fungus is widely scattered in the soil it is all the more surprising that it has not been incriminated more often as a source of epidemic spread. A factor which possibly contributes to this state of affairs is that most studies on the epidemiology of fungus infections have been made in cities, and such infections may not be investigated when they occur in country districts. Difficulties in transport and either the necessity of sending patients a distance to hospital or unwillingness to collect appropriate samples, together with the rapid response made to treatment of infections with this fungus, all contribute. Another which is possibly applicable only in rural communities was noticed in this epidemic. Treatment of one patient was tantamount to treating several in that, once a diagnosis had been reached on one patient, a number made their own diagnosis and proceeded to share the same ointment pot. Once a patient was satisfied with his own clinical improvement the appropriate medicament was rapidly loaned out to some other group of sufferers. In the present instance this admirable community spirit certainly militated against collection of appropriate skin samples.

Although 13 patients developed lesions on their arms, only two had them on their hands, possibly because the patients washed only their hands after work. There was no history of trauma, but it is not impossible that the coarse texture of the cucumber plants could have caused mild trauma of exposed parts of the body. Under greenhouse conditions the skins were moist with sweat. Although the first lesions seen in the surgery were dry and scaly, half of the total patients had lesions which showed vesicle formation and two patients developed florid ringworms with marked inflammatory reaction. The lesions in the secondary outbreak were all minor and without inflammatory response; that is to say, the ringworms contracted by spread from patient to patient appeared to be less virulent. The two florid lesions with marked inflammatory reactions were contracted from soil.

Multiple ringworms were found only in those patients infected in the greenhouse. Untreated, the ringworms ran a self-limiting course of five to six weeks. Whitfield's ointment was effective in all cases treated.

Two months later two of the patients were seen again, and still showed some discoloration of the skin at the site of their ringworms.

Conclusion

An epidemic of ringworm infection of glabrous skin due to *M. gypseum* is described. This was originally contracted from infected soil and subsequently spread by contact.

Our thanks are due to Dr. J. G. Holmes, who originally suggested the diagnosis, and to Dr. James Gentles not only for his superior mycological skill but also for his literary ability.

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STUDIES IN THE EPIDEMIOLOGY OF TINEA PEDIS

VI. TINEA PEDIS IN A BOYS' BOARDING-SCHOOL

BY

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It is generally believed that tinea pedis is a common complaint of boys' boarding-schools, yet we have been unable to find in the literature any report of a mycologically controlled survey of such a school. The community life and emphasis on sports would, indeed, lead one to expect a high incidence in these establishments. To check this, and to compare the situation with that in day-schools (English and Gibson, 1959, 1960b), we have paid two visits to a small boarding-school for boys.

The Subjects

The school catered for about 200 boy boarders aged from 7 to 18. There were no bathrooms, but all boys took morning showers twice a week and used the same shower baths after games. The school had its own swimming-bath, open in the summer only, to which organized visits were paid once or twice a week; senior boys were also allowed to use the bath in their own time. Visits by boarders to public swimming-baths were officially prohibited, but the school bath was used by 150 day-boys, who might also be using public baths.

Leather lace-up shoes were worn outdoors, light leather slippers indoors, and appropriate footwear for sports and gymnastics. Socks were always worn, but their material was not recorded.

Methods

The boys' feet were classified according to their condition into the first five groups of Holmes and Gentles (1956). Scrapings were taken from the interdigital spaces of all boys, whether they showed lesions or not, and from any lesions elsewhere on the foot, and were examined by the methods used previously in this work (English and Gibson, 1959). About 55% of the specimens were large enough for microscopical examination as well as culture.

The first visit to the school was made in October, 1958, the second eight months later, in June, 1959.

After the first visit, only the names of boys with *Trichophyton rubrum* infections were disclosed to the authorities so that treatment might be offered. All other boys, whether infected or not, continued as usual, being treated as and when they or the school authorities considered it necessary on clinical grounds alone. Unfortunately, it was impossible to obtain details of the boys so treated, but the numbers were probably small. After the second visit the names of all infected boys were disclosed.

Results

At the first visit 212 boys were seen, at the second 215: 197 of these were present on both occasions.

