

# 18 Pathology 2026: The Future of Laboratory Medicine and Academic Pathology

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***Traverse: Into The Future***

*by Je' Free*

*What I say now may be elementary –  
Once man unravels time and its mystery  
We travel to the past by memory  
Imagination's what our future will be*

*Delve in the theories of the human minds  
It's heaven or hell or in between those lines  
Push to one direction, a radical turn  
We see this paradox a great concern*

*We have explored it almost endlessly –  
How we can change the course of history  
Kaleidoscopic the world seems to be  
We need a mechanism to set us free...*

## **INTRODUCTION**

The future of laboratory medicine and academic pathology are inextricably linked. Predicting the future is considered by many to be a dangerous pursuit, not given to scientific validation, rather to conjecture. It is with the lines above echoing in my head that I write this chapter. Laboratory medicine in the past 30 years has achieved major advances, yet before attempting to predict the future for laboratory medicine and academic pathology in these islands, I think it is fitting for us to analyse where we as a discipline are now and how we are perceived by our medical/scientific colleagues, the public at large and our political and governmental masters.

In order to achieve this critical analysis, I will firstly carry out a SWOT (strengths, weaknesses, opportunities, threats) analysis of laboratory medicine and academic pathology in the year 2006.

### **Strengths of Laboratory Medicine and Academic Pathology as Assessed in 2006**

We are fortunate to have a young vibrant scientific and medical staff in laboratory medicine who are highly motivated and committed to excellence, while sometimes working in difficult

situations. There is a good standard of pathology practice in the UK and Ireland, with a major emphasis on diagnostic excellence, proficiency and accreditation. Greater numbers of clinical laboratories have now achieved accreditation and there is an expectation in the general public's mind that clinical laboratories are doing 'right by the patient', notwithstanding controversies over cytopathology screening in recent years.

Laboratory medicine still attracts bright medical and scientific graduates to work in the field, but this may not be sustainable in the future (see below).

The Royal College of Pathologists, the Association of Clinical Biochemists and Institute of Medical Laboratory Scientists (UK) and the Association of Medical Laboratory Scientists (Ireland) all operate successful and properly structured trainings schemes and provide further educational opportunities for members. The Pathological Society of Great Britain and Ireland, through their bi-yearly meetings and publication of the *Journal of Pathology*, acts as a strong advocate for academic pathology in these islands.

Greater research funding opportunities are now available to all pathology disciplines, and indeed young medical and scientific staff are encouraged to undertake research and pursue higher degrees as part of their professional development. Many pathology laboratories have now specifically set aside 'seed funding' to encourage staff to initiate research and to obtain preliminary research data in order to successfully compete for national/international research funding.

The biotechnology sector and reagent suppliers continue to seek the establishment of strategic research links with pathology laboratories in the UK and Ireland. Often this is pursued in an unstructured way with no specific operational guidelines for laboratories currently available. Specific R&D initiatives with third party companies are to be welcomed, because of the synergy that is achieved between basic science and the clinical laboratory. Access to future technology platforms, chemistries, etc. is to be welcomed, as this provides a vital spring board for innovation in our laboratories going into the future.

In general, laboratory scientists and physicians are not comfortable dealing with intellectual property rights (IPR) issues and discovery exploitation. This needs fundamental review by our college and professional bodies. The exploitation of discovery and protection of IPR are vital for the continuance of basic and translational research in our laboratories with/without the cooperation of external biotechnology interests. The informality of 'trying out a kit or testing reagents' for suppliers is no longer acceptable in a modern laboratory environment.

### **Weaknesses of Laboratory Medicine and Academic Pathology as Assessed in 2006**

It is generally accepted that service demands are increasing year on year, with little strategic investment by health strategists and planners in pathology departments. Currently, there appears to be insufficient time for strategic thinking by laboratory scientists and physicians, with the emphasis largely on turn-around times and productivity, reflected in new contractual arrangements for medical practitioners in laboratories. Most of us complain about increasing workloads, but in the process do not pursue or indeed present the requisite analysis in order to overcome this difficulty. This problem requires fundamental analysis and correction. Most of us encounter inappropriate testing requests, duplication of requests and inappropriate use of direct laboratory testing facilities where point of care testing would adequately suffice.

Medical staffing shortages, particularly in histopathology, have highlighted problems with recruitment and maintenance of staff, which for that discipline in particular may have serious repercussions in the future.

Inadequate funding structures for laboratories are universally encountered by all of us. It is common to see pathology and radiology services in hospitals/trusts competing for 'residual' finance, even though specific service plans have been developed for the laboratory. We appear to

be perceived as being peripheral, almost superfluous to general hospital activity. It is clear that our budget advocacy skills need significant sharpening if we are to compete with clinical disciplines in our hospitals/trusts. The development of directorate models has gone some way to addressing this, but has not cured the problem. Strategic *in silico* business modelling needs to be pursued by every laboratory medicine directorate in order to achieve the necessary recurrent income and capital investment stream to maintain activity and achieve strategic growth. Often, strategic growth is sacrificed on the altar of expediency, which we should not tolerate.

In recent years, laboratory infrastructure (premises and plant) has improved but there are still serious deficiencies. In Ireland, for example, capital depreciation analysis is not performed in public hospitals, which negates the normal capital depreciation cycle and makes it difficult for laboratories to achieve significant capital infrastructural resourcing.

