Mackie & McCartney

Practical Medical Microbiology

EDITED BY

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THIRTEENTH EDITION

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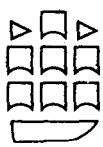

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Organization of the clinical bacteriology laboratory

FUNCTION

The main work of a clinical bacteriology laboratory is to examine specimens from patients for the presence of potentially pathogenic micro-organisms, to detect antibodies to such organisms, to determine the sensitivities of infecting organisms to antimicrobial drugs, and to assess the infective potential of environmental materials. The purpose is quickly and economically to obtain information that will help clinicians to treat their patients or public health officers to prevent the spread of infection in the community. It is to serve the needs of clinical and preventive medicine, rather than the advancement of microbiological science. But subject to these priorities, there is also an obligation to record and investigate new facts encountered in the course of the work.

As most laboratory staff have been trained in microbiology as a science, and many of them also in research, they may tend to regard the examination of a specimen as a research exercise and seek to obtain results with the degrees of precision and certainty required in research, but a patient's interest is generally better served by an early report of the provisional identification of a potential pathogen, and its probable antibiotic sensitivities, than by a delayed report with a precise and confirmed identification. Infections can progress very rapidly, so that speed of reporting is often more important than absolute certainty of the finding. In particular circumstances, however, detailed identification of an infecting organism may be required as a guide to clinical management or as a help in epidemiological tracing.

The principal problems of organizing a bacteriological service are determining the choice and sequence of tests to be applied to each category of specimen, how far the search for pathogens should be pressed, how far isolates should be characterized, the proper balance between economy of labour, speed of reporting and precision of results, what patterns of nomenclature and phrasing should be used in reports, and what new methods should be introduced to exploit advances in medicine and science.

The service should be provided economically and the work should be cost-effective. Labour and resources should not be wasted in gathering information unneeded by the clinician or health officer just because it may be of interest to the microbiologist. Laboratory staff should not be overloaded by the requirement to undertake unnecessary procedures, lest their enforced hurry should cause them to make mistakes in the essential investigations. If there are sufficient resources, some applied research can and should be done on the materials received in a clinical laboratory, but the projects should be carefully planned, with defined objectives, and should generally be done prospectively, and separately from the routine diagnostic work. The quality of the information about patients ordinarily received in the laboratory and the degree of precision of the methods appropriate to clinical needs are likely to be inadequate for the purposes of retrospective research. Thus, a research project loosely based on routine diagnostic work on to which some extra investigations have been grafted is unlikely to yield worthwhile results.

In addition to their main task of providing helpful reports on submitted specimens, the staff

of the laboratory have other duties. They should take steps to inform all potential users of the service about the range of investigations available, the supply of specimen containers, the procedures for collecting specimens and the arrangements for transmitting them to the laboratory. They should also be prepared to answer requests for advice on the type of investigations that might be helpful in the diagnosis of particular cases and on the interpretation and significance of findings. They should identify findings that require urgent referral, e.g. by telephone, to the clinician or health officer and they should be prepared to give advice on antibiotic treatment and preventive measures when the recipient of a report may fail to draw the proper conclusions. Other duties of senior staff include the formulation of advice on the investigation of outbreaks of infection, preventive measures to be taken in such outbreaks, procedures for the control of hospital infections and procedures for the sterilization and disinfection of surgical and medical equipment. They should also take part in the in-service education of various categories of health service staff in matters relating to the occurrence, diagnosis and prevention of infection.