TABLE I.—*Incidence of Lesions and Infection According to Age*

Age	1st Visit (October)							2nd Visit (June)						
	No. of Boys	Boys with Lesions		Boys with Infection		Boys with Lesions and Infection		No. of Boys	Boys with Lesions		Boys with Infection		Boys with Lesions and Infection	
		No.	%	No.	%	No.	%		No.	%	No.	%	No.	%
7	1	0		0		0		—	—		—		—	
8	3	2		0		0		3	0		0		0	
9	5	2	34	2	17	1	9	5	3	48	0	0	0	0
10	6	3		1		1		7	4		0		0	
11	32	9		5		3		14	7		0		0	
12	30	14	47	3	10	2	7	37	18	49	5	14	3	8
13	35	18	51	6	17	5	14	35	28	80	6	17	6	17
14	37	18	49	10	27	6	16	35	26	74	8	23	6	17
15	30	22	73	10	43	7	23	36	27	75	8	22	7	19
16	21	16		8		8		23	17		6		6	
17	6	3	66	0	31	0	31	12	9	79	4	28	4	28
18	6	3		2		2		8	8		2		2	
Total	212	110	52	47	22	35	17	215	147	68	39	18	34	15

Because of the small numbers, results for boys of 11 and under have been averaged, as have those for boys of 16 and over. The incidence of lesions and of infection at both visits are shown separately in Table I, previous work by many authors having demonstrated that, in many cases, lesions of the feet cannot be attributed to fungus infection.

Lesions

The total incidence of lesions of all types increased significantly ($P<0.001$) by 16% between the two visits: the incidence of lesions increased with age at both visits. This increased incidence with age would account for part of the increase between visits, but not for the whole, as the time lapse was only eight months. Possibly the warmer weather at the second visit had some effect.

Twenty-four group IV and V lesions (fissures and vesicles) were seen—7 at the first visit and 17 at the second: of all these only three occurred in boys of 12 and under. This tendency to cracking and vesiculation at the second visit might again, therefore, be attributed either to the slightly increased age of the boys or to the warmer weather. There were 67% group II lesions and 27% group III lesions at the first visit and 58% and 29% respectively at the second.

Table II indicates the chronicity of lesions of non-fungal origin in the 142 boys who were seen at both visits but infected at neither. A minority of all boys never had lesions, but only 15% of boys of 12 and under had lesions at both visits, compared with 34% of all boys.

Nineteen of the boys who were seen at both visits, and who had both lesions and infection at the first, were clear of their infection at the second, but 15 of these still had lesions on the second occasion.

TABLE II.—*Chronicity of Lesions of Non-fungal Origin*

Age-group	Lesions at–						Total
	Both Visits		One Visit		Neither Visit		
	No.	%	No.	%	No.	%	
All boys ..	48	34	50	35	44	31	142
12 and under ..	8	15	24	44	22	41	54

Infection

Table I shows that the total incidence of infection, including lesion-free "carriers," was higher at the first visit than at the second, but this was not statistically significant: the number of boys with infections accompanied by lesions was approximately the same at both visits. This occurred despite the fact that at the second visit the boys were a little older, the weather was warmer, and the total incidence of lesions was higher. There was a tendency, which was not statistically significant, for the incidence of infection to increase with age.

The *interdigitale* type of *Trichophyton mentagrophytes* was overwhelmingly the predominant fungus in the school. At the first visit this organism was isolated from 41 boys, *T. rubrum* from four, both fungi from one, and one boy was microscopically positive only. At the second visit *T. mentagrophytes* was isolated from all the infected boys except two, who were microscopically positive only.

Lesion-free "Carriers"

At the first visit 11 boys with no lesions were found to be harbouring a dermatophyte. When these boys were examined at the second visit six were free of infection though three of them had developed lesions; four remained infected and had developed lesions; and only one was still in the "carrier" state. All "carriers" at both visits were boys of 15 and under.

Recovery

It has been stated that boys infected with *T. mentagrophytes* at the first visit were not told of their condition. Of these boys 40 were seen again at the second visit,

TABLE III.—*Recovery in Boys Infected with T. mentagrophytes*

Age	No. Infected			No. Recovered	
	With Signs	"Carriers"	Total	No.	%
12 and under	7	4	11	11	100
13 ,, over	22	7	29	10	34
All ..	29	11	40	21	52

and Table III shows that, by then, all 11 of those of 12 years and under had recovered, but that this was true of only 10 (34%) of the 29 over 12 years old. These figures suggest the possibility of a certain resistance to the disease in the younger boys.

Comparison with Day-schools

Results for 11–14-year-old boarders can be compared with those for day-boys in local authority senior schools, obtained at a previous survey (English and Gibson, 1959), though there will be a very slight discrepancy in age (English and Gibson, 1960b).

The total incidence of lesions at the first boarding-school visit was very similar to that in day-schools; at the second visit it was significantly higher ($P<0.001$). It may be noted that this second boarding-school visit was the only one in any school carried out in summer.

There was also a much higher incidence in the boarding-school, at both visits, of vesicular and erythematous lesions and of cracking.