The concept of tenure track promotion has not been embraced by British and Irish pathology. Although we encourage young scientific graduates to pursue research and achieve higher degrees, the non-reward system stymies significant career advancement in laboratory medicine for most of our bright, highly qualified scientists. We are all aware of the migratory tendencies to industry, etc. by such scientists, who represent a huge intellectual loss to laboratory medicine in the public sector. The politicians' mantra 'people are our greatest resource' is so true, particularly in laboratory medicine, but the people resource in laboratories is, I feel, often undervalued and poorly supported. Strategic tenure track programmes need to be developed for young science and medical graduates in laboratory medicine disciplines in order to retain and develop expertise in our disciplines.

The perception of pathology by the general public, particularly in wake of the recent organ retention controversy, is one of not understanding what pathology is, what pathologists/laboratory scientists do or indeed the relevance of pathology to modern medicine. I believe that in the past 20–30 years we, as laboratory medicine practitioners, have further re-enforced this idea of 'remoteness' from general hospital and community-based medicine because we have retreated to our laboratories and have not engaged with the general public to explain what laboratory medicine or to contextualise its role in modern medicine. Currently there are no substantive education outreach programmes in second-level education that critically examine career structure in laboratory medicine or indeed explore the world of laboratory medicine.

In the university sector, pathology-related subjects have been under pressure to be maintained in core curricula. Indeed, the traditional pathology department has disappeared from some of our medical schools and is on the edge of extinction in others. This has major implications for the future in our inability to attract good medical graduates to enter laboratory medicine disciplines. Without direct exposure to pathology subjects, to pathology laboratories and to pathologists and laboratory scientists, medical students will be unable to make informed decisions in relation to future careers in laboratory medicine.

How we view ourselves and how we are viewed by health administrators also constitutes a major weakness today. In general, pathologists and medical laboratory scientists are not good at marketing our skills base and tend to interact badly with the media. Health planners see laboratory medicine as low priority and constantly criticise us for not thinking strategically and in a business-like fashion. This is a valid criticism and one that needs addressing as we move forward into a more business- and strategy-focused healthcare sector.

## **Opportunities for Laboratory Medicine and Academic Pathology as Assessed in 2006**

Enormous opportunities still exist for all laboratory medicine disciplines. Because our 'bread and butter' business is diagnostic testing, the whole area of diagnostic test/kit development and the impact of *in vitro* diagnostic (IVD) directives, etc. has brought into sharp focus the role of

clinical and academic laboratories in diagnostic test development. Until now, test development and refinement has proceeded on an *ad hoc* basis, with clinical laboratories offering limited and non-contextualised testing for major reagent/kit manufacturers. There is now an absolute need for a standardised approach in this area with definition of IPR, discovery and the concept of added value being defined in any interaction between the laboratory and third part suppliers. To put it bluntly, kit and chemistry verification are central to successful technology platform development by industry, and laboratory medicine must see itself as a strategic partner in such a development.

The era of 'personalised medicine' offers enormous opportunities for laboratory medicine disciplines in the future, particularly in the area of devices, remote patient monitoring and custom-designed DNA, RNA and protein chips (see below).

New emerging technologies, including robotics, humanoid technology, lab-on-chip devices, nanodevices and patient 'smart' implants, will in the future offer unique opportunities for laboratories to develop new core business areas (discussed below).

The ability to form research networks within hospitals and universities and externally with industry offers a unique vehicle for laboratory medicine to achieve academic advancement. By placing laboratory medicine at the core of technology development in our hospital and medical schools, we will ensure a significant element of future-proofing for pathology. Strategically, pathology departments should even now be planning for future integration with the biotechnology sector through the development of 'bio-incubator units' in laboratories in order to develop translational cores in laboratory medicine.

The 1990s have seen unprecedented economic growth in the West. However, economies and economic growth usually follow cyclical trends: 'the boom bust cycle'. No-one knows for how much longer the 'boom cycle' will continue but it is certain that a decline will eventually supervene. Laboratory medicine is perceived as expensive by healthcare strategists and planners, with high staffing, capital and infrastructural costs, and consequently a sustained increase in base costs. It is clear that these costs, while sustainable in the current economic climate, are not sustainable in the long term. The lack of a unified and universally applied cost base analysis model for laboratory medicine disciplines again highlights the vulnerability in the current situation. Currently in Ireland a conversation has commenced in relation to the provision of laboratory medicine services in the Republic in order to achieve high economic cost benefit, controlled cost base and high quality service. Indeed, the provision of laboratory services in public hospitals is coming under increased scrutiny and how new models can be developed into the future is being assessed. The interaction between the public and private sectors has also received much attention and will become a dominant factor in relation to how laboratory medicine services are delivered in the future (see below).

## **Threats to Laboratory Medicine and Academic Pathology as Assessed in 2006**

If we remain as we are and do not alter the way we are perceived, we risk marginalisation of laboratory medicine. We need to change disciplines or parts of disciplines in order to redefine who we are, what we are and what we do.

We need to develop a strategic out-reach education programme and identify a national figure who will serve as an advocate for laboratory medicine, its mission and its role. We need to target specifically second-level education in education programmes organised by the Royal College of Pathologists and/or professional bodies.