STAFFING

The staffing of a clinical bacteriology laboratory will vary with the kind and extent of the clinical and preventive services it supports and the availability of finance and accommodation. In Britain, a microbiology laboratory serving the needs of the hospitals, public health authorities and family doctors of a population of about 250 000 will commonly receive about 150 000 specimens a year. Its staff may ideally include three senior, 'career-grade' graduates, e.g. two trained in medicine and microbiological science (Consultant) and one non-medically-qualified scientist trained in microbiological research (Top-grade or Principal-grade scientist). There should also be one or two medical or science graduates in the training grades that lead to the senior posts. The largest group of staff, e.g. about 20, will be 'technicians' (Medical Laboratory Scientific Officers) with either university degrees in science or technical college qualifications. These MLSOs might include a Senior Chief MLSO, in charge of the technical staff, 3–5 Chief or Senior MLSOs, 10 qualified Basic-grade MLSOs and perhaps about 5 Junior MLSOs in training. There will also be a number, e.g. 5–7, of laboratory aides, cleaners, porters and glassware cleaners, and about 4–5 clerical staff who type, issue and file copies of reports.

Medically qualified staff have a special role in organizing the laboratory work in the way best adapted to serve the needs of clinical and preventive medicine, in determining the kinds of examinations to be made on particular specimens and in deciding the content of reports. They are also qualified to give advice on the interpretation of results and on problems of diagnosis, prevention and treatment, and to appreciate the implications of advances in medicine for the kind of investigations the laboratory should be prepared to undertake.

Research-trained scientists have a special role in introducing and evaluating new tests and procedures, and in establishing systems of internal quality control. They are qualified by their training, their familiarity with current literature and their habit of communication with other scientists to appreciate the implications of advances in science for laboratory technology.

Technical staff carry out most of the procedures at the laboratory bench. They become highly proficient in these procedures and experienced in the most efficient way of organizing work at the bench. Senior technical staff have a major responsibility for day-to-day control of the work of technical staff, and for their recruitment, training and discipline. They generally also have a responsibility for the maintenance of equipment, laboratory safety and the ordering and control of supplies.

Whilst the greatest use should be made of the special skills of each category of staff, there should be no unnecessary, rigid demarcation of their duties. As far as practicable, staff in the different categories should work side by side and learn as much as possible of each other's skills and knowledge. Thus, medically qualified staff

should not confine themselves to reporting and advisory duties, but should become technically proficient in the common bench procedures so as to gain a full understanding of relevant scientific, training and management issues. Scientific and technical staff should acquire from their medically qualified colleagues as great as possible an understanding of the medical relevance of their work, so that when medically qualified staff are absent, they may undertake reporting and advisory duties within the agreed limits of their competence. Flexibility, cooperation and goodwill among the different categories of staff are essential for the efficient performance of work in a clinical laboratory.

MANAGEMENT

In Britain recently there has been controversy about the form of management of clinical laboratories, whether there should be an appointed director of the laboratory or a consensus management by a laboratory committee representing all categories of staff, and whether, if there is a director, he should be medically, scientifically or technically qualified.

Traditionally, a director of the laboratory has been appointed by the employing health authority and made responsible for all aspects of the running of the laboratory, including standards of performance, expenditure and control of staff. Though formerly such appointments were permanent, employers may now retain the right to transfer the headship from time to time. As the running of a clinical laboratory requires the making of many immediate decisions, management by a committee seems wholly inappropriate. There should be a director who can make decisions without delay. He should, however, determine his policies after wide and frequent consultation with senior members of the different categories of staff, taking advantage of the special skills and experience of each, and those consulted should be assured that their expert views and advice are effectively taken into account. A laboratory committee may usefully serve as a means of consultation, but the director should have the responsibility for making the final decisions.

The day-to-day management of a clinical laboratory includes much that the director can delegate to other senior staff. Generally, he should delegate to the head of the technical staff most of the managerial work relating to the allocation of duties to technical staff, the recruitment, training and discipline of technical staff, laboratory safety, the maintenance of equipment and buildings, and the ordering of supplies. Similarly, he may delegate responsibility for supervising the quality control of test procedures to a senior member of the scientific staff.

