Surgeon-anatomist to robotic technician? The evolving role of the surgeon over three centuries

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Summary
In the 18th century, anatomy was the principal science underlying surgical practice. Over the next three centuries, the scientific basis of surgery changed dramatically. Morbid anatomy led to the understanding of organ-based pathologies that allowed surgeons to remove, reconstruct and in some cases replace internal organs. In the 19th century, the new science of microbiology facilitated antisepsis, then asepsis as surgery progressed from a craft to a scientific discipline. Yet many surgeons believed that surgery was not merely a science but also an art, in which the creativity of the doctor was necessary for progress. Surgical advancement depended on creative individuals with innovative flair, prepared to pioneer often risky procedures in the face of mainstream opposition. The 20th century saw a series of changes that made such individualism more difficult. 'Scientific Management' when applied to surgery decreed that procedures be performed according to predetermined schedules, a drive to uniformity producing better outcomes and diminishing individual variation. Yet inventive individuals continued to produce surgical advances. In the 21st century, moves toward standardisation developed further. The escalating safety culture in surgery moderates the introduction of novel, potentially riskier procedures, while more and more regulation increasingly requires surgeons to adhere to guidelines and protocols, further restricting surgical individualism. Moreover, the role of the individual is further diminished, as surgical care is delivered by teams, both in deciding management in major cases and in the operating theatre. The introduction of robotics into surgery has led to the suggestion that the role of the surgeon may become that of a technician. Will these constraints, and greater patient involvement in decisions, allow tomorrow’s surgeons the freedom to innovate? We believe that the pioneering spirit, imagination and flair will not be lost. Tomorrow’s surgeons must remain doctors, showing the compassion and empathy that robots cannot provide.

Keywords
Changing physician behaviour, evidence-based practice, history of medicine, microbiology, pathology, surgery

Introduction
Since the 18th century, advances in our understanding of disease and innovations in science and technology have together expanded the range of conditions amenable to surgical treatment. As surgery has advanced, so the role of the surgeon has changed and continues to change. In this article, we have selected examples to demonstrate the evolving role of the surgeon from the latter half of the 18th century through to the 21st century and speculate how this might further develop in the future.

18th century
Surgeon anatomists
For much of the 18th century, British surgery was largely based on only one science; the study of anatomy, mainly inspired by the first Edinburgh professor of anatomy Alexander Monro primus (1697–1767) and by the brother surgeon-anatomists William (1718–1783) and John Hunter (1728–1793), who established a celebrated anatomy school in London. Anatomy was at the heart of surgical education and training, and surgical knowledge and technique advanced through an increasing understanding of anatomical structure and function. In London, William Hunter studied midwifery under William Smellie (1697–1763) and published on the gravid uterus. His collection – including his art, books and curiosities – is now housed at the University of Glasgow. John Hunter, often described as the father of scientific surgery, was an experimentalist who would employ the results of his experiments in making clinical decisions.1 John’s prestige did much to change surgery from a manual craft to a scientific discipline. Among the many influenced by the Hunter brothers was John Bell (1763–1820), an...
Edinburgh-based surgeon and anatomist who emphasised that the practice of surgery must be based on the study of surgical anatomy. Bell stressed the teaching of anatomy related to surgery and his many books on the topic were influential, due to his acclaimed anatomical illustrations. A talented artist, with an interest in classical artworks, John Bell also wrote Observations on Italy, in which he described the relationship between anatomical correctness and art. He intended that his anatomical plates should combine the aesthetic with the functional, hoping that they would be judged as ‘excelling in what is beautiful; yet, not wanting in what is useful’.

The study of anatomy was evolving in the late 18th century with increasing emphasis on morbid anatomy, the analysis of the structure of diseased organs. In the last decade of the 18th century, Mathew Baillie (1761–1823), a nephew of William and John Hunter who inherited their anatomy school, published The Morbid Anatomy of some of the most Important Parts of the Human Body (1793), in which he portrayed morbid anatomy as an independent science, describing correlations between clinical features of disease and pathological change.

