CHAPTER 1
INTRODUCTION TO CLINICAL LABORATORIES

Key learning topics

- The role of the nurse in patient testing
- The five sub-disciplines of clinical pathology
- Clinical laboratory staffing and costs

Patients may be subjected to many kinds of investigative procedure. These range in complexity from ward or clinic based measurements familiar to all nurses, such as determining body temperature, pulse and blood pressure, through monitoring of heart function by electrocardiographic (ECG) machines to body imaging techniques, such as X-ray, computed tomography (CT) and magnetic resonance imaging (MRI) scan. All of these require the presence of the patient; they are performed on the patient, if not by nurses, at least often in their presence.

In contrast, all the investigations described in this book are performed on samples removed from the patient. The remoteness of patients from the site of laboratory testing might engender the understandable though misguided perception that laboratory testing has little to do with nursing care. In fact an understanding by nursing staff of the work of clinical laboratories is important for several reasons.

Nurses are in a unique position to satisfy the need expressed by many patients for information about the tests that they are subjected to. Recent research[1] confirms the intuitive notion that patients want to understand the purpose of tests and significance of their test results. This may be to allay fears and anxieties among those who have never undergone such a test before, or it may simply reflect a right to know. Most laboratory tests are only minimally invasive but can only be done with a patient's implied informed consent. Of course many patients will express no interest, but some have questions that must be addressed.

Understanding Laboratory Investigations: A Guide for Nurses, Midwives and Healthcare Professionals, Third Edition. Chris Higgins.

Nurses sometimes have responsibility for the collection and timely, safe transport of patient samples. It is vital that anyone collecting samples is aware of the importance of good practice during this pre-testing phase.

Nurses are frequently involved in the reception of laboratory test results. It is important that they are familiar with the terminology and format of laboratory reports and are able to identify abnormal results, particularly those that warrant immediate clinical intervention.

For many years nurses have performed limited testing of blood and urine samples (e.g. blood glucose and urine dipstick testing) in wards and clinics. With advances in technology, an ever increasing repertoire of tests can now be performed, within minutes, outside the laboratory in clinics and wards by nursing staff. This so called 'point of care testing' is particularly well established in intensive care, coronary care and emergency room settings where speed of analysis has proven benefit for patient care. It is important that nurses involved in the analysis of patient samples understand the pitfalls, limitations and clinical significance of this aspect of their work.

Traditionally, doctors have had sole responsibility for both requesting and interpreting laboratory test results, but the developing role of the clinical nurse specialist has required that some nurses become involved in both of these processes. In any case all