The key area of managerial decisions, to which the director must give the greatest personal attention, concerns the strategy and organization of the service. He has to decide how the work is to be deployed among the different sections of the laboratory, the duties to be undertaken by the different categories of staff, the kinds and sequences of examinations to be done on the different categories of specimens, the arrangements for determining the content and wording of reports, and the arrangements for reporting urgent results and proffering advice to clinicians. He must also decide when new methods are to be introduced and old ones discarded.

As such decisions require a balanced assessment of clinical usefulness, scientific reliability and economy of resources, and an understanding of continuing advances in medicine and science, it is preferable that the person appointed to direct a laboratory should be qualified in both medicine and microbiology, and trained in the methods and practice of scientific research. If no one with this combination of qualifications is available, the person appointed as director must be supported by advice from staff and other colleagues having the special knowledge and experience he lacks.

ELEMENTS OF THE SERVICE

Guidance to users

The laboratory should issue guidance to potential users of the service in a leaflet or booklet

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distributed to hospital units, medical staff, family doctors and environmental health officers. This leaflet should give the address and telephone number of the laboratory, the times for the normal receipt of specimens and the arrangements for the emergency 'call-out' of staff out of hours and the supply of specimen containers and request forms. It should also outline the range of examinations undertaken in the laboratory and describe the correct procedures for collecting each kind of specimen from the patients and for sending specimens to the laboratory, including the safety precautions to be observed with specimens likely to contain specially dangerous pathogens.

Delivery of specimens

There must be clearly defined arrangements for the collection of specimens from users of the service and their safe delivery to the laboratory. Collection and delivery are usually done by the portering service within the hospital in which the laboratory is located, and by a special van service from other hospitals, clinics and general-practice health centres. Suitable trays or boxes should be provided for safe transport of the specimen containers. If specimens are to be delivered to the laboratory by mail, the postal regulations specifying the types of container and packaging must be observed (see Appendix 2).

Request forms

Request forms should be designed in such a way as to require the clinician to give all the information that may be needed by the laboratory staff to enable them to determine what kind of examinations to make on each specimen and to assist them in interpreting the findings. The form should have indicated spaces for information about the nature and source of the specimen, the type of examination requested, the patient's name, age, sex, address, occupation and recent foreign travel, the hospital unit, and the signature, address and telephone number of the requesting physician.

Clinicians often request examinations in imprecise terms, such as 'culture and sensitivity' or 'pathogens please'. The microbiologist therefore needs to be given some information about the patient's clinical condition or the clinician's provisional diagnosis to enable him to decide the range of pathogens for which he should search. The request form should ask for this information. Details of any current antibiotic therapy should also be required, for it may help the microbiologist to interpret the results of culture and to select antibiotics for sensitivity tests.

Many laboratories use the request form as a work sheet at the bench, so that the worker can be guided by its information in his choice of tests, interpretation of results and wording of reports. For this purpose, the request form should have a space reserved for the record of the laboratory work and it may be advantageous to have request forms submitted in duplicate so that one copy can be used at the bench and the other kept fair.

Reception of specimens

For safety, the reception of specimens should be undertaken in a room separate from the reporting office and the working laboratories. The work should be done by staff trained in the appropriate safety precautions and the procedure for dealing with leaking specimens. The specimens are unpacked and 'booked in'. The latter process is the recording of information about the patient and specimen. It is generally done by writing in a reception book the patient's name and the kind, place of collection and date of arrival of the specimen. A laboratory serial number is allotted to each specimen and triplicates of it are affixed to the specimen container, the request form and the entry in the reception book. The reception record is required when questions arise about the arrival or non-arrival of specimens, or the stage of their examination when reports are delayed. After being booked-in, the specimens, with their request forms or entries on a work sheet, are distributed to the sections of the laboratory in which they are to be examined. Where records are computerized, the booking-in is done by entry of the patient and specimen information into a computer file and most or all of the information on the request

form may be thus recorded. The computer may then be used to prepare work sheets.