We need to redefine laboratory medicine and support the advancement of 'clinical pathology/laboratory medicine' akin to the US model, making the pathologist/laboratory scientist more accessible and visible to clinical colleagues and other healthcare workers. The laboratory needs to be redefined in terms of its role in the hospital, and the community as a centre of diagnostics that is important and pivotal to the needs of the patient.

We need specifically to address how pathology is taught in our medical schools and arrest the erosion of pathology teaching that is currently taking place.

We need to resist fragmentation of traditional laboratory medicine disciplines away from laboratories. Currently haematology and immunology, having significant clinical contact, are moving more towards becoming clinical medicine disciplines, which will further erode the cohesiveness of diagnostic and academic laboratory medicine.

## **LABORATORY MEDICINE AND ACADEMIC PATHOLOGY IN 2026**

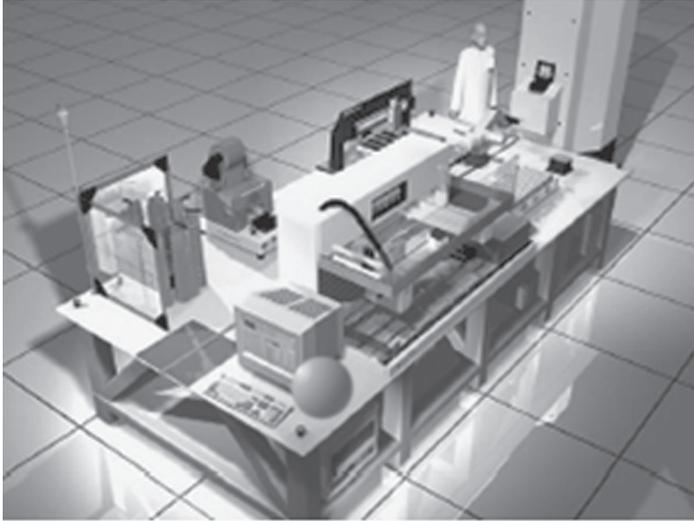
In 2026, laboratory medicine will be fundamentally different to practice in the year 2006. We will have come through a turbulent economic cycle of boom and bust and fundamental reviews of economic cost of healthcare provision will have taken place. The modern medicine environment will be organised on a hub and spoke motif: large supra-regional tertiary centres (hubs) and smaller local treatment centres (spokes). Laboratories will also be organised on a similar basis. Throughout the UK and Ireland, pathologists and laboratory scientists, in collaboration with venture capitalists, will have established limited liability companies in order to tender for laboratory services in their region. Variable success will have been achieved, with some companies facing liquidation or receivership. An extremely competitive market will exist, with two or three large private laboratory providers dominating and potentially controlling up to 35% of former public hospital laboratory practice. Significant benefits for the exchequer with reduced operating laboratory costs will be achieved. Significant investment in R&D by major private laboratory service providers will achieve strategic growth in the sector. Strategic alliances between large pharmaceutical companies and private laboratory service providers, to provide pharmacogenomic and metabologenomic biosensor diagnostic services in the home, will attract significant stock market interest and intensify debate in relation to artificial cell therapies for diabetes and hypertension.

### **The Environments in Which we will Work**

The mix of public/private laboratories in the UK in 2026 will be around 35% private and 65% public, but it is anticipated that by 2030 the ratio will be almost equal. New laboratories will be built in green field sites adjacent to major routeways in the UK and in Ireland (see Fig. 18.1). The new laboratory facilities will offer state-of-the-art ergonomically designed modular laboratory units with high reliance on robotic and humanoid features. Modular 'all-contained' drop-down units will feature prominently in new laboratories, offering greater flexibility and expandability.

High dependence on robotics, automated specimen handling, automated specimen tracking and humanoid technology will greatly simplify the management and tracking of specimens within the laboratory. The hub laboratories will provide diagnostic services in the following areas:

- Cellular Sciences
- Blood Chemistry
- Clinical Microbiology and Infectious Disease
- Diagnostic Molecular Pathology
- Cytogenetics
- Devices and Microsystems
- Information technology

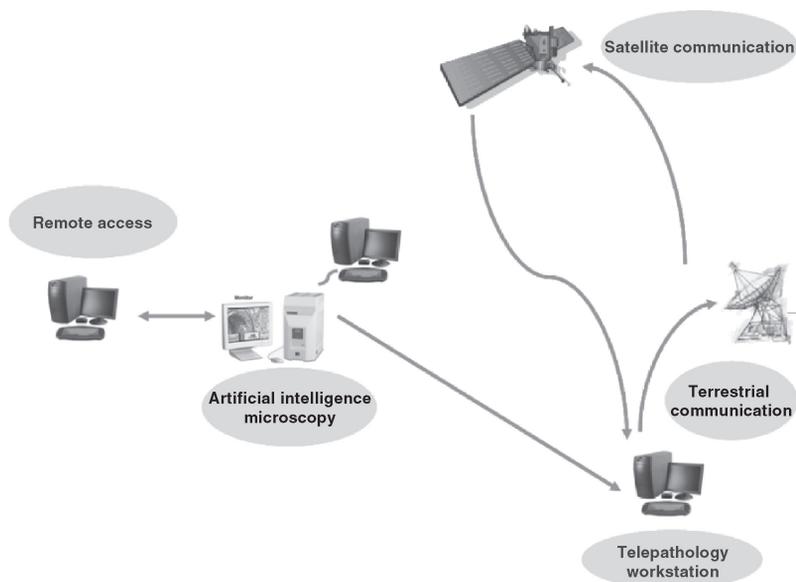


**Figure 18.1** Interior and exterior of a modern laboratory in the year 2026, showing modular open laboratories built to high specification and ergonomically designed.

