VOLUME XXXVII JANUARY, 1937 No. 1

INFECTION OF THE AIR OF SCARLET-FEVER WARDS WITH *STREPTOCOCCUS PYOGENES*

BY W. A. BROWN, M.D., D.P.H.
Late Senior Medical Officer, Infectious Hospitals Service, London County Council

AND V. D. ALLISON, M.D., D.P.H.
A Medical Officer of the Ministry of Health

(With a Diagram in the Text)

IN the investigation of various problems associated with hospital administration in the treatment of scarlet fever, one of the questions which arose was the occurrence and significance of infection of the air with *Streptococcus pyogenes* in multiple-bed wards. It was suspected that the organisms would be present in the dust and air of scarlet-fever wards and could be isolated in pure culture. Subsequent serological identification of any strains isolated would enable a correlation to be made between the serological types present in the air and those found in the patients in the ward. The serological types mainly found as a cause of scarlet fever in London at present are Types 1, 2 and 4; other types occurring very much less frequently as a cause of scarlet fever are Types 3, 5, 6, 8, 11, 12, 23 and 25. It was expected that any strains found in the air of scarlet-fever wards would belong to these types.

Experiments were therefore carried out to isolate *Strept. pyogenes* from the air of scarlet-fever wards, and the method employed was to expose six blood agar plates to the air in each of three wards for a fixed time of 3 hours during three different periods of the 24 hours, viz.: (1) night, 12.30–3.30 a.m.; (2) morning, 7.30–10.30 a.m.; (3) afternoon, 1.30–4.30 p.m. Four of each batch of six plates were placed on lockers, about 2 ft. 6 in. high, beside the beds of patients, while the remaining two plates were exposed on tables in the middle of the ward.

The plates were then incubated and the number of colonies of *Strept. pyogenes* which developed on each plate were counted. The findings are shown in Table I, which gives the numbers of colonies of *Strept. pyogenes* on each plate in the six different sites of exposure during the three time periods.

The absence or extreme paucity of *Strept. pyogenes* during the night period is noteworthy: this is probably due to the stillness of the air resulting from quiet respiration, cessation of general movement about the ward, and the absence of air currents set up by such movement and by the opening and shutting of doors.

Table I. *Scarlet fever, three wards. Numbers of colonies of* Strept. pyogenes *on exposed plates*

Time of exposure	Sites of exposure A	B	C	D	E	F	Total
I.M. Ward: 22 beds, 22 patients, 13. i. 36							
Night, 12.30–3.30 a.m.	—	—	—	—	—	—	—
Morning, 7.30–10.30 a.m.	13	19	6	10	14	8	70
Afternoon, 1.30–4.30 p.m.	4	2	2	2	4	4	18
						Total	88
N.S. Ward: 22 beds, 22 patients, 14. i. 36							
Night, 12.30–3.30 a.m.	1	—	1	—	—	—	2
Morning, 7.30–10.30 a.m.	33	20	31	20	28	26	158
Afternoon, 1.30–4.30 p.m.	23	24	24	10	27	18	126
						Total	286
I.V. Ward: 22 beds, 19 patients, 15. i. 36							
Night, 12.30–3.30 a.m.	1	—	1	14	—	3	19
Morning, 7.30–10.30 a.m.	30	62	55	105	47	35	334
Afternoon, 1.30–4.30 p.m.	32	45	51	30	41	29	228
						Total	581

Dimensions of wards (in feet): 120 × 26 × 13.
All wards face south and have cross-ventilation.
Windows between all beds on each side of ward, with large ventilator above.
Ventilators open day and night.
Windows on one side of ward open during daytime, shut at night.

The numbers of colonies found on the plates exposed during the morning period afford a striking contrast, as there is now evidence of a heavy air infection with *Strept. pyogenes*. The high colony counts are almost certainly related to the morning activity in the wards—washing and treatment of patients, making of beds, sweeping the ward floor, cleaning the ward furniture and serving of meals, associated with a continual to and fro movement of staff and opening and shutting of doors.