Sections of the laboratory

Because the specimens received each day are so numerous, they are normally divided among different groups of staff working in different rooms. Usually one or other of two methods of division, or a combination of the methods, is used. By the first method, all specimens of all kinds received from a particular user group, e.g. a limited number of clinics, hospital wards or general practices, are allocated to a given group or section. The advantages of this method are that staff have the continuous experience of dealing with all kinds of specimens and are helped to correlate the results for different kinds of specimen received from the same patient. Job satisfaction from the varied work and the ability to tailor examinations and interpretations to the needs of individual patients are features of this approach.

By the second method, all specimens of particular kinds are allocated to sections specializing in the examination of these kinds of specimen. Thus, all specimens of urine might be allocated to one section, all specimens of faeces to another, all specimens of pus, exudates and cerebrospinal fluid to a third, all serological specimens to a fourth, and so on. This method of division has great advantages for speed of working, economy of labour and reliability of results. The staff of the section acquire special dexterity in the relevant procedures for their kinds of specimens; they are undistracted by the need to alter procedures from specimen to specimen, have all the required equipment and materials close to hand, and can organize their work on a repetitive, mass-production basis. Because, however, the range of their experience would otherwise be limited, the staff should from time to time be rotated among the different sections so they can learn all branches of the laboratory's work. Special arrangements need to be made to ensure that the results for different kinds of specimens from the same patient are, when significant, considered together. A useful practice to this end is for the staff of all sections to meet together for a few minutes at the same time each day to report verbally and discuss any important or puzzling findings.

Choice of tests

There is much scope for variation between laboratories in the choice of isolation methods to be applied to each kind of specimen and the choice of identification tests to be applied to each kind of potentially significant microbial isolate. The laboratory should have a carefully considered and clearly formulated policy for the selection of stains, culture media, biochemical tests, serological tests and antibiotics for sensitivity tests to be used in the examination of each kind of specimen, clinical condition and microbial isolate.

A balance must be struck between the extra precision and reliability of results to be gained from the multiplication of isolation methods and identification tests and the need for economy in labour and materials. The greatest effort should be made to diagnose the more serious infections with epidemic potential, but in most infections the use of more than two or three methods of culture is hardly justified by the small improvement gained in the probability of isolating the pathogen.

The degree of precision with which microbial isolates are characterized should be determined by the likely clinical or epidemiological value of a precise identification. When commensal bacteria with potential pathogenicity are isolated from a hospital patient, the clinician generally requires no more detailed information than that a potential pathogen is present and the range of its antibiotic sensitivities. Such an isolate, therefore, may justifiably be identified no further than as, for example, a coliform bacillus, non-haemolytic streptococcus, albus staphylococcus or Gram-negative anaerobic bacillus. In some cases there is a clinical or epidemiological need for full speciation of the isolate, or even for its subspecies typing at a reference laboratory, but these cases are exceptional. They may be recognized by the microbiologist as they arise in the course of his daily work, and then be given special attention. This selective approach avoids

the waste of labour and materials incurred in fully characterizing the majority of isolates, for which precise species identification is unnecessary.

Reading of results

The results of bacteriological examinations usually become available in stages on successive days. Microscopical observations on stained films may be obtained on the day of receipt of the specimen and, if significant, be given in a preliminary report to the clinician. Taken in conjunction with the clinical information on the request form, they may help to guide the choice of culture media on which the specimen is to be inoculated. The growths in the primary cultures are usually observed after overnight incubation, i.e. on the second day, when the findings help to determine what further identification tests and what antibiotic sensitivity tests are to be done on subcultures. The results of these later tests are generally available on the third day, when the content of the final report can be decided.

For some types of examination, for example that of urine for significant bacteriuria, diarrhoeal faeces for enteropathogens or sera for specific antibodies, the sequence of test procedures, the criteria for reading the results and the phrasing to be used in reports can be clearly defined in a manual of instructions. It may then be satisfactory to have the results of these examinations read and recorded by technical or scientific staff. For specimens such as those from the respiratory tract, blood cultures and infected exudates, however, where the clinical significance of different organisms needs to be assessed in relation to the clinical information given about the patient, it is preferable that the reading of the primary cultures and the determination of reports should be done by senior, medically qualified staff.

