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Computer printing and filing of microbiology reports

1 Description of the system

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SYNOPSIS From March 1974 all reports from this microbiology department have been computer printed and filed. The system was designed to include every medically important microorganism and test. Technicians at the laboratory bench made their results computer-readable using Port-a-punch cards, and specimen details were recorded on paper-tape, allowing the full description of each specimen to appear on the report. A summary form of each microbiology phrase enabled copies of reports to be printed on wide paper with 12 to 18 reports per sheet; such copies, in alphabetical order for one day, and cumulatively for one week were used by staff answering enquiries to the office. This format could also be used for printing all the reports for one patient. Retrieval of results from the files was easily performed and was useful to medical and laboratory staff and for control-of-infection purposes. The system was written in COBOL and was designed to be as cost-effective as possible without sacrificing accuracy; the cost of a report and its filing was 17·97 pence.

In many departments of microbiology the number of specimens examined now approaches, and in a few departments may exceed, 100 000 each year. The conversion of laboratory results into readable reports and the filing of copies of the reports have until recently been done manually by laboratory and office staff, but mechanical methods of reporting and filing deserve consideration. In 1971 an evaluation of computer-assisted reporting and filing (CARF) compared with a manual method was proposed at this hospital. From a review of the literature and visits to laboratories in Britain, Scandinavia, and Australia it was apparent that cost-effective methods of CARF were restricted in their range of microbiological tests, specimen types, and organism names, probably because the programs were written for a small computer, as in the Institute for Medical and Veterinary Science, Adelaide, and in the original system at the Queen Elizabeth Hospital, Birmingham (Whitby and Blair, 1972) where virus serological tests are reported manually. The system at the Danderyd Hospital, Stockholm was written for a large computer and used two visual-display units (VDUs) to enter microbiology results, but only 60 out of 250 daily results could be entered by the two VDUs. Only a small number of distinguishable specimen types can be recorded in the computer system at King's College Hospital, London where input is by mark-sensed cards (Ayliffe and Chalke, 1973) and at the Institute for Clinical Bacteriology, Uppsala where input is by optical-mark-recognition documents (Bergqvist and Bengtsson, 1975).

Many microbiologists like the request form with the clinical history to be available when reports are being signed but this is not a feature of the system at the Karolinska Hospital, Stockholm (Ericsson, 1968).

Cost-effectiveness is not a feature of microbiology computer systems in the (USA Kobernick and Mandell, 1974; Lindberg, 1965); and test-billing appears to have had priority over the provision of a complete range of microbiologically important features. Vermeulen *et al* (1972) described a cost-effective system with the results kept not in a computer file but on cards; later a complete computer file was described (Vermeulen *et al*, 1974). Virus and serological tests were not included in the system at Cardiff, Wales (Farrar *et al*, 1975). Computer filing of reports was not described for the systems at

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Charing Cross Hospital, London (Andrews and Vickers, 1974) and the Prince of Wales Hospital, Randwick, New South Wales (Harvey *et al*, 1972). An evaluation of our system at Northwick Park is described separately (Goodwin, 1976).

Objectives

We set out to devise a computer system that would meet the following requirements.

1 The codes and dictionaries should include every medically important microorganism, antibiotic, and microscopic, cultural, and serological test. It should not often be necessary for technicians to make manuscript additions to reports for data not coded in the computer. Specimens not from patients, such as from the pharmacy, animals, and apparatus, must be recorded and be distinguishable.

2 Each specimen, including multiple specimens from one patient, should be identifiable by a free-text description of defined maximum length that appears on the computer-printed report and in the computer-printed day-book, but need not be stored in the computer file. A sufficient number of distinguishable specimen types should be identifiable in the computer file. [In our system the technician delineated the specimen type when he punched the report—see 'Procedure in the laboratory'.]

3 Technicians should make their reports computer-readable, thus enabling results to be entered simultaneously from many areas in the laboratory and avoiding the need for a punch operator who would be an additional and weak link in the system.

4 Recording of antibiotic-sensitivity disc tests should be by means of the zone-size, eliminating personal bias or ignorance in interpretation of these tests. The computer would be programmed to deduce and print 'sensitive' or 'resistant'.