The incidence of infections accompanied by lesions in the comparable age-group in the boarding-school, constant at 12% at both visits, was nearly double the

TABLE IV.—*Comparison of 11–14-year-old Boarders with Boys from Local Authority Day-schools (English and Gibson, 1959)*

	Boarding-school		Day-schools
	1st Visit	2nd Visit	
% lesions	43	65	40·3
,, infection and lesions	12	12	6·6
,, "carriers"	6	3	1·5*
,, group III, IV, and V lesions out of total lesions	27	45	10

* Estimated from a sample taken from a school with 8·9% infection. No "carriers" were found in a school with 2·2% infection.

average in the day-schools and compares with a 9% incidence in the most highly infected day-school. The percentage of "carriers" in this day-school was also very much lower than in the boarding-school.

Discussion

The high incidence of tinea pedis in this boarding-school supports the ideas put forward in a previous article (English *et al.*, 1960) regarding factors of seed and soil in cross-infection. The boys' footwear, like that of pupils of day-schools, was of a type which would be likely to render their feet suitable soil for fungal growth: their communal life would offer many more opportunities for the dissemination of the organisms than would be the case with day-boys. This combination could be expected to result in a higher infection rate than in day-boys. It is also possible that more boarders than day-boys come to school having already contracted the infection in their families, for pupils in boarding-schools are drawn from higher social classes than those in local authority day-schools and there are indications that the risk of cross-infection is greatest in families of high social class (English and Gibson, 1960a).

"Carriers"

Most workers have found lesion-free "carriers" in populations they have surveyed, and various guesses regarding their significance have been made (Ajello *et al.*, 1945; Sulzberger and Baer, 1955). No one, apparently, has re-examined these people to find out the fate of their infections, though Marples and Chapman (1959) suggested this course, and Strauss and Kligman (1957) mention such a study without giving details. We have been able to follow up 11 "carriers" and to show that only one still carried the fungus on lesion-free feet eight months after the initial examination. We therefore believe that true carriers of tinea pedis are rare: in most cases we are probably dealing with incipient or resolving infections, not with the true carrier state where "host resistance is preventing clinical manifestation" or where "the fungus is a saprophyte" (Holmes and Gentles, 1956).

Rosenthal *et al.* (1956) believe that cross-infection is not important in clinical disease, but that such disease occurs when a dermatophyte, carried on the feet of most people, becomes active because "soil" conditions become suitable. If so, one would expect an approximately equal incidence of "carriers" in all communities of similar age-group. In fact we have shown, by comparing boarding and day-boys, that the "carrier" rate rises with the incidence of visible infections, an observation that is compatible with the idea that in most cases "carrying" is merely a stage in a clinical infection.

Lesions and Infection

So many workers in so many parts of the world have reported that the presence of lesions in the toe-webs does not necessarily indicate fungous infection, that we feel that this must now be accepted as fact. As to whether the presence of lesions of non-fungal origin predisposes to fungal infection (Meenan, 1953; Marples and Chapman, 1959), the evidence is far more conflicting. That the overall incidence of lesions in a community is in no way related to the infection rate is shown by comparing our two visits to the boarding-school, where lesions but not infection rose in the summer, and also by comparing the day-schools with each other (English and Gibson, 1959).

If lesions, in themselves, predispose to infection one would expect to find that boys with persistent lesions were particularly prone to tinea pedis. Yet 34% of boys in this school had lesions at both visits but fungal infection at neither. Figures for 56 uninfected boys from local authority day-schools who were examined three times over a period of two years are also of interest in this connexion. Of these, 8 (14%) had lesions on all occasions, 30 (54%) had them at one or two of the examinations, and only 18 (32%) were free of lesions during the whole period.

On the other hand, the tendency in boarders for both lesions and infection to rise with age might indicate that lesions can predispose to infection, particularly as both persistent lesions and persistent infection were far less common in younger boys.

The high recovery rate in the younger boarders suggests the possibility of a certain resistance to infection not present in older boys. If this is indeed so, it might well be due to the better condition of the feet of the younger boys as indicated by fewer and less persistent lesions, and our suggestion (English and Gibson, 1959) that low infection rates in younger children are due entirely to the shorter exposure to risk must be modified.

It is clear from the above that there is no single, direct relationship between lesions and infection, but some connexion probably exists. Possibly the coexistence of lesions with some other factor or factors unknown is crucial.

Summary

The pupils of a boarding-school catering for about 200 boys were examined for tinea pedis on two occasions, with an eight-months interval between. At the first visit 52% of the boys had lesions and 22% were infected with dermatophytes; at the second visit 68% had lesions and 18% were infected. The *interdigitale* type of *Trichophyton mentagrophytes* was the most important causal fungus, but *T. rubrum* was also isolated at the first visit. The situation is compared with that in local authority day-schools visited previously.