Senior staff, both medical and scientific, should from time to time take part in reading the results for all types of specimens. They should check unexpected or anomalous findings and any finding of serious clinical or epidemiological significance, e.g. that of the presence of tubercle or typhoid bacilli. They should be alert to the possibility of findings being the result of mistakes, as by the mislabelling of cultures, transfers between the wrong tubes, or the use of faulty reagents or contaminated media, and should decide when tests must be repeated for confirmation of the results. When many examinations have to be made, even skilled and conscientious workers may from time to time make mistakes. Staff should be encouraged to recognize and report any likelihood of their having made a mistake, and should not be made afraid to confess the possibility.

Wording of reports

The aim of the clinical microbiologist is to provide clinicians and health officers with reports that are understandable, instructive and relevant as well as reliable. The laboratory should therefore have a carefully considered policy for the wording of reports and all staff should adhere to that policy. If different members of staff are left free to choose the nomenclature of micro-organisms and the pattern of interpretative comment for their reports, a confusing variation is likely to result. The recipients of reports can most quickly learn the significance of particular results if they are reported consistently in the same terms. If the same result is reported in different terms on different occasions, the recipient may be led to imagine that differences of significance are implied.

There are advantages in using the colloquial and clinically indicative names of micro-organisms, e.g., typhoid bacillus, Sonne dysentery bacillus, coliform bacillus, commensal-type neisseria and non-cholera vibrio, rather than the formal names, e.g., *Salmonella typhi*, *Shigella sonnei*, *Enterobacter aerogenes*, *Neisseria pharyngis* and *Vibrio cholerae* serotype 23. Where formal names are used, their frequent changing in pursuance of the recommendations of international committees of nomenclature should be avoided. If use is to be made of a formal name thought likely to be unfamiliar to the report's recipient, an interpretative comment should be added, e.g. 'Culture yielded a profuse growth of *Enterobacter aerogenes*, a saprophytic coliform bacillus that may be acting as an opportunistic pathogen in this patient'.

The laboratory's policy for reports should specify not only the wording of interpretative comments, but also the circumstances in which the different comments are to be made. It should, for instance, lay down the circumstances in which the finding of albus staphylococci in a blood culture is to be reported with the comment, 'probably a contaminant from the skin', and without giving its antibiotic sensitivities, and the different circumstances, as in a compromised patient, when the finding is to be reported as 'possibly of clinical significance' and the antibiotic sensitivities given. Similarly, the policy should define the circumstances in which the finding of small or moderate numbers of pneumococci or haemophili in sputum should be reported with their antibiotic sensitivities, so implying a probable clinical significance, and the circumstances in which that finding should be reported as probably due to contamination of the sputum with organisms from the throat, or left unreported.

A policy is also required for reporting the finding of acid-fast bacilli in different specimens. Thus, their finding in sputum might be reported, 'Acid-fast bacilli resembling tubercle bacilli seen in film. Cultures for tubercle bacilli have been set up and will be reported later.' But their finding in urine might be reported more cautiously, 'Acid-fast bacilli seen in film, which, although also alcohol-fast, may be commensal smegma bacilli. Cultures for tubercle bacilli have been set up and will be reported later.'

Particular care must be given to the policy for the wording of negative reports. These should be phrased in such a way as to indicate which pathogens were sought and not found. They should not suggest that tests had been made for a wide range of pathogens when, indeed, methods for detecting only a few types of pathogenic bacteria had been used. The uninformed recipient of a report on a throat swab that 'No pathogens were found' might well imagine that a search had been made for every kind of respiratory-tract pathogen, including viruses, mycoplasmas and chlamydias, when the specimen had been cultured only for pyogenic bacteria.