The air infection has somewhat decreased in the early afternoon when conditions are considerably quieter, a smaller staff being on duty and the rounds finished; a few of the convalescent patients were up and dressed from about 10 a.m. This infection of the air probably continues to decrease as night sets in, until it becomes absent or negligible. It may be remarked that the total number of colonies of *Strept. pyogenes* on any plate rarely exceeded 10 per cent of the total number of colonies of all organisms. Staphylococci formed the great majority of the organisms on all plates, while sporing organisms and fungi were rare; pneumococci were not found on any of the plates.

Serological examination of all the colonies of *Strept. pyogenes* found on the exposed plates was carried out, and the results for the three wards are shown in Tables II–IV. A proportion (6·5 per cent) of all the colonies could not be identified serologically, but the remainder were classified into nine serological types, viz. Types 1, 2, 4, 5, 8, 9, 11, 23 and 25; of these the prevalent epidemic types 1, 2 and 4 accounted for 81·6 per cent of the total, although the other six serological types represented are not infrequently associated with clinical scarlet fever.

Table II. *Scarlet fever, Intramuscular serum ward. Serological types of colonies of* Strept. pyogenes *on exposed plates*, 13. i. 36

Time of exposure	Sites of exposure: A Strains	B Strains	C Strains	D Strains	E Strains	F Strains	Total Strains
Night, 12.30–3.30 a.m.	—	—	—	—	—	—	—
Morning, 7.30–10.30 a.m.	T. 5 1 T. 8 7 Nil 5 13	T. 2 1 T. 4 1 T. 8 7 T. 11 2 T. 25 1 Nil 7 19	T. 2 1 T. 8 2 T. 25 1 Nil 2 6	T. 2 1 T. 4 2 T. 8 2 T. 11 2 Nil 3 10	T. 8 11 T. 23 1 Nil 2 14	T. 2 1 T. 8 2 T. 11 1 T. 25 2 Nil 2 8	T. 2 4 T. 4 3 T. 5 1 T. 8 31 T. 11 5 T. 23 1 T. 25 4 Nil 21 70
Afternoon, 1.30–4.30 p.m.	T. 8 2 Nil 2 4	T. 11 1 T. 25 1 2	T. 25 1 Nil 1 2	T. 8 1 T. 23 1 2	T. 8 1 T. 11 2 Nil 1 4	T. 8 2 Nil 2 4	T. 8 6 T. 11 3 T. 23 1 T. 25 2 Nil 6 18

Summary:

	Strains
T. 2	4
T. 4	3
T. 5	1
T. 8	37
T. 11	8
T. 23	2
T. 25	6
Nil	27
Total	88 (61 typed, 27 untyped)

T. = type no. nil = untyped strains

Table III. *Scarlet fever, Non-serum-treated ward. Serological types of colonies of* Strept. pyogenes *on exposed plates*, 14. i. 36

Time of exposure	Sites of exposure: A Strains	B Strains	C Strains	D Strains	E Strains	F Strains	Total Strains
Night, 12.30–3.30 a.m.	T. 23 1	—	T. 4 1	—	—	—	T. 4 1 T. 23 1 2
Morning, 7.30–10.30 a.m.	T. 1 13 T. 2 1 T. 4 2 T. 9 1 T. 11 2 T. 23 10 Nil 4 33	T. 1 13 T. 2 1 T. 4 1 T. 23 4 Nil 1 20	T. 1 10 T. 2 2 T. 4 17 T. 11 1 Nil 1 31	T. 1 5 T. 2 5 T. 4 4 T. 23 4 Nil 2 20	T. 1 8 T. 2 3 T. 4 10 T. 23 6 Nil 1 28	T. 1 7 T. 2 11 T. 4 2 T. 11 1 T. 23 5 26	T. 1 56 T. 2 23 T. 4 36 T. 9 1 T. 11 4 T. 23 29 Nil 9 158
Afternoon, 1.30–4.30 p.m.	T. 1 9 T. 2 4 T. 4 4 T. 23 5 Nil 1 23	T. 1 15 T. 4 5 T. 11 1 T. 23 1 Nil 2 24	T. 1 9 T. 2 4 T. 4 5 T. 23 3 Nil 3 24	T. 1 6 T. 2 1 T. 4 2 T. 23 1 10	T. 1 8 T. 2 3 T. 4 9 T. 11 2 T. 23 4 Nil 1 27	T. 1 4 T. 2 2 T. 4 3 T. 11 3 T. 23 4 Nil 2 18	T. 1 51 T. 2 14 T. 4 28 T. 11 6 T. 23 18 Nil 9 126