5 The computer should reject reports that contain microbiological nonsense and from which important facts have been omitted.

6 The time between a technician entering results and the receipt in the laboratory of computer-printed reports should be as short as possible, and during this interval the worksheet should remain in the laboratory so that telephone enquiries could be answered.

7 When reports are being signed the request form with the clinical history and the technician's notes on the back should be conveniently available.

8 Computer monitoring of the reception and reporting dates should generate warnings of overdue reports.

9 Copies of reports should be in a compact form suitable also for cumulative printing of all reports for one or more patients, or printing of selected lists, for example of all reports containing *Staphylococcus aureus*.

10 The computer file of reports should be complete and correct so that information can be provided to clinicians, control-of-infection staff, laboratory staff, and for research. Retrieval from the files should be simple, and it should be possible for enquiries to be based on any part of the report. Sorting and presentation of the results should be possible by any part of the specimen details.

11 Enquiries to the laboratory for past results should be quickly answerable.

12 Alternative methods of reporting should be available in case of breakdown.

13 The system should be as cost-effective as possible without sacrificing accuracy.

14 Because an ICL 1900-series computer would be used to write the system it should be transferable to other NHS ICL computers.

Material and Procedures

CHOICE OF METHODS TO MAKE REPORTS COMPUTER-READABLE

Patient and specimen details recorded on paper-tape allowed free-text description of the specimen. For producing the tapes, two Olivetti tele-typewriters were used; they allowed back-up for breakdown, and have been in use simultaneously as the number of specimens has increased.

Results of laboratory tests were recorded on IBM Port-a-punch cards which have numbered and pre-scored punch-sites in 40 columns. A card is put into a special holder-board and the scored perforations are pushed out with a stylus. This is a cheap and flexible method that already has been used in a hospital (Grönroos, 1970). The use of several Port-a-punch boards allowed simultaneous input from all areas of the laboratory. Two colours of card were used, green for urine specimens and buff for all others. Special cards were printed with bold numbers, stippling of alternate columns, and appropriate vertical lines (fig 1). The stippling and lines enabled the correct column to be punched at the bottom of the card, reducing a tendency to drift to the next column. The Division of Medical Illustration made strips of column headings on transparent celluloid; these were stuck to the plastic template that is inserted into the Port-a-punch board to guide the technicians when they were punching results (fig 2).

PATIENT IDENTIFICATION AND MICROBIOLOGY REQUEST FORMS

Patients seeing consultants in the hospital, and patients from whom specimens are sent by general