19th century

Art in surgery

John Bell’s younger brother Charles (1774–1842) also had multiple talents as surgeon, anatomist, physiologist and artist. His anatomical contributions included the identification of the muscles of facial expression and their innervation by the facial nerve.

William Osler (1849–1919) reflects further upon the relationship between science and art in medicine, writing that ‘Medicine is a science of uncertainty and an art of probability’. Albert Schweitzer (1875–1965) regarded medicine as not only a science but also an art, in which the individuality of the doctor interacts with that of a patient. The individuality of the surgeon was paramount in the 19th century but, as we shall see, has been progressively diminished since.

Surgery extends

Until the 19th century, surgery had been largely limited to wound and ulcer care, minor skin excisions and what Charles Bell described as the ‘great operations’ of surgery – skull trepan, hernia repair, limb amputation, ligation of aneurism and lithotomy for bladder stones. With increasing knowledge from morbid anatomy about the pathology of internal organs, from the mid-19th century, surgeons were able to consider entering body cavities and removing diseased organs for the first time.

Yet little surgery had been performed within the abdominal cavity because of the risk of introducing infection, which was frequently fatal. Abdominal surgery began with ovariotomy, the excision of ovarian cysts, when Ephraim McDowell (1771–1830) in Kentucky reported the first successful performance of this procedure in 1809. In Britain, Thomas Spencer Wells (1818–1897), who performed his first ovariotomy in 1857, published each of his cases in detail and robustly justified the procedure in the medical press. Yet the mortality rate when he published his first 50 patients in 1862 was 34%, mainly from infection, and most surgeons took the view that the high mortality did not justify performing the operation. Other more common operations also carried disastrously high postoperative infection and mortality rates. Joseph-François Malgaigne (1806–1865) in 1842 reported a 70% mortality rate following lower limb amputation in Paris, similar to the rate at the London Hospital between 1852 and 1857.
New science advances surgical progress

The developing understanding of the germ theory of disease and the advancing role of laboratory medicine would change all this. The decline in post-operative infection and mortality came from a new science, microbiology.

The French chemist Louis Pasteur (1822–1895) produced the evidence that microbes cause fermentation and putrefaction, a finding which revolutionised the understanding of infection. The German pathologist Rudolf Virchow (1821–1902) wrote Cellular Pathology, which set out the basis of the cellular theory of disease, where the cell is the basic structure of all living matter. Virchow dedicated his English language edition of Cellular Pathology to John Goodsr (1814–1867), professor of anatomy in Edinburgh, who had developed the ‘omni cellule e cellule’ theory that cells arose from other cells and that tissues were composed of organised, specialised cells. These concepts influenced the practice of surgery, by increasing the understanding of the nature of disease, based on a new science – microscopic anatomy. The idea that many pathological conditions were organ-based was one that led to organ excision and progressively to organ reconstruction or in some instances, replacement.

The 19th century also saw the introduction of other major advances in surgery based on scientific discoveries and applied to the care of patients. At that time, surgery was dominated by individualists who followed their own ideas in the practice of surgery, often based on personal experience and tradition rather than evidence.

The introduction of anaesthesia was clearly ground-breaking. William Osler later wrote, ‘Search the scriptures of human achievement and you cannot find any to equal the beneficence of the introduction of Anaesthesia, Sanitation, with all that includes, and Asepsis’.1

Based on Pasteur’s work, Joseph Lister (1827–1912) applied carbolic acid dressings to sterilise surgical wounds, progressing to treating instruments, ligatures and wounds with carbolic solution and the concepts of antisepsis developed further in the latter half of the 19th century. In Edinburgh, James Syme (1799–1870), professor of clinical surgery (and Lister’s father-in-law), had introduced what became known as the ‘cleanliness and cold-water school of surgery’. He advocated the washing of surgeons’ hands and washing of the patients’ skin with soap and water in the operating room, along with meticulous haemostasis.