Summary:	Strains
T. 1	107
T. 2	37
T. 4	65
T. 8	1
T. 11	10
T. 23	48
Nil	18
Total	286 (268 typed, 18 untyped)

Table IV. *Scarlet fever, Intravenous serum ward. Serological types of colonies of* Strept. pyogenes *on exposed plates*, 15. i. 36

Time of exposure	Sites of exposure: A Strains	B Strains	C Strains	D Strains	E Strains	F Strains	Total Strains
Night, 12.30–3.30 a.m.	T. 4 1	—	T. 4 1	T. 4 14	—	T. 4 3	T. 4 19
Morning, 7.30–10.30 a.m.	T. 1 8 T. 4 20 Nil 2 30	T. 1 34 T. 4 27 Nil 1 62	T. 1 12 T. 4 41 Nil 2 55	T. 1 15 T. 4 90 105	T. 1 14 T. 2 3 T. 4 27 Nil 3 47	T. 1 9 T. 4 24 T. 5 1 Nil 1 35	T. 1 92 T. 2 3 T. 4 229 T. 5 1 Nil 9 334
Afternoon, 1.30–4.30 p.m.	T. 1 7 T. 4 24 Nil 1 32	T. 1 9 T. 4 35 Nil 1 45	T. 1 23 T. 2 1 T. 4 25 Nil 2 51	T. 1 7 T. 4 22 Nil 1 30	T. 1 8 T. 4 32 Nil 1 41	T. 1 9 T. 4 18 Nil 2 29	T. 1 63 T. 2 1 T. 4 156 Nil 8 228

Summary:	Strains
T. 1	155
T. 2	4
T. 4	404
T. 5	1
Nil	17
Total	581 (564 typed, 17 untyped)

The three wards concerned in the investigation were all the same size (dimensions in feet: $120 \times 26 \times 13$) and each contained the same number of beds—twenty-two. The I.M. (Intramuscular serum-treated patients) and the N.S. (Non-serum-treated patients) wards each contained twenty-two patients, while the I.V. (Intravenous serum-treated patients) contained nineteen patients. We have not been able to account satisfactorily for the differences in the degree of air-infection of the three wards taking into consideration such factors as (1) the number of patients convalescent and allowed up, (2) the number of patients with complications associated with discharges, especially rhinorrhoea, (3) direction and speed of wind and (4) number and position of windows and ventilators open. It is interesting, however, to note with regard to (2) that the percentage of complicated cases in the N.S., I.M. and I.V. wards were at this time 27, 13 and 30 respectively. Unknown factors were the relative efficiency of the ward maids in sweeping and cleaning the wards and the relative amount of staff activity in the wards.

It was not found possible at the time to swab the noses and throats of the patients in the wards on the days that the plate exposures were carried out, owing to the unexpected amount of work involved in the serological identification of such a large number of strains of *Strept. pyogenes* isolated from the air.

A further investigation was subsequently carried out on another scarlet-fever ward, in which the patients were swabbed (nose, throat and complicating discharges) on the same day during which plate exposures were made. Tables V–VIII show the findings and the diagram illustrates the general lay-out of the ward with the positions of the beds of the patients and the sites of exposure of the plates. The ward (B 1) contained twenty-three patients, thirteen being in beds and ten in cots. No patients were allowed out on the balcony. Each window, except those on either side of the balcony door, is surmounted by a large ventilator. The windows open during the investigation were as follows (see Diagram):

Left side. Top half of each window 18 in. down with the exception of windows Nos. 4 and 6, counting from the entrance.

Right side. Top half of each window 18 in. down with the exception of windows Nos. 10 and 11, counting from the entrance.

All ventilators open.

Balcony door shut.

Wind. East-south-east, slight.

Dimensions of ward (in feet): $120 \times 26 \times 13$.