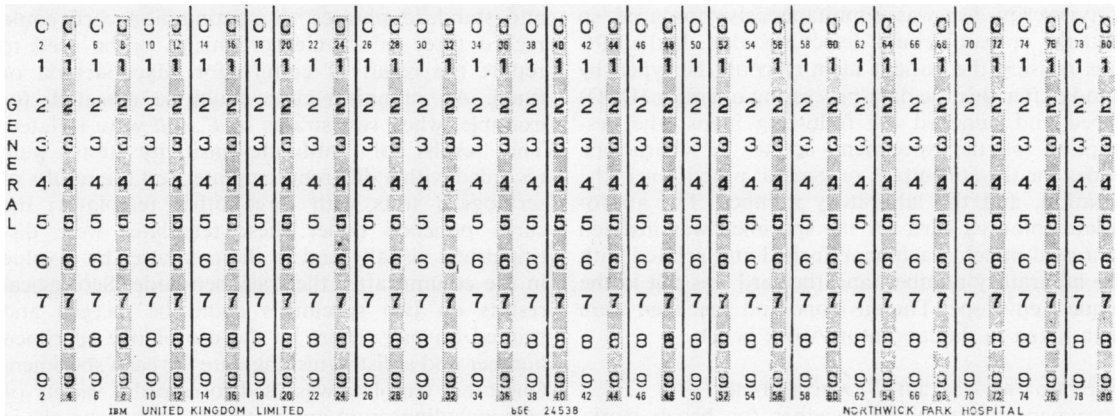

Fig 1 *Data-entry document: IBM Port-a-punch card with overprinting*

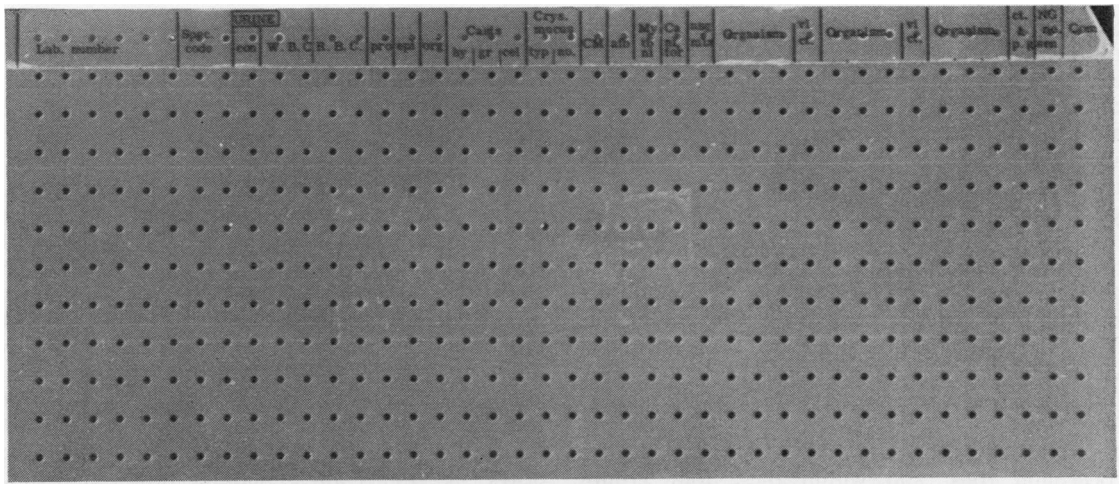

Fig 2 *Plastic template for Port-a-punch board with column-heading strip*

practitioners are registered and allocated a hospital number with a check letter. In the central records department the surname, forenames, age, sex, date of birth, and hospital number are printed on self-adhesive labels and are made computer-readable on a side-punched card (SPC) that also contains these details in typescript. Twenty such labels and cards are made for each patient and are kept in the patient folder.

The microbiology request form was printed on envelopes. The patient's identity label was stuck on the outside of the envelope—or sometimes the details were handwritten—and an SPC was put in the envelope, which accompanied the specimen to the laboratory. All the departments of pathology used the SPCs. When specimens arrived from general practitioners an SPC and three labels were obtained from the folder and put in the envelope. The labels were sent with the report to the general practitioner and could be used for subsequent specimens.

PROCEDURE IN THE LABORATORY OFFICE

Each specimen was allotted a five-digit laboratory number with a preceding modulus-11 check digit; self-adhesive labels bearing this number were put on the specimen container and on the request envelope. The patient and specimen details were made computer-readable by generating paper tape from an Olivetti tele-typewriter that had an SPC reader, and

a typescript list was simultaneously produced so that the operator could detect mistakes. If the SPC was missing the patient identity could be typed by hand. After this the data-processing operator (DPO) typed and punched the following items: the description of the specimen—up to 36 characters, codes for the consultant or general practitioner, the location, and the laboratory number. The appropriate coloured card for the specimen was inserted in a card-punch machine, punched and printed with the laboratory number, and the card was put in the request envelope. The envelope and specimen were then taken to the laboratory work bench.