The surgeon Robert Lawson Tait (1845–1899) had trained under Syme and also under James Young Simpson (1811–1870), the obstetrician who was the first to use chloroform as an anaesthetic. Tait later practised in Birmingham and became an enthusiastic advocate of the cleanliness and cold-water school. Until 1870, he had assiduously adhered to the details of Lister’s new antiseptic practice but, having found them wanting, devised his own regimen and became one of Lister’s fiercest critics. Tait promoted a regimen of surgical cleanliness: hand washing with soap and water, cleansing the patient’s skin in theatre with soap and water and turpentine for dirty cases, boiling his instruments and ligatures in water and washing the peritoneal cavity with water. Tait claimed not to use antiseptics (although he used turpentine), and in reality practised aseptic surgery before the term was invented.

20th century

Asepsis developed in the 1890s and in the early 20th century and it was further advanced by the surgeon William Arbuthnot Lane (1856–1943) who was effectively the first to routinely perform internal fixation for fractures of the lower limb. Lane also advanced aseptic surgery with his ‘no-touch’ technique. Surgeons’ hands were not allowed into the wound, his instruments were long handled to keep hands away from the tissues. Possible contamination was further reduced by these being given to the surgeon using other instruments and not by hand. Yet Lane was severely criticised and despite his success many surgeons still felt it was not justifiable to open a fracture and to risk introducing the possibility of infection. In a way, Tait and Lane exemplify the fearless surgeon described by the American surgeon Frederic Shepard Dennis (1850–1934) who wrote in 1905, ‘There is no science that calls for greater fearlessness, courage and nerve than that of surgery’. These surgeons embodied the attributes of fearlessness and courage but mainstream surgical opinion, conservative by nature, disapproved of what they perceived as reckless and risky innovation. Both men were certainly innovators and individualists whose contributions were to improve surgical outcomes.

At the beginning of the 20th century another influential change occurred, diminishing the role of such individualists, the introduction of ‘Scientific Management’ from industry. The concept of scientific management was created by the American engineer Frederick Winslow Taylor (1856–1915), who wrote ‘the aim of scientific management is to reduce men to act as nearly like machines as possible so that the workforce is no longer to be made up of individuals’. Taylor’s work was complemented by that of another American engineer, Frank Gilbreth,
(1868–1924) who published *A Primer in Scientific Management*, in which he described an ideal factory in which ‘every operation was performed according to predetermined schedules and definite instructions. By this means errors are prevented instead of being corrected’. Gilbreth encouraged specialisation, suggesting that a factory worker ‘needs a great deal of knowledge about his speciality, rather than a little knowledge about many kinds of work’.

The orthopaedic surgeon Robert Jones (1857–1933) applied scientific management principles to the care of his patients at the Royal Southern Hospital in Liverpool. Charles Macalister (1860–1943), a physician at the hospital at that time, wrote

> [Jones] got through an immensity of work. He had around him a number of helpers, some of them medically trained... others nursing staff trained in the application of splints and plaster of Paris... others kept an eye on the home conditions of the patients with reference to their feeding and regular attendance for massage, or other special treatment.

Robert Jones later applied this approach to workers during the construction of the Manchester Ship Canal and when Director of Military Orthopaedics in World War I, for the treatment of wounded soldiers. The medical historian Thomas Schlich noted that ‘Jones reorganised orthopaedic care by segregating patients according to their injury and introducing new modes of division of labour, standardization of supplies and clinical procedures, and continuity of patient care and aftercare’. In this way, Jones ensured that all staff conducted the same treatment according to predetermined schedules along defined instructions. By adopting these repetitive, practised movements, the surgical staff acted in much the same way as a machine and was a new way of viewing the human team and the organisation of labour. This could be seen as a prelude to the surgical guidelines, protocols and robotic surgery of the 21st century. As this approach was applied to surgery with uniformity in practice, standardisation of treatment and specialisation, the views and opinions of the individual surgeon became less relevant as the modern era of scientific surgery dawned.