The results of the plate exposures are comparable with those obtained from the three wards previously examined in a similar manner, viz. negligible infection of the air during the night hours, a steep rise in the degree of infection in the morning, followed by a slight decrease of infection during the afternoon.

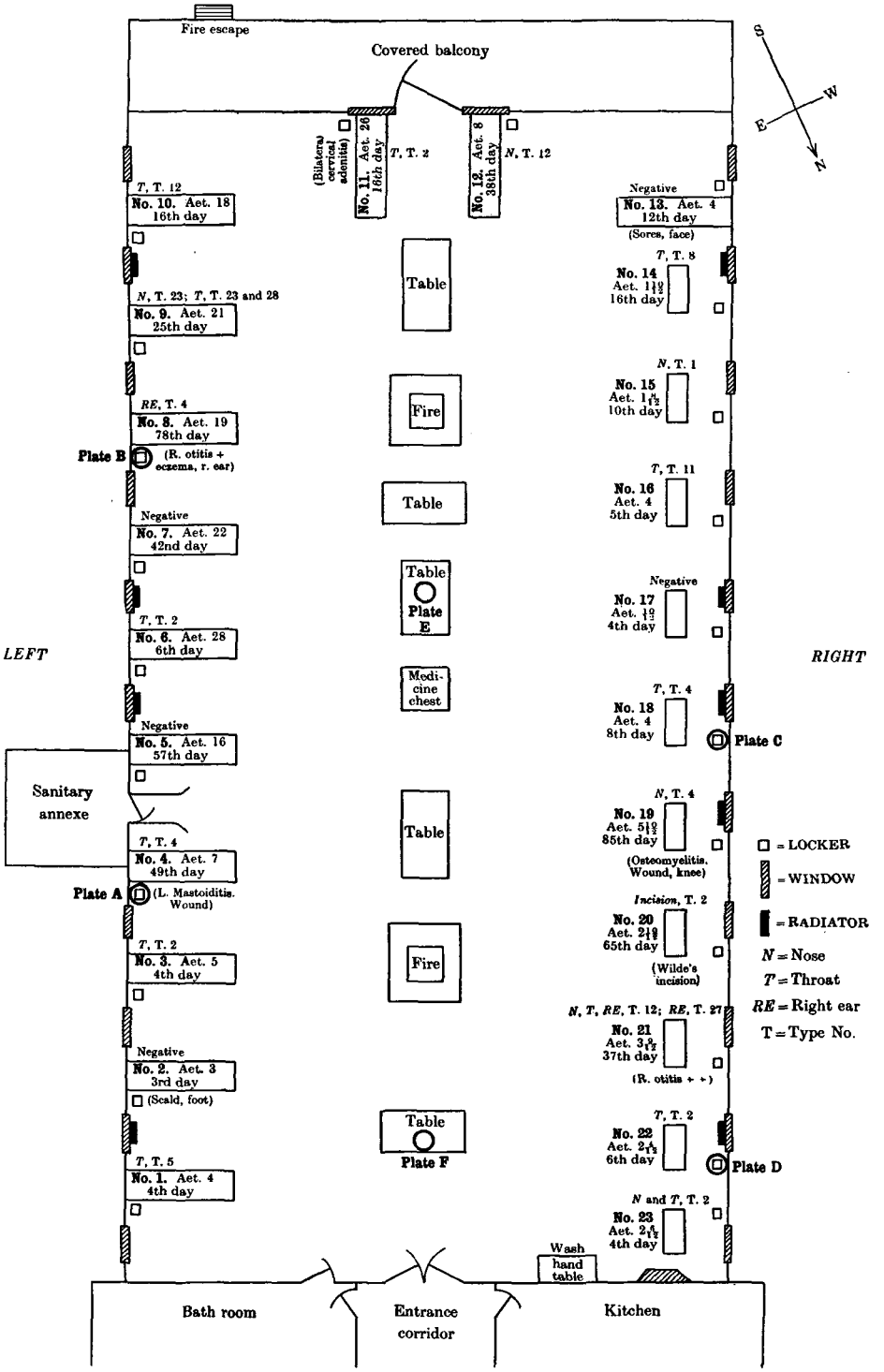
Of the 210 colonies of *Strept. pyogenes* isolated from the plates, all but twelve (5·7 per cent) were identified serologically, and fell into one or other of six different serological types—Types 2, 4, 5, 8, 12 and 23, all of which were