If a throat swab from acute sore throat has been examined for *Streptococcus pyogenes* the report might properly read, 'Mixed throat organisms present. *Streptococcus pyogenes* not found. Viruses, mycoplasmas and other pathogens not sought.' Similarly, if faeces from simple acute diarrhoea has been examined only for salmonella, shigella and campylobacter, the report should read, 'No salmonella, no shigella, no campylobacter.'

Issue of reports

A variety of arrangements are adopted for the issue of reports. Commonly, the bacteriologist reading the tests writes what is to be reported in an abbreviated form on the worksheet or, if it is used as a worksheet, on a reserved space on the request form. The clerical staff who type the report then translate the abbreviation into the proper, agreed phraseology. To economize in the labour of typists, short-cut methods are often used, particularly in the preparation of 'negative reports', which may comprise up to 80% of the total. Standardized reports may be affixed with an inked stamp or self-adhesive pre-printed label to a reserved space on the request form, or a copy of that form, which is then returned to the physician as the report. This procedure saves the typist the need to copy the patient's identification data as well as the report itself.

All the completed reports should be scrutinized quickly for credibility by senior, preferably medical staff before signature and issue. Anomalous findings may sometimes be detected at this stage, or findings that require urgent consultation with the physician. The signature on the report should be that of the director of the laboratory or a senior staff member to whom the director has delegated the responsibility. It indicates to the recipient whom he should approach for further information or advice about the investigation of the patient or the interpretation of the findings.

Copies of the reports should be filed in the laboratory for later reference and for response to enquiries. A simple system should be adopted, allowing the easy retrieval of recent reports. Reports of long-term interest, e.g. those of findings of tuberculous infection, should be preserved for many years, but negative reports

of transient interest may be discarded after a few months. As the responsibility for preserving reports of laboratory findings rests with their recipients, or the hospital records officer, the laboratory needs only to preserve copies of reports to meet its own purposes.

Computerization of reports

There are considerable advantages to be gained from the computerization of laboratory reports and records, and it is likely that when good systems have been well proven their use will become general. The primary aim should be to substitute the rapid, accurate operation of a computer for the slow, laborious and occasionally inaccurate manual work of clerical staff in the booking-in of specimens, the preparation of work sheets and reports, and the filing and retrieval of records.

It is important that the system adopted should not delay or distort the schedule of laboratory work or interfere with changes and developments. It should be sufficiently flexible to enable the bacteriologist to add comments to individual reports and allow changes in the laboratory's policy for the wording of reports to be easily implemented. The request and report forms and other documentation should be designed to permit an immediate reversion to reporting by hand-writing, typing or the affixing of stamps in the event of a computer breakdown.

Request forms may be submitted in duplicate on copying paper and both copies marked on reception with the laboratory's specimen accession number. One copy may then be sent at once with the specimen to the work bench, where its information about the patient may guide the bacteriologist in his choice of tests and interpretation of results; the findings and the result to be reported may be written in a reserved space on it. The other copy may be retained in the reception office, where the clerical staff may copy from it the specimen number and patient data into the computer file. That file serves as a booking-in record and can be obtained as a printed list two or three times a day for reference. The bacteriologist may enter his report directly into a computer terminal or mark it on the request form and pass the form to clerical staff to enter the report into the computer. The computer links the report to the patient data through the specimen's accession number and prepares a final copy for issue through an automatic printer, so obviating typist's work and errors.

Although its primary role is to minimize the need for clerical work in the preparation of reports, computerization confers other advantages in the storage and retrieval of records. It enables the quick retrieval of information about particular patients and the rapid production of cumulative reports on them. It makes easy the derivation of laboratory statistics of various kinds, e.g. the number of specimens of each kind or from each different clinical unit received in a given period, the number of specimens yielding each different species of pathogen, or the antibiotic sensitivities of isolates of particular pathogens. Trends in infection or in the evolution of drug resistance can thus easily be monitored and survey data can be stored and analysed for service or research purposes.