PROCEDURE IN THE LABORATORY

Specimens are grouped together for bench work, with separate areas for urine, faeces, respiratory specimens, general specimens, and serology. Each area had its own unique strip of column headings, appropriate for the type of specimen, on a plastic template used in the Port-a-punch board. The technicians recorded the bench work on the back of each envelope in the usual way. When the report—or an interim report—was ready it was punched on a card. The report included a two-digit code for the specimen chosen from a list of 99 types; this became the specimen name in the computer file. Then there were values in separate columns for the results of microscopy, three columns for each microorganism to be reported, and in the last columns values that generate standard phrases such as 'Candida not isolated'. The code for a microorganism was chosen from a list that included all medically important viruses, rickettsiae, myoplasmas, bacteria, yeasts, fungi, and parasites, which were given a number from 001 to 999. The bacteria were grouped into Gram-positive cocci and rods and Gram-negative cocci and rods, and within these four groups organisms were listed alphabetically. Unused numbers were left between genera. Commonly isolated bacteria were allocated numbers easy to remember and to punch, such as 111 for *Staph. albus* and 555 for *Escherichia coli*. These organism codes were also used to record serological tests with unusual organisms such as *Yersinia enterocolitica*. When a few polymorphs were seen in a Gram-film and this was written by the technician as +, a value of one was punched on the card; when there were a moderate number of polymorphs and the technician wrote this as ++ the value 2 was punched; and when there were many polymorphs, +++, value 3 was punched. For urine and CSF specimens the numbers of leucocytes and erythrocytes were recorded. Tests that were not performed were not recorded on the card. Each card contains enough columns for the microscopy results, three organisms, and standard phrases. A continuation card could record three other microorganisms or be used to report the result of culture for Mycobacteria or fungi. An organism code could be repeated, for example, when two strains of *E. coli* were isolated. The results of antibiotic-sensitivity tests were recorded with a different template, and the results of serological tests with three other templates; the cards punched under these templates were distinguished visually and in the computer by a value in the column after the specimen code. Serological results on two specimens could be merged and printed on one report by the use of one specimen number and a distinguishing date for each specimen. One other template was used to record a variety of tests including serum-antibiotic concentrations, phage types of *Staph. aureus*, the antigenic structure of Salmonella, and minimum inhibitory and bactericidal concentrations of antibiotics.

COMPUTER PROCESSING

Punched cards were collected twice daily and inserted between instruction cards to form a program pack. Paper tape from the tele-typewriter and the cards were taken to the computer—an ICL 1903A. The data were processed by a suite of 13 COBOL programs that incorporated 6 PLAN subroutines. The specimen details (SD) were used to produce a list of specimens received, in alphabetical order of patients' names, twice daily and cumulatively each week. The SD were married by the laboratory number to the punched cards to produce printed reports in number order; an example is shown in figure 3. Printing of microbiological nonsense was almost eliminated by the different arrangement of columns for each group of specimens and type of results. For organisms that were sensitive to first-line drugs, the results for second-line drugs were suppressed from the report but were filed in the computer. These suppressions could be overruled by punching an appropriate value in the last column.

Each microbiological report-word or phrase existed also in a parallel 'summary' dictionary in a fixed-length and often abbreviated form. This dictionary was used to print once daily, and cumulatively once weekly, an alphabetical list of reports on wide paper that was kept in the laboratory office for reference in response to telephone enquiries. Up to 18 reports were printed on one sheet (fig 4). A summary of the daily results was printed also in laboratory-number order to provide a convenient spare copy for members of the laboratory staff and to allow delayed reports to be quickly identified because these occurred particularly among the first results in the printout.

Because microbiology reports are issued from

NORTHWICK PARK HOSPITAL

MICROBIOLOGY REPORT

[redacted]

M MAST [redacted]

X 03.05.72

Consultant/GP	Ward/Dept.	Date received
DR M.LIBERMAN	DAY WARD	13.08.74

Specimen MSU Type 10

MICROSCOPY:
<5 LEUCOCYTES / MICROLITRE <5 RBC / MICROLITRE

CULTURES YIELD: ESCHERICHIA COLI
<100 000 PER ML

SULPHONAMIDE	S
CO-TRIMOXAZOLE	S
AMPICILLIN	R
TETRACYCLINE	S
NITROFURANTOIN	S

Ward/Dept.	Lab. number	Specimen type	Date of report	R416 72-1
DAY WARD	22567	URINE	15.08.74	MICROBIOLOGY