Of 11 lesion-free "carriers" seen at the first visit only one was still carrying the fungus on lesion-free feet eight months later: this suggests that true carriers are rare, the majority of such cases representing either incipient or healing infections.

The relationship to fungal infection of lesions of non-fungal origin is discussed, and it is concluded that, though such lesions may sometimes predispose to fungal infection, other, unknown, factors are also involved.

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STUDIES IN THE EPIDEMIOLOGY OF TINEA PEDIS

VII. THE CIRCULATION OF INFECTION

BY

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> "In recent years there has been increasing recognition that although there may be specific and necessary causes of certain diseases, these do not provide a complete account of causation. A whole network of circumstances, inherited and environmental, determine the genesis, course, and effects of disease."—Lord Cohen of Birkenhead, *The Observer*, March 6, 1960.

Previous articles in this series (English and Gibson, 1959a, 1959b, 1960a, 1960b; English *et al.*, 1960, 1961) have shown that the incidence of tinea pedis varies in different communities situated in the limited geographical area of the City of Bristol and its immediate surroundings. Evidence has been put forward that this variation is largely due to differing opportunities for contact with an exogenous source of infection.

This is contrary to the views of Sulzberger and Baer (1955), who believe, as do many other workers who adhere to their school of thought, that "tinea pedis is not transmissible in the ordinary sense." These authors, putting forward what might be called the "flare-up" theory, state that "there is much evidence that in parts of the world where tinea pedis is prevalent, many, if not most, *grossly uninfected* subjects actually do carry fungi here or there on the feet" (p. 12, their italics), and they argue that whether or not clinical disease results depends on the personal resistance of the subject. They give no details of the evidence they mention. Yet a few lines earlier, in the same article, they have written, "One of the most instructive of the recently acquired facts is the observation that the skin of most *human beings free from clinically active tinea pedis appears to have a remarkable ability to rid itself of fungi*, even when exposed to relatively massive, not to say overwhelming, quantities under experimental conditions" (p. 12, their italics). Their own experimental work (Baer *et al.*, 1956) and that of Strauss and Kligman (1957) support this latter statement.

Baer *et al.* soaked one foot of each of 54 subjects in a footbath containing a suspension of *Trichophyton mentagrophytes* and examined scrapings from these feet at weekly intervals for the next six weeks. They were able to re-isolate the fungus from only one subject, though they obtained microscopically positive scrapings from a further 26. This extraordinarily high rate of failure to grow the fungus from subjects who were microscopically positive (and who presumably were not using fungicides) suggests that most of the fungal elements seen were no longer viable. The sporadic nature of the microscopical evidence is also strange: of the 26 subjects whose exposed feet were microscopically positive, 18 were positive at only one of the 6 examinations; and of the 8 who were positive more than once, only 3 were positive in two successive weeks. In addition, of all the 26, only 8 were positive in the first week after exposure.

The authors do not state whether their subjects were asked to take any precautions against infecting themselves from outside sources during the follow-up period. If this was not done, such extraneous infection might well account for their isolation from the exposed feet of two of the subjects of dermatophytes other than *T. mentagrophytes*, and possibly also for some of the sporadic positive microscopical results from both exposed and control feet.

Sulzberger *et al.* (1942) found that tinea pedis and cruris very rarely spread in families, and this work is used by Sulzberger and Baer (1955) as further evidence of the lack of importance of transmission as a cause of clinical disease. The inadequacy of the methods used to obtain these results has been discussed elsewhere (English, 1957; Many *et al.*, 1960).

Strauss and Kligman (1957) placed massive inocula in the interdigital spaces of persons with clinically normal feet and subjected the feet to treatments designed to produce warm, moist conditions over long periods of time. Even with such extreme methods they state that "most infections were transient, and usually fungus elements were found on only one or two (subsequent) weekly examinations." Infections were not induced by imposing warm, moist conditions on normal uninoculated feet.

Clearly a subject with an inherent resistance to tinea pedis will not contract the disease *despite* the fact that he has been in contact with it: that he will continue to carry the fungus on lesion-free feet over long periods seem most unlikely, on the available evidence, in more than a very small percentage of cases. For a subject with temporarily or permanently lowered resistance tinea pedis is transmissible: he may contract the disease if, *and only if*, he has recently been exposed to it. This is the only reasonable explanation for differing infection rates in communities of similar types.

Factors Determining the Incidence of Tinea Pedis

The ideas put forward in the present article, based on findings in Bristol, serve only to underline the results of Gentles and Holmes (1957) in their careful investigation