By the middle of the 20th century, surgery had evolved dramatically because of the improvement in anaesthesia, asepsis, blood transfusion, antibiotics, imaging and more. But further change was to come with the influence of technology on surgical practice. Nevertheless, during this period the pioneers of surgery were still in many respects in the mould of the pioneers of the turn of the century. They were individualists who, driven by the desire to improve outcomes, pioneered new treatments for their patients.

One example was John Charnley (1911–1982), who pioneered the modern era of total hip arthroplasty. In his own workshop, Charnley designed and made his own instruments and implants (Figure 2), assisted by a skilled technician, Harry Craven (1928–2007). Charnley also worked with industry, particularly with Charles Thackray and Co., to develop the implants, and with Howorth Airtech to develop clean-air systems which ensured a significantly reduced risk of bacterial contamination.

Further technological advances in the 20th century included improved endoscopic lighting and optics, which, together with chip-camera systems, facilitated the onset of minimally invasive surgery. In the last decade of the century, ‘key-hole surgery’ rapidly came to replace open surgery for many common procedures.

### 21st century

The continuing drive to improve surgical safety and outcomes saw the widespread introduction of the surgical safety check list in the early 21st century. The Institute of Medicine published *To Err Is Human* in
2000 and showed that some 98,000 deaths in healthcare in the USA were preventable. The report recognised that larger surgical teams interacting around increasingly high technology inevitably raised the risk of complications. The widespread use of a Safe Surgery checklist introduced by the World Health Organization exemplified the increasing safety culture in surgical practice. The importance of human factors in the operating theatre was increasingly recognised as relevant to improving surgical outcomes, as were non-technical skills, for example situation awareness, decision making, teamwork and communication. As Scientific Management influenced practice at the start of the 20th century, models such as Systems Engineering Initiative for Patient Safety are becoming influential at the start of the 21st.

Surgical technology at the beginning of the 21st century saw the introduction of robotic surgery, which requires further specialist training by the surgeon. It also requires a different mindset, as the surgeon is usually seated at a console visualising the procedure via a screen some distance from the patient (Figure 3).

While applicable at present to a minority of procedures, its use is increasing. The Future of Surgery, a report commissioned by the Royal College of Surgeons of England (RCSEng), predicted that robot-assisted surgery will involve the use of ever smaller and smarter surgical robots, ‘micro-robots that are swallowed or otherwise implanted can navigate the body to fix medical issues and are then expelled’. The urologist John Wickham (1927–2017) predicted that ‘surgeons appear almost destined to become pure technologists despite the hope that they will remain the all-encompassing physician who operates’. In 1994, Wickham envisaged a surgical team that would be led by a Director of Interventional Therapy and would include: endoscopists; interventional radiologists; anaesthetists; bioengineers; nurse practitioners; and the surgeon. The Future of Surgery drew similar conclusions predicting that surgeons will need to become ‘multi-linguists, understanding the language of medicine, genetics, surgery, radiotherapy, and bioengineering’. Interwoven with these concepts of specialised technical skills of the surgeon is Technoscience, the interrelationship between the state, academia and industry. This includes availability of resources, the training and specialisation of the surgeon, and the standardisation of approach, as surgical activity is increasingly governed by regulators. All of these factors are apparent throughout the world in current healthcare programmes. However, as Geoffrey Bowker and Susan Starr pointed out in Sorting Things Out, ‘Standards have significant inertia and can be very difficult and expensive to change’. James C Scott, the American political scientist and anthropologist, wrote in Two Cheers for Anarchism, ‘The gospel of efficiency, is that technical training and engineering solutions implies a world directed by a trained rational professional elite’. He concludes that ‘Human nature seems to shun a narrow uniformity in favour of variety and diversity’. Scott’s view debunked the concept of a professional elite dictating universally applicable solutions suggesting that individualism is a fundamental human trait.