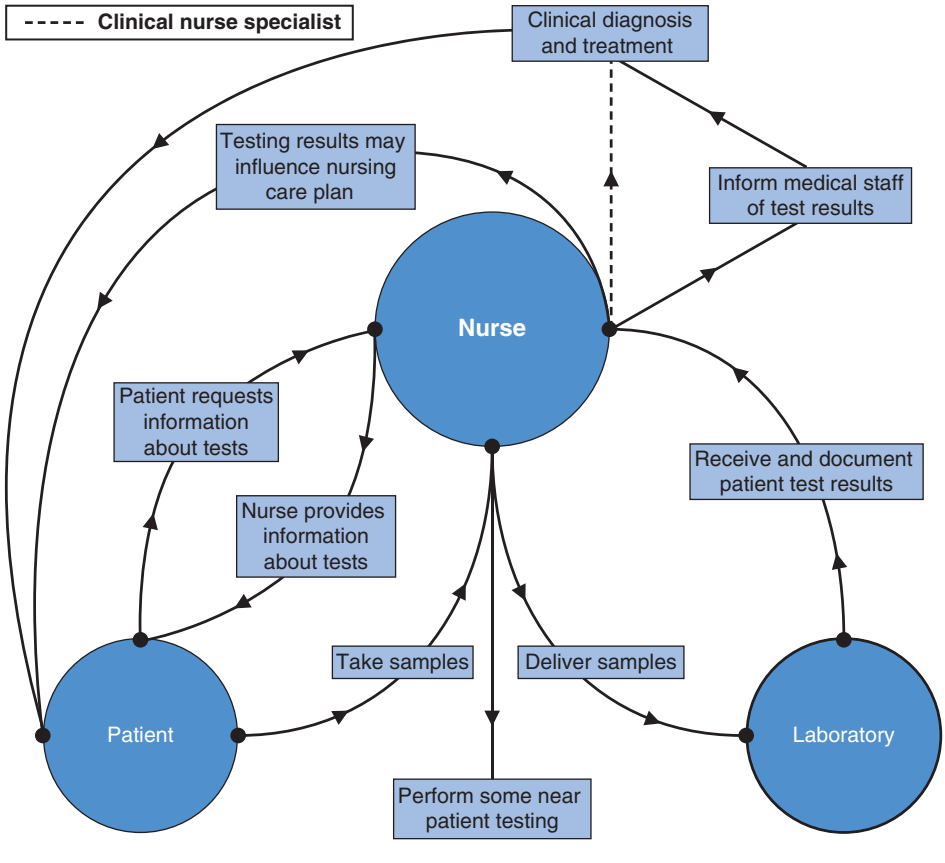

Figure 1.1 Nursing staff involvement in testing of patient samples.

qualified nursing staff members have to make judgements about how the results of laboratory tests might impact on the formulation of nursing care plans for their patients.

Finally, there are those nurses whose professional role requires especially detailed knowledge of the work of the laboratory as well as close co-operation with laboratory staff. These include haematology nurse specialists, blood transfusion nurse specialists, infection control nurses and diabetic nurse specialists. Figure 1.1 summarises the role of nursing staff in laboratory testing.

All the tests described in this book are performed – although, as has been made clear not exclusively so – in clinical pathology laboratories. The second part of this introductory chapter serves to describe in outline the work of the five sub-disciplines of clinical pathology. The range of samples tested is listed in Table 1.1.

Table 1.1 Range of samples used for laboratory investigation.

	Sample type
Chemical analysis	Usually blood or urine Less common: ● Faeces ● Cerebrospinal fluid (CSF): this is the fluid that surrounds the brain and spinal cord ● Pleural fluid: this is the fluid that surrounds the lungs in the pleural cavity and is only obtainable when there is abnormal accumulation, a condition called pleural effusion ● Ascitic fluid: this is the fluid that surrounds the abdominal organs in the peritoneal cavity and is only obtainable when there is abnormal accumulation, a condition called ascites
Haematological analysis	Usually blood only Less common: ● Bone marrow aspirate ● Bone marrow biopsy
Microbiological analysis	Common: ● Urine ● Faeces ● Sputum ● Swabs of any (potentially infected) accessible site including: throat, nose, eye, wound, vagina Less common: ● Cerebrospinal fluid ● Pleural fluid ● Vomit ● Skin scraping
Histopathological analysis	Tissue samples (biopsy) only
Cytopathological analysis	Urine Sputum Cellular material obtained by scraping the surface of organs or aspirating abnormal fluids (e.g. cysts)
Immunological analysis	Usually blood only

The clinical chemistry laboratory

(also known as chemical pathology, clinical biochemistry)
Clinical chemistry is concerned with the diagnosis and monitoring of disease by measuring the concentration of chemicals, principally in blood plasma (the non-cellular, fluid portion of blood) and urine. Occasionally, chemical analysis of faeces and other body fluids, for example cerebrospinal and pleural fluid, is useful.

Blood plasma is a chemically complex fluid containing many inorganic ions, proteins, carbohydrates, lipids, hormones and enzymes, along with two dissolved gases, oxygen and carbon dioxide. In health the concentration in blood of each chemical substance is maintained within limits that reflect normal cellular and whole body metabolism. Disease is often associated with one or more disturbances in this delicate balance of blood chemistry; it is this general principle that underlies the importance of chemical testing of blood for the diagnostic process. The range of pathologies in which chemical testing of blood and urine has proven diagnostically useful is diverse and includes disease of the kidney, liver, heart, lungs and endocrine system. Diseases that result from nutritional deficiency can be identified by chemical analysis of blood. The cells of some malignant tumours release specific chemicals into blood. Measurement of these so called tumour markers allows a limited role for the clinical chemistry laboratory in the diagnosis and monitoring of some types of cancer.

