THE ENVIRONMENTAL CONTROL OF EPIDEMIC CONTAGION

I. AN EPIDEMIOLOGIC STUDY OF RADIANT DISINFECTION OF AIR IN DAY SCHOOLS

By

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INTRODUCTION

The experiments described in this paper were undertaken in the fall of 1937, as a test of the hypothesis (1) that the confined atmospheres of our habitations constitute the vehicle for the *epidemic* spread of contagion. Even though *endemic* incidence (person-to-person type of spread) may be due to any one of several modes of spread such as physical contact, direct hits by Flügge droplets, or air, the phenomenon of epidemic contagion (the dynamic network of person-to-group infection) is indicative of spread through the medium of a common source: air. If epidemic respira-

tory contagion can be controlled by radiant disinfection of air, then air must be such a vehicle of spread.

Improvements in ultraviolet light sources and bacteriologic methods for the study of sanitary ventilation have made it practicable to eliminate microorganisms from enclosed atmospheres at rates hitherto impossible. During cold weather, economy limits the number of air changes per hour through mechanical displacement to some 10 or 20 changes at most while, with radiant disinfection, it is possible to secure bacterial elimination which is equivalent to 100 air changes per hour, even with indirect irradiation and without erythemal exposure of the occupants.

When the experiments were begun the art of radiant disinfection of air was less clearly understood than now, although irradiation had already been used to prevent surgical infections (2, 3), and hospital cross-infections (4, 5). Such infections, however, inasmuch as they occur among "closed aggregations," i.e., among persons dwelling continuously within the same atmosphere, afford prima facie evidence of infection within a given atmosphere. Control of contagion in "intermittent aggregations," on the other hand, necessitates the locating of the atmosphere within which infections are contracted, since obviously disinfection of a confined atmosphere can prevent only those infections contracted within it.

While homes provide aggregations of susceptible children and while the study of secondary attack rates of childhood contagions in families (where the factor of exposure can be assumed) has contributed much to an understanding of the communicability of these diseases, the use of the family unit for study of the effect of radiant disinfection of air on the spread of contagion was not feasible. Day-schools, however, bring together groups still largely susceptible to childhood contagions, and irradiation of their atmospheres seemed entirely practicable.

Experiment I. A study of radiant disinfection of air in the Germantown Friends School

The choice of the Germantown Friends School for the experiment has proved an excellent one. It has afforded the obvious advantage of providing an intelligent and cooperative group of educators and parents. Furthermore, the careful records of all childhood contagions and of colds and other respiratory infections, which had been kept by the school physician (T.S.W.) over the period of 5 years preceding the experimental session of 1937–38, have provided a background against which to evaluate the experimental findings.

The school includes a primary department (grades 1–4), an intermedite department (grades 5–8), and a senior department (grades 9–12); and each grade is divided into two sections. The two sections of the primary grades have little more association with each other than with other classes in the department. In the intermediate and senior departments, however, the grades are divided into sections with boys and girls in each section, but for some studies the grades are divided into a section of boys and a section of girls. The sections of the grades in these departments cannot, therefore, be considered separately as is done in the primary department.

It is an educational tenet of the school authorities that children profit by some association with older and some with younger children. Extracurricular activities (drama groups, sports, etc.) which bring together children of different grades are encouraged. This prac-

tice is clearly reflected in the pattern of spread of the contagious diseases.

Two kindergarten groups, for 4- and 5-year-old children, have been disregarded in this study because they are not comparable with the regular school groups, since they are each separately and more spaciously housed, do not join the extracurricular activities, do not use the common lunchroom or halls, have shorter hours, and are kept out of doors as much as the weather permits.

There is a school physician at the Germantown Friends School. He is in attendance for an hour or more in the early morning and his private office is less than a square from the school. Prior to the experiment, efforts had been made to exclude from school children with colds or in the prodromal stages of contagions, and no change was made in this routine following the installation of lights. Nor could there have been any change in the official Pennsylvania regulation that if a contagious disease occurred in a home, all susceptible children were quarantined. (This regulation was repealed during July, 1941.)

In the fall of 1937, ultraviolet lights were installed in one of the two home rooms of each of the 4 grades of the primary department. The music room, library, nature room, halls, lunchroom, rest room and gymnasium were also irradiated. The control group shared all the irradiated atmospheres except those of the home rooms, and even their home rooms ventilated to the irradiated hallways. Detailed study of the pattern of spread of contagious disease during the first experimental year and during previous years, however, led to the conviction that much infection took place outside the home rooms but within the school, as indicated by the large number of introductions into the classes, and by the simultaneity of these introductions into different classes. Moreover, the so-called "control" group of the primary department was actually a partially irradiated group, since the pupils shared the irradiated common rooms, even though their home rooms were unirradiated. Prior, therefore, to the opening of school in the fall of 1938, the 4 home rooms of the control group were equipped with bactericidal lamps. In short, an effort was made at that time to wall off the entire primary group from the rest of the school in so far as its air supply was concerned. This was not, of course, entirely possible. The irradiation of the large auditorium where the children attend "assembly" once a week, for example, presented technical difficulties and would have added considerably to the expense. (The consequence of omitting its irradiation, as revealed during the spring of 1940, could hardly have been foreseen.)

The upper classes, while they serve as a basis for comparison, are in no sense a "control." Even though attack rates are computed among susceptible children only, the "susceptible density" i.e., the interspacing with immunes, varies too greatly for the groups to be truly comparable.

Design of installation

It seemed a reasonable assumption that control of epidemic contagion among normal aggregations would not require the amount of sanitary ventilation which was needed to protect open wounds or to isolate the sick in hospitals. While in the latter situations, infected dust may be a common source of spread, the hypothesis upon which the experiments were based is that the spread of epidemic contagion is effected largely through the breathing of infected droplet nuclei freshly expelled by carriers or by patients in the prodromal stages of disease,

and that these nuclei are especially vulnerable to radiant energy (1).

Only *indirect* irradiation is used in the classrooms of the Germantown Friends School. Central radiant sources convert the upper portion of the air into irradiation chambers. Two crossed burners [3] mounted in shallow aluminum pans are suspended approximately 4 feet below the center of the nonreflecting ceiling. Half the light radiates directly through a mean distance of about 5 feet, and the remaining half is reflected upward from the fixture with a loss of approximately 50 per cent (figure 1).

There is no system of ventilation other than windows, and the lower portion of the room thus ventilates to the upper irradiated portion only by natural convection currents. An extensive study has been made of the sanitary ventilation of the Germantown Friends School and the other schools of the experiment and will be reported elsewhere (6). It can be said here that the removal rates of test microorganisms are increased almost tenfold, by this system of indirect radiant disinfection, equivalent in sanitary effect to ventilation rates of approximately 50 air changes per hour.

Exposure of occupants to ultraviolet radiation is determined by time and intensity. Only where exposure seems negligible has it been deemed permissible to utilize direct radiation in the Germantown Friends School, although this is the most efficient method of air purification. The halls have been so treated because the burners could be placed at a considerable height and the fixtures so tilted that persons receive direct rays only at far ends of the hall. Moreover the children remain in the halls for short times only in going back and forth to other rooms. The dining rooms, where a stagger system