Fig 3 *Computer-printed microbiology report*

[redacted] FAECES	MUMTAZ F MISS FORMED	AGE 27 YRS DR J.M.GUMPEL SALMON.SHIG.NOT ISOL.	FLETCHER WARD	28/05/75	19230
[redacted] CSF	ESTHER F MRS APPEARANCE CLEAR AND COLOURLESS NO BACTERIAL GROWTH	AGE 86 YRS DR H.M.HODKINSON <1 LEUCOCYTES/MICROL	DRYDEN WARD <1 RBC/MICROL	28/05/75	19232
[redacted] BLOOD CULTURE	ALBERT M MR NO GROWTH AFTER 24 HRS	AGE 27 YRS DR A.J.LEVI	HERRICK WARD	28/05/75	19240
[redacted] URINE/MSU	MAXINE F MRS <5 LEUCOCYTES/MICROL <5 RBC/MICROL ESCH.COLI <100 000 / ML SENS. TO SULPHA CO-TRIMOX AMPICILL. TETRACYC. NITROFUR.	AGE 20 YRS MR A.FISHER	ANTENATAL CLINIC	28/05/75	19243
[redacted] SPUTUM	JOYCE F MRS APPEARANCE MUCOPURULENT STAPH.AUREUS SENS. TO FLUCLOX. CO-TRIMOX TETRACYC. RES. TO PEN.	AGE 66 YRS MR A KARK ACID-FAST BAC.NOT SEEN USUAL BACT.FLORA,ALSO	DAY WARD	28/05/75	19246
[redacted] BLOOD CULTURE	GLADYS F MRS NO GROWTH AFTER 24 HRS	AGE 71 YRS MR A KARK	GALEN WARD	28/05/75	19250
[redacted] EYE SWAB	LIONEL M MR STAPH.ALBUS SENS. TO NEOMYCIN CHLORAM. MICROCOCCUS SP SENS. TO NEOMYCIN CHLORAM.	AGE 61 YRS DR I.CHANARIN	FLEMING WARD	28/05/75	19253
[redacted] ULCER SWAB	LIONEL M MR * STAPH.ALBUS	AGE 61 YRS DR I.CHANARIN POLYMORPHS NOT SEEN ORGANISMS NOT SEEN	FLEMING WARD	28/05/75	19254
[redacted] RECTAL SWAB	LIONEL M MR SALMON.SHIG.NOT ISOL.	AGE 61 YRS DR I.CHANARIN	FLEMING WARD	28/05/75	19255
[redacted] WOUND SWAB	RICHARD M MR POLYMORPHS NOT SEEN	AGE 75 YRS MR B.B.PORTER ORGANISMS NOT SEEN NO BACTERIAL GROWTH	EDISON WARD	28/05/75	19256

Fig 4 *Cumulative list of results with abbreviated phrases, for office use*

1-72 days after the specimen is received the computer file containing the SD needed to be scanned at each run and updated. After reports were issued they might have to be modified or corrected, and so for specimens that yielded no bacterial growth the SD were held for three days, and for those that yielded growth the SD were held for eight days. With 190 specimens a day our SD file contained up to 2300 records—300 000 characters. The file of programs to process the data contained about 400 000 characters and the file of report and summary phrases contained 160 000 characters. These files together with the other data and work files totalled about 3½ million characters. With 190 specimens a day about 30 000 characters were entered daily on paper-tape and cards. For the reports, summaries, list of specimens, and error lists about 7000 lines were printed daily.

TURN-AROUND TIME AND SIGNING OF REPORTS

Cards were collected at 11.00 and 14.30 hours and reports were available for signing by 12.00 and 15.15 hours. The request envelopes awaiting reports were filed in the office in laboratory-number order, and the reports were printed in the same order, so that as the reports were signed the envelopes were conveniently available for checking the clinical history and the technician's work-notes. If a technician wished to see or to make manuscript additions to a report before it was signed, an asterisk value was punched; these reports were printed at the end of the run and were given to the technician before being signed.

ERROR AND OVERDUE REPORTS

The computer rejected the paper tape and cards related to three types of error and indicated these in three printed lists that the DPO and technicians used when correcting the errors.

Paper-Tape Validation Report

This listed items for which essential portions of the patient or specimen identification had been omitted or wrongly punched.

Card-Error Report

This listed cards that included values outside the permitted range for each column, or with inconsistencies detectable by the computer, such as staphylococci sensitive to penicillin and resistant to methicillin.

Match-Error Report

This listed inconsistencies between two cards for the same specimen and cards for which there were no valid specimen details.

The DPO extracted the rejected cards after each run and attached them to the relevant error report. The technicians resubmitted corrected cards.

Overdue Reports

This list contained details of specimens for which primary or later reports had been delayed beyond the usual time; the time at which overdue warnings were given varied according to the type of test.

COMPUTER FILE OF RESULTS

After the reports had been composed and printed by the computer they were put into the 'recent results file' (RRF) that contained reports for the immediately previous three months. Reports older than three months were transferred to the main archive file on magnetic tape once weekly. It was economical to keep the RRF relatively small; 12 weeks was the longest expected interval between results for one specimen, for example for culture for Mycobacteria, and thus the RRF had to contain results for three months. Our RRF contained 12 000 records with a total of about 4 000 000 characters.

An attempt to update the RRF with different results without a correction value on the card generated a 'clash message', and the results on that run for that specimen were not put into the RRF. Such a clash could occur when a result was punched for a second time, for example a report from a reference laboratory included a different result of a test that had already been reported from our laboratory. A clash was avoided only if new results from the reference laboratory were punched, or if all the results were punched with a correction value on the card; this then replaced all results previously submitted on a similar card. This correction facility was available on all cards and produced a relevant sentence on the report sent to the clinician. However if a correction value was punched but a previous result was not in the RRF this produced a clash message and the result was not entered in the RRF: the result had then to be resubmitted without a correction value. It was found that 3% of runs contained a clash-error message.

INTRODUCTION OF THE SYSTEM

From September 1971 to June 1972 a preliminary coding of the microbiological data was made. In June 1972 an analyst/programmer was appointed. With the help of the Division of Computing and Statistics Clinical Research Centre an estimate of 60-77 weeks was made for writing and testing the system. Nine large COBOL programs, 4 small COBOL programs, and 6 PLAN subroutines were

written and tested by 31 December 1973. Clerical staff were taught how to interpret error-reports and summaries for telephone enquiries during October and November 1973. In each work-area of the laboratory for a separate period of two weeks the technicians produced manual and computer-printed reports, and the four main areas of the laboratory were so tested in November and December 1974. The reports were shown to clinicians and their suggestions were incorporated in the layout. For a month from 11 February 1974, one ward and one outpatient clinic received only computer-printed reports. From 14 March 1974 all reports from the department were produced by the computer.

Acceptance by laboratory staff of the constraints of a computer system took several months, but the recording of laboratory tests was found to be easily understood by the technicians because the method was conceptually similar to previous manual methods. Familiarizing senior medical staff with the method of input was more difficult because they did not often enter data. However new technicians entering the laboratory found remarkably little difficulty in learning how to enter results. Dealings with computer staff, monitoring the output of office staff, supervising the DPO, monitoring the overdue sheets, and interpretation of 'clash-errors' and relevant action to resubmit results remained with us, but about half-an-hour a day would enable a senior technician to supervise these activities.

CHANGES IN THE SYSTEM SINCE INTRODUCTION

Some of the formats allow for the addition of extra tests, and several have been added since the system started. One column of the sputum headings was found to be unused and was replaced with a more useful test. The names of new consultants and general practitioners were easily added to the list, and more organisms were inserted in the code.

Technicians asked for some changes to the specimen code. This necessitated a search of the computer file to identify and change the code in reports already in the file. Reports in the RRF were replaced by corrected reports, but results in the archive file were changed by entering the new result with the old date and laboratory number, then deleting the original result from the archive. Usually the code to be changed had been relatively little used. Changes to the report wordings were rarely required but were easily achieved; computer programming was required if there was an alteration in the number of values that could be punched in any one column.

RETRIEVAL FROM THE FILES

Interrogations of the files to re-print results had a turn-around time of 40 minutes, and in urgent cases this could be reduced to 10 minutes. However it was found that a visual search of cumulative results for each week more quickly revealed the recent reports of one patient.

The ICL 'FIND 2 multiple-enquiry system' was used as a basis from which microbiology enquiry-programs were developed. A basic pack of instruction cards allowed the insertion of 'request' cards specifying the type of results to be counted or printed, and 'sort' cards specifying the order in which the results would be printed. For example for the control-of-infection sister the reports of wound swabs were sorted and printed primarily by wards, by consultant, and then by patients' names alphabetically, with each patient's results in reception-date order. This list was also used by the control-of-infection officer to check that he had seen the request envelopes of each wound swab, and often the list showed that he had not seen some envelopes. At intervals the results of specimens from babies were printed to help the monitoring of infections of these patients. Retrieved results were printed in summary format. Each month the numbers of specimens from different locations were listed to help the chief technician to prepare his annual returns. Urine results in alphabetical order for the previous week, month, or quarter were useful to technicians; and the DPO could be asked by any technician to extract all the previous results from a particular patient.

Security was similar to that of a manual system, while more specific extraction from the file, for example for all isolates of *Neisseria gonorrhoeae*, could be performed only by a consultant microbiologist. To determine the percentage of each species of bacteria sensitive to each antibiotic a special COBOL program had been written.

Interrogation of the files for research purposes has so far been rare. However one enquiry analysed the relationship between increasing numbers of leucocytes in the urine and the isolation of significant numbers of bacteria. It was possible to subdivide the numbers of leucocytes into any number of categories, for example less than 5, 5-9, 10-49, 50-99, 100-399, 400-699, 700-999, >1000 per μl, and to count the number of significant isolates in each category.

COST

Each computer-printed report cost 17·97 pence; the items that contributed to the cost are detailed by Goodwin (1976). Each report required 5·6 seconds computer time (6 pence) and this included time for updating the files and printing the daily summaries.

PROBLEMS OF THE SYSTEM AND POSSIBLE IMPROVEMENTS

Several minor problems required attention during

the first four months of running the system; for example the correct age of the patient was not always printed in the summary of the results; and overdue messages were not always deleted when a report had been entered.

Incompletely separated perforations on the backs of the cards were found fairly often but were detected readily by the DPO before the cards were submitted to the computer.

There were two fairly serious omissions from the codes; a report of an RPCFT on a cerebrospinal fluid could be printed on a report but could not be stored under the title CSF in the computer file; and antibiotic concentrations for fluids other than serum could not be reported. Both these omissions could, and would eventually, be included in the system.

Serum specimens other than for the VDRL test required the punching of an interim 'master' card that put the specimen on a 'serology awaited' list and avoided the result being counted as overdue. The serology-awaited list proved to be not as useful as anticipated, and the master-card process could be eliminated but this would require re-programming.

Reports were delayed when rejected cards were not quickly corrected, but the number of 'overdue reports' decreased from an average of 12 per day to 5 per day, and most of the latter were specimens that had genuinely needed longer investigation in the laboratory.

The limitation of being able to enter cards and paper tape on only two occasions during the working day meant that some reports were delayed overnight before they could be printed and sent to the wards. This was because the research computer did not have outlying terminals.

The permanent computer file was planned to be arranged with all the results for one patient grouped under the patient's hospital number. However 20% of results in the RRF had a patient's name without a valid hospital number. It was thus decided to keep the archive and the RRF in laboratory-number order.

It was a considerable inconvenience that the computer was five minutes' walk away from the department. It would have been a great improvement to have in the pathology area facilities for input of data and for line-printing that allowed input and output at least four times a day.

To reduce errors a small powerful processor with a large disc capacity would allow an on-line input method to identify errors at source and prevent their being entered.

The Olivetti tele-typewriters proved totally reliable, and the second-hand IBM card-punch required only one service in 12 months. None of the Port-a-punch boards had to be replaced. The ICL 1903A computer or its line printer had on average one minor breakdown a month. If reports were likely to be delayed by more than three hours hand-written interim reports were issued, and the computer file was completed later. For the very few results that were not ready by 14.30 hours reports could be handwritten or telephoned; pregnancy tests were done in the haematology department. However a greater emergency occurred when a run failed, either because of inexperienced computer-operators or because there was an error in the job pack submitted by the DPO. Such program failures occurred about once every six weeks and required skilled interpretation and careful, time-consuming restoration of the files. In the comparison with a manual system (Goodwin, 1976) it is mentioned that punching reports took slightly longer than handwriting, and an extra hour of technician time was required daily to correct and re-enter rejected cards. However with the manual system the office staff interrupted technicians more frequently to obtain reports before answering telephone enquiries.

Perhaps the most serious problem of the system was inherent in the fact that it had been developed with the minimum of staff. Responsibility for developing the system, the training of staff, and dealing with the early problems rested on a very narrow foundation—one microbiologist and one analyst/programmer. When the analyst left in September 1974 our problem-solving capacity was reduced by 50%. It was extremely fortunate that she was available by telephone to help with emergencies. A new divisional programmer was appointed in January 1975 but her services had to be shared with other departments in the Division of Pathology.

Discussion

All objectives were achieved apart from the temporary situation that two types of results mentioned under Problems could not be coded. Otherwise it was possible to send out every type of report by the computer system, including tests on sterility specimens, and all kinds of serological tests on any organism including, eg, *Candida parapsilosis*, the minimum bactericidal concentration of cephazolin for *Eikenella corrodens*, and the titre of precipitins to budgerigar droppings.

After a year the computer system operated smoothly, although at least twice a week technicians asked us for assistance in dealing with some minor aspect of a match error, and how to insert a correct result. We were still given, and assessed, four of the daily monitoring lists including any clash-error report. However it was not unreasonable

that a consultant microbiologist for part of his time should be required to maintain a system that ensured that reports were issued speedily and that none had been overlooked, that enquiries to the laboratory for results could always be answered, and that special analyses of results could be produced.

The advice of the Division of Computing and Statistics was invaluable; Mr M. Healy, head of the division, suggested Port-a-punch boards as cost-effective. Dr E. C. Coles warned that requirements such as a monitoring visual-display unit would add at least £30 000 to the development costs and require five man-years extra systems-analysis; an interrogation facility once an hour producing a print-out would provide the same information and is acceptable within the normal work flow of the microbiology department. This help contributed to the relatively low cost of 17·97 pence per computer report that compared favourably with that of 32 pence per report in another system that did not file results (Andrews and Vickers, 1974). Nevertheless the computer reporting system was substantially more expensive than the manual system it replaced which cost 10·28 pence per report (Goodwin, 1976). It had to be decided whether this cost was justified by the improved service it offered.

The choice of methods to make reports computer-readable was influenced by the fact that an optical-mark-reader was not available at our hospital and, with a limited budget, could not be purchased. A single machine would not have provided backup and would be a weak link. However it was recognized that with Port-a-punch cards incompletely separated perforations would be a hazard and they were found in each batch of cards submitted, so that it was essential for the DPO to scrutinize the backs of the cards carefully and remove these incompletely separated perforations. Only two colours of card were chosen because if more had been used it would have been time-consuming to change cards in the card punch. The system of Lindberg (1965) with 122 different cards would have been extremely costly in materials and personnel. Rejected cards due to card errors or match errors provided a useful visual record of the data submitted so that the technician could appreciate his mistake.

On-line verification of data as it was submitted would have been preferable and would have saved the time of the DPO extracting the cards and of the technicians re-submitting new cards; reports would not have been delayed due to card rejections.

The choice of COBOL for the system rather than FORTRAN—commonly used in medical computing—was made because microbiology data do not involve arithmetical processes but require logical operations on codes and phrases.

To produce computer-printed reports, either a free-text or a coded system may be used; the former requires a large computer, and input is slow and may delay the production of reports. A coded system allows speedy entering of results, provides more possibilities of analysing the data, and is more economical of computer time which is the main expense of a computer system.

Microbiological specimens such as sputum may require the accumulation in the computer file of three or four reports appearing at long intervals. Warnings of overdue reports at each of these stages were found to be very useful.

Computer-hardware requirements for microbiology should be integrated with those of other pathology laboratories. Reliable machines and backup facilities—which means duplicated machines—are essential for a hospital pathology service. For microbiology a batch-processing mode is adequate, using a remote-job-entry terminal with regular access to a large processor. Even the largest clinical chemistry department could be served by a small front-end computer linked to a large computer (Flynn, 1965). The most efficient configuration of computer equipment to provide a complete service for all pathology laboratories remains to be devised, but probably it should be based on two mini-computers acting as a remote-job-entry terminal to a large computer.

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