DIAGRAM

WARD B1. GROUND FLOOR. 23 BEDS

Dimensions (in feet): 120 × 26 × 13

Patients Nos 5, 7, 8 and 9 allowed up and had tea at table—PLATE E



https://doi.org/10.1017/S0022172400034768 Published online by Cambridge University Press

Table V. *Scarlet-fever ward B* 1: 23 *beds. Numbers of colonies of* Strept. pyogenes *on exposed plates*, 12–13. v. 36

Time of exposure	Sites of exposure A	B	C	D	E	F	Total
Night, 12.30–3.30 a.m.	2	1	0	1	0	0	4
Morning, 7.30–10.30 a.m.	20	16	14	19	22	23	114
Afternoon, 1.30–4.30 p.m.	15	18	11	23	9	16	92
							210

Table VI. *Scarlet-fever ward B* 1: 23 *beds. Serological types of colonies of* Strept. pyogenes *on exposed plates*, 12–13. v. 36

Time of exposure	Sites of exposure A Colonies	B Colonies	C Colonies	D Colonies	E Colonies	F Colonies	Total Colonies
Night, 12.30–3.30 a.m.	T. 2 1 T. 4 1 2	T. 8 1	—	T. 2 1	—	—	T. 2 2 T. 4 1 T. 8 1 4
Morning, 7.30–10.30 a.m.	T. 2 10 T. 4 5 T. 23 5 20	T. 2 13 T. 4 2 ? 1 16	T. 2 5 T. 4 4 T. 23 4 ? 1 14	T. 2 11 T. 12 7 ? 1 19	T. 2 12 T. 4 5 T. 5 3 ? 2 22	T. 2 14 T. 4 6 T. 23 1 ? 2 23	T. 2 65 T. 4 22 T. 5 3 T. 12 7 T. 23 10 ? 7 114
Afternoon, 1.30–4.30 p.m.	T. 2 6 T. 4 3 T. 12 1 T. 23 4 ? 1 15	T. 2 13 T. 4 4 ? 1 18	T. 2 4 T. 4 3 T. 23 4 11	T. 2 15 T. 4 2 T. 12 4 ? 2 23	T. 2 7 T. 4 2 9	T. 2 11 T. 4 3 T. 23 1 ? 1 16	T. 2 56 T. 4 17 T. 12 5 T. 23 9 ? 5 92

T. = type no. ? = untyped strains

Table VII. *Scarlet-fever ward B* 1: 23 *beds*, 12–13. v. 36

A. Distribution of serological types isolated from patients (23) and staff (6)

Type	No. infected
1	1
2	7
4	4
5	1
8	1
11	1
12	3
23	1
27	1
28	1
Negative	10
	*31

* Two patients with two serological types.

B. Distribution of serological types isolated from all exposed plates

Type	No. of colonies
2	123
4	40
5	3
8	1
12	12
23	19
?	12
	210

? = untyped strains.

Table VIII. *Scarlet-fever ward B* 1: 23 *beds. Percentage of* Strept. pyogenes *in cultures from swabs and the serological types when present*, 12–13. v. 36

Date	Patient no.	Age years	Day of disease	Nose	Throat	Complication	Serological type no.
12. v. 36	1	4	4th	—	25%	—	5
	2	3	3rd	—	—	Scald (leg)—	—
	3	5	4th	—	90%	—	2
	4	7	49th	—	20%	Mastoid—	4
	5*	16	57th	—	—	—	—
	6	28	6th	—	20%	—	2
	7*	22	42nd	—	—	—	—
	8*	19	78th	—	—	Right otitis 30%	4
	9*	21	25th	30%	75%	—	*N*, 23; *T*, 23 and 28
	10	18	16th	—	60%	—	12
	11	26	16th	—	5%	—	2
13. v. 36	12	8	38th	3 cols.	—	—	12
	13	4	12th	—	—	—	—
	14	$1\frac{10}{12}$	16th	—	1 col.	—	8
	15	$1\frac{8}{12}$	10th	2 cols.	—	—	1
	16	4	5th	—	4 cols.	—	11
	17	$\frac{10}{12}$	4th	—	—	—	—
	18	4	8th	—	100%	—	4
	19	$5\frac{10}{12}$	85th	10%	—	—	4
	20	$2\frac{10}{12}$	65th	—	—	Wilde's incision 100%	2
	21	$3\frac{9}{12}$	37th	90%	98%	Right otitis 60%	*N* and *T*, 12; *ear*, 12 and 27
	22	$2\frac{4}{12}$	6th	—	20%	—	2
	23	$2\frac{6}{12}$	4th	98%	30%	—	2
	Staff						
	Br.	—	—	—	—	—	—
	Co.	—	—	—	—	—	—
	Cu.	—	—	—	—	—	—
	Ho.	—	—	—	—	—	—
	Tu.	—	—	—	6 cols.	—	2
	Wo.	—	—	—	—	—	—

