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Engineering Tomorrow's Therapies:
From Organ Preservation to Oncological Drug Delivery and Spinal Surgery

What do planes, flowing blood, ship propellers, solid tumours, and spinal discs have in common?

Engineering is not just a set of skills, but a way of thinking that leads to unconventional and ubiquitous problem-solving. Core expertise in fluid mechanics, heat and mass transfer, acoustics and waves, and control engineering can find wide-ranging applicability across several medical disciplines ranging from transplantation to oncology, orthopaedic surgery, dermatology and even immunology.

This lecture will first describe the development of the worlds' first normothermic organ perfusion device, intended to fool organs intended for transplantation into thinking that they are still inside the body during preservation. From initial concept to pre-clinical validation, first-in-human trials and widespread commercial and clinical adoption, the challenges and opportunities associated with translating research into technology to achieve biomedical impact will be discussed.

The portability of engineering skills into other disciplines will then be explored. The concepts of sheer stress and yield strength are just as applicable to human cells and biological tissues as they are to man-made structures. Mechanical and thermal stresses caused by physical modalities, such as ultrasound, can be exploited to enable non-invasive and minimally invasive surgery to destroy, repair or replace tissues selectively at depth within the body. Repairing the intervertebral disc to restore spinal function will be put forward as a case study.

In cancer, tumour physiology presents a formidable barrier to the delivery of current and emerging anticancer therapeutics, including small-molecule-containing nanomedicines, oncolytic viruses, and therapeutic antibodies. Engineering-based approaches for enhancing mass transport thus have a major role to play in enabling drugs to overcome the elevated intratumoural pressure, sparse vascularity and dense extracellular matrix encountered in the majority of solid tumours. These physical transport mechanisms are also directly applicable to facilitating transport of vaccines across the skin, and in stimulating immune responses in patients, further enhancing the relevance and potential impact of engineering in helping the world move past the recent Covid-19 pandemic.

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Professor Constantin Coussios is the Director of the Oxford Institute of Biomedical Engineering. He received his BA, MEng and PhD in Engineering from the University of Cambridge and was elected to the first statutory chair in Biomedical Engineering at the University of Oxford in 2011, with special responsibility for drug delivery and therapeutic devices. He founded and heads the Biomedical Ultrasonics, Biotherapy and Biopharmaceuticals Laboratory (BUBBL), a research group of 4 faculty and some 45 researchers working on a wide array of therapeutic applications. Prof. Coussios received the UK's Institute of Acoustics' Young Person's Award for Innovation in Acoustical Engineering in 2007, was elected as Secretary-General of the International Society for Therapeutic Ultrasound between 2006-2010 and was honoured with the Society's Fred Lizzi award in 2012. He was elected as the youngest ever Fellow of the Acoustical Society of America in 2009, and received the Society's Bruce Lindsay award in 2012. In 2008, he was one of two academic founders of the Oxford University spin-out OrganOx Ltd., which has developed a novel normothermic perfusion device for improved liver and kidney preservation prior to transplantation through to first-in-man trials, first sales, randomized trials (Nature 2018) and NICE approval. In 2014, he co-founded OxSonics Ltd, which is commercializing cavitation-enhanced oncological drug delivery, and in 2016 he co-founded OrthoSon Ltd, which is developing minimally invasive replacement of the intervertebral disc. In 2017, he received the Silver Medal of the UK's Royal Academy of Engineering for his contributions to organ preservation and ultrasound-enhanced drug delivery. In 2019, he was elected a Fellow of the Royal Academy of Engineering.