The safe and effective delivery of some drug therapies depends on measuring the blood concentration of those drugs. This is just one aspect of the broader monitoring of treatment role that the clinical chemistry laboratory serves.

Most chemical testing of blood and urine is performed on highly sophisticated, automated machinery. Modern clinical chemistry analysers can perform up to 1000 tests per hour; 20 or more different chemical substances can be measured simultaneously on these analysers using a single blood sample. Results of the most commonly requested tests, which include nearly all those discussed in this book, are usually available within 12–24 hours of receipt of the specimen. More rarely, requested tests may be performed just once or twice a week, and a small minority are only performed in specialist centres. Nearly all clinical chemistry laboratories provide an urgent 24 hour per day service for a limited and defined list of tests; results of such urgently requested tests can usually be made available within an hour.

Critically ill patients being cared for in intensive care units and emergency rooms often require frequent and urgent monitoring of some aspects of blood chemistry. In these circumstances blood testing is performed by nursing staff, using dedicated analysers sited close to the patient; this represents one aspect of point of care testing.

The haematology laboratory

Haematology is concerned principally with the diagnosis and monitoring of diseases that affect the number, size and appearance of the cellular or formed elements of blood. These are: the red blood cells (erythrocytes), the white blood

cells (leucocytes) and platelets (thrombocytes). The full blood count (FBC) is probably the most frequently requested laboratory test and certainly the most frequently requested haematology test, reflecting the range of common and less common disorders which affect both the numbers and appearance of blood cells. It is in fact not one but a battery of tests.

Modern haematology analysers are able to process FBC tests at the rate of up to 400 samples per hour. The detailed information about the blood cells which these analysers provide has dramatically reduced the number of specimens that need to be examined under the microscope, but the microscope remains an essential tool to the haematologist for examination of bone marrow biopsy specimens and, in some circumstances, blood.

Apart from the cells in blood, haematology is also concerned with measurement of the concentration of some of the proteins present in blood plasma that are involved in the complex process of blood coagulation.

Disorders of blood in which haematology testing is vital include haematological malignancy (e.g. the leukaemias, Hodgkin's disease, myeloma), anaemia and diseases in which disturbances of blood coagulation result in an increased tendency to bleed (e.g. haemophilia) or an increased tendency for blood to coagulate within blood vessels (e.g. deep vein thrombosis). Some haematology tests including the FBC are useful in the diagnosis or clinical management of common, non-haematological diseases. For example, infectious disease is usually associated with an increase in the number of white blood cells. Anaemia is often a feature of kidney disease, chronic inflammatory disorders such as rheumatoid arthritis and some diseases that result from nutritional deficiency.

Many patients at risk of heart and blood vessel (cardiovascular) disease are prescribed medication that inhibits the process of blood clotting (coagulation). This anticoagulation therapy must be monitored by regular blood testing to prevent bleeding, a potentially dangerous side effect of such therapy.

Most haematology test results are routinely available within 12–24 hours. However if the need is clinically justified, results of some haematology tests, including FBC, can be made available within an hour, at any time of the day or night.

The clinical microbiology laboratory

Clinical microbiology is concerned with the diagnosis and monitoring of disease caused by infective agents, mostly bacteria but also viruses, fungi and parasitic worms. Much of the work involves isolation and identification of bacteria from many sorts of sample, including urine, sputum, faeces, blood, cerebrospinal fluid and swabs taken from a variety of infected sites. Bacteria can sometimes be seen by examining these specimens under the microscope, but more precise identification can only be made after culture, or 'growth' of bacteria on nutrient enriched media. One of the problems encountered by the microbiologist when dealing with clinical specimens is that many bacterial species are normally present in many sites around the body; indeed in some cases they are essential for normal health. The

microbiologist must isolate those that are pathogenic (i.e. cause disease) from those that are normally present, and from any environmental bacterial contaminant introduced during sample collection. Some body fluids are normally sterile; these include blood, cerebrospinal fluid, and fluid aspirated from joints and the pleural cavity. Bacteria isolated from these sites are always pathogenic.