- Forensicogenomics
- Stem Cell Biology and Biobanking

Indeed the Royal College and Professional Associations will have ratified the above consolidated laboratory discipline list and will have issued strict guidelines in relation to professional qualifications and training in each unitary discipline for medical and scientific laboratory staff.

The introduction of advanced practitioner scientists, clinical diagnostic scientists, skills mix managers and audit managers within the laboratory environment will revolutionise how we, as practitioners of laboratory medicine, will deliver our service to the healthcare sector.



**Figure 18.2** Reporting schema for cellular science in 2026, including use of artificial intelligence microscopy (AIM) and terrestrial and satellite communication.

## Cellular Science

In 2026, the EUROPATH consortium, bringing together public and private laboratories throughout the European Union to develop vital sign technology (tele-medicine), will be a major focus for cellular science laboratories in the UK and Ireland. The schema will involve the use of satellite communication, remotely controlled microscopy, artificial intelligence microscopy (AIM), widespread high-speed hyper-band internet communication and telepathology workstation platforms remotely accessible from within and without the laboratory. In addition, an element of terrestrial communication will be involved in this new super-highway cellular science diagnostic service (see Fig. 18.2).

Within the UK and Ireland, telesynergy will be achieved between many hub laboratories in the areas of cellular science oncological pathology, with free exchange of digital imaging in real time between centres. The EUROPATH consortium will offer a virtual ‘stat’ reporting system that will allow instantaneous access to pathologists throughout the European Union. This new system will effectively allow 24-h, 7 days a week virtual pathology coverage in cellular science for European citizens and will herald a new era in global healthcare approaches.

The development of new artificial intelligence (AI) automated cytoscreening technology with automated robotic preparation will revolutionise how we practice cytopathology within cellular science laboratory medicine. Artificial intelligence rare cell event monitoring (RCEM) with protein tag labelling of abnormal cells will be in routine use, in parallel with lab-on-chip detection of human papilloma virus (HPV) genotypes using real-time PCR and nucleic acid base amplification chips. Greater than 95% of laboratories will offer a fully automated cytoscreening service as a primary screening tool. The advent of multivalent HPV vaccines will have a major impact on cervical cytology services throughout the European Union. The need for pre- and post-vaccination assessment using cervical cytology will increase dramatically the workloads in cytopathology laboratories. Non-gynaecological cytopathology will continue to grow significantly, with the greater use of molecular proteomic and metabolomic genetic assays on single- and group-cell aspirates.

The new era of nuclear magnetic resonance (NMR) microscopy will have arrived. This will allow cellular pathologists to look at patterns of cells in a tissue and facilitate examination of cells for the presence, absence or mutation of genes that control growth and function and will facilitate examination of specific markers of disease. The magnetic resonance microscope will allow, for the first time, non-invasive three-dimensional visualisation of single cells in living tissues. It will exquisitely allow cellular diagnostics and allow us to view intracellular and extracellular distribution of water and molecules within cells, it will be an important diagnostic adjunct in the assessment of artificial cell systems that will be used in disease treatment and molecular pharmacology. Nuclear magnetic resonance microscopy will allow the visualisation of contrast labels, substrates and materials, including monoclonal antibodies in normal tissues and organs and lesions derived therefrom, and will be a major breakthrough in cellular sciences. These new innovations will allow investigation of cellular metabolism in individual cells and tissues in real time (cellular metabolo-imaging). CytoNMR (cNMR) and newer generation technologies, including atomic sensitivity NMR, will lead to further advances in the assessment of individual cells and tissues at a subcellular/atomic level.

## Blood Sciences

In 2026, the integration of haematology, transfusion medicine, biochemistry and immunology into a unified blood sciences discipline will have been achieved, largely reflecting the organisational infrastructure of modern laboratories based on open-design modular laboratories with high dependence on robotics and humanoid technology. Nanotechnology, bio-robots and microdevice detection systems (Microsystems) will be pervasive and will have revolutionised the analysis of bloods and blood-derived products in the laboratory. New specimen identification chips (Spec-Chip) will provide sample identification and incorporation of patient records within the sample cuvette and will revolutionise sample tracking within blood sciences.

The use of the personal profile chip (PPC) in haematology will be largely accepted and available for cardiovascular disease, autoimmune disease and detection of cancer signatures in peripheral blood. The majority of PPCs will be etched silicon wafers encompassing a number of biosensing technologies, including mechanical, electrochemical, chemi-luminescence and optical. The PPC will be a semi-permanent implant, fully compatible with neighbouring tissues. The first generation of PPCs will read by passing a hand-held scanner device over the implant. It is anticipated that in the future PPCs will be read by remote telemetry. The PPC will be supplied with a memory bank of genetic and biochemical data that are directly related to major diseases and the disease from which the individual is known to be at risk from a pertinent family history. The PPC will be organised on the following basis: with a flow-through chamber for blood with channels, lanes and compartments in which cells are identified and sorted by size. In another chamber the sorted cells are analysed chemically and a third section of the chip will be used for drug delivery if required. Phenotypic monitoring gene chips (PMGCs), which have the capacity to analyse directly genes in cells and tissue *in vivo*, will be introduced.