N = nose; *T* = throat; cols. = colonies.

* Patients convalescent and allowed up.

https://doi.org/10.1017/S0022172400034768 Published online by Cambridge University Press

isolated from one or more patients in the ward at the time of exposure of the plates. The epidemic types 2 and 4 accounted for 163 colonies, 77·6 per cent of the total.

Swabs from five out of the twenty-three patients and five out of the six members of the ward staff were negative as regards *Strept. pyogenes*. The serological type infecting the largest number of persons was Type 2 (isolated from six patients and one nurse), and this type was also represented by the largest number of colonies on the exposed plates, 123 (58·6 per cent) out of 210. Next in order is Type 4 (isolated from four patients) represented by forty colonies (19 per cent).

Type 23 is represented in the ward by only one patient (No. 9), but accounts for nineteen colonies (9 per cent) on the plates; this patient was one of four allowed up, and this may account in part for the degree of air-infection with this type, although Plates B (nearest to her bed) and E (table at which she had tea) did not yield any organisms of this type. Of the other three patients allowed up, No. 8 had a right otitis media from which Type 4 was isolated and Nos. 5 and 7 were negative.

Type 12 infecting three patients accounts for twelve colonies (5·7 per cent) on the plates. Type 5 (one patient, No. 1) yielded three colonies from the plates and Type 8 (one patient, No. 14) one colony. Types 1, 11, 27 and 28, each isolated from one patient, were not found on the exposed plates.

An analysis of the serological types infecting the patients in relation to the numbers and serological types of colonies found on exposed plates in their neighbourhood is shown in Table IX. In only one situation (Plates D) do the numbers of colonies and the serological types of *Strept. pyogenes* found seem to bear any relation to the types infecting patients in the vicinity. Types 2 and 4 appear to be widespread in the ward air and comprised a large proportion of the colonies on all plates on which *Strept. pyogenes* was present. Type 5 (Plate E, Morning) and Type 8 (Plate B, Night) were found solely on plates at some distance from the only patients (Nos. 1 and 14) infected with these types.

A point of interest is that three of the serological types (2, 4 and 12) most frequently found on the plates were also isolated from patients with infected discharges from complications (two patients with otitis media and one with a Wilde's incision), but this may be due to coincidence as such complications are not ordinarily the source of air-borne infection.

The significance of these findings is not easy to assess, partly on account of the many complicating factors already mentioned and partly because it does not seem possible to trace further the importance of the air as a vehicle of infection. The period of time during which haemolytic streptococci maintain their virulence in the air or dust and the minimum infecting dose of such organisms for human beings are unknown factors, although Colebrook, quoted by White (1936), has found that cultures of haemolytic streptococci from dust kept for 25 days showed no diminution of virulence for mice.