Having isolated and identified a species of pathogenic bacteria, the next step is to test the sensitivity of the organism to a range of antibiotics. This information helps in deciding which antibiotic therapy is likely to be most effective in eradicating the infection.

Blood testing plays an important and evolving role in detecting infections that are caused by organisms difficult to isolate by culture. During any infection the immune system produces specific antibodies directed at specific antigens present on the surface of the invading organism. A rising amount of the antibody in blood provides evidence of current infection.

Specific antigens present on the surface of microorganisms also provide a means of identifying infective agents. Testing blood for the presence of viral antigens is an important means of diagnosing viral infections such as those which cause hepatitis and acquired immune deficiency syndrome (AIDS).

Some microbiological investigation may take from several days to several weeks to complete; this delay is governed largely by the speed of bacterial growth in culture. Initial microscopical examination can be performed immediately on receipt of the specimen if clinically necessary, and results can usually be made available on the day the sample is received in an interim report.

Clinical microbiology laboratories operate a 24 hour service for the rare cases when urgent culture and microscopical examination of samples is necessary. These include suspected cases of immediate life threatening infections of blood (septicaemia) and central nervous system (meningitis).

Quite apart from their diagnostic role, hospital microbiology laboratories play an important role with infection control nurses in the monitoring and prevention of nosocomial infectious disease, that is infectious disease acquired by patients whilst in hospital – an ever present problem, which impacts on the working life of all nursing staff.

The blood transfusion laboratory

Blood transfusion is concerned with the provision of a safe supply of blood and blood products. In contrast to other pathology departments, blood transfusion has limited diagnostic function. In some senses its function more resembles a pharmacy, in that its main purpose is to supply therapeutic products. Transfusion of whole blood is very rarely practiced nowadays; rather specific components of whole blood are transfused. The most frequently transfused blood product is red cells, to correct anaemia and to replace blood lost during surgery or as a result of trauma or complication during childbirth. Much less commonly, the white cells of blood, platelets and the proteins present in blood plasma are therapeutically useful.

The National Blood Service (NBS) is responsible for the collection and supply of safe (disease free) donated blood products to hospital blood transfusion laboratories. Here, each donated unit of red cells must be tested for compatibility with the patient's blood before it can be transfused. The transfusion of incompatible blood products can have very serious health consequences and is potentially fatal. Advances in compatibility testing have ensured that compatible red cells can be made available for transfusion usually well within an hour of a patient's blood sample arriving in the laboratory; this service is available 24 hours a day.

The blood transfusion department also has an important specific diagnostic role for some forms of haemolytic anaemia, in which the body produces antibodies against its own red cells. One important aspect of this work is haemolytic disease of the newborn, a potentially fatal condition in which the red cells of the developing foetus are destroyed by antibodies present in the mother's blood. All pregnant women are routinely tested for the presence of such antibodies.

The histopathology laboratory

(also known as morbid anatomy, cellular pathology)

Histopathology, the oldest of all pathology disciplines, is concerned with the diagnosis of disease by microscopical examination of tissue samples (biopsies). The rationale for this approach is that disease processes, for example, malignancy, inflammation, infection etc., are characterised by specific changes at the tissue and cellular level, which are evident when tissue is viewed under the microscope. There are many ways of recovering tissue samples from the body. Tissue from the gastrointestinal tract, lungs and urinary tract are commonly sampled at the time of endoscopic examination. An endoscope is an instrument used to visually examine internal organs directly by fibre optics. The instrument includes small forceps which can be used to remove small pieces of tissue during the examination. Tissue may be taken during surgery by incision or excision biopsy. Incision biopsy is the removal of a sample cut from an area of diseased tissue, whereas excision biopsy involves removal of the whole area of diseased tissue.