The use of diagnostic nano-robots in blood sciences will be commonplace and will be particularly useful in the dynamic monitoring of diabetes, ischaemic heart disease, hypertension, the metabolic syndrome and inherited inborn errors of metabolism (see Devices section).

## Clinical Microbiology and Infectious Disease

Clinical microbiology and infectious diseases will have undergone major innovation by the year 2026. Enhanced microbiological, virological and mycological susceptibility testing, advanced environmental monitoring, direct molecular microbiological epidemiology and organism strain identification with infectious disease tracking and population microgenomics will be pervasive. Microbiology and infectious disease will rely heavily on lab-on-chip devices,

including automated DNA, RNA and protein/peptide extraction chips coupled to organism identification chips and sequencing chips giving real-time analysis of patient specimens. Hand-held microbiology detection devices will offer real-time dynamic monitoring of infectious diseases in the primary care setting, remotely monitored by laboratories. The development will bring increased workload for the devices and clinical microbiology/infectious disease sections of all our laboratories.

The rise in bioterrorism events throughout the world, particularly with recombinant viral and fungal pathogens, will focus increased attention in clinical microbiology and infectious disease departments in relation to the identification and monitoring of bioterrorism in the field and within the hospital environment. Newly developed bioterrorism hand-held devices for the top eight infectious pathogens worldwide will be available for monitoring efforts in this area.

## **Diagnostic Molecular Pathology**

Diagnostic molecular pathology in 2026 will encompass the following sub-disciplines:

- Diagnostic genomics
- Transcriptomics
- Polysomics
- Proteomics
- Peptidomics
- Pharmacogenomics
- Metabologenomics

The use of high-density 500000 to 1 million SNP (short nucleotide polymorphism) diagnostic assays will be pervasive in laboratories. High-density cDNA array profiling of tumours will be commonplace. Custom-designed personalised SNP and cDNA and protein arrays will be available. High-density antibody and protein chip arrays will be used for the analysis of immune diseases and to assess the immune response to tumours in the context of therapy. Tumoural transcriptomics, polysomics and proteomics will form a substantial portion of diagnostic report formulation. As in blood sciences, patient-specific and disease monitoring chips will be widely available in order to monitor disease activity. Individual patient genome signature profiling will be commonplace, with the attendant ethical issues in relation to this type of screening. Individual laboratory and chip devices for specific disease monitoring will be available by custom design. The greater integration of metabologenomics, proteomics and peptidomics will allow us to further stratify treatment responses in certain disease conditions. The integration of basic sciences and clinical diagnostic molecular pathology will further achieve academic advancement for the discipline of laboratory medicine. Molecular pathology will be highly reliant on the devices section of laboratories, particularly in the area of microsystems (lab-on-chip devices, microfluidics, nanotechnology, etc.).

## **Cytogenetics**

Twenty-four-colour chromosome karyotyping/spectral analysis of tumours will be offered routinely in haematological malignancies and solid tumours. In addition there will be more widespread use of interphase cytogenetics, fine gene locus mapping and locus-specific sequencing of novel disease loci in patients with specific monitoring of locus-specific changes following treatment.

## Devices and Microsystems

Electrochemical detection of infectious agents, gene mutations, specific gene transcripts and proteins will be possible through the use of devices that can be used in the primary healthcare setting. The PPC (see Blood Sciences section) will be in widespread use. The use of nanodevices and smart implants will be pervasive in the device sector of laboratory medicine. Laboratory medicine will work very closely with microsystem engineers, developing new surfaces for chip devices, chip milling formats, micropore systems, microfluidic systems and nano/picolitre technologies, in the design and formulation of lab-on-chip devices for use in hand-held formats, 'black-box' doctor's office format and in integrated laboratory chip devices.

Microelectromechanical systems (MEMS) will be developed to inoculate individual red cells as they travel through capillaries. The use of nanoparticles will be used to direct targets for specific cells or tissues. The ability of nanoparticles to seek out cells and identify specific molecules with the ability to report dynamically the presence or absence of molecules will act as an initiation point for treatment procedures and will feature prominently in diagnostic blood science departments.

Nano-encapsulation and nanorobot technology will facilitate the delivery of drugs to specific parts of the body by means of the use of magnetic fields. This is likely to boost therapeutic benefit while minimising side-effects on other parts of the body. The use of nanorobots in blood sciences will be dominant, particularly in the monitoring of haematological malignancy, anaemia, ischaemic heart disease, hypertension, diabetes and inborn errors of metabolism and the metabolic syndrome. The use of 'smart implants' will also offer endless potentials. These 'smart implants' consisting of nanosensors will have the ability to detect DNA sequences in the body, enabling simpler and more effective diagnosis. For example, implant devices could dispatch a signal to pump the release of a therapeutic agent, i.e. insulin in diabetic patients.

Smart medical implants including intelligent artificial chips may have the ability to detect and destroy bacteria, for use in molecular microbiology. These smart medical implants (MEMS) will contain sensors with the ability to identify microorganisms and then trigger the release of specific antibodies stored within the implant. Medical devices using biosensors and fuel cells will be in widespread use by 2026. One such approach in ischaemic heart disease could be where the implantable device would monitor the release of natural chemicals in ischaemic heart disease, such as troponins, which indicate that a heart attack is eminent. Another approach could use a subcutaneous biosensor implanted under the skin surface connected to a second device (an optical fibre) designed to be inserted into blood vessels near the heart. This second sensor could potentially couple to a cardiac pacemaker that may be required by the patient with ischaemic heart disease, thereby directly regulating the pacemaker device. This will result in a new discipline in clinical medicine (therapeutic nanodevices).

The use of microfluidic fuel cells will revolutionise the use of long-running medical implants. These miniature devices will provide long-term power for medical devices such as implants to detect glucose levels in diabetics. In general fuel cells require an ion conducting membrane or selective catalyst of the electrode to separate the fuel-containing fluids, which has proved problematic in relation to the development of smart devices implantable in patients. The use of microfluidics and taking advantage of how fuels flow in small channels (in that they do not mix) will mean that fuels can be separated without the use of membranes in such smart devices. Fuel cells will work in tandem to provide power under pulsating conditions that mimic blood flow in the normal body.

The use of the PPC, which is implanted under the skin, will allow instant access to a patient's record. This device will transmit a signal to a scanner that allows healthcare professionals to confirm a patient's identity and obtain detailed information from an accompanying database linked to that patient. The use of implantable radiofrequency identification (RFID) microchips will be widespread in the year 2026. These new devices will allow active real-time autonomous monitoring of many conditions, particularly those involved in metabolic control.

The introduction of humanoid technology into laboratories in 2026 will be finally realised. Currently several multinational corporations, including Honda, are developing humanoid technology for potential use in the laboratory context. Greater artificial intelligence capacity in these humanoid forms will greatly simplify laboratory workflow procedures in the future.

### **Information Technology**

Information technology will feature very prominently in laboratories in the year 2026. The laboratory system of the future will:

- Focus on patients, enabling integration of community and hospital care and will increase the quality of care in patient outcomes through the integration of laboratory practice with the delivery of patient care.
- Deliver quality services that are responsive and sustainable.
- Use clinical outcomes as a primary measure of laboratory service efficacy.
- Coordinate the laboratory service delivery within health regions provincially and between hub and spoke laboratories.
- Employ various strategies, i.e. selected consolidation of testing, appropriate automations and standardisation (common laboratory information systems), to achieve cost effectiveness while attending to patient, clinician and systems needs.
- Employ information technology that facilitates the operation and management of the laboratory system and the delivery and management of healthcare.
- Utilise the systems approach to quality management issues and will foster the training, recruitment and retention of human resources within the laboratory system in order to pursue excellence.

Specialist scientists with degrees in information technology and laboratory medicine technology will be to the forefront in the development of information technology within our laboratories in 2026. They will have a pivotal role in relation to the interface between laboratories and their respective hospitals and between laboratories regionally and nationally.

### **Forensicogenomics**

There will be widespread use of SNP genotyping high-density arrays for the forensic identification of persons, samples and the exclusion of perpetrators of crime. In addition, RNA and PPCs will be available for forensic identification. The recently published international Hap Map (HM) and subsequent updates and the combined DNA index system (CODIS) will be widely used in 2026. These maps and systems will facilitate a unified approach to the forensic identification of patients/perpetrators of crime. Forensicogenomics will be performed by selected laboratories within the hub and spoke motif of laboratory organisation. It is anticipated that forensic science services will be partially privatised in the future, which will require further standardisation of procedures and methodologies for participant laboratories providing forensicogenomic services.

### **Stem Cell Biology and Biobanking**

Biobanking and stem cell biology will be extremely important components in laboratory medicine in the year 2026. Areas of development will include adult stem cell biology, tumour stem cell biology and somatic cell therapy. Stem cells will be selectively harvested and expanded for various

therapies, including vehicles for gene therapy, and to genetically and cellularly engineer organs such as liver, pancreas or central nervous system cells to treat a myriad of diseases. Traditional blood banks and pathology departments will become cell banks or gene banks, where repositories of blood stem cells with attendant processing facilities will be available. Some of these processing facilities will involve changes to specific cell types that may need to be replaced or corrected, generated or expanded by adding appropriate genes and growth factors. Reconstituted blood cells and growing tissues, and organs and organoids reconstituted in three-dimensional matrixes, will become a reality.

Organ culture in 2026 will become a reality. The availability of bio-artificial livers, hearts, etc. using cell entrapment technology (CET) will have expanded enormously. Clearly developments in biobanking, stem cell biology, generation of organs/organoids and organ culture will involve other medical disciplines and will be increasingly interdisciplinary. The whole area of adult stem cell biology and embryonic stem biology will need careful ethical guidance and will require a significant input from medical laboratory physicians, scientists and ethicists in the future.

## ACADEMIC PATHOLOGY IN MEDICAL SCHOOLS IN 2026

There will be widespread rationalisation of schools in the UK and the Republic of Ireland by 2026. In Ireland, I anticipate that four medical schools will provide medical, dental and paramedical education. It is anticipated that medical schools will be professional graduate schools much akin to the current US model. There will be an international network of medical schools throughout the European Union, with complete reorganisation of the current medical school complement. Medical schools will be required to support 300–400 graduate entrants per year, offering state-of-the-art facilities including virtual tele-medicine, nano-medicine and molecular medicine courses.

Academic pathology departments in medical schools in 2026 will largely have disappeared in the context of active expanding service departments. This appears a surprising statement but largely reflects the current decline of academic pathology departments in the UK and Irish medical schools unless we, as a discipline, fundamentally redefine ourselves in the future and seize the initiative and set out a bold agenda for academic pathology. One consequence of the current marginalisation of academic pathology in medical schools will be our inability to attract medically qualified graduates into laboratory medicine. I anticipate that there will be less medically qualified trainees available, particularly in the laboratory-based disciplines of cellular sciences, forensic genomics, cytogenetics and molecular pathology. It is anticipated that the more clinically based disciplines such as haematology, immunology and clinical biochemistry will still be able to attract medically qualified trainees to their disciplines. With less medically trained trainees, this will bring about a fundamental realignment of how pathology diagnostic services are provided in laboratories. Today in 2006, the concept of consultant-led diagnostic services is foremost in all of our minds. However, the concept of medical-consultant-led diagnostic services in the year 2026 will not be sustainable if we are unable to attract medically qualified trainees. In this regard, I believe that there will be more consultant medical scientists, advanced medical science practitioners and skills mix managers within our laboratories who are not medically qualified.

The position of Professor of Pathology will largely have disappeared from medical schools in the year 2026. Individuals will still be called professors of a particular pathology discipline with individual chairs in divisions of clinical sciences or will have devolved very strategic areas of expertise, e.g. Professor of Pathology Microsystems, or Professor of Tumoural Proteomics. Haematology, immunology and clinical biochemistry will continue to interface academically with clinical medicine disciplines. However, the cellular science disciplines of histopathology

and cytopathology will largely remain laboratory based and will suffer from a lack of medical scientific graduate entrants into the discipline. However, molecular pathology and cytogenetics will be pivotal in terms of a laboratory/clinical medicine translational base and may offer growth opportunities within laboratory medicine going forward.

## **EDUCATION OF MEDICAL LABORATORY SCIENTISTS AND BIOCHEMISTS IN LABORATORY MEDICINE IN 2026**

Strategic national centres of teaching and research excellence for medical scientists and clinical biochemists will in place by 2026. I anticipate that there will be formalised professional and academic MSc, PhD and DSc programmes for medical scientists and clinical biochemists who wish to avail themselves of this. There needs to be a diploma/membership of the Royal College of Pathologists for scientists who wish to pursue advanced practitioner status in their relevant pathology disciplines. In some disciplines such as cellular science (e.g. cytopathology) there will be an absolute need for specialised vocational MSc and PhD courses organised by laboratories with the support of local health agencies to further encourage, support and attract scientists into this discipline. Advanced practitioner courses and diplomas will have to be supported at this time. Indeed, the need for continuing professional development (CPD) will also require funding from source funders within our laboratories.

## **HOW DO WE MOVE FORWARD TO ACHIEVE EXCELLENCE IN 2026?**

In the earlier part of this chapter I carried out a SWOT analysis of pathology in 2006. Although there are many strengths and many opportunities, there are significant weaknesses and threats in all disciplines within laboratory medicine. I believe that pathology needs to redefine itself as a unitary discipline and redefine its position within modern medicine, within society and within the world.

We need to develop greater advocacy skills for our disciplines and establish a European Pathology Forum to formulate strategies for education, research, service development and staff recruitment.

- We need to establish academic career advancement programmes, including tenure-track programmes for medical staff, medical trainees, medical laboratory scientists and biochemists.
- We need to encourage the formation of centres of research excellence in laboratory medicine based on the hub and spoke motif as outlined above.
- We need to establish pathology fellowship training programmes for medical and science trainees within laboratory medicine disciplines.
- In addition, we need to establish industrially supported MD, PhD and DSc studentships for medical and scientifically qualified graduates within laboratory medicine. This I believe is key in terms of achieving growth going forward for all laboratory disciplines in the greater family of laboratory medicine.

Laboratory medicine scientists and physicians need to be more proactive in spearheading service developments in pathology arising from the translational research they carry out and we need to properly address intellectual property rights and exploitation issues in relation to the fundamental basic science research that is currently being performed in laboratory medicine academic

departments so that this is translated to the laboratory bench and exploited by the laboratories. Laboratories need to take a lead role in the biobanking, genome resource banking and national cancer genome survey initiatives that have recently been launched.

Most importantly, laboratory medicine needs to think like a business! We need to develop a pathology corporate strategy in our medical schools and hospitals to:

1. Attract external funding from the biotechnology sector (national and international agencies).
2. Establish international research and education networks.
3. Establish endowed studentships for MD, PhD, MSc and DSc students.
4. Establish endowed lectureships and professorships in laboratory medicine with significant support from biotechnology and industry partners.

Furthermore, we need to examine critically the role of private income generation and its potential use as seed capital funding for strategic academic, technological and scientific development within our laboratories. Pathology departments should now be establishing business translation incubator units (BTIUs), in collaboration with hospital institutions, universities and industrial/biotechnology partners. This is fundamental in relation to achieving growth within laboratory medicine. It allows significant technology transfer, access to 'blue sky' technology, access to innovative thought processing in relation to new chemistries and technology platforms that are currently being developed by the biotechnology sector. We need urgently to develop significant expertise in IPR in order to cope with the exploitation of discovery. Pathology disciplines should now start to provide essential core facilities for medical schools in order to regain the initiative and re-establish laboratory medicine/pathology as a fundamental discipline within medical schools. Such core facilities could include cDNA, CGH array facilities, tissue biobanks and laser capture microdissection, to mention just a few.

However, in the final analysis, laboratory medicine will only succeed based on its people resource. We need to create the pyramid effect in attracting and maintaining people of excellence in service and academic pathology. Mentoring programmes for medical and science graduates within laboratory medicine are extremely important in order to encourage the best, to retain the best and to ensure that the best seek academic advancement for themselves and their discipline. Only by employing this pyramid effect will we see strategic growth within laboratory medicine and protect a rich heritage that has been passed on to all of us.

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### The sleeper down from Glasgow

In arranging the Winter meetings of the Society the committee showed scant, indeed no regard for Scottish traditions at Hogmanay (New Year's eve): the advent of New Year was always a cause for celebration, sometimes indeed (even frequently) more rumbustious than those for Christmas. It was traditional to 'first foot' neighbours and friends, to toast the New Year in uisge beatha (whisky) and the celebrations always ran into the first week of the New Year: indeed it was not uncommon to toast and wish friends a Happy New Year well into January. Winter meetings were not unknown to start on the 3rd of January and this was certainly an incursion on the traditional celebrations, as for that matter were meetings beginning on any date in the first week of the year.

The Glasgow contingent for the meetings was a large one combining the academic staffs at the Royal and Western Infirmaries – Professors, Senior Lecturers and Lecturers (and in the late 1960s the last group comprised 12). We travelled back and fore on British Rail sleepers: 2nd class, two berths per compartment with departures at both Glasgow and Euston being 23.50 hrs and a requirement to disembark no later than 08.00 hrs. Certainly on the outward

journey there was much social intercourse and in keeping with time honoured custom drinks were exchanged; it is true to say that much whisky was consumed, but never to excess! The senior staff were generous but carefully abstemious; single malts were a specialty and in particular Talisker was the favourite – suited me well as part Sgiathanach (Skyeman): the juniors were sometimes experiencing their first single malt and there was the occasional mishap – one visiting trainee from East Africa found whisky to his liking and required some gentle care on arrival at Euston: there were occasional spillages and sometimes confusion reigned on trying to get back to one's own compartment only to find the sleeping car attendant had re-allocated what he presumed was a vacant bed/compartment.

On arrival at Euston we separated and made for our respective hotels: the Royal group favoured the Cora Hotel (Woburn Place/Southampton Row) while the Western group were more up-market and enjoyed the luxury of the Bloomsbury hotels – the Ivanhoe and Kenilworth being favoured: additionally they reminded us of our Scottish literary heritage. However, when the meeting was at Oxford I recall the Royal group enjoying the luxury of the Randolph Hotel while we struggled furiously to keep warm in a stony, frigid, mediaeval College.

There was keen competitive rivalry between the two departments. Which one had the more papers accepted? Which ones were best presented? The 'Path Soc' meetings filled the juniors with fear and trepidation – serial ranks of Professors in the first few rows many of whom could spot a hair on the slide or a crack in the sections at a distance of 50 yards and this without spectacles; and woe betide any who read their script. The junior members from the Royal were apparently always advised to slip a Vitamin C tablet into their mouths just before beginning their delivery: it certainly avoided 'drying out', but on one occasion a now senior retired pathologist taking part in a telecast popped in a tablet without realising it was effervescent – the result was spectacular!

Socialising also took place in the course of the meeting, we discriminating Scots preferring the elegant a la carte cuisine of some Soho restaurants to the table d'hôte of St Ermin's Hotel in the dingy surroundings of Victoria and where the dinner was wont to be held. On one such occasion the waiter asked for orders for the dessert and one of our group caused consternation when he demanded a 'pokey hat' (ice cream cone) and would not countenance refusal. It was our wont to continue some carousing on our return to the hotels in the evening. These were the days of last drinks at 22.00 hrs and one depended on the night porter getting us the necessary night cap. On one occasion 10 whiskies were ordered, and after a seemingly interminable wait a somewhat disgruntled porter eventually delivered. He was immediately asked for 10 more and again belatedly returned with but only 5 glasses and announced that the hotel had run out of whisky! A new venue was chosen for next year.

I have had various accounts of the following incident and can only vouch for the veracity of there having been a major shindig. Was it the Cora or the Randolph Hotel? Was the party in one of the Professors' rooms? Did the couple next door complain or did they join the festivities? In any event a shelf (or was it a wash-hand basin?) in the room was supporting a large collection of bottles and glasses when someone leaned heavily against it, detaching the shelf from the wall and releasing a cascade of bottles and drinks on the floor! The next morning when the incident was reported to the reception manager he re-assuringly remarked 'don't tell me the shelf has come away from the wall again'.

These are some of the printable fond memories of the sleeper trips and the winter meetings of the Path Soc, representing the usual extension of the Hogmanay celebrations for us Glaswegians. The recollections are now a little dim and the detailed accuracy less certain – whether due to amnesia close to the event or whether due to long-term memory impairment I am uncertain. The

cameraderi engendered by these trips was unique and allowed the two departments to first foot each other and begin the year in good fellowship.

**Roddy MacSween**

*I have not mentioned any names in the above, but I would acknowledge input from Professors Fred Lee and David Murray and Drs Peter Macfarlane and George Lindop*