Laboratory manual

A prime responsibility of the director of a laboratory is to compile or supervise the compilation of a laboratory manual of procedures, comprising a collection of instruction sheets for the different sections of the laboratory. The manual should lay down the policy of the laboratory for the kinds and sequence of examinations to be made on each of the different kinds of specimen, the criteria for determining the content of reports, and the standardized wordings of reports.

The adherence of staff to the provisions of the manual should be supervised. Reliance on the verbal communication of policy on procedures from older to newer staff, or from departing to arriving staff in sections of the laboratory subject to staff rotations, is highly unsatisfactory because it often leads to the introduction of unauthorized variations in procedure, and an important drift in technology may escape the notice of senior staff.

As the bench procedures to be laid down in

the manual should be chosen with a view to practicability, reliability and economy of labour at the bench as well as their clinical value and scientific precision, the content of the manual should be determined only after full consultation with the technical and other staff concerned with the work.

The manual should include details or clear references to the methodology of all the tests to be used. Much of the hard work of its preparation may be avoided if sections of a textbook are acceptable. Preferably, copies of relevant sections should be reproduced in the manual for immediate reference at the bench. The manual should also specify the selection and sequence of tests to be applied to each different category of specimen, e.g. pus, sputum, urine and faeces, including the variations to be adopted when the available clinical information indicates the need for special or extra examinations. For example, the manual might specify that throat swabs from persons over 4 years old suffering from acute sore throat, for which the request is only 'pathogens please' or 'culture and sensitivity', should be examined only for *Streptococcus pyogenes* and only by culture on aerobic and anaerobic blood agar plates bearing bacitracin and penicillin disks for identification and sensitivity testing. It might instruct that Vincent's organisms, candida, diphtheria bacilli or other respiratory-tract pathogens should be sought only if specifically requested by the physician or if the patient data on the request form included certain specific indications of the relevant infection.

The manual should further state the types of colonies on primary culture plates that are to be picked for identification and sensitivity tests, the kinds of tests to be applied to these isolates and the criteria for identifying significant pathogens. The criteria for including particular findings in reports and the phraseology of reports should also be laid down.

ACCOMMODATION

The extent and arrangement of laboratory accommodation are constrained by what is available in old buildings and, in new hospitals, usually to a considerable degree by financial and architectural considerations. It is beyond the scope of this book to advise on the design of new laboratories and such advice should be sought from bodies such as central health departments and the Public Health Laboratory Service. Requirements for laboratory safety must be taken into account at an early stage of design.

Some points of importance merit mention here however. The accommodation should be sufficient for the contemporary volume of work with a substantial reserve to provide for a probably progressive yearly increase in demand. It should be capable of flexible use and rearrangement to meet changed patterns of working. Excluding circulation space, corridors, animal rooms, cloakrooms, toilets, etc, about 1000 m^2 of floor space would be required for a bacteriology and virology service meeting the present level of needs of a population of about 250 000.

The groups of staff dealing with the main sections of general bacteriological work may be accommodated in separate bays in a large, open-plan laboratory, or in separate adjacent laboratories. The head technician supervising the technical staff in these laboratories should have a closely adjacent office. At least 10 m^2 of floor space should be available per person. In addition to adequate bench areas for the orderly, uncramped arrangement of specimens, tests and equipment, e.g. 2–3 m of bench per technician, and free wall space for floor-standing equipment, each laboratory should have sufficient office bays, or areas with desks, to enable technical and other staff to perform their paperwork away from the potentially contaminated benches where the bacteriology is done. The director and other senior staff will require separate offices and laboratories. Corridors and passageways should be kept clear and unrestricted by equipment or stored materials.

A special suite of laboratories and offices is required for virology and special laboratories are required for particular functions in bacteriology. A separate room with exhaust ventilated safety cabinets is required for work with dangerous pathogens such as tubercle bacilli and brucellae that may be transmitted by the air. A large room

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