Before transport to the laboratory, biopsy samples must be 'fixed' in a chemical fixative, usually formalin, to preserve structure. This process can take from a few hours to a whole day depending on the size of the specimen. In the laboratory 'fixed' specimens are impregnated with paraffin wax, allowed to harden and then cut into very thin sections just 3–5 µm thick. These wafer thin sections are then mounted on glass microscope slides and stained with chemicals, before examination under the microscope. The whole process from reception of specimen to issue of a histopathological report can take from one to four days depending on the size of the biopsy sample. Sometimes it is important to make a diagnosis very quickly, and in these circumstances a frozen section is performed. Tissue is 'fixed' immediately by freezing. This process allows tissue sections to be cut almost immediately the sample is removed from the patient. The sections are stained and examined under the microscope. This rapid technique allows a diagnosis of, for example,

breast cancer to be made rapidly whilst the patient remains anaesthetized on the operating table. Armed with a laboratory report that confirms malignant disease, the surgeon can proceed immediately to surgical treatment.

Microscopical examination of tissue removed from the patient is probably most widely used in the diagnosis and staging of malignant disease in organs throughout the body. It is also used in the differential diagnosis of non-malignant disease of all body organs. It has a role in the diagnosis of connective tissue and skin disorders and in the early diagnosis of tissue rejection among patients who have received transplanted organs.

Clearly all histopathological tests are invasive, often requiring surgical intervention to recover samples. Both financial and patient safety consideration ensure that, unlike other laboratory investigations, histopathological investigations are reserved for those patients in whom there is a strong suspicion of serious disease. In many cases this suspicion will have been raised by the abnormal results of blood and urine tests performed in other pathology laboratories, so that histopathological examination of tissues can represent the final stage in laboratory diagnosis.

Finally, post mortem examinations to determine cause of patient death are conducted in the hospital mortuary, which is administratively part of the histopathology department.

Cytopathology

Cytopathology is a sub-discipline of histopathology. Whereas histopathology is concerned with microscopical examination of tissue samples, the focus of the cytopathologist is the cells that are normally exfoliated from the epithelial surface of organs. Sample recovery is less invasive than that required for histopathological investigation. Typically cells are scraped from the surface of organs such as the cervix, the mucosal surface of the duodenum and stomach and lungs. Cells can also be recovered by aspiration using a fine needle and syringe, from the pleural and peritoneal cavities, or from solid tumours, for example, in the breast. The cells are spread onto a glass microscope slide, fixed and stained and then examined under the microscope. Cytopathology is almost exclusively concerned with diagnosis of pre-malignant and malignant disease. The cervical smear test, used to screen all women for risk of cervical cancer, accounts for a large proportion of the workload of the cytopathology laboratory.

The immunology laboratory

Clinical immunology laboratories are concerned principally with blood testing for the diagnosis of autoimmune diseases, in which the body's normally protective immune system produces antibodies against its own tissue antigens. These self-reacting, destructive antibodies are called autoantibodies. The detection in blood of organ specific autoantibodies is helpful in the diagnosis of many diseases with an autoimmune component including coeliac disease, thyroid disorders, pernicious anaemia, systemic lupus erythematosus (SLE) and autoimmune disease of kidney and liver disease.

Laboratory staffing

Clinical laboratories are staffed by graduate trained biomedical scientists (BMS), who are responsible for the analysis of samples and the overall day to day management of the laboratory departments. They are helped in the analytical task by medical laboratory assistants (MLAs) who may have the additional responsibility of blood sample collection (phlebotomy) from patients. Cytoscreeners are a specially trained group whose work is confined largely to the examination of cervical smears.