Cruickshank (1935) has shown that the frequent occurrence of septic

Table IX. *Scarlet-fever ward B* 1: 23 *beds. Numbers and serological types of* Strept. pyogenes *on exposed plates in relation to the serological types isolated from patients in the vicinity*

Plate	Serological types and number of colonies on plates: Type	Colonies	Patients in the vicinity and serological types isolated from them		
A	2	17	No. 3	Smith	Type 2
	4	9	No. 4	*Freeland*	Type 4
	12	1	No. 5	Churchman*	Negative
	23	9			
	?	1			
		37			
B	2	26	No. 7	Lacy*	Negative
	4	6	No. 8	*Fuller*	Type 4
	8	1	No. 9	Pitt*	Types 23 and 28
	?	2			
		35			
C	2	9	No. 17	Gibbs	Negative
	4	7	No. 18	*Ratcliffe*	Type 4
	23	8	No. 19	Campion	Type 4
	?	1			
		25			
D	2	27	No. 21	Mead	Types 12 and 27
	4	2	No. 22	*Beasley*	Type 2
	12	11	No. 23	Warwick	Type 2
	?	3			
		43			
E	2	19	None (Plate on dining table in centre of ward)		
	4	7			
	5	3			
	?	2			
		31			
F	2	25	None (Plate on table in middle of ward near entrance door)		
	4	9			
	23	2			
	?	3			
		39			

* Patients convalescent and allowed up.

Patients' names in italics indicate that exposed plates were placed on the lockers beside the beds of these patients.

infection following severe burns is due to *Strept. pyogenes*, that the infection takes place in the majority of cases after the patients are admitted to hospital, and that numerous haemolytic streptococci may be isolated from the dust and air of the burns ward, by exposure of blood agar plates. Control plates exposed in a medical and a surgical ward yielded respectively no haemolytic streptococci and a few colonies. One of us (V. D. A.) had the opportunity of examining some of the strains isolated by Dr Cruickshank and found that strains isolated from eight cases of burns, obtained over a period of 3 weeks,

all belonged to one serological type (Type 4); in another instance Type 23 was isolated from the air of the ward and from the lesion in a case of burns in the ward at the time.

White (1936) has also recently isolated haemolytic streptococci from the dust of single-bed wards in which puerperal fever patients, infected with *Strept. pyogenes*, were being nursed. In most instances the strain isolated from the dust was found to be serologically identical with that infecting the patient. In investigations such as these it is often impossible to eliminate infection by contact with hands, instruments, etc., but White reports a case of pharyngitis in a ward maid in which the evidence is strongly in favour of infection by dust.

In an earlier investigation we found that various serological types of *Strept. pyogenes* could readily be isolated from toys (beads, pencils, etc.) used by children in scarlet-fever wards, also from swabs of the patients' dining table and lockers and from floor dust. The serological types isolated and identified from these sources corresponded to the types found in cultures from the nose and throat of the eight patients in the ward at the time. Furthermore, out of the eight patients, only one still carried the primary infecting type of *Strept. pyogenes* found when he was admitted; all the other seven patients were carrying fresh serological types of *Strept. pyogenes* with which they had become infected in the ward.

The occurrence of infection and cross-infection with *Strept. pyogenes* in scarlet-fever, measles and diphtheria wards has been fully confirmed by the recent work (paper in preparation) we have done, and while contact, direct or indirect, is probably of considerable importance in the transmission of infection, the possibility of infection via the air other than that due to droplets cannot be dismissed.

Summary

1. The air of four large scarlet-fever wards was found to contain large numbers of haemolytic streptococci, most of which could be identified serologically. In one ward the serological types identified were found to correspond to the types infecting patients in the ward.

2. The degree of infection of the air with haemolytic streptococci showed considerable variation during the 24 hours. During the night, infection was absent or negligible, in the morning there was a steep rise followed by a slight fall in the degree of infection during the early afternoon. This variation is probably associated with the degree of air movement in the ward produced by the ward staff in the execution of their duties.

3. Haemolytic streptococci were widespread in the ward air and the serological types identified were not confined to the neighbourhood of patients infected with a particular type.

4. Though contact with infected hands, instruments, books, toys, etc., is probably of considerable importance in the transmission of infection with

Strept. pyogenes, and though droplet transmission no doubt occurs as in other infections of the respiratory tract, yet the possibility of infection via the air cannot be dismissed, especially in multiple-bed wards in which patients infected with many different serological types of haemolytic streptococci are being nursed.

REFERENCES

CRUICKSHANK, R. (1935). *J. Path. and Bact.* **41**, 367.
WHITE, E. (1936). *Lancet*, i, 941.

(*MS. received for publication* 21. IX. 1936.—Ed.)