All this begs the question: are advances in surgery made by inspired chance by individuals – as by Charnley and the application of polyethylene in total hip arthroplasty – or by adhering to evidence-based scientific surgery as set out, for example, in NICE guidelines? The predictions of Wickham and the Future of Surgery are right in that surgeons are now team members. They are also in part technicians who must be familiar with sciences such as...
bioengineering and molecular biology but remain essentially team players, a far cry from the surgeons of the past where the views of the individual surgeon were paramount.

This also, to some extent, rejects Charles Bell’s position of the artistic ideal of surgery and raises the question of whether surgery can have any lingering pretentions to be an art form. The *Future of Surgery* talks of the changing relationship between the patient and the surgical team. How will this affect the patient’s perception of the surgeon, the individual perceived by patients as the one in whom they have to trust, in some cases with their lives?

The relationship between the patient and the surgeon can become complicated. The historian John Pickstone (1944–2014) argued ‘Doctor does not have the experience of dealing with a particular illness day in and day out, but the patient does and therefore patient groups are better informed’. There is now increasing emphasis on personalised care leading to greater patient involvement in decision making, a concept promoted by NHS England in *Shared Decision Making*, by The Academy of Medical Royal Colleges in *Choosing Wisely* and, of course, by patient support groups. The view of the patient about the management of their condition is ever more important. The landmark UK Supreme Court ruling in the Montgomery case in 2014 effectively gave patients the right to make their own informed decisions about their treatment, having been told the risks and benefits by the surgeon. So reason, and now the law, demands the use of evidence-based medicine when deciding which (if any) surgical procedure to recommend to a patient. Pressured by such patient involvement and increasingly constrained by guidelines, protocols and regulators, can there be any role for the surgeon to show the creativity, individualism and imagination needed if surgery is to progress?

In other words, will tomorrow’s surgeons have the freedom to develop and create innovative procedures and new techniques and technologies? In the drive to uniformity promoted by Taylor and Gilbreth, can there still be a place for the pioneers, the innovators, the Taits, Lanes and Charnleys? Taylor studied surgeons in training and argued that with scientific management the trainee surgeon would have ‘the best up to date knowledge, instead of reinventing things and would be able to use his own originality and ingenuity to make real additions to world knowledge’. On the other hand, the RCSEng report *Introduction of New Technology or Techniques in Surgery* stated that ‘there is no place for the maverick surgeon who proceeds without appropriate peer review or training’. It goes on, ‘Surgeons have a duty to consider carefully whether or not the innovation has a real patient benefit, at an affordable cost, both in terms of morbidity and mortality and of cost effectiveness compared with established procedures’.

Surgery has changed out of recognition since the latter part of the 18th century. Major advances in anaesthesia, imaging, transplantation and surgical technology, to name but a few, have long since displaced anatomy as the scientific basis of surgery.

**What then is the likely future role of surgeons?**

Surgeons are members of multidisciplinary teams, planning patient management and explaining to the patient not only possible benefits but also possible risks, complications and failures with their consequences. They are also part of a theatre team interacting increasingly with Technoscience. They will adhere all the more to evidence-based guidelines, protocols and policies. But at the centre of this will be the individual patients placed under the care of individual surgeons for treatment. Someone needs to retain ultimate responsibility for that patient’s care and that should surely be the surgeon.

Surgeons will remain more than simply technicians; yes, they will interact more with and rely on innovative technology; yes, they will adhere increasingly to those guidelines and protocols; yes. And yet surgeons should always be doctors, listening to and supporting the patients, showing them concern, compassion and empathy. Hopefully among their number will be some with pioneering spirit, imagination and flair, still able to innovate and advance surgical treatment for the benefit of all. The creative artistic, literary and investigative talent seen today among 21st-century British surgeons, heirs of the Hunters and the Bells, gives us confidence that the speciality will continue to pioneer advances.

The romantic poet John Keats (1795–1821) wrote in the *Fall of Hyperion* ‘sure a poet is a sage, a humanist, physician to all men’. A surgeon, in a comparable way when treating a patient under their care, is a repairer and healer of the body and should aim to be both a humanitarian and a physician to all.

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