Each laboratory department is headed by a medically qualified doctor of consultant status who has specialised in one area of laboratory medicine (in some cases a non-medically qualified clinical scientist fulfils this role). They provide consultancy for doctors and nurses on all aspects of laboratory medicine, so that they might advise both on the most appropriate laboratory investigation in particular cases, and the clinical significance of test results. Haematology consultants also have clinical responsibility for the care of patients suffering haematological disease (e.g. leukaemia). Medical consultants attached to clinical chemistry departments are often responsible for the clinical care of patients suffering diabetes and other metabolic and endocrine disorders, whilst a microbiology consultant advises doctors on the most effective use of antibiotic therapy and is responsible, with the control of infection nurse, for the formulation and implementation of the hospital control of infection policy.

Medically qualified histopathology consultants examine tissues prepared by biomedical scientists and make a histopathological diagnosis based on this examination. They provide diagnostic and prognostic advice to the medical team caring for cancer patients, although their clinical input is by no means confined to this patient group. They also perform all post-mortem (autopsy) examinations, with the assistance of an anatomical pathology technician.

Scope, workload and costs

The influential, government initiated Carter Review of Pathology Services[2,3] determined that 70–80% of all healthcare decisions regarding diagnosis and treatment are influenced by the results of laboratory tests. The Review provides the most reliable national data on pathology workload and costs. An estimated 500 million clinical biochemical tests and 130 million haematology tests are conducted each year in National Health Service (NHS) clinical laboratories across England. Additionally, 50 million microbiology requests are processed and 13 million histopathology slides along with 4 million cytology slides are examined. Demand for pathology testing rises at the rate of 8–10% per year. Primary care (GP) test requests account for around 40% of total laboratory workload, the rest is generated within hospitals (both inpatient and outpatient departments). Carter estimates the annual cost of NHS pathology services in England to be close to £2.5 billion, equivalent to 3.5% of the total NHS budget. The median (average) cost of a routine high-volume laboratory test – which describes nearly all of those discussed in this book – varies between hospitals and pathology discipline: clinical biochemistry (average: £1.00

per test, range: £0.50–2.80); haematology (average: £2.40 per test, range: £1.50–3.70); microbiology (average: £6.10 per test, range: £4.00–9.40) and histopathology (average: £48.10 per test, range: £21.40–73.40).

The modernisation of pathology services[4] – begun a decade ago and reflected in recommendations of the Carter Review – continues. The principal aim is to identify novel ways of delivering high quality pathology services that are responsive to patient needs and are cost effective. This has included an expansion of point of care testing, with nurses and other non-laboratory healthcare professionals becoming more involved in patient testing. The potential for economy of scale with centralisation of routine (non-urgent) pathology services in regional centres is receiving active consideration and in some hospitals pathology services have been rationalised so that haematology, blood transfusion and clinical biochemistry laboratories are combined to form one 'blood science laboratory'.

As in all other areas of patient care, successful clinical laboratory investigation depends on teamwork; nurses are important members of that team. Good communication between nursing and laboratory staff can help to ensure that resources consumed in delivery of pathology services are used to best effect for the patient.

References

1. Boyd, J., Hazy, J. and Sanders, S. (2007) Communicating and understanding laboratory tests: what matters? *Lab Medicine*, 38:680–84.
2. Department of Health (2006) Report of the review of NHS pathology services in England. Chaired by Lord Carter of Coles: an independent review for the Department of Health, HMSO (available on line: accessed May 2011).
3. Department of Health (2008) Report of the second phase of the review of NHS pathology services in England. Chaired by Lord Carter of Coles: an independent review for the Department of Health, HMSO (available on line: accessed May 2011).
4. Department of Health (2005) Modernising pathology: building a service responsive to patients, HMSO.

Useful Websites

www.ibms.org – website of the Institute of Biomedical Sciences – the professional organisation that represents biomedical scientists, the largest group of pathology laboratory staff.

www.rcpath.org – website of the Royal College of Pathologists – the professional organisation that represents pathologists, medically qualified laboratory staff.

www.acb.org.uk – website of the Association of Clinical Biochemistry – the professional organisation that represents non-clinical scientists working in clinical chemistry laboratories.

www.labtestsonline.org.uk – website for patients about clinical laboratory tests – includes a wealth of information about the work of pathology laboratories.