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A microcomputer system for the collection and analysis of antibiotic sensitivity test data

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SUMMARY A microcomputer system for the routine collection and analysis of microbiological data is described. A digitising tablet is used as a method of data input. A series of analysis programmes was developed to allow investigation of the distribution of organisms in relation to the type of specimen in which they occur, the origin of the specimen and also to examine their associated sensitivity patterns. In this instance a Commodore PET was used, though other microcomputers could be similarly employed with equal facility.

One of the needs of a microbiology department is to be able to follow the developing resistance patterns of isolates so that antibiotic usage can be modified not only overall but also in specific instances where such therapy is being given. The time taken to apply conventional methods of data processing to such tasks is dauntingly high and it was therefore decided to use a microcomputer system to enable such data to be analysed from the results produced in a laboratory handling the work of a district hospital complex. Previous computing developments in microbiology[1-4] have tended to use expensive minicomputers. The same data can be used to follow cross-infection patterns, thus making the application doubly useful. Such input and analysis of data began in September 1980.

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ITEMS OF INFORMATION STORED

Table 1 shows the items of information which can be collected. The categories of "Patient Related," "Specimen Related" and "Laboratory Determined Data" provide natural divisions of information. Up to four separate isolates can be accommodated for each specimen. Each isolate can be tested against an

Table 1 *Summary of information stored for each completed laboratory sensitivity test*

SUMMARY OF INFORMATION STORED

PATIENT RELATED DATA	SPECIMEN RELATED DATA	LABORATORY DETERMINED DATA
NAME	LABORATORY NUMBER	PUS CELL AND RED CELL COUNTS (urines only)
DATE OF BIRTH	DATE OF RECEIPT OF SPECIMEN	ORGANISM(S) ISOLATED
SEX	TYPE OF SPECIMEN	ANTIBIOTIC SENSITIVITY DATA
	HOSPITAL	REPORTED ANTIBIOTICS (up to 4 per isolate)
	WARD	

appropriate subset of antibiotics chosen from the main set of up to 33 antibiotics. A sensitivity test result can be described as "intermediate" if so required. The antibiotic sensitivities reported to the clinician are listed since these are restricted in accordance with present antibiotic policy. A total of 116 characters (or bytes) is required to store the information relating to each patient and up to 3400 such entries (approximately six months of workload) can be stored on one floppy disc.

HARDWARE CONFIGURATION

Figure 1 summarises the hardware configuration of the system. The microcomputer utilised is a Commodore PET (type 3032); mass storage is provided by a Computhink 0·8 Mb capacity dual drive floppy disc unit. A small digitising tablet (Summagraphics "Bit Pad One") is used to input sample information into the PET while an Anadex DP9501 matrix printer produces hard copy. Both the digitising tablet and the printer are driven by a dual IEEE to RS232 interface. The initial capital expenditure of about £4000 was considered modest and the entire system can be easily accommodated on a large desk top. Such computing facilities can, in theory, be provided by several other microcomputer systems. The present system is used for other tasks in the laboratory, including gentamicin assay calculations, gentamicin dose level predictions and also critical concentration calculations.

SOFTWARE CONSIDERATIONS

With the exception of a small assembly language routine which is used to read characters rapidly from the digitising tablet, all programming has been carried out in BASIC. Additional commands for floppy disc usage are available as an integral part of the Computhink floppy disc unit. Programme development is estimated to have required six man months of effort. The interpreter mode of implementing BASIC was considered adequate for the tasks involved in the input of data and also for its analysis; it provides also an uncomplicated operating environment for both programme development and routine usage by laboratory staff.

DATA INPUT

To those unskilled in typing techniques, the entry of complex data via a keyboard presents formidable problems which may be unsatisfactorily resolved by recourse to complex codes; difficulties may also be encountered in the control of such programmes. It has been found advantageous to use a small digitising tablet, the layout of which provides the operator with various "command," "data input" and "control" options (Fig. 2). Each time the pen-like stylus of the digitising tablet is depressed within the active area (28 cm × 28 cm) of the tablet, the co-ordinates of the given point are sent to the microcomputer for decoding. If, for example, the place of origin of the specimen is being entered, the stylus is first depressed

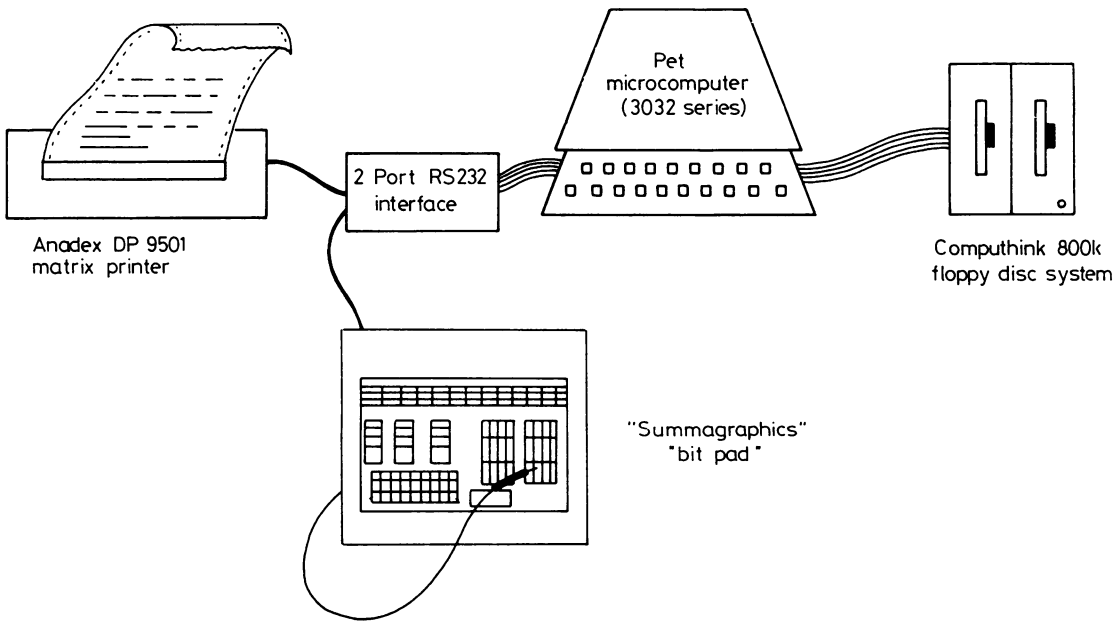

Fig. 1 *Hardware configuration of the microcomputer system.*

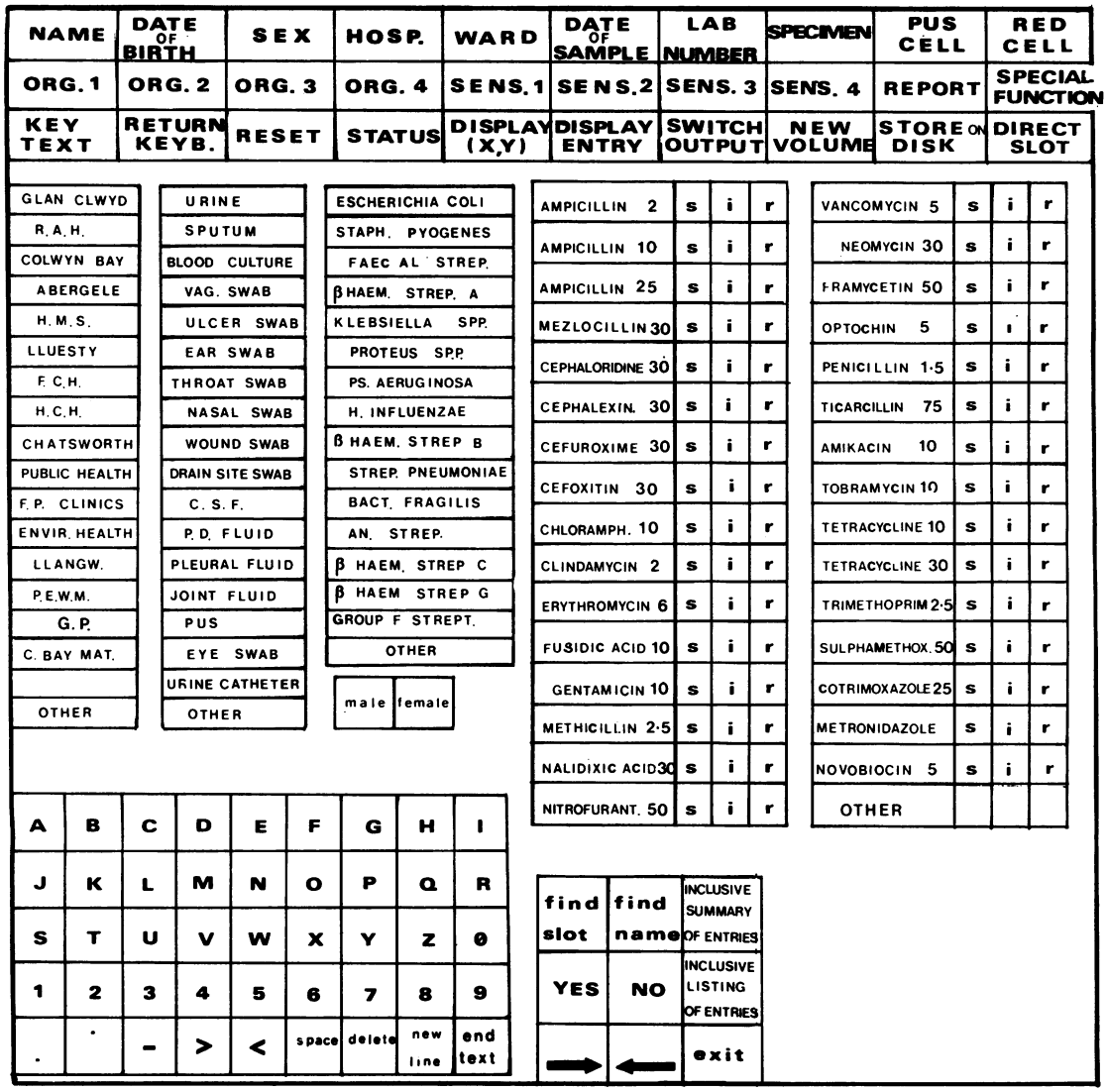

Fig. 2 *Layout of the "active" area of the digitising tablet which serves both for input of data and programme control.*

within the upper "HOSPITAL" box and then depressed within the specific hospital required in the list of hospitals (which also includes other sources —for example, GP). Similarly when antibiotic sensitivities are being entered, the specific organism number—for example, SENS 1 or SENS 2, is declared and then the required sensitivity pattern is "input" merely by selecting "S" (sensitive), "I" (intermediate) or "R" (resistant) opposite the required antibiotics. As many antibiotics as required can be input in this way for a given organism. When a new "command" is specified by depressing the stylus in the relevant upper "command" area, input of the antibiotic sensitivity data for the selected organism is terminated.

Items of input requiring text such as patient name, ward and laboratory number can be input using the text input area of the digitising tablet (lower left corner Fig. 2) or if required, entry of such details can be carried out using the PET keyboard. This latter facility is available when the "KEY TEXT" option is selected from the uppermost "command" area. The input of data is aided by "control" options such as "DISPLAY ENTRY" and

"STATUS" (summarises items of information still to be input). It is possible to retrieve and amend entered data if necessary. A group of "special function" options are available for general management of the stored information (lower centre section Fig. 2).

After the successful implementation of the input programme utilising the digitising tablet, a separate programme for keyboard entry of all laboratory data was developed as a backup facility. This only involved modifying the original programme so that "commands" and "items of information" could be specified from the keyboard directly using simple numeric codes related to the rows and columns of the digitising tablet layout. Operation of this alternative data input programme is essentially identical to the original, with the user referencing a slightly modified version of the layout of the digitising tablet to aid selection of coded input.

In both programmes the input of data and control of the programme is determined by the physical layout of the digitising tablet. Those with secretarial skills prefer the use of keyboard input.

Analysis of information: aims and methods

Figure 3 illustrates the various modes of analysis available for processing data on the nature and origin of the specimen and also on the corresponding sensitivity test patterns observed. In each of the separate analyses, it is possible to vary the degree of selectivity of scanning of the stored data. In this way very specific information can be obtained—for example, about the pattern of infection within a given hospital ward or, if an overall appraisal is required, the data for the whole district can be analysed for a chosen factor. In Fig. 3 a solid line around each category specified implies that in the scanning of the sample data, no match will be sought for that particular category.

Each analysis is carried out separately with the data on the floppy disc being scanned sequentially. If required, the analysis programme can scan several floppy discs. It is possible to load the machine with up to 10 separate analysis tasks and allow each procedure to be carried out sequentially and unattended.

MAIN MODES OF ANALYSIS

Five main methods are described.

(i) *Occurrence of organisms at a specific location*
This is utilised to analyse the organisms occurring in, for example, a given hospital or a ward within a hospital. It is also possible, as in all modes of analysis, to examine data from general practitioner

Fig. 3 *Representation of the available options for each of the main analysis modes. A bold arrow indicates the possibility of seeking no match of the specific category being examined in each sample.*

specimens which approaches almost 20% of the total laboratory sensitivity test work load. When the nature of the specimen is not specified, the final analysis printout will list the organism distribution for all types of specimen encountered.

Thus it is possible to obtain rapidly, for a selected environment, reliable information relating to the nature and relative frequency of occurrence of organisms in a variety of specimens. Table 2 illustrates the use of this mode of analysis and lists the results of specific enquiries for infections of the urinary tract. The option to list the major items of information of *each* specimen falling within the limits set for the scan allows individual specimens to be followed up if required. The final summary, however, makes no reference to specific patients. Thus at present, results may be slightly weighted by large numbers of such specimens from individual patients.

(ii) *Scan for an organism in various locations*
This facility is used to trace rapidly the distribution of a specific organism. The option to list the main

Table 2 *Format of printout giving a summary of all infections of the urinary tract recorded in the first three months of operation of the system*

SUMMARY OF INFECTIONS AT A GIVEN SITE

SOURCE = URINE TOTAL NUMBER OF POSITIVE SPECIMENS = 472

ORGANISM	NO. OF OCCURRENCES	% OF TOTAL POSITIVE SPECIMENS
Escherichia coli	280	59.5
Staphylococcus pyogenes	18	3.8
Faecal Streptococcus	40	8.5
B Haemolytic Streptococcus GROUP A	1	0.2
Klebsiella spp.	54	11.4
Proteus spp.	30	6.4
Pseudomonas aeruginosa	25	5.3
B Haemolytic Streptococcus GROUP B	3	0.6
B Haemolytic Streptococcus GROUP C	1	0.2
Acinetobacter spp.	1	0.2
Staphylococcus epidermidis	14	3.0
Streptococcus spp.	1	0.2
Enterobacter spp.	3	0.6
Citrobacter spp.	1	0.2

items of information for each specimen falling within the limits set for the scan is an essential part of the analysis. It is probable that searches for less frequently occurring organisms will be carried out using this mode.

(iii) *Calculation of antibiotic sensitivity data for specific organisms*

This mode of analysis provides information about the effectiveness of antibiotics against a specified isolated organism. The analysis allows sensitivity test data to be calculated for specified categories of specimens obtained from an identified source (Fig. 3). The variability of antibiotic sensitivities with time—for example, from month to month, for a constant subset of specimens can be investigated. Thus information relating to hospital-acquired infection can be examined separately from that derived from specimens received from the community. The option to print out the sensitivity data of each "matched" sample using this mode of analysis provides a useful means of checking stored information for transcription errors. Also atypical sensitivity patterns can be rapidly identified from observing this form of output. Table 3a shows a summary of antibiotic sensitivity tests performed on *Escherichia coli* isolates from urines at Glan Clwyd Hospital which has a bed complement of over 400. Table 3b shows a similar summary for specimens obtained via GPs. In both tables data from the first 1700 samples collected have been used.

(iv) *Scan for specific organism sensitivity pattern*

This mode is used to detect the distribution of specific antibiotic sensitivity patterns for a given organism. If required specific hospitals or a ward within a hospital can be examined in isolation. The sensitivity pattern which is to be scanned for is input at the keyboard. Only antibiotics declared "S," "I" or "R" in the keyboard input are sought to be compared with antibiotic sensitivity data of each sample. In this way, a single antibiotic can be set in the keyboard input if required, with the analysis retrieving all those samples which are coincident with the scan antibiotic and the degree of sensitivity. If required a more complex sensitivity pattern can be input at the keyboard incorporating typically five or six antibiotics each with a set level of sensitivity. In addition, the maximum number of permissible mismatches between the keyboard input and the stored specimen data can be varied as required. Usually the number of such allowed deviations is set to one or two for complex scans in order to take account of possible borderline assessments. The emergence of an organism showing a new and therefore probably more complex antibiotic profile may be monitored by this mode of analysis.

(v) *Summary of reported antibiotics*

The antibiotics reported for the organisms isolated can be examined in a manner similar to the previous analyses. For example, laboratory-generated "rec-

Table 3 (*a*) *Format of printout summarising the results of antibiotic sensitivity tests performed on Escherichia coli isolates from specimens of urines received during the first three months of operation of the system from patients in the District General Hospital;* (*b*) *results from General Practitioner patients* (*see text*)

CALCULATED SENSITIVITY SUMMARY

(a)

ANTIBIOTIC (Disc content μg.)	No. of ISOLATES TESTED	% SENS.	% INTER.	% RESIS.
Ampicillin 25	196	62.2	4.2	33.6
Mezlocillin 25	13	14.3	21.4	64.3
Cephaloridine 30	13	23.0	38.5	38.5
Cephalexin 30	13	84.6	7.7	7.7
Cefuroxime 30	13	84.6	7.7	7.7
Cefoxitin 30	13	84.6	7.7	7.7
Gentamicin 10	196	98.5	0.0	1.5
Nalidixic Acid 30	196	91.3	0.5	8.2
Nitrofurantoin 50	196	90.3	4.1	5.6
Ticarcillin 75	57	54.4	3.5	42.1
Amikacin 10	57	94.6	3.6	1.8
Tobramycin 10	13	69.3	7.7	23.0
Trimethoprim 2.5	196	77.1	0.5	22.4
Sulphamethoxazole 50	196	49.0	1.5	49.5
Cotrimoxazole 25	51	64.7	2.0	33.3

(b)

ANTIBIOTIC (Disc content μg.)	No. OF ISOLATES TESTED	% SENS.	% INTER.	% RESIS.
Ampicillin 25	105	64.4	2.9	32.7
Mezlocillin 25	3	0.0	0.0	100.0
Cephaloridine 30	3	0.0	66.7	33.3
Cephalexin 30	3	66.7	33.3	0.0
Cefuroxime 30	3	100.0	0.0	0.0
Cefoxitin 30	3	66.7	33.3	0.0
Gentamicin 10	105	99.0	1.0	0.0
Nalidixic Acid 30	105	93.3	1.0	5.7
Nitrofurantoin 50	105	97.1	1.0	1.9
Ticarcillin 75	18	66.7	0.0	33.3
Amikacin 10	18	100.0	0.0	0.0
Tobramycin 10	3	100.0	0.0	0.0
Trimethoprim 2.5	105	92.3	0.0	7.7
Sulphamethoxazole 50	105	62.0	0.0	38.0
Cotrimoxazole 25	23	74.0	0.0	26.0

ommended" antibiotic therapy appropriate for isolates of *Escherichia coli* from urines for a given hospital/ward between inclusive dates can be determined directly. It is planned to use the output of this mode of analysis to compare recommended antibiotics with those actually prescribed by clinicians. This is seen as an essential element in an effective antibiotic policy.

The antibiotics selected for reporting for each isolate when retrieved by the scanning procedure can be listed along with other relevant data of the particular specimen. Table 4 shows the format of the summary of reported antibiotics thus obtained for a particular set of specimens.

Each main mode of analysis serves to provide information about the pattern of infection obtained from a given viewpoint, with no one facility providing a comprehensive assessment. In relation to empirical prescribing of antibiotics, the most likely organism in the type of specimen received has first to be determined on the basis of previous observations. In turn the most effective antibiotic therapy can be predicted assuming the presence of the given organism and utilising the cumulative information gathered on that type of specimen. It must be emphasised that such information must not be regarded as

Table 4 *Format of printout summarising the antibiotics reported to clinicians for all isolates of Staphylococcus pyrogenes for the month of October 1980*

SUMMARY OF REPORTED ANTIBIOTICS*

ANTIBIOTIC (Disc content μg.)	NUMBER OF TIMES REPORTED	FREQUENCY REPORTED AS % OF NO. OF ISOLATES
Cephaloridine 30	1	1.1
Chloramphenicol 10	4	4.3
Clindamicin 2	5	5.4
Erythromycin 5	51	54.8
Fusidic Acid 10	9	9.7
Gentamicin 10	7	7.5
Methicillin 2.5 †	51	54.8
Nitrofurantoin 50	3	3.2
Neomycin 30	15	16.1
Framycetin 50	18	19.4
Penecillin 1.5 *	17	18.3
Tobramycin 10	1	1.1
Tetracycline 10	4	4.3
Sulphamethoxazole 50	3	3.2
Cotrimoxazole 25	26	28.0

* PENICILLIN DISC CONTENT EXPRESSED IN UNITS
† METHICILLIN USED FOR LABORATORY TESTING; FLUCLOXACILLIN REPORTED TO CLINICIANS

sacrosanct and eligible for immediate translation to clinical practice. Evaluation of all results must be subjugated to stringent medical analysis and in this the medical microbiologist must be in close liaison with his clinical colleagues.

PERFORMANCE OF THE SYSTEM

The PET computer system is considered to perform satisfactorily with regard to the speed of programme operation for both input and analysis of data. In the input programme the use of the digitising tablet is considered to simplify the control of the functions available and also to allow rapid input of the complex data by inexperienced operators. An average time of input of all data for one sample is about two minutes. The digitising tablet facility approaches very closely a "codeless" data input system.

INTERACTION OF THE SYSTEM WITH THE LABORATORY

The stored information is also available to assist the general day-to-day management of the department. At regular intervals the complete data base is sorted in alphabetical order of patient name: this allows rapid access to results of specific patients. A printout of this information is a useful laboratory reference.

Conclusion

A computer system has been successfully developed, using hardware of modest cost, for the routine collection and analysis of microbiological data. Methods of analysis permit various tasks to be undertaken, the most useful of which are the determination of the relative frequence of occurrence of different isolates in various types of specimens and the monitoring of their antibiotic sensitivity patterns. The project was designed to accommodate the requirements of a Microbiology Department in a District General Hospital complex, with outlying Community Hospitals and General Practitioner services. Enhancement of the system is possible, but the immediate need is for short-term assessment as opposed to long-term storage. It was considered a major feature of the project that the local requirements of the microbiology laboratory could be incorporated into the running system.

The help and advice of Dr FB Jackson is acknowledged. We also wish to thank our colleagues for their co-operation.

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