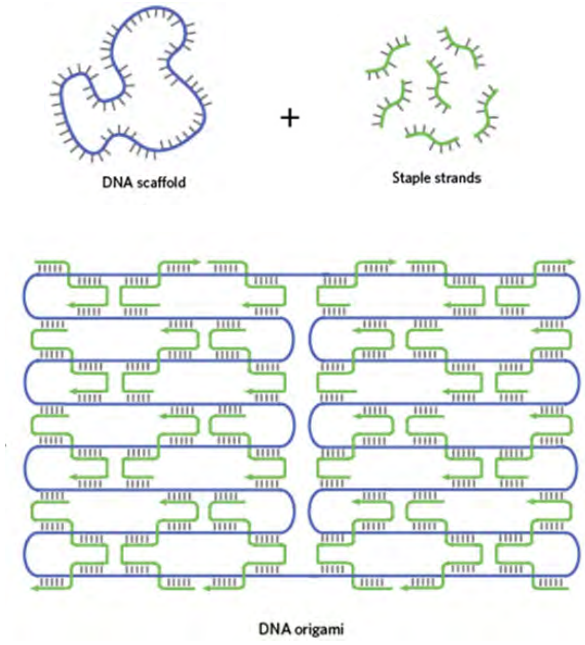


Figure 2: The folding of a single-stranded 'scaffold' strand from the intramolecular cross-linking of 'staple strands'

Bioengineering advances in DNA origami have furthered developments in other scientific branches, such as medicine, where it offers the potential to attenuate the health, economic and social effects of diseases. Within therapeutics, dynamic DNA nanostructures present the pivotal advantage of controlling the bioavailability of drugs through molecular payload systems. Kurth Gothelf of Aarhus University has developed DNA origami boxes that can release their contents, such as drugs, in response to specific, external DNA or RNA sequences ('keys'). The widespread social advantages of controlled drug delivery are apparent in treating multi-drug resistant cancers that metastasise and do not respond to chemotherapy; leading to one's long-term physical deterioration and diminishment in quality of life. Likewise, the financial costs of drug-resistant tumours contribute to Australia's $6.3 billion economic burdens from cancer care.

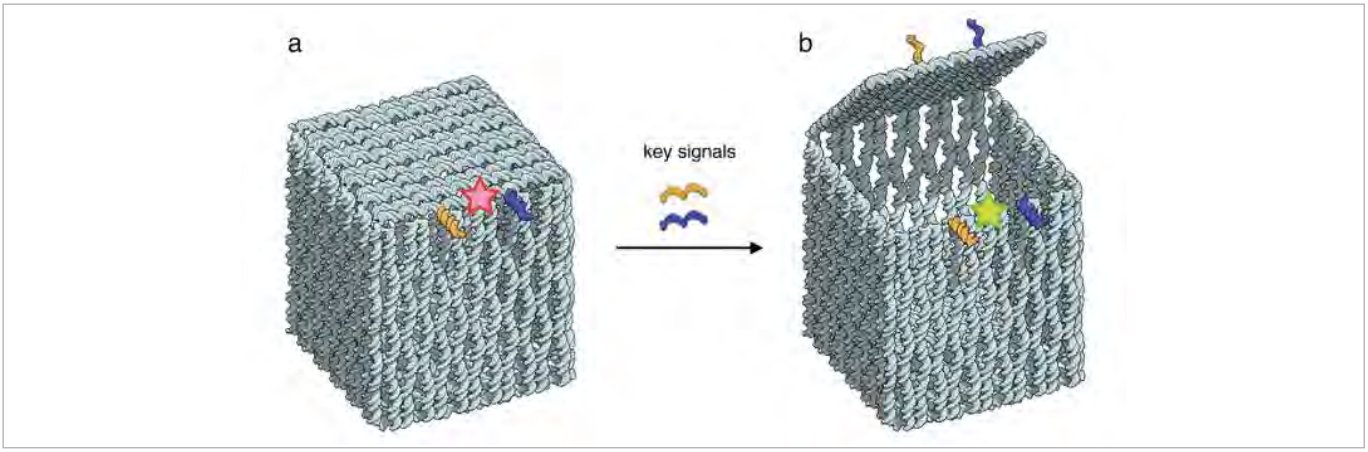


Figure 3: A 3D illustration of a DNA origami box opening in response to DNA/RNA 'keys'(Dumé, 2009)

An understanding of how chemotherapy resistance has arisen from cancerous cells extruding chemotherapy drugs via transport proteins (efflux pumps), has driven researchers to consider gene-silencing techniques, such as RNA interference, to deactivate such 'drug efflux' mechanisms. The targeting capabilities of DNA origami provide a platform for the intracellular release of small interfering RNA (siRNA) molecules and chemotherapeutic agents which synergistically eliminate multi-drug resistance cancers while leaving healthy cells undamaged. By offering to promptly and directly decimate tumours, DNA origami may mitigate the financial burdens and deterioration of physical and emotional health engendered from enduring cancers and the long-term use of chemotherapy drugs. The technology has, thus, garnered widespread acceptance and support amongst bioengineers and nanomedicine physicians, as well as encouragement from the general public.

Conversely, developments in the fields of computational science and engineering (CSE) have furthered bioengineers' understandings of the self-assembly mechanisms taking place in DNA origami. The development of the second-generation CaDNAno, open-source software by the Wyss Institute and the University of California has leveraged computational modelling so researchers may visualise nanostructures and 'staple strands'. Through CaDNAno's implementation, scientists have gathered an understanding of how architectural factors, such as variations in the distribution of 'staples' and 'scaffold' strand routing may be integral to improving folding efficiency, as well as aid in erecting novel and complex DNA constructions. Thus, engineering insights offered through advancements in CSE have been vital to understanding the prospects and limitations of 'bottom-up' DNA origami fabrication methods, and facilitate its diverse construction and applications.

Nevertheless, the infancy of DNA origami has presented the potential for unanticipated implications that have hindered its applications across fields. Within clinical drug-delivery, scientists have expressed the need to evaluate the immunogenicity of exogenous, 'non-self' DNA nanostructures with a dissimilar chemical composition to the host organism DNA (e.g. from different cytosine methylation patterns). The potential for the long term stimulation of the adaptive (acquired) immune system and production of pro-inflammatory cytokines may result in severe tissue damage and blood coagulation. Similarly, the technology's novelty has limited the assessment of its long-term hazards within the biomedical industry. Ke et al. (2018) postulate that the introduction of foreign bacteriophage DNA, such as that of M13, may interfere with host cell mRNA and engender undesirable gene regulation, or result in its lasting integration into an organism's genome. Thus, despite the pioneering biomedical potential of DNA origami, further assessment of its pharmacokinetic and pharmacodynamic behaviour in-vivo is required to determine its cytotoxic risks in clinical drug applications. By consequence, this underscores the necessity of pre-clinical in-vivo studies in animals by which the monitoring of DNA origami's localisation and effects may aid in determining its inherent risks within organisms. In turn, opportunities are provided to address its shortcomings in-vivo to ensure its safe application. Wang et al. (2017), for instance, posit that the chemical modification of 'staple strands', "*such as the introduction of modified phosphoramidites* (derivatives of nucleosides) *… [may] render them biologically inert"* and resolve inflammatory complications.

DNA origami, nevertheless, has drawn conflicting opinions over the effects of its widespread application. Public apprehension has risen over the growing military interest in DNA origami, with the United States' Defence Advanced Research Projects Agency (DARPA) funding its use for creating nanoelectronics circuitry and speciality materials. Scientists, such as Cédric Invernizzi of the Spiez Laboratory, have further expressed unease at DNA origami incentivising military use and catalysing *"socio-political calculations regarding the utility of DNA-inspired weapons",* such as DNA nanorobots capable of introducing virulent substances in humans. The social consequences of loading DNA origami scaffolds with toxic biological agents has led to a re-analysis of the proscriptions of the Biological and Toxin Weapons Convention (BTWC) and resulted in greater regulation over nanotechnology developments. However, despite prevailing concerns, the rapid and novel progress in the development of DNA origami has limited the evaluation of its global and social implications beyond nanomedicine and left its future inconclusive.

The propounded future developments of DNA origami that build on its wide scope of existing applications offer the promise to resolve some of humanity's greatest challenges for sustainable growth. As crude oil sources decline and carbon emissions enhancing the greenhouse effect increase, the World Energy Council has cited shifting energy sources to renewables such as hydrogen fuel and solar energy as fundamental to global sustainability. Current applications of DNA origami entail its use a scaffold for proteins bound by manganese to create a

photosynthetic system, known as Photosystem II, that can split water into hydrogen ions and oxygen. Hao Yan of Arizona State University draws attention to leveraging such applications for the mass production of artificial leaves with the ability to oxidise water and produce hydrogen fuel. Hence, DNA origami poses a resolution to the polluting and energy-intensive production methods of hydrogen fuel, which is considered an indispensable energy source by Australia's Chief Scientist, Dr Alan Finkel. Additionally, further advancements in Photosystem II offers a platform for novel solar cell technology and artificial light harvesting. Through further research, combining artificial photosynthesis with modern energy storage solutions offers a sustainable method for the production of renewable electricity on a global scale to serve society's increasing energy demands. Developments in the photovoltaic applications of DNA origami, thus, potentially offer a host of benefits to future users of this technology incentivised by the likely energy challenges earth will face.

Ultimately, DNA origami's prospective social and economic advantages through its influence on engineering and medicine have led to its broad appeal. While the applications and limitations of DNA origami have been scrutinised by scientists; balancing the comprehensive proof-of-concept studies demonstrating its potential benefits against its in-vivo therapeutic risks and the social implications that may arise from its misuse, a vast amount of further research is still required to assess its future scope and effects on society at large.

References

American Cancer Society, 2016. *Chemotherapy Side Effects.* [Online] Available at: https://www.cancer.org/treatment/treatments-and-side-effects/treatment-types/chemotherapy/chemotherapy-side-effects.html2 [Accessed 27 May 2019].

Bustamante, C., Bryant, Z. & Smith, S. B., 2004. Ten years of tension: single-molecule DNA mechanics. *nature,* Volume 421, pp. 432-427.

Chanrasekaran, A. R., 2017. *Building Nanoscale Structures with DNA.* [Online] Available at: https://www.the-scientist.com/features/building-nanoscale-structures-with-dna-31234 [Accessed 25 May 2019].

Conway, N. & Douglas, S., 2016. *Cadnano.* [Online] Available at: http://cadnano.org [Accessed 27 May 2019].

Douglas, S. M., Bachelet, I. & Church, G. M., 2012. A Logic-Gated Nanorobot for Targeted Transport of Molecular Payloads. *Science,* 335(6070), pp. 831-834.

Douglas, S. M. et al., 2009. Rapid prototyping of 3D DNA-origami shapes with caDNAno. *Nucleic Acids Research,* 37(15), pp. 5001-5006.

Douglas, S. M. et al., 2009. Rapid prototyping of 3D DNA-origami shapes with caDNAno. *Nucleic Acids Research,* 37(15), pp. 5001-5006.

Dumé, B., 2009. *Nano-box breaks size records.* [Online] Available at: https://physicsworld.com/a/nano-box-breaks-size-records/ [Accessed 25 May 2019].

Fellet, M., 2019. *Nano DNA Origami Could Prevent Kidney Failure.* [Online] Available at: https://aabme.asme.org/posts/nano-dna-origami-could-prevent-kidney-failure [Accessed 27 May 2019].

Genesis Nanotechnology, Inc., 2018. *Can Nanotechnology Solve the Energy Crisis?.* [Online] Available at: https://genesisnanotech.wordpress.com/2016/08/08/can-nanotechnology-solve-the-energy-crisis-2/ [Accessed 26 May 2019].

Gray, R., 2017. *The biggest energy challenges facing humanity.* [Online] Available at: http://www.bbc.com/future/story/20170313-the-biggest-energy-challenges-facing-humanity [Accessed 26 May 2019].

Hemmig, E. A. et al., 2016. Programming Light-Harvesting Efficiency Using DNA Origami. *Nano Letters ,* Volume 16, p. 2369–2374.

Hydrogen Strategy Group, 2018. *Hydrogen for Australia's future,* Commonwealth of Australia: Australian Government | Minister for the Environment and Energy.

IAP, 2015. *The Biological and Toxin Weapons Convention | Implications of advances in science and technology.* s.l., IAP.

Jong, W. H. D. & Borm, P. J. A., 2008. Drug delivery and nanoparticles: Applications and hazards. *International Journal of Nanomedicine,* 3(2), pp. 133-149.

There is enough DNA in the average person's body to stretch from the sun to Pluto and back — 17 times

Umair Ahmad 2017

https://steemit.com/science/@umair.ahmad/there-is-enough-dna-in-an-average-person-s-body-to-stretch-from-the-sun-to-pluto-and-back-17-times

Ke, Y., Castro, C. & Choi, J. H., 2018. Structural DNA Nanotechnology: Artificial Nanostructures for Biomedical Research. *Annual Review of Biomedical Engineering,* Volume 20, pp. 375-401.

Khan Academy, 2019. *DNA structure and replication review.* [Online]
Available at: https://www.khanacademy.org/science/high-school-biology/hs-molecular-genetics/hs-discovery-and-structure-of-dna/a/hs-dna-structure-and-replication-review
[Accessed 25 May 2019].

Kommeri, J., 2016. *Computer-aided design software for cus- tom nucleic acid nanostructures,* Helsinki: Aalto University.

Kumar, V. et al., 2016. DNA Nanotechnology for Cancer Therapy. *Theranostics,* 6(5), p. 710–725..

Lentzos, F. & Invernizzi, C., 2018. *DNA origami: Unfolding risk?.* [Online]
Available at: https://thebulletin.org/2018/01/dna-origami-unfolding-risk/
[Accessed 27 May 2019].

Liu, J. et al., 2018. A Tailored DNA Nanoplatform for Synergistic RNAi / Chemotherapy of Multidrug-Resistant Tumors. *Angewandte Chemie,* 57(47), pp. 15486-15490.

Longley, D. & Johnston, P., 2005. Molecular mechanisms of drug resistance.. *The Journal of Pathology,* 205(2), pp. 275-292.

Michelotti, N., Johnson-Buck, A., Manzo, A. J. & Walter, N. G., 2011. Beyond DNA origami: A look on the bright future of nucleic acid nanotechnology. *Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology,* 4(2), pp. 139-152.

Paddock, C., 2018. *'DNA origami' tackles multidrug-resistant cancer cells.* [Online]
Available at: https://www.medicalnewstoday.com/articles/323800.php
[Accessed 25 May 2019].

Ramakrishnan, S., Ijäs, H., Linko, V. & Keller, A., 2018. Structural stability of DNA origami nanostructures under application-specific conditions. *Computational and Structural Biotechnology Journal,* Volume 16, pp. 342-349.

Ranjbar, R. & Hafezi-Moghadam, M. S., 2016. Design and construction of a DNA origami drug delivery system based on MPT64 antibody aptamer for tuberculosis treatment. *Electron Physician,* 8(2), p. 1857–1864.

Reif, J. & Kimbrough, P., 1999. *DARPA YEARLY TECHNICAL REPORT ,* Durham: Duke University.

Rothemund, P. W., 2018. *Paul W.K. Rothemund.* [Online]
Available at: http://www.dna.caltech.edu/~pwkr/
[Accessed 25 May 2019].

Rothemund, P. W. K., 2006. Folding DNA to create nanoscale shapes and patterns. *nature,* Volume 440, pp. 297-302.

Sanderson, K., 2010. *What to make with DNA origami.* [Online]
Available at: https://www.nature.com/news/2010/100310/pdf/464158a.pdf [Accessed 25 May 2019].

Simmel, F. C., 2012. DNA origami – art, science, and engineering. *Frontiers in Life Science ,* 6(1-2), pp. 3-9.

Smith, D., 2009. *DARPA's "Programmable Matter" Project Creating Shape-Shifting Materials.* [Online]
Available at: https://www.popsci.com/military-aviation-amp-space/article/2009-06/mightily-morphing-powerful-range-objects
[Accessed 27 May 2019].

Surana, S., Shenoy, A. R. & Krishnan, Y., 2015. Designing DNA nanodevices for compatibility with the immune system of higher organisms. *nature Nanotechnology,* 10(9), pp. 741-747.

TWIST Bioscience, 2017. *Introducing DNA Origam.* [Online]
Available at: https://twistbioscience.com/company/blog/dnaorigami
[Accessed 25 May 2019].

TWIST Bioscience, 2018. *A Simple Guide to Phosphoramidite Chemistry and How it Fits in Twist Bioscience's Commercial Engine.* [Online]

Available at: https://twistbioscience.com/company/blog/ASimpleGuidetoPhosphoramiditeChemistryandHowitFitsinTwistBioscience%27sCommercialEngine
[Accessed 26 May 2019].

UNODA, 2017. *Biological Weapons |The Biological Weapons Convention | Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction.* [Online]
Available at: https://www.un.org/disarmament/wmd/bio/
[Accessed 26 May 2019].

Wang, P. et al., 2017. The Beauty and Utility of DNA Origami. *Chem,* 2(3), pp. 359-372.

Whilton, F., 2018. *Cancer costs Australian health services over $6 billion a year: new research Read more at https://www.cancercouncil.com.au/media-release/cancer-costs-australian-health-services-6-billion-year-new-research/#394KdP3o2eid23iV.99.* [Online]
Available at: https://www.cancercouncil.com.au/media-release/cancer-costs-australian-health-services-6-billion-year-new-research/
[Accessed 28 May 2019].

WHO, 2018. *Tuberculosis.* [Online]
Available at: https://www.who.int/news-room/fact-sheets/detail/tuberculosis
[Accessed 25 May 2019].

Wikifoundary, 2009. *Explain the significance of complementary base pairingThis is a featured page.* [Online]
Available at: http://ibbiology.wikifoundry.com/page/Explain+the+significance+of+complementary+base+pairing
[Accessed 24 May 2019].

Woolf, I., 2019. *DNA ORIGAMI KILLS CANCER.* [Sound Recording] (Diffusion Science Radio).

Yabroff, K. R., Lund, J., Kepka, D. & Mariotto, A., 2014. *Economic Burden of Cancer in the US: Estimates, Projections, and Future Research,* Philadelphia: Cancer Epidemiology, Biomarkers & Prevention .

Yoo, J. & Aksimentiev, A., 2013. In situ structure and dynamics of DNA origami determined through molecular dynamics simulations. *PNAS,* 110(50), pp. 20099-20104.

EmDrive launching towards the future

Words by Dinan Perera

1957 – Sputnik is launched, the first artificial Earth satellite.

'It should be possible to explain the laws of physics to a barmaid' – Albert Einstein

Introduction

From the first rocket to launch a space probe (Sputnik) into space on October 4, 1957, numerous attempts to reach for the moon and beyond have been made by humans. The expanding universe has endeavoured scientists to launch and send massive objects into the skies with the power of what comes from the ground. The major problem was that that to achieve these, vast amounts of energy and hence fuel is required. With new technology, science fiction could become non-fiction, as the advancements have seen the first-ever engine which does not require fuel. However, will this invention launch towards the horizons for us to explore, or not be practical and come crashing down?

RF Resonant Cavity Thruster

The RF Resonant Cavity Thruster, or EmDrive, is one of the first-ever rocket engines, it is claimed, that can achieve propulsion without the use of fuel. During the early 2000s, scientists theorised this new drive which used electromagnetic waves.

So far, we have been using fuels to help launch rockets into space. Many of them carry liquid hydrogen as their major propellant for the following reasons:

1. Specific Impulse

This gives an idea of how much the rocket will accelerate or get pushed for a unit of fuel used. Hydrogen provides the highest specific impulse compared to any other chemical rocket.

2. Exhaust Velocity

Newton's second law states that the higher exhaust velocity of expelled gas increases the momentum of the rocket. Hydrogen on combustion with oxygen provides the highest exhaust velocity. Exhaust Velocity also gives an indication of how much energy is produced by a unit of propellant

3. Least energy wastage

The breaking of bonds of fuel to get the energy also requires energy. The oxidation of hydrogen produces only one product, water. Other hydrocarbon-based fuels produce a lot of products that reduce the extractable energy.

4. Can be used as a coolant

Hydrogen is stored at a very low temperature as a liquid to increase the amount that could be carried. This cold hydrogen is also used as a coolant for the rocket engine. This helps in both cooling the engine and converting it into gaseous state before it enters the combustion chamber.

5. Pollution-free.

Since the product of combustion with hydrogen and oxygen is only water, there is no pollution emitted to the environment.

The Russian scientist Konstantin Tsiolkovsky developed a rocket equation to describe the motion of a vehicle that follows the basic principle of a rocket: a device that can apply acceleration to itself using thrust by expelling part of its mass with high velocity and propelling forward due to the conservation of momentum. In order to understand this equation, the following concepts also should be studied;

1: Delta-V

Delta-V defines the amount of energy that a rocket needs for it to reach a certain destination.

2: Exhaust speed

The difference between the rocket speed and the propellant speed is called the exhaust speed. For the best chemical rockets, the exhaust speed is around 3,000 meters per second. When electric propulsion is used, exhaust speeds can be up to 20,000 meters per second or more. Exhaust velocity, as stated earlier gives an indication as to how much energy is required to attain speed.

3: Mass Ratio

The mass ratio measures the total rocket mass for a destination divided by the initial mass of the rocket without the propellant. Therefore, higher Mass ratio's will result in more propellants being used.

Tsiolkovsky formulated his Rocket equation as

Carrying hydrogen will use lot of space restricting room for any payload. For a typical rocket, the total mass of the vehicle might be distributed in the following way;

90% of rocket is propellants; 6% is the structure (tank, engine, fins, etc.) and 4% can be payload. Payload may be satellites, astronauts or spacecraft that will travel to space.

However, this new EmDrive propeller is able to allow large payloads as it does not need any propellant.

How does the EmDrive work?

EmDrive is not like any other rocket propulsion device as it does not use chemical propellants as its main fuel. With referral to the 'Rocket Equation', one of the major problems which scientists faced was using too much propellant to achieve a specific Delta-V.

The EmDrive uses Electromagnetic energy and electricity as its main 'fuel' for achieving thrust. All electromagnetic waves contain momentum. They obtain their energy from the change in momentum by absorbing or reflecting on surfaces. Therefore, the force that an electromagnetic wave produces can be formulated from the equation;

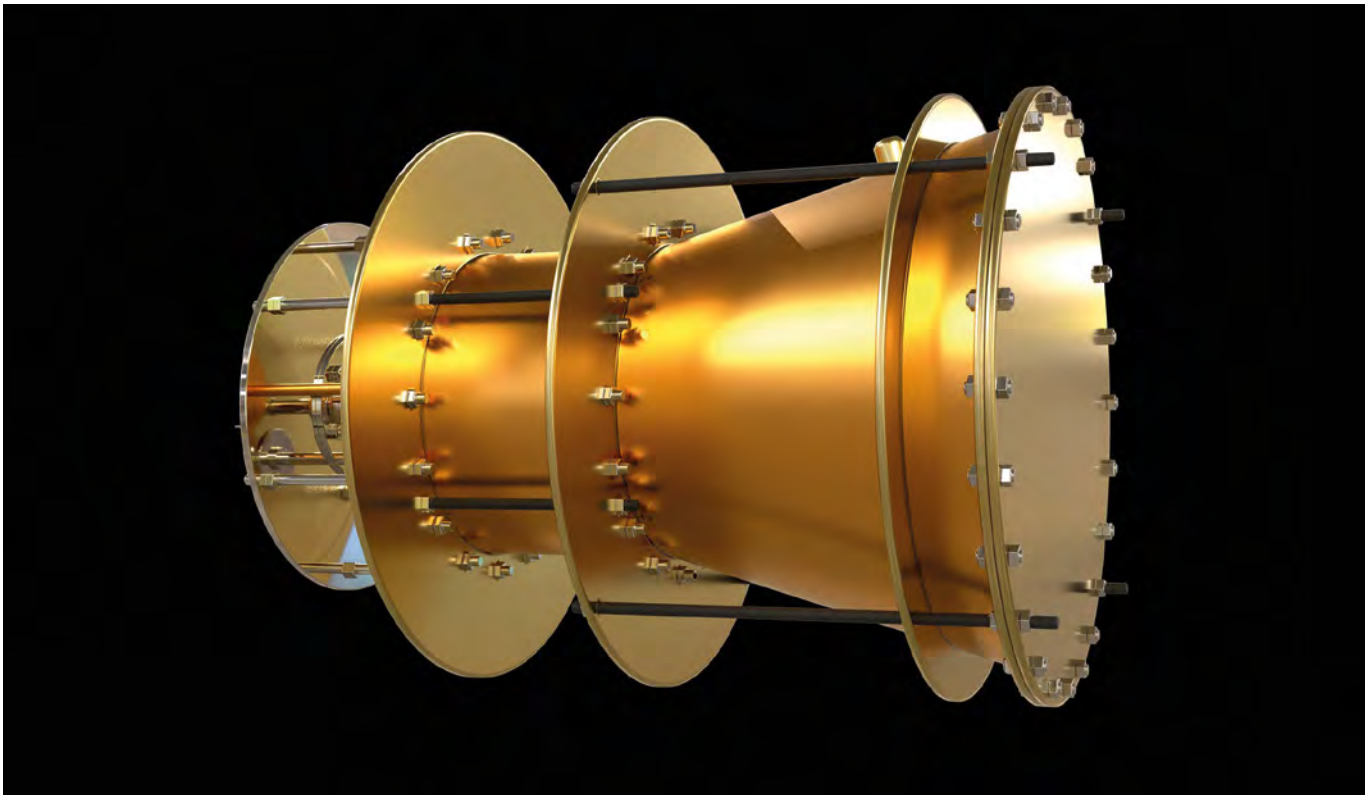


Figure 1: The EmDrive

Where ‘F’ is the force, P the Power and C the Speed of light. From this, scientist believed that through electromagnetic waves, it would be possible to produce thrust from the force created in waves by changing momentum.

Therefore, scientists modelled the EmDrive system to try and achieve this. They used a magnetron, an electron tube which produces microwave photons from electrons controlled by a magnetic field, to shoot out microwave photons to a frustum. The frustum is a metallic cone-shaped structure, which enables the photons to reflect on its surface. The waves that come out, bounce back and forth off the inside of the structure, they would impart their force onto the ends of the frustum. Newton’s Third Law states every action has an equal and opposite reaction, therefore the larger force demonstrated in below diagram shows the larger end exerting a greater force, to which the opposing force would create a thrust.

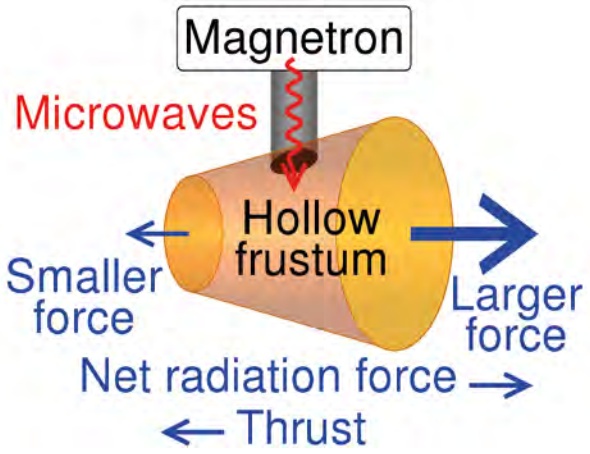


Figure 2: Structure of EmDrive

In Simple terms

EM drive is a metal drum, full of microwave photons bouncing around inside it millions of times a second. As they bounce back and forth, they generate a small pushing force on each end of the drum.

If the drum is a cylinder, the force at each end cancel out and nothing happens. But EM drive is tapered with one end wider than the other, creating a net force, which will move the drum forward. This pushing from inside breaks Newton’s 3rd law.

Breaking foundations of laws of physics

The new EmDrive creates extreme controversy by contradicting the well-established laws of physics. This new drive would be able to create thrust without the need of propellants, or Exhaust velocity. This would mean that rockets either go further or faster. However if this drive worked, it would break our understanding of the laws of physics. The structure of the drive is a completely closed frustum, therefore, it is theorized that the waves would bounce off the structure, and there would be a force from the inside that pushes the surface. However, the controversial concept of the EmDrive is how the inside forces will indeed perform a thrust in the opposite direction and propel the rocket forward.

The major issue from this theory is that the rocket would accelerate forwards, without any force exiting the rocket. There is a reaction force of propelling forwards, but there is no action force acting in the opposite direction. Mathematical physician John Baez described this as ‘sitting inside a car and making it roll forwards by pushing on the steering wheel’. The rocket is expected to propel forward, without any force which goes out in opposite direction.

So far

Few attempts in verifying this claim have been made. Almost all tests carried out, gave inconclusive results. The best so far for EmDrive enthusiasts from NASA (by Harald White's team) who recorded a thrust of 1.2 milli-newtons per kilowatt (a force you feel if you place seven grains of rice on your palm.)

This measured force is tiny but still more than 100 times stronger than that generated by a solar sail. If generated continuously, even one milli-newton could be enough to propel a spacecraft to tremendous speeds, given enough time.

Is the EmDrive really 'Impossible'?

The issue of whether or not a reaction does indeed not need a reaction force will be tested by scientists and used to determine whether or not the EmDrive is impossible. UK scientist Martin Tamjar and his team hope to publish their results in the journal Acta Astronautica in August according to Wired magazine.

If it were true, unlike Einstein who would think from his quote, it would be not that simple to teach the laws of physics, if the impossible truly become possible.

References

Cosmosmagazine.com. (2019). *NASA measured 'impossible' EM thrust – but is it really a big* |

Cosmos. [online] Available at: https://cosmosmagazine.com/technology/nasa-measures-impossible-em-thrust-how-big-a-deal-is-this [Accessed 17 Jun. 2019].

Elizabeth Walker. (2019). *Rocket Principles*. [online] Available at: http://web.mit.edu/16.00/www/aec/rocket.html [Accessed 8 Jul. 2019].

Grc.nasa.gov. (2019). *Rocket Mass Ratios*. [online] Available at: https://www.grc.nasa.gov/WWW/K-12/rocket/rktwtp.html [Accessed 8 Jul. 2019].

Hutson, E. (2019). *What is the EmDrive and why is it so controversial?*. [online] Wired.co.uk. Available at: https://www.wired.co.uk/article/nasa-emdrive-warp-drive [Accessed 11 Jun. 2019].

Medium. (2018). *Rocket Science 101: The tyranny of the rocket equation*. [online] Available at: https://medium.com/teamindus/rocket-science-101-the-tyranny-of-the-rocket-equation-491e0cf4dc6a [Accessed 9 Jun. 2019].

YouTube. (2019). *Roger Shawyer Explaining The Basic Science behind #EmDrive*. [online] Available at: https://www.youtube.com/watch?v=wBtk6xWDrwY [Accessed 9 Jul. 2019].

ZME Science. (2019). *EmDrive propulsion that 'breaks laws of physics' will soon be put to the test*. [online] Available at: https://www.zmescience.com/science/emdrive-propulsion-055432/ [Accessed 20 Jun. 2019].

The known universe is made up of 50,000,000,000 galaxies

https://www.nature.com/articles/d41586-019-02899-5

Astronomy and Astrophysics

Staid to showy: galaxies undergo ultra-quick makeovers

Voyager vignette

Words by Angus Russell

1977 – Voyager 1 is launched to study the outer Solar System.

During the summer of 1977, space probes Voyager 1 and 2 took to space. As they launched for a never returning journey, they left behind an angry thundering road, seismic vibrations which made the ground walk left and right, and bright flames with a vantablack trail of grim death. Funny enough Voyager 2 launched before Voyager 1.

Their objective; to explore our outer solar system but most importantly to push the boundaries of space aviation that the human race was limited to. The voyagers symbolised more than some photos of planets, they show the phenomena of Earth-bound humans and how we as humanity has made it possible to travel beyond our expectations.

For example, Voyager 1 completed its planned mission by reaching Jupiter in 1979 and Saturn in 1980 but sent back data which speculated the Earth-like moon Titan has a liveable surface for humans. Is it possible to live on Titan then? Hypothetically yes, physically no, you would run out of oxygen within three minutes and die a painful choking death. Nevertheless, this allows us to dream, to believe that there are more moons and planets like Earth which allows for life forms to prosper.

As for Voyager 2, it reached Jupiter in 1979, Saturn in 1980, Uranus in 1986 and Neptune in 1989 but didn't just put on the handbrake and vanished from existence. The probes didn't stop at their last planned destination. Both probes kept going and going travelling through interstellar space. They persist even though their objective is over. In a sense the probes carry on like we humans continue to live life after achieving our personal goals.

So, the probes have no answer for 'are we there yet?' Because they are in space, and space is a lapse, a gap, a still, a breach, a thing so wordsdon'tlooklikethis, space is dark, endless, a void, cold and in fact absolute zero. Space is empty yet full at the same time and doesn't stop expanding. It's an endless vacuum so there's nothing in the probes way to slow them down, they will continue to travel through space at speeds up to 17 Kilometres per second…

Forever.

Or until they blow up because of a malfunction within their dying nuclear batteries, encounter an asteroid or extra-terrestrial life, a planet, or even return back to us.

Yes, that's right, the Voyages will eventually return home. Our solar system is travelling through the galaxy at speeds that is 15 times faster in the same direction as the Voyagers' current speed. Therefore, in a few hundred million years our paths will eventually intercept again like the separated main characters in a Hollywood romance. Earth will most probably be devoid of humans, but space may not, humanity may be scattered all over the galaxy.

But it can make you happy to think that after all those years in a dark gloomy space, that our own creation will return home.

Orion Nebula. Photo by Bryan Goff

Changing history at the nano level

Words by Yash Giri

1982 – Development of scanning probe microscope to observe and manipulate nanoparticles.

Nanotechnology refers to technology that is comprised of particles between 1 and 100 billionths of a metre in size. This technology has been responsible for many modern scientific breakthroughs, one of such being 'nanowarming', where nanoparticles are manipulated to rewarm donated organs that have been frozen in the lead up to transplantation. This development arose out of society's desire to reduce the size of organ waiting lists and hence save the lives of the people on such lists.

Currently, following harvesting organs are stored at low temperatures (cryopreservation), which slows down the metabolic processes of the cells so that they do not expend stored resources and become damaged. The problem with conventional freezing of organs is that when tissue is cooled below freezing, the water molecules within the tissue freezes as well. When this happens, the water molecules gather together and arrange themselves in such a way so as to form ice crystals which expand on the outside of the cells. This pushes the cells inwards, leaving them damaged and squashed between the ice crystals; hence reducing their vitality for transplant. However, scientists developed another technique of freezing that does not result in the formation of damaging ice crystals – vitrification. In this process, cryoprotectants with very high solute concentrations are added to prevent the water molecules from gathering together to form ice, meaning that instead of freezing, water molecules move slower as they are cooled. Once the temperature drops below -100 degrees Celsius, water molecules become locked in place and a glassy solid is formed. It is important to note that in this process, the water has become solid without freezing; hence it is vitrified. The lack of damage to vitrified tissue as opposed to conventionally frozen tissue.

However, even with vitrification, tissue damaging ice crystals can still form during the rewarming process. With the current gold standard for rewarming – convection warming – cracking and crystallisation are caused in tissues larger than a few millilitres. This arises due to the fact that convection warming involves the placement of tissues in a fluid that is heated, thereby creating a convection current. The problem is that this method does not uniformly or quickly heat the organ, resulting in certain parts having more thermal energy than others – creating thermal mechanical stress that leads to the formation of cracks within the tissue; hence reducing viability for transplant.

Overall, this drastically reduces the number of harvested organs available to be transplanted to around 40%. Moreover, the number of organs donated in the first place has also reduced due to the reduction in deceased organ donors in recent times due to advances in medical care resulting in the saving of more lives. Also, the number of usable organs is reducing because donors are becoming older and less healthy, whereby one third of donors were over 60 in 2017 compared to only 17% 10 years ago, and last year 25% of organs were taken from obese patients compared to 12.5% a decade ago. All of this contributes to a shortage of organs able to be successfully transplanted, meaning that patients have to stay on organ donation waiting lists for longer. There has been an increase in waiting list times for kidneys over the past two decades. This has some detrimental effects as in the UK, 249 patients died whilst on the waiting list for an organ transplant due to shortages in donation. As a result, public debate in the UK has been influenced as there are calls from the UK public to mitigate the problem, evident by the Welsh people successfully lobbying their government to implement an opt-out system, whereby donation is mandatory unless patients ask to be removed from the registry; hence increasing the amount of people on the registry.

This public debate has also motivated scientists at the University of Minnesota to address the organ shortage problem by developing a method to successfully rewarm vitrified tissues (i.e. rewarming organs without causing tissue damage) and so potentially decreasing the number of harvested organs thrown away due to degradation. The researchers decided to develop a new method of rewarming whereby they submerge the tissue into a cryoprotectant solution that contains silica-coated iron oxide nanoparticles. MRI equipment, including a copper coil was used to create an alternating magnetic field around the sample. The electromagnetic waves generated had minimal effect on the tissue but instead heated the magnetic iron oxide nanoparticles, which in turn rewarmed the tissue. This rewarming was uniform because the nanoparticles had silica coating, allowing them to be evenly dispersed within the solution. Moreover, the method also allowed for the rapid heating of the tissue, warming it at 100 to 200 degrees Celsius per minute – 100 times faster than convection warming.

However, there are some limitations to this breakthrough as it was tested on cryopreserved pig arteries and heart tissues in systems up to 50mL in volume. This means that the method will have to be scaled up to accommodate entire organs, which will require testing on larger systems and further optimisation of the method. Hence there is insufficient data on how the technology will work for larger systems (greater than 50mL), limiting the researchers' conclusion that the technology could successfully rewarm human organs. Furthermore, in order to make the 'nanowarmed' tissues usable, the iron-oxide first must be washed out of the sample. After doing their best to remove the nanoparticles, the researchers used a technology called SWIFT to detect the presence of nanoparticles, and found minimal levels of nanoparticles remaining behind. This is an example of a risk that needs to be addressed because the accumulation of nanoparticles in organs can cause chronic inflammation, as host macrophages process nanoparticles, mediating host inflammatory and immunological biological responses.

Although, if the limitations are addressed and the technology is successful, lives will not only be saved through reducing organ waiting lists but there will also be economic benefits as the cost

Photo by Michael Longmire

of medical care for patients who require organ transplants is far greater than the cost of having a transplant. For example, the cost of one kidney operation and a lifetime's supply of anti-rejection drugs equals that of three years' dialysis.

In conclusion, the 'nanowarming' breakthrough is very limited in that it has only been proven to work for systems up to 50mL size, far smaller than human organ systems. Moreover, there are potential risks with it such as potential accumulation of nanoparticles which can lead to chronic inflammation. However, if these limitations are addressed, the scientists at the University of Minnesota will be able to make a tangible and measurable contribution to the improvement of society by decreasing the number of donated organs thrown away due to damage during the rewarming process. This will contribute to a reduction in deaths on the organ donation waiting list. Though, the fact that the scientists are currently working on addressing these errors shows that they are committed to the saving of lives in the future.

References

Basic principles of cryopreservation n.d., Food and Agriculture Organisation of the United Nations, pdf, accessed 19 June 2018, <http://www.fao.org/docrep/016/i3017e/i3017e04.pdf>.

Choi, C 2017, Reviving Frozen Organs: Nanotech May Pave the Way, Live Science, accessed 19 June 2018, <https://www.livescience.com/58098-nanotech-may-revive-frozen-organs.html>.

Gao, Z 2017, 'Improved tissue cryopreservation using inductive heating of magnetic nanoparticles', Science Translational Medicine, vol. 9, no. 379, 1 March, accessed 18 June 2018, <http://stm.sciencemag.org/content/9/379/eaah4586>.

Groundbreaking technology successfully rewarms large-scale tissues preserved at very low temperatures 2017, University of Minnesota, accessed 18 June 2018, <https://cse.umn.edu/news-release/groundbreaking-technology-successfully-rewarms-large-scale-tissues-preserved-low-temperatures/>.

Knapton, S 2015, Organ donation crisis threatens hundreds of lives, The Telegraph, accessed 18 June 2018, <https://www.telegraph.co.uk/news/health/news/11749503/Organ-donation-crisis-threatens-hundreds-of-lives.html>.

National Institute of Biomedical Imaging and Bioengineering 2017, Nanotechnology helps rewarm fast-frozen donor tissue, enabling long-term viability, U.S. Department of Health & Human Services, accessed 18 June 2018, <https://www.nibib.nih.gov/news-events/newsroom/nanotechnology-helps-rewarm-fast-frozen-donor-tissue-enabling-long-term>.

Paying to live n.d., The Economist, accessed 18 June 2018, <https://www.economist.com/democracy-in-america/2011/12/07/paying-to-live>.

Shubhika, K 2013, 'Nanotechnology and medicine - The upside and the downside', International Journal of Drug Development & Research, accessed 26 February 2018, <http://www.ijddr.in/drug-development/nanotechnology-and-medicine--the-upside-and-the-downside.php?aid=5003>.

What is Vitrification? 2018, Alcor, accessed 19 June 2018, <https://alcor.org/Library/html/vitrification.html>.

Time travel – the impossible task … or is it?

Words by James Newman

1985 – First screening of Back to the Future which grew in popularity and ended up becoming a trilogy of films.

When the word Time Travel comes up in a conversation, some of you may think of the *Back to the Future* trilogy, others *Doctor Who* and some the great event that could be witnessed using time travel. But in this article, I will give you some of the scientific facts surrounding time travel. There are different ways in which you can time travel. The first, and most commonly thought of idea, is of a backward or forward movement through time to another point in the Earth's timeline. The second idea is the idea that you can either move faster or slower than how we're moving now. For example, if right now we're travelling at 1 minute per minute, could we, say, travel at 2 minutes per minute or 30 second per minute? However, despite our best efforts, we're still no closer to actually possessing the ability to time travel. There are many ideas currently circulating on how we could possibly ever achieve time travel and the main ones that I will be shedding light on (and no, one of them is not the popular theory that the US government is hoarding that ability) is FTL (faster-than-light) travel and the concept of travelling through wormholes.

Travelling at the speed of light

Debate has reigned through many conspiracists as to whether time travel is indeed possible but as of right now time travel using the FTL idea is impossible. To be able to travel through time, in the generally held conception of time travel, you would need to be able to travel at a speed that is faster than light and as of right now there is no machine available (at least to the knowledge of the public!) that is able to achieve this. It's widely believed that to travel at the speed of light you would need an infinite energy source. But to travel beyond that you would need to have a source that was more powerful than an infinite source, which is very much impossible right now. But to even be able to travel faster than the speed of light you would need to be able to travel faster than 300,000,000 m/s. The fastest plane there is right now can travel at 7,200 km/h or roughly 2,000 m/s so you would need to be able to travel at least 150,000 times faster than the North American X-15. But this is nothing compared to the fastest rocket on earth which went at approximately 365,000 km /h or 101,000 m/s which means that we would have to find a fuel powerful enough to propel the craft almost 3000 times faster than the fastest rocket that's been recorded. However, it's extremely (emphasize on the **extremely**) unlikely that an energy source of this power and magnitude will ever be found. This is due to the law of causality. The law of causality shows us that every action (or cause) there will be an event caused by this original action (effect). However, if the fuel or energy source was every found then it would violate this law and the concept of cause and effect would lose all meaning.

Travelling through Wormholes

However, there may be an alternate way to travel through time. Einstein's theory of gravity allows for the possibilities of wormholes to be established in space. Einstein's theory has taught us that the force of gravity is a consequence of massive warps in time and space. In other words, wormholes. Wormholes are created due to the fact that if a large amount of mass is squeezed into a certain area, then space-time starts to become warped and time starts to slow down. Even light is unable to escape this gravitational pull, leading to the formation of a black hole. The closer you get to the wormhole, the slower a clock would tick. This concept leads us to the next idea. If two wormholes are aligned with each other, there is a possibility for us to be able to cross the bridge and move back into the time when the wormhole was created. However, we wouldn't be able to go back in time further than the wormhole. Alas this has also proved to be an unlikely way to time travel properly. Caltech physicist Kip Thorne, by the use of a partial unification of general relativity with quantum physics, was able to suggest that any wormhole that would allow time travel would collapse instantly upon its formation, also crushing anything inside of it. However, for you aspiring time-travellers out there, Thorne was able to provide some promising news – he solved the grandfather paradox. The grandfather paradox is as follow: suppose you travelled back in time and accidentally (I won't point fingers for the purpose of this thought experiment) killed your grandfather before your father was born, hence leaving you unable to be born. Thorne found that for point masses travelling through a wormhole, no initial conditions created this type of paradox, which is good news for you time-travelling folk. However, there may be a way for the wormhole theory to work - dark energy. This is the name given to the energy that is speeding up the universe's rate of expansion, rather than slowing it down. Scientists are unsure as to what exactly this dark energy is, but they know that it makes up most of the universe as we know it. As mentioned before, a wormhole will only work as long as the mouth of the wormhole is held open to allow something to travel through it. To achieve this there is the requirement of negative energy which scientists believe doesn't exist in our everyday world. However, this seems to be a solution which at this time is out of the grasp of humanity. But scientists are yet to give up hope on finding something to solve the time travel conundrum. Technology is advancing so rapidly that they believe that one day time and space might even be under our control.

Now whether you believe in the possibility of time travel or not, I hope to have informed you on the scientific facts surrounding time travel at this point in time. In summary there are two methods that amongst the scientific community are viewed as the most likely ways that it will be eventually achieved. The first method is travelling faster than the speed of light. However, this

Photo by Jason Leung

is an extremely difficult process as you would have to have a powers source that is more than infinitely powerful. The second method relates to the formation of wormholes and our ability to travel through said wormholes. When a wormhole is formed it creates a link back to the time when the wormhole was created. However, it has been found that currently upon the creation of these wormholes they are being destroyed. Using this method, you also wouldn't be able to move further back in time than that exact point in time. As you can now see currently there is no possible way to travel through time. What do you think? In the future, will we be able to travel back to the times long gone or skip forward entire ages of civilization? All the trials and tribulations will be worth it to travel through time (as long as it's not in a blue box!).

References

BBC News. (2019). *'We can build a real time machine'*. [online] Available at: https://www.bbc.com/news/science-environment-44771942 [Accessed 24 Aug. 2019].

Howthingsfly.si.edu. (2019). *How fast could the fastest rocket ship fly? | How Things Fly*. [online] Available at: https://howthingsfly.si.edu/ask-an-explainer/how-fast-could-fastest-rocket-ship-fly [Accessed 24 Aug. 2019].

MiGFlug.com Blog. (2019). *The 10 Fastest Aircraft in the World | MiGFlug.com Blog*. [online] Available at: https://migflug.com/jetflights/the-10-fastest-aircraft-in-the-world/ [Accessed 24 Aug. 2019].

Millington, P. (2019). *Stephen Hawking's final book suggests time travel may one day be possible – here's what to make of it*. [online] The Conversation. Available at: https://theconversation.com/stephen-hawkings-final-book-suggests-time-travel-may-one-day-be-possible-heres-what-to-make-of-it-106566 [Accessed 24 Aug. 2019].

Physics.org. (2019). *Is Time Travel Possible?| Explore | physics.org*. [online] Available at: http://www.physics.org/article-questions.asp?id=131 [Accessed 24 Aug. 2019].

Spaceplace.nasa.gov. (2019). [online] Available at: https://spaceplace.nasa.gov/review/dr-marc-space/time-travel.html [Accessed 24 Aug. 2019].

Wireless electricity investigation - WiTricity's technology

Words by Thomas Johnson

2006 – The wireless charger is patented

Modern-day society is so dependent on energy with its accessibility and viability being of paramount importance. We have become a technologically advanced and consequently dependent animal and consequently, the productivity of society is reliant on the ability for these technologies to be powered. Thus, the innovation that improves our ability to transfer energy and particularly electrical energy is of utmost value to society and is therefore in high demand. Society demands for such is heavily influencing the production of not only greener energy sources, contributing to smaller carbon footprint but too, faster, more expedient, and cheaper means of distributing such electrical energy to both corporate enterprises and the community. Consequently, the transfer of energy is increasingly becoming an area of consideration of scientists and physicists who strive to meet the commercial demands that are influencing the research conducted within the scientific fields. This societal pressure, for example, has nurtured the development of technologies such as WiTricity's wireless electricity, capable of transferring electricity through the medium of air. Nikola Tesla first designed such a system in 1901 where he proposed the development of "Wardenclyffe" a wireless electricity station that could transmit electricity wirelessly to the whole of America, but his ambitions were cut short by the restrictions in the technology of his era. Is it not until now that mankind, through the collaborative efforts of a multitude of enterprises, that of both governing bodies for financial support, organisations such as MIT to provide the scientific equipment to develop such technology and physicists capable of developing the required technology, that Tesla's dream could come to fruition. It is consequently apparent that without this interplay between modern-day society and our advance understanding of science, the development of such technology would not have been achievable, and society could consequently not reap the benefits.

In 2006 MIT Professor and WiTricity founder, Marin Soljačić, patented a design for wireless charging utilising the understanding of magnetic resonance and induction. Magnetic resonance relies upon the same principle responsible for the functioning of a transformer, being magnetic induction, but while a transformer required a medium of an iron core, magnetic resonance utilises air as its medium. When an alternating current is sent through a wire the electrical current produces an alternating magnetic field that flows in a direction that opposes the change magnetic flux produced, this direction is determined through the use of Len's Law. If a second coil were to be placed in the magnetic field it will experience a constant change in flux resulting from the alternating current in the primary coil, producing an induced electromagnetic force, according to Faraday's Law. This force will produce a magnetic field that opposes the change in flux and consequently, electrons will flow in the secondary coil producing an alternating current such that the electricity has been transferred from the primary coil, through the air, to the secondary coil.

(See diagram on the right hand page)

The issue surrounds the relatively short-range ability of this system as the strength of a magnetic field decreases as range increases. Soljačić realised that by using a magnetic resonator or electric current with a specific alternation he could couple the coil's resonance such that the transfer of electricity could occur more successfully at longer distances. Thus, a receiving device could be placed at a distance from the power source and receive constant electrical energy allowing the device to receive electricity similarly to that of a computer receiving Wi-Fi not only increasing the convenience of using technology but similarly breaking free from the current restrictions with electrically powered technology. Despite this, the transfer of electrical energy via this means is still relatively inefficient and consequently time-consuming and costly.

The development of wireless electricity technology comes with numerous hurdles, previously unsurmountable by Tesla, but societal pressures and influences have allowed scientists to overcome the challenges faced to develop such technology, or at least start too. While the main influencing factors of the development of wireless electricity are commercially driven, companies such as Disney are investing time and money into developing such wireless electricity technology for the sake of innovation and driving the development of scientific understanding.

WiTricity's development of their wireless electricity technology, the front runners in the development of this type of technology, was and is heavily influenced by the backing and support provided by BMW a company that see great commercial benefit their product. This is because as societal awareness surrounding mankind's impact on the enhanced greenhouse effect and climate change increases so too does the demand for carbon-neutral means of living. Renewable electricity energy provides a solution for this with solar panels, rechargeable batteries, and electric cars all foreseeably playing a fundamental part in such a future. Consequently, the profitability of producing green products which are, in many cases, electrically powered, has and will continue to increase exponentially, driving the creation of markets for such products which BMW sees great potential in with the boom of the electric vehicles market. Such vehicles are expected to make up 52% of all road vehicles by 2040 globally with a Europe-wide ban on ICE vehicles being imposed in 2030.

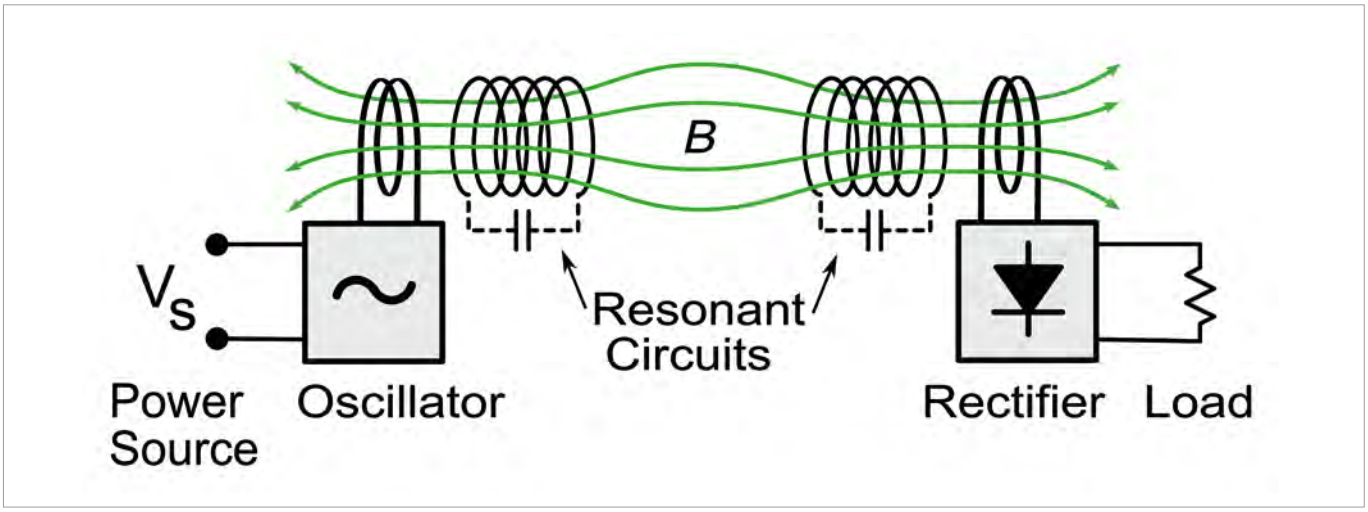


Diagram of magnetic resonance coupling

BMW, like many other companies, has turned to developing and producing electric vehicles as a result. This paired with the desire to stand out from competitors in what is and will continue to become a saturated market, companies such as BMW are seeking technological advantages over their competitors to sell their product and increase profits, influenced itself by the consumer's desire for new invitation. This action is evident within any competitive market with one such example of this evident in the rivalry between Apple and Samsung. Samsung's introduction of wireless charging to its Galaxy-S7 phone saw a 12% increase in sales in comparison to the iPhone equivalent model released that year, the iPhone-7.

BMW has consequently reached out to the company of WiTricity striking a partnership, supporting, funding and consequently influencing the development of their wireless electricity to incorporate that technology within their wireless cars making it more attractive to the potential buyers. BMW has just in June 2019 announced that they will be utilising the new technology in a wireless charging system for their electric cars. Their charging system, while still not developed is planned to be placed on or in the ground and provides charging to a parked electric car that is positioned roughly above it. Thus, it is apparent that the influences from BMW, who are socially influenced by the consumer, as driven the development of WiTricity's wireless electricity which has allowed meaningful technologic innovation and deepening of scientific knowledge to occur bettering society and its functioning.

While the scientific knowledge required to develop wireless electricity was already known, the testing, design, and production of both commercially available charging units and energy-efficient systems required detailed collaborative efforts between governing officials, scientists and businesses to be successful. This collaborative work requires substantial time and effort and without the societal influences, the collaboration required to achieve the outcome would not have been possible.

The production of WiTricity's technology not only required collaborative efforts between MIT professors and students using their state-of-the-art facilities but it similarly required detailed consultation with health professionals and governing agencies such as the FDA's Centre for Devices and Radiological Health to ensure the magnetic resonance was safe for humans and regulated. In conjunction with this, WiTricity required extensive communication and collaboration with BMW to successfully incorporate their product within a complicated car in a commercially viable and convenient manner. It was only through these meticulous interactions that an idea could be turned into a product that is safe, affordable and commercially accessible capable of being implemented within society.

The work done by WiTricity and similar companies are pushing the boundaries on the applications and uses of electricity. The long-range transfer of energy efficiently is the next step, potentially being able to provide the ability for electric drones, surveillance planes, satellites, deep ocean submarines, and even deep space crafts to be powered by wireless electricity indefinitely. The Unities States military has identified interests in utilising this technology in their attach drones allowing them to be in the air indefinitely. While this is amazing to consider wireless electricity is currently limited by the low efficiently of current magnetic resonance technology restricting its effective use to short-range transitions for now.

Ultimately, it is through the societal influences and collaborative efforts from interdisciplinary parties that technologies such as wireless charging for cars. Through these efforts the understanding and scope for the transfer of electricity via magnetic resonance have become clearer opening the doors for future developments, potentially drastically changing our current technology's capabilities, changing our lives. This being said the current limitations surrounding energy loss in the system highlight that much more must be done for this to drastically contribute to society.

References

Atlas Obscura. 2019. Nikola Tesla Built a Giant Tower to Send Wireless Electricity Around the World - Atlas Obscura. [ONLINE] Available at: https://www.atlasobscura.com/articles/what-is-wardenclyffe-tower-nikola-tesla. [Accessed 20 September 2019].

BBC News. 2019. Could we soon charge our phones through the air? - BBC News. [ONLINE] Available at: https://www.bbc.com/news/business-34604842. [Accessed 20 September 2019].

BC Sustainable Energy Association. 2019. Reasons People Love the Electric Car | BC Sustainable Energy Association. [ONLINE] Available at: https://www.bcsea.org/electric-car-ten-reasons-why-people-love-you. [Accessed 20 September 2019].

Climate Change in Australia. 2019. Climate Change in Australia. [ONLINE] Available at: https://www.climatechangeinaustralia.gov.au/en/. [Accessed 20 September 2019].

Digital Trends. 2019. When Will We See Wireless Charging Across Distance? | Digital Trends. [ONLINE] Available at: https://www.digitaltrends.com/cool-tech/wireless-charging-over-distance-barriers/. [Accessed 20 September 2019].

Electronic Design. 2019. 11 Myths About Magnetic-Resonance Wireless Charging | Electronic Design. [ONLINE] Available at: https://www.electronicdesign.com/power/11-myths-about-magnetic-resonance-wireless-charging. [Accessed 20 September 2019].

Encyclopedia Britannica. 2019. Magnetic resonance | physics | Britannica.com. [ONLINE] Available at: https://www.britannica.com/science/magnetic-resonance. [Accessed 20 September 2019].

Ergon Energy. 2019. Benefits Of Electric Cars - Ergon Energy. [ONLINE] Available at: https://www.ergon.com.au/network/smarter-energy/electric-vehicles/benefits-of-electric-vehicles. [Accessed 20 September 2019].

Futurism. 2019. Jellyfish Thrive on Pollution and Climate Change. Now They're Taking Over. [ONLINE] Available at: https://futurism.com/jellyfish-thrive-pollution-climate-change. [Accessed 20 September 2019].

IFLScience. 2019. Disney Researchers Make Wireless Power Transfer Breakthrough | IFLScience. [ONLINE] Available at: https://www.iflscience.com/technology/disney-researchers-make-wireless-power-transfer-breakthrough/. [Accessed 20 September 2019].

Photo by Torbjorn Sandbakk

Investopedia. 2019. How Apple And Samsung Compare ... And Coexist. [ONLINE] Available at: https://www.investopedia.com/articles/markets/102714/how-apple-and-samsung-compare-and-coexist.asp. [Accessed 20 September 2019].

livescience.com. 2019. Wireless Electricity? How the Tesla Coil Works | Live Science. [ONLINE] Available at: https://www.livescience.com/46745-how-tesla-coil-works.html. [Accessed 20 September 2019].

Optimizing Wireless Charging to Make It Faster and More Efficient - 1246655. 2019. Optimizing Wireless Charging to Make It Faster and More Efficient - 1246655. [ONLINE] Available at: https://event.webcasts.com/starthere.jsp?ei=1246655&tp_key=759d084905&sti=ecn_rhodeschwarz_062719_news?cmpid=regwallcontent&utm_source=Deeper%20Insights. [Accessed 20 September 2019].

Quartz. 2019. Electric car forecasts are all over the map — Quartz. [ONLINE] Available at: https://qz.com/1620614/electric-car-forecasts-are-all-over-the-map/. [Accessed 20 September 2019].

ScienceDaily. 2019. MIT Demonstrates Wireless Power Transfer -- ScienceDaily. [ONLINE] Available at: https://www.sciencedaily.com/releases/2007/06/070607171130.htm. [Accessed 20 September 2019].

SlashGear. 2019. BMW 530e wireless electric car charging lands in US - SlashGear. [ONLINE] Available at: https://www.slashgear.com/bmw-530e-wireless-electric-car-charging-lands-in-us-31578752/. Accessed 20 September 2019].

Tesla's folly – why Wardenclyffe didn't work. 2019. Tesla's folly – why Wardenclyffe didn't work. [ONLINE] Available at: http://moreisdifferent.com/2015/02/22/teslas-folly-why-wardenclyff-didnt-work/. [Accessed 20 September 2019].

U.S. Food and Drug Administration. 2019. The FDA's Role | FDA. [ONLINE] Available at: https://www.fda.gov/radiation-emitting-products/mri-magnetic-resonance-imaging/fdas-role. [Accessed 20 September 2019].

Wikipedia. 2019. Wireless power transfer - Wikipedia. [ONLINE] Available at: https://en.wikipedia.org/wiki/Wireless_power_transfer. [Accessed 20 September 2019].

WiTricity. 2019. BMW drives the future of electric vehicle wireless charging with WiTricity technology • WiTricity. [ONLINE] Available at: https://witricity.com/bmw-drives-future-electric-vehicle-wireless-charging-witricity-technology/. [Accessed 20 September 2019].

WiTricity. 2019. Japanese Automotive Leader Furukawa Electric to Test WiTricity Wireless EV Charging System • WiTricity. [ONLINE] Available at: https://witricity.com/japanese-automotive-leader-furukawa-electric-test-witricity-wireless-ev-charging-system/. [Accessed 20 September 2019].

WiTricity. 2019. WiTricity CEO to Kick off Wireless Power Week 2019 with Keynote about Wireless Charging's Role in Future of Mobility • WiTricity. [ONLINE] Available at: https://witricity.com/witricity-ceo-kick-off-wireless-power-week-2019-keynote-wireless-chargings-role-future-mobility/. [Accessed 20 September 2019].

WiTricity. 2019. WiTricity Continues Building Momentum in China with VIE • WiTricity. [ONLINE] Available at: https://witricity.com/witricity-continues-building-momentum-china-vie/. [Accessed 20 September 2019].

Würth Elektronik Group. 2019. WE Home | Würth Elektronik (Wurth Electronics) Group. [ONLINE] Available at: https://www.we-online.com/web/en/wuerth_elektronik/start.php. [Accessed 20 September 2019].

www.ncbi.nlm.nih.gov. 2019. Magnetic Resonance Safety. [ONLINE] Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4848040/. [Accessed 20 September 2019].

Is PETase a solution to plastic pollution?

Words by Seran Perera

2016 – Discovery of PETase enzyme

The global issue of plastic pollution in marine ecosystems and landfills has pressured scientists to develop measures of combatting this problem, through their understanding of science and its impact on society. With enough plastic thrown into landfill yearly to circle the Earth four times, along with the alarming statistics outlined in Figure 1, there is growing debate discerning the most effective scientific solution to plastic pollution. One promising innovation comes from the unexpected discovery and development of PETase, an enzyme that degrades PET plastics. This investigation explores the influences prevalent in the discovery and development of PETase, and consequently the applications and limitations of this enzyme in resolving the issue of plastic pollution.

In 2016, Japanese scientists made a breakthrough discovery when testing bacteria within a bottle recycling plant. They found that a particular bacterium, *Ideonella sakaiensis 201-F6,* could digest plastic contained in many single-use drink bottles, namely polyethylene terephthalate (PET). PET is the most commonly manufactured plastic polymer due to high chemical resistance, high strength to weight ratio, shatterproof properties and transparency. However, its high chemical resistance means that PET plastic is non-biodegradable. This property leads to the accumulation of PET plastics within landfills and marine environments, detrimental to the ecosystem and its resident fauna. There have been previous discoveries of organisms which could degrade potentially these plastics, such as wax worm caterpillars. This was discovered in 2017 by the Institute of Biomedicine & Biotechnology of Cantabria, when caterpillars interacting with plastic were found to contain PET's hydrolysed product, ethylene glycol, suggesting the digestion of PET. However, this discovery was disputed by Professor Till Opatz's team at Johannes Gutenberg University, suggesting the compound detected was not ethylene glycol, but rather proteins of similar structure within the caterpillar. Ultimately, a 'gold-standard' testing for plastic breakdown was developed, whereby isotopically labelled plastic was fed to the organism of interest, and the radioactive material in compounds synthesised by the organism are detected. Through such testing, the enzyme in the bacteria identified for PET breakdown was PET hydrolase, or PETase. As depicted in Figure 2, PETase is primarily responsible for catalysing the hydrolysis of PET into its monomers, which the bacteria use as a carbon food source.

Following this discovery, scientists at the University of Portsmouth analysed the nature of PETase, to understand how it developed from the natural selection of *Ideonella sakaiensis 201-F6*. The team examined PETase using the Diamond

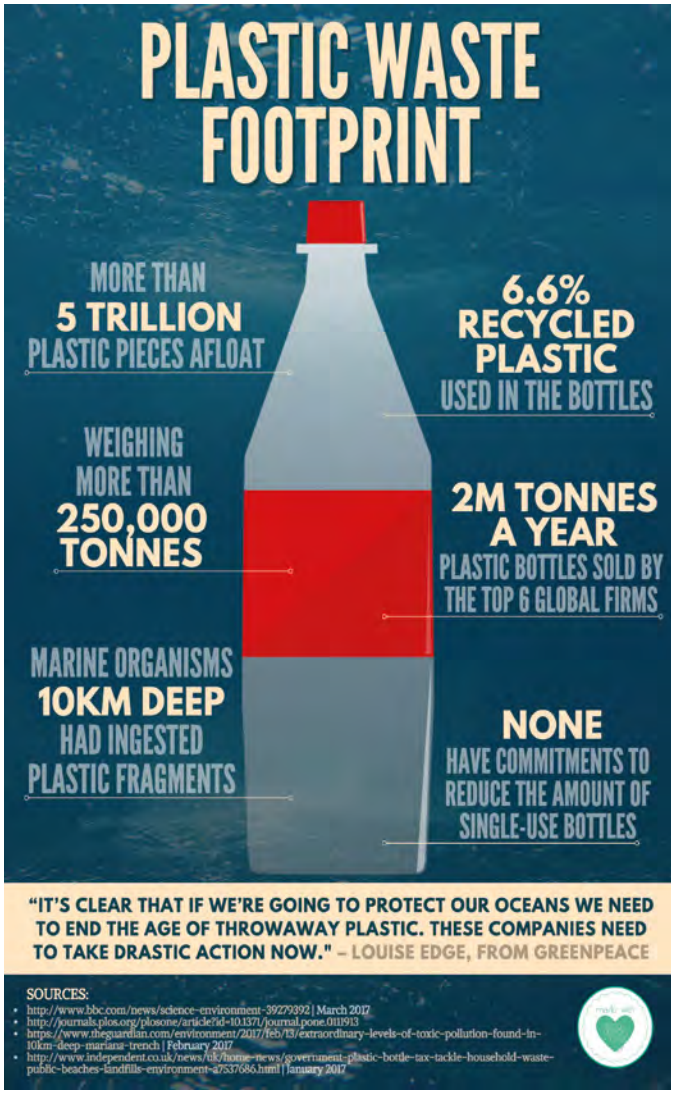


Figure 1

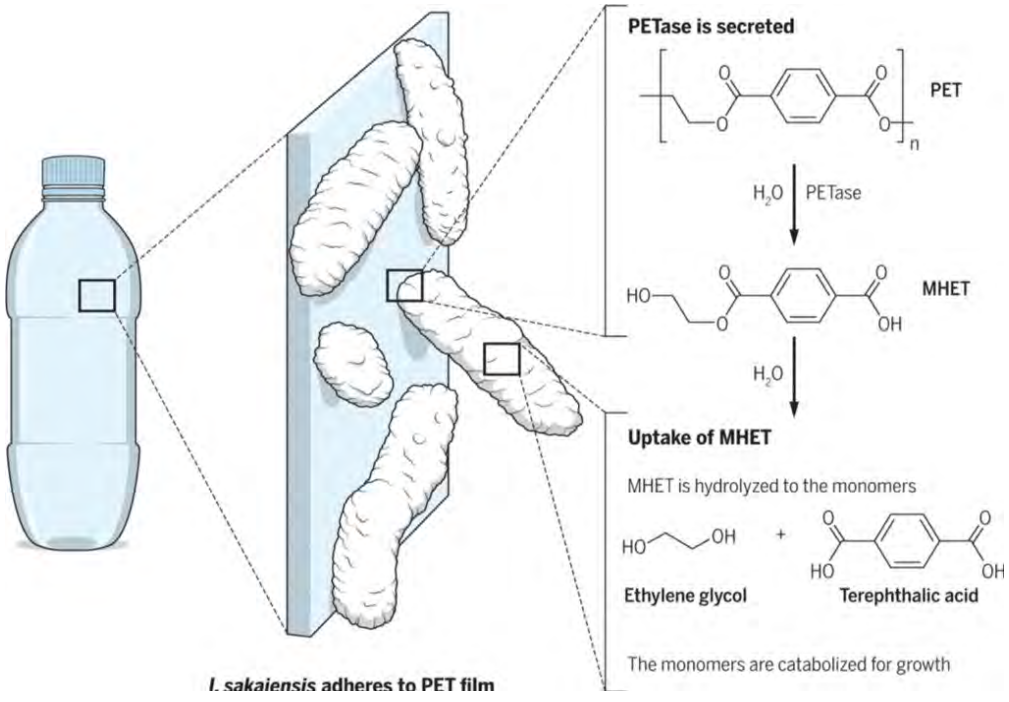
Light Source, a machine which produces X-rays 10 billion times brighter than the sun, to determine its precise atomic structure. As modelled in Figure 3, PETase was identified to be structurally analogous to cutinase, an enzyme which catalyses the hydrolysis of cutin wax present in leaves. Its larger active site, allowing it to have greater access to the concealed PET substrate in plastic, suggested PETase arose from bacteria which adapted to their PET-environment by hydrolysing PET. However, when modifying the unique amino-acid structure of PETase's active site to mimic that of cutinase, scientists stumbled on an enzyme which could depolymerise PET within weeks, much faster than naturally occurring PETase. This discovery provided evidence that scientists could artificially engineer enzymes of greater functionality or efficiency, with Professor John McGeehan from the University of Portsmouth highlighting that PETase's function has potential to be optimised further using enzyme development technology.

Firstly, the understanding and use of supercomputers and industrial processes have influenced the advances in plastic recycling solutions through PETase. After utilising X-ray crystallography to determine the structure of PETase, supercomputers were employed to advance the scientist's understanding of how PETase interacts at a molecular scale. According to the co-leader of research on PETase, Gregg Beckham, scientists used computer simulations to determine the specific mechanism which allows PETase to bind to its substrate, which was pivotal in verifying the action of PETase. The researchers were given access to the Extreme Science and Engineering Discovery Environment, a supercomputer which allowed the modelling and virtual simulation of the formation of an enzyme-substrate complex. Therefore, the cross-disciplinary interaction between computer mechanics and the biophysical actions of enzymes has influenced scientists' understanding of the active site of PETase, and how altering this could improve the enzyme's efficacy in recycling plastics. Furthermore, one prospective use of PETase is to transport it into 'extremophile bacteria', which survive temperatures above 70C. The knowledge that plastics reach a viscous glassy chemical state at these temperatures, through current practises in industrial processes, suggests PETase could degrade plastics 10-100 times faster, due to increased substrate availability and average kinetic energy of particles. However, it is vital that PETase does not denature at these temperatures, as this will inhibit its structurally-contingent function. Nevertheless, the understanding behind the chemical properties of PET, biological factors governing enzymatic activity, and the conditions present in industrial processes, has influenced the current and prospective advancements of PETase technology to benefit society.

Furthermore, the discovery and development of PETase have arisen through unexpected consequences of scientific observation, providing greater means of applying science to combat social issues. Firstly, a team of Japanese scientists found PETase within a bottle-recycling factory, an unexpected consequence of standard scientific inspections. The accumulated landfill of plastic bottles awaiting recycling provided a niche micro-ecosystem, whereby its limited resources provided preference towards bacteria which eventually possessed the ability to digest plastics. This unforeseen consequence offers insight into the adaptability of organisms to suit their environment and provides scientist with an understanding of how nature can overcome problems which society cannot. Furthermore, another beneficial outcome was the bioengineering of PETase to have increased functionality. By assessing the similar nature of PETase and cutinase, scientists were effectively able to manipulate the enzyme's critical 3D amino acid structure. This allowed scientists to produce a bioengineered enzyme with a higher enzymatic activity than its natural counterpart. This provides a prospective insight into further improving the functionality of this enzyme, to provide a faster recycling process. For example, scientists hope to discover new enzymes or modify the active site of PETase to breakdown other consumer plastics such as high-density polyethylene used in jugs, bottle caps and water pipes, or low-density polyethylene used for plastic bags.

However, to effectively understand the role of PETase within plastic recycling, a holistic evaluation of the economic, environmental, ethical and social impacts of its implication is crucial. Firstly, consideration of the significant cost of engineered enzymes, and for the further investment needed to implement PETase within industrial processes, is required to effectively implement PETase into current recycling practises. Due to the highly accessible nature of manufactured (virgin) PET, there is corporate pressure for recycling methods to remain economically viable, so that it remains a desirable method of sourcing plastics for businesses. However, there are economic

Figure 2



benefits of effective recycling, arguably offsetting any current financial concerns regarding PETase use. With the cost of disposal, according to the 2016 rate of $50.60 USD per tonne, equating to $110 million US dollars per year for PET plastics alone, the use of PETase is desirable to mitigate these costs, as such government funds could be reallocated towards healthcare or education. This further aligns to the environmental benefits of implementing PETase for plastic recycling, as the 100,000 marine deaths resulting from plastic entanglement could be prevented through dispersing PETase into marine environments, effectively preserving environmental tourism and marine ecosystems. However, understanding how plastics are dispersed within the ocean is necessary to deduce the most effective method of distributing PETase to degrade floating plastics. Additionally, our limited knowledge of the presence of bacterial growth and dangerous microbes in floating plastics means this potential health hazard requires ethical consideration if human intervention was implemented. Through deeper examination, a social issue arises in our tendency as humans to address the consequences of a problem rather than the root of the cause. As a consumer-orientated society, we need to understand the importance of managing plastic use effectively, due to our finite resources and unsustainable reliance of overflowing landfills. In this regard, the reuse and recycling of plastics in a sustainable manner would negate the need for damage control of plastic pollution with PETase. Ultimately, with current recycling practises for PET, such as metal-catalysed depolymerizations, a holistic evaluation of these factors is crucial to understand the niche role of PETase in plastic recycling.

Ultimately, the discovery of PETase has resurfaced the prominent factors and issues concerning plastic build-up in landfills and marine environments. Specifically, the ability of scientists to bioengineer PETase to degrade plastic more efficiently has pushed PETase as the forefront of combatting plastic waste. However, the development of PETase is in its early days, with economic and social concerns regarding the impact of its immediate use. Nevertheless, the manner of its discovery presents how interactions between science and society can uncover new avenues of innovation, such as further optimising the efficacy of PETase or implementing the enzyme into extremophile bacteria, to mitigate against any possible consequences of PETase to society, so it becomes a successful solution against plastic waste.

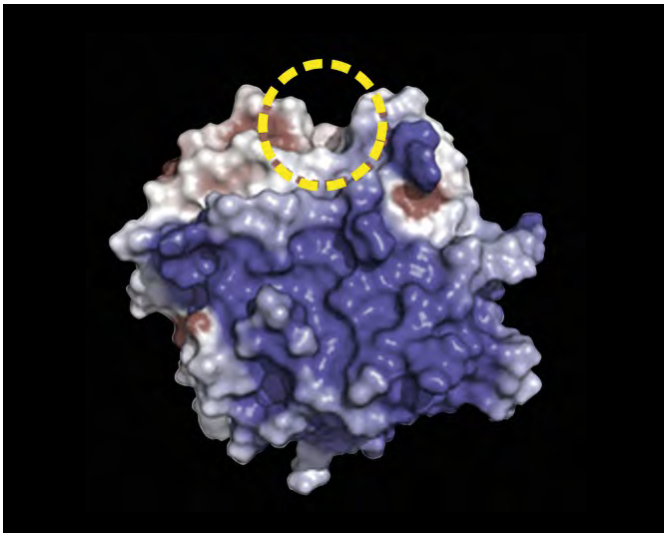


Figure 3

References

American Council on Science and Health. (2018). *Genetically-Engineered Enzyme Recycles Plastic 1,000X Faster Than Nature*. [online] Available at: https://www.acsh.org/news/2018/04/17/genetically-engineered-enzyme-recycles-plastic-1000x-faster-nature-12849 [Accessed 25 May 2019].

Carrington, D. (2018). *Scientists accidentally create mutant enzyme that eats plastic bottles*. [online] The Guardian. Available at: https://www.theguardian.com/environment/2018/apr/16/scientists-accidentally-create-mutant-enzyme-that-eats-plastic-bottles [Accessed 25 May 2019].

Chemical & Engineering News. (2018). *Plastics recycling with microbes and worms is further away than people think*. [online] Available at: https://cen.acs.org/environment/sustainability/Plastics-recycling-microbes-worms-further/96/i25 [Accessed 25 May 2019].

Creative Mechanisms. (2016). *Everything you Need to Know About The World's Most Useful*

Plastic. [online] Creativemechanisms.com. Available at: https://www.creativemechanisms.com/blog/everything-about-polyethylene-terephthalate-pet-polyester [Accessed 25 May 2019].

Ecogreenlove. (2017). *Plastic Waste Footprint [Infographic]*. [online] Available at: https://ecogreenlove.com/2017/04/19/plastic-footprint/ [Accessed 25 May 2019].

Environmental Defense Fund. (2018). *Are plastic-eating bacteria the solution to ocean pollution? It's not that simple, science shows*. [online] Available at: https://www.edf.org/blog/2018/07/13/are-plastic-eating-bacteria-solution-ocean-pollution-its-not-simple-science-shows [Accessed 25 May 2019].

ExtremeTech. [online] ExtremeTech. Available at: https://wwwextremetech.com/extreme/224678-plastic-eating-bacteria-set-to-revolutionize-waste-disposal [Accessed 25 May 2019].

Krumins, A. (2018). *Plastic-eating bacteria set to revolutionize waste disposal –*

Phys.org. (2018). *Supercomputers help design mutant enzyme that eats plastic bottles*. [online] Available at: https://phys.org/news/2018-06-supercomputers-mutant-enzyme-plastic-bottles.html [Accessed 25 May 2019].

ScienceDaily. (2018). *Engineering a plastic-eating enzyme*. [online] Available at: https://www.sciencedaily.com/releases/2018/04/180416155619.htm [Accessed 25 May 2019].

The Conversation. (2018). *How plastic-eating bacteria actually work – a chemist explains*. [online] Available at: https://theconversation.com/how-plastic-eating-bacteria-actually-work-a-chemist-explains-95233 [Accessed 25 May 2019].

Trevino, J. (2018). *This "Mutant Enzyme" Breaks Down Plastic*. [online] Smithsonian. Available at: https://www.smithsonianmag.com/smart-news/scientists-accidentally-create-mutant-enzyme-can-break-down-plastic-180968881/ [Accessed 25 May 2019].

University of Portsmouth, (2019). *Could a mutant enzyme solve the planet's plastic problem?* [online] Available at: https://www.port.ac.uk/research/research-features/mutant-enzyme [Accessed 25 May 2019].

Watson, R. (2017). *The Cost to Landfill MSW in the US Continues to Rise Despite Soft Demand – SWEEP*. [online] Nrra.net. Available at: https://nrra.net/sweep/the-cost-to-landfill-msw-in-the-us-continues-to-rise-despite-soft-demand [Accessed 25 May 2019].

Bacteriophage Therapy; a solution to antibiotic resistant bacteria

Words by Max Parsons

2019 – Bacteriophage therapy is discovered

Bacterial resistance to antibiotic medicines has become an increasingly prevalent issue in today's civilisation. Antibiotics are becoming less effective in treating bacterial infections in patients, arising from the improper prescription of antibiotics. It takes scientists up to 10 years to develop and have an antibiotic treatment approved, meaning that there is a dire need for new developments in this technology. A favourable new method of treatment in 2019, is through the use of bacteriophages. Bacteriophages are viruses that have the ability to kill bacteria. In this report, all scientific and ethical issued will be discussed to determine the viability of using bacteriophages in patient treatment.

The use of bacteriophages to treat pathogenic infections is defined as 'phage therapy' and it has the ability to treat patients suffering from bacterial infections where antibiotic treatments have failed. Phages are found abundantly naturally wherever bacteria exist; including soil, plants, animals and in the oceans. Phages have a simple structure, depicted in figure 1, comparable to a regular viral particle; including a capsid containing DNA, a collar and a tail. Therefore they do not have the ability to reproduce independently and rely on host bacterial cells to be able to replicate. Phages used in treatment undergo the lytic cycle where the tail attaches to receptors on bacterial cells, the phage then injects its DNA into the cell, the DNA replicates and new phage particles are produced after utilising the nutrients and protection inside the bacterium. The phages continue to replicate until the bacterial cell begins to swell and bursts, releasing hundreds of new phages which repeat the process in new hosts.

Phage therapy firstly begins with the obtainment of phages from the environment. This is a very simple task as there are upwards of a nonillion bacteriophages in the oceans, soils, and air. The phages are then isolated and purified, where a form of cell culture called the double agar method is implemented, which produces a plaque rich in bacteriophages. From this plaque, the phages are sterilised and filtered in order to remove any bacteria remaining in the sample. The individual phages are then tested to see how effective they are at infecting and killing bacteria, its genome is also sequenced in order for it to be identified in the future. The phages used to treat patients are very specific as the proteins in the 'tail' bind to a specific receptor on the bacterial cell and it is, therefore, a challenge to find the appropriate mixture of phages for therapy. Once strains of phages that have the ability to kill bacteria are identified, they are rigorously tested for safety and efficacy. If issues arise in this testing their genomes can be edited to improve or help minimise the effects of these concerns. After this process is complete the mixture of bacteriophages are put into what is called a phage 'cocktail' and are administered to the patient. The cocktail allows for the greatest chance of the phages to overcome the infection in the patient.

The use of bacteriophages as a way of killing bacterial infections poses as a contemporary method of defeating multidrug-resistant bacteria. The most prevalent of these are infections such as tuberculosis that often arise in cystic fibrosis patients. The patients are administered antibiotics to treat these bacterial infections which often results in these bacteria building resistance to them over time. With this consistent threat of drug-resistant bacteria, the use of phages could be implemented as a 'back up' to antibiotic treatments. The past accumulated knowledge regarding bacteria is extensive and well understood by scientists, this allows for the new contemporary method of phage therapy to be created with the influence of the understanding in this area.

As the structure of bacteriophages is very similar to that of a regular viral particle, a phage's behaviour is also comparable. Where it will either follow a lytic cycle, a lysogenic cycle or both depending on the strain. A lytic cycle is the same for all viruses and bacteriophages with the ability or requirement to do so. This broad understanding of the method of how viruses replicate influenced the possible shortcomings of using bacteriophages in humans as treatment. The underlying fear was that the phages would begin to destroy human cells after the bacterial infection had been eliminated. This concern was then later proved to be redundant, as individual strains of phages are specific to a singular species of bacteria. Similarly, treatment with antibiotics kill bacteria indiscriminately and this often results in the destruction of beneficial bacteria in the gut. However, phages are tested and modified to only kill one specific type of bacteria. Because of this, phage therapy opens up new opportunities for the use of bacteriophages as a broader treatment option. Where they could be genetically modified for more specialised uses and could be further coupled with the DNA editing system CRISPR-Cas9 in order to only kill antibiotic resistant bacteria. The prospects of phage therapy have the possibility of influencing from a social perspective, a large range of patients without the requirement of antibiotic treatment and could solve the increasing issue of drug-resistant bacteria.

The development of phage therapy has largely become achievable because of the collaboration of scientists across the world. A recent example of the success of phage therapy in treating infections in a patient with cystic fibrosis was achieved by Graham Hatfull, a Howard Hughes Medical Institute Professor at the University of Pittsburgh. Hatfull successfully genetically engineered bacteriophages to treat a patient whose *Mycobacterium* infection had built resistance to traditional antibiotics. Hatfull communicated to a colleague at London

Hospital where this patient was being held and collaborated with him on this task. Hatfull, who is a molecular geneticist, had collected 15,000 vials of bacteriophages, over 3 decades, from across the world. Hatfull had created a program at his University which gave students the opportunity to hunt for phages. Throughout the past decade, 20,000 students worldwide have contributed to this program and helped build this collection. This engagement with students meant that they were given the opportunity to study the phages, purify them and test their efficacy. Which was beneficial as students from the other side of the world were able to assist in the creation of a phage cocktail that saved a patient's life.

Similarly, whilst in Egypt, a patient became infected by a drug-resistant bacterial strain called *Acinetobacter baumannii,* and was flown back to California where he was treated by a phage cocktail obtained from sewage in Texas. Bacteriophages are so accessible and diverse in that they can be obtained almost everywhere on the planet. This allows for the connection of institutes, universities, hospitals, etc. across the world to help treat patients that have little to no options remaining. The European Union has invested 5 million Euros towards the research into phage therapy and similarly, the USA has approved of a phage strain that kills meningitis triggering bacteria, in foods. The science of bacteriophages which was once ruled out as a possible treatment has been renewed as an opportunity as a result of international communication and collaboration between scientists to help treat patients.

The most prevalent goal for the use of bacteriophages as a medicinal practice is to use phage therapy as a first response to bacterial infections instead of antibiotics. Where in the future this treatment could be extended to a broader range of diseases and infections. However, accompanied by this are ethical and social considerations. Currently, the main issue with phage therapy is that their efficacy has not been extensively tested. Where if a clinician was to subject a patient to a possibly hazardous therapy, there are moral issues of the patient's safety that must be considered. Additionally, if a patient's health is at stake and phage therapy is the only option, then the therapy must be considered over research and cost-reducing benefits.

On the other side of the spectrum, there are also ethical considerations surrounding the extraction and separation of bacteriophages from the environment. As they are naturally occurring in bacteria, bacteriophages play a major role in the regulation of bacterial populations in nature. The ethical issue relates to how the genetic engineering of bacteriophages should not occur as it affects the natural genome of a living organism. However, it is argued that viruses such as bacteriophages are not actually considered living and are instead defined as particles, therefore ethically, the effects of using bacteriophages as a method of treatment for patients, are reduced.

Ultimately, as the administration of common antibiotics continues to increase in today's society, the development of drug-resistant strains of bacteria will similarly become more prevalent and harder to treat. The clinical implementation of phage therapy has the potential to not just be a backup for when antibiotics fail, but they could become the primary method for fighting bacterial infections. Genetic engineering of the phages holds merit as a way of expanding the use of bacteriophages in a broader range of diseases and infections. Whilst further influencing and inspiring new medicinal technologies that could change the world in the future.

References

Brzozowska E, e. (2019). [The functions of bacteriophage proteins]. - PubMed - NCBI. [online] Ncbi.nlm.nih.gov. Available at: https://www.ncbi.nlm.nih.gov/pubmed/21502693 [Accessed 4 Jun. 2019].

Khan Academy. (2019). *Bacteriophages*. [online] Available at: https://www.khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/bacteriophages [Accessed 27 May 2019].

Morgridge.org. (2019). [online] At: https://morgridge.org/wp-content/uploads/Bacteriophage-fact-sheet.pdf [Accessed 27 May 2019].

Mullan, D. (2019). *Isolation and purification of bacteriophages*. [online] Dairyscience.info. Available at: https://www.dairyscience.info/index.php/isolation-and-purification-of-bacteriophages.html [Accessed 27 May 2019].

Nature News & Comment. 2019. Phage therapy gets revitalized: Nature News & Comment . [ONLINE] Available at: https://www.nature.com/news/phage-therapy-gets-revitalized-1.15348. [Accessed 27 May 2019].

Phage Therapy: Beyond Antibacterial Action. www.ncbi.nlm.nih.gov. 2019. [ONLINE] Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5974148/. [Accessed 27 May 2019].

Phage therapy. www.ncbi.nlm.nih.gov. 2019. [ONLINE] Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5547374/. [Accessed 27 May 2019].

Science in the News. 2019. Bacteriophage: A solution to our antibiotics problem? How we can us a virus to fight bacterial infection. [ONLINE] Available at: http://sitn.hms.harvard.edu/flash/2018/bacteriophage-solution-antibiotics-problem/. [Accessed 27 May 2019].

ScienceDaily. (2019). *Phage therapy treats patient with drug-resistant bacterial infection*. [online] Available at: https://www.sciencedaily.com/releases/2019/05/190508134554.htm [Accessed 27 May 2019].

Taking Bacteriophage Therapy Seriously: A Moral Argument. https://www.hindawi.com/journals/bmri/2014/621316/. (2019). [Accessed 27 May 2019].

When Viruses Infect Bacteria | NSF - National Science Foundation. 2019.[ONLINE] Available at: https://www.nsf.gov/news/news_summ.jsp?cntn_id=120974. [Accessed 27 May 2019].

The average human body carries ten times more bacterial cells than human cells

E. Coli under the Microscope
Types, Techniques, Gram Stain and Hanging Drop Method

https://www.microscopemaster.com/e-coli-under-microscope.html

Hebrew University researchers create embryo cells from skin cells

Words by Alexander Yantchev

2019 – Embryonic cells from are created from skin cells at Hebrew University

Modelling embryonic disease has been difficult due to different factors of embryo development such as their variable growth, and the size of the structures. This has led scientists to research and develop more methods in which embryonic diseases and dysfunctions can be modelled and observed. Also, with scientific knowledge and technologies growing exponentially, the artificial creation of human life appears possible in the future. In 2019, a collaborative effort at the Hebrew University of Jerusalem (HU) led to the development of a technique that transforms skin cells into three cell types that form early stage embryos, extraembryonic stem cells.

In order to understand this research, a base understanding of the biological concepts is required. Meiosis takes place in the reproductive organs to form sperm and egg gametes that go on to fuse and undergo fertilisation with one another to form a blastocyst. Following this process, the embryonic stem cells in the blastocyst undergo asymmetrical cell divisions; divisions which result in variable cell fates for each daughter cell, with three cell types being formed that make up early stage embryos: Epiblast cells, primitive endoderm cells, and trophoblast cells.

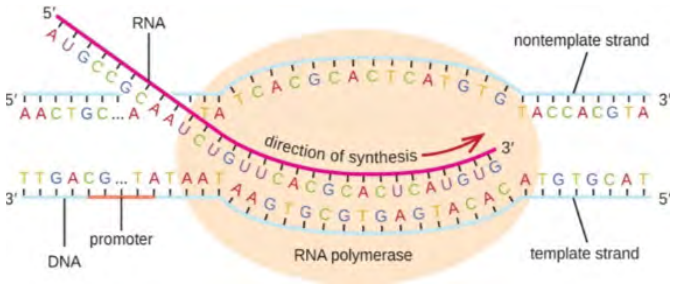


Figure 1: mRNA formation by the process of transcription

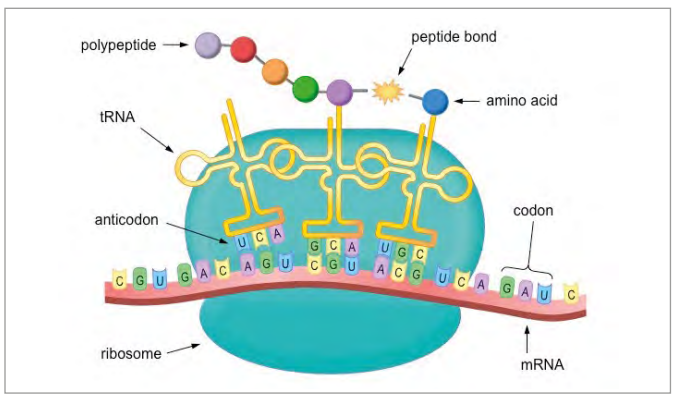


Figure 2: Translation occurring in the ribosome

The HU researchers pondered about creating these three cell types from pre-existing fibroblast cells found in skin tissue and discovered that it was possible through the utilisation of various transcription factors.

Transcription is a crucial process in gene expression, which involves the copying of one strand of DNA to make an mRNA molecule. This is achieved through the enzyme RNA polymerase which links RNA nucleotides to their appropriate corresponding bases on the DNA strand, forming a corresponding mRNA molecule, as can be seen in the pink strand in Figure 1. The non-template strand code ultimately determines the proteins produced in the cell.

This molecule makes its way out of the nucleus to the ribosome where translation occurs to form an amino acid chain as seen in figure 2, with these chains eventually producing a protein. The variation of the proteins in varying cells is what is referred to as gene expression, which ultimately decides the function of the cell.

Transcription factors (TF's) are proteins that regulate the process of transcription, acting either as activators or repressors. They attach to promotor binding sites on the DNA sequence as can be seen in figure 3 and 4 below, and either prevent or allow RNA polymerase to bind. By regulating transcription, the TF's therefore decide whether certain genes are expressed, and hence determine the proteins formed. Transcription being enabled by a TF can be observed in figure 3 below, and transcription being disabled by a TF can be seen in figure 4.

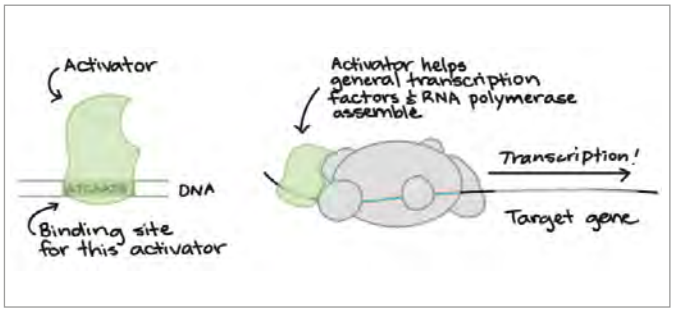


Figure 3: Activator TF's

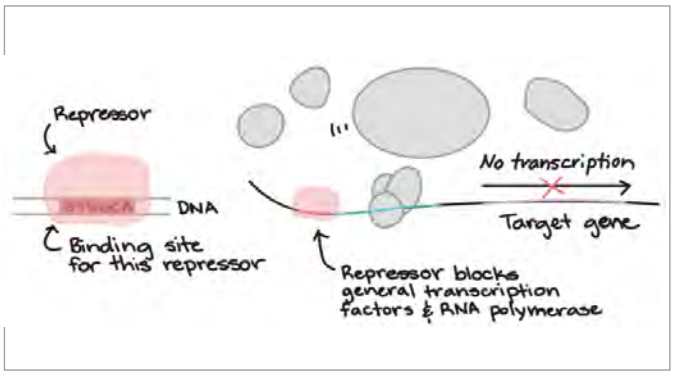


Figure 4: Repressor TF's

The transcription factors used by the researchers, Gata3, Eomes, Tfap2c, Myc, Esrrb could be manipulated to reprogram pre-existing fibroblast cells into induced pluripotent, trophoblast, and extraembryonic endoderm stem cells, the cells responsible for the formation of extraembryonic biological structures such as the placenta and umbilical cord, required for the growth of an animal.

The study incorporated a range of different teams from different fields in the Hebrew University which allowed for a more scientifically diverse and refined study. Dr Yossi Buganim of the Department of Developmental Biology and Cancer Research devised and led the study, Dr Oren Ram from the Institute of Life Science conducted the ChIP sequencing, a technique used to analyse interactions between the proteins and DNA of a cell, and Professor Tommy Kaplan from the HU's School of Computer Science and Engineering analysed the sequences of RNA, assessed genome-wide chromatin accessibility and analysed the ChIP output. Other doctoral students also collaborated, ultimately to form a complex scientific model that could further the ability for embryonic disease modelling to occur. The original article was published in "Cell Stem Cell", a peer reviewed scientific journal. The method in which it was communicated allowed for the collaboration of multiple researchers to create a refined document, with multiple sources of verification and review of the research and data presented, essential for the formation of a scientifically valid article. The article was then manipulated in a format that was more readable and accessible to the public, published on various news websites with examples being ScienceDaily and the Times of Israel, which lacked more scientific language and quality however enabled it to be communicated to an ordinary audience. The research paper featured multiple sources that led the direction of the experiment, the most significant being research done in 2006 by a Japanese research team involving the induction of pluripotency of skin cells. Prior to the Hebrew University's experiment, the Japanese team was able to generate embryonic stem cells from skin cells, however the embryo grown lacked extra-embryonic tissue such as placenta and umbilical cords that were required for the embryo to survive. This prior research acted as the foundation for the Hebrew team's experiment and formulation of a new scientific goal, an example of collaboration between the two teams, which allowed for the HU team to extend beyond the problems faced in the previous study. Collaboration between the team of scientists and various biomedical laboratories and institutes also occurred in order to source antibodies to be used in the experiment; examples being Bethyl Laboratories for obtaining the Nanog antibody used in marking the pluripotent stem cells, and the Cdx2 antibody from the Biogenex laboratory used in transcription factor encoding.

The research conducted by the team utilised mouse embryos and mouse embryonic fibroblasts extracted from dissected mice, which opens the door to ethical considerations regarding the utilisation of animals in scientific research and presents a strong argument against the dissection of such mice to extract their embryos which can be observed in figure 5 and 6. The University Joint Ethics committee and the Hadassah Medical centre together approved the study protocol in relation to animal welfare, however animal rights supporters are typically strongly against the exploitation of animals in any circumstance, including in experiments, and thus the potential ethical complications of this research prove it difficult for this scientific development to be communicated to a wider audience. However, it can also be argued that there was clear justification for the use of mouse embryos for the development of more complex scientific understandings of embryonic models and artificial formation of life as there are limited alternatives. A new technological development named "organs-on-chips" contain lab-grown human cells that imitate human physiology as well as responses to drugs and diseases, however the intelligence of this system cannot extend to the creation of the embryos that could be utilised for this research.

The research conducted was heavily influenced by the use of a variety of computer software's used to form graphical models, tables, and calculations. For example, the previously discussed process of ChIP analysis conducted by Professor Tommy Kaplan utilised the software "ChIPSeeker", and overall the investigation utilised a total of 13 different programs as some can be seen in Figure 5. The use of this complex computer software integrated with other fields of science and mathematics allowed for the creation of a detailed scientific document that could effectively be shared with a sophisticated audience, and the ability for more accurate conclusions to be derived from the data.

The further development in embryology also significantly influences the ability for the teaching of more detailed embryo models to occur in the field of science, and the ability for these models to be used to observe formations of embryonic diseases and dysfunctions for teaching, and application in saving pregnancies and lives.

While the development does not involve the actual formation of a full embryo from skin cells, the importance of this development cannot be understated as it is an essential step in paving the way for the possibility for artificial human embryos to be produced through fibroblast cells. The creation of such embryos from skin cells can extend to be useful in a laboratory, minimising the need for animal experimentation by presenting the possibility for research on artificial cells and organs instead.

The investigation also significantly impacts the greater population of society through the potential creation of a new method for embryonic disease to be modelled through the creation of artificial embryos, which could potentially save pregnancies and offer early treatments to a range of dysfunctions that could make their way into the life of a human, potentially saving lives.

The collaborative efforts of the study resolve the need for more complex embryonic models required to map and diagnose complex embryonic diseases, and it drives more modern and intelligent comprehension of new possible techniques for the creation of lab-grown artificial human life.

References

Bbc.co.uk. (n.d.). BBC - Ethics - Animal ethics: Experimenting on animals. [online] Available at: http://www.bbc.co.uk/ethics/animals/using/experiments_1.shtml [Accessed 6 Jun. 2019].

Benchetrit, H., Jaber, M., Zayat, V., Sebban, S., Pushett, A., Makedonski, K., Zakheim, Z., Radwan, A., Maoz, N., Lasry, R., Renous, N., Inbar, M., Ram, O., Kaplan, T. and Buganim, Y. (2019). Direct Induction of the Three Pre-implantation Blastocyst Cell Types from Fibroblasts. [online] ScienceDirect. Available at: https://www.sciencedirect.com/science/article/pii/S1934590919301171 [Accessed 6 Jun. 2019].

Clancy, S. (2008). DNA Transcription. [online] Nature.com. Available at: https://www.nature.com/scitable/topicpage/dna-transcription-426 [Accessed 6 Jun. 2019].

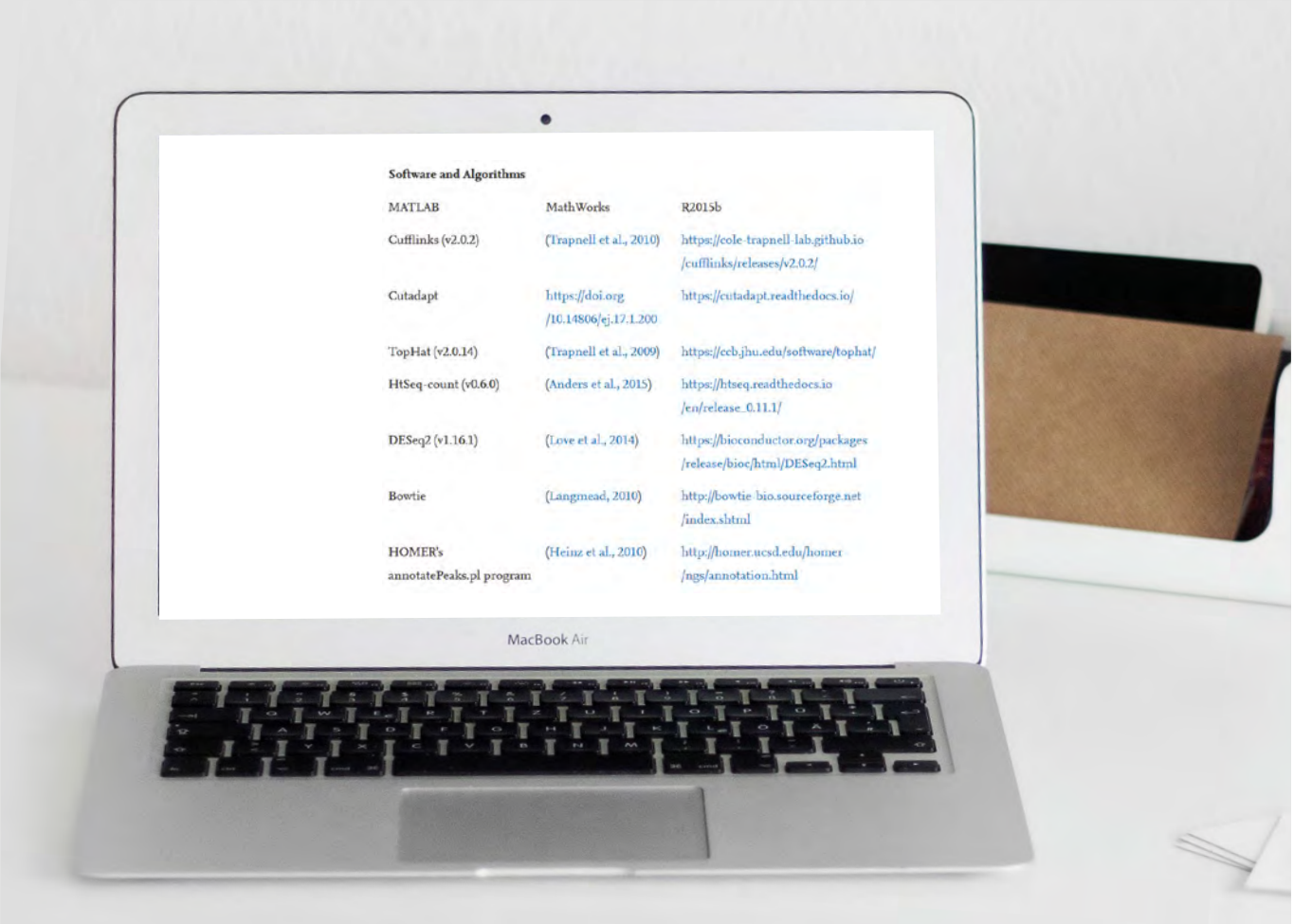


Figure 5

Courses.lumenlearning.com. (n.d.). RNA Transcription | Microbiology. [online] Available at: https://courses.lumenlearning.com/microbiology/chapter/rna-transcription/ [Accessed 7 Jun. 2019].

Dabbs, D. (2010). Diagnostic immunohistochemistry. 3rd ed. Philadelphia, PA: Saunders/Elsevier, pp.206-255.

Hill, D. (2018). Embryology Models - Embryology. [online] Embryology.med.unsw.edu.au. Available at: https://embryology.med.unsw.edu.au/embryology/index.php/Embryology_Models [Accessed 6 Jun. 2019].

Ib.bioninja.com.au. (n.d.). Translation. [online] Available at: https://ib.bioninja.com.au/standard-level/topic-2-molecular-biology/27-dna-replication-transcri/translation.html [Accessed 7 Jun. 2019].

Khan Academy. (n.d.). Transcription factors. [online] Available at: https://www.khanacademy.org/science/biology/gene-regulation/gene-regulation-in-eukaryotes/a/eukaryotic-transcription-factors [Accessed 7 Jun. 2019].

Nature.com. (2014). Gene Expression. [online] Available at: https://www.nature.com/scitable/topicpage/gene-expression-14121669 [Accessed 6 Jun. 2019].

ScienceDaily. (n.d.). Fertilisation. [online] Available at: https://www.sciencedaily.com/terms/fertilisation.htm [Accessed 6 Jun. 2019].

ScienceDaily. (2019). Embryo stem cells created from skin cells. [online] Available at: https://www.sciencedaily.com/releases/2019/05/190502143437.htm [Accessed 6 Jun. 2019].

Sciencedirect.com. (2014). Transcription Factors - an overview | ScienceDirect Topics. [online] Available at: https://www.sciencedirect.com/topics/neuroscience/transcription-factors [Accessed 6 Jun. 2019].

Solomon, S. (2019). Hebrew University researchers create embryo stem cells from skin cells. [online] Timesofisrael.com. Available at: https://www.timesofisrael.com/hebrew-university-researchers-create-embryo-stem-cells-from-skin-cells/ [Accessed 6 Jun. 2019].

Thermofisher.com. (n.d.). Chromatin IP (ChIP Assays) | Thermo Fisher Scientific - UK. [online] Available at: https://www.thermofisher.com/au/en/home/life-science/protein-biology/protein-biology-learning-center/protein-biology-resource-library/pierce-protein-methods/chromatin-ip-chip-assays.html [Accessed 6 Jun. 2019].

Www2.le.ac.uk. (n.d.). The Cell Cycle, Mitosis and Meiosis — University of Leicester. [online] Available at: https://www2.le.ac.uk/projects/vgec/highereducation/topics/cellcycle-mitosis-meiosis [Accessed 6 Jun. 2019].

Wyss Institute. (2019). Human Organs-on-Chips. [online] Available at: https://wyss.harvard.edu/technology/human-organs-on-chips/ [Accessed 6 Jun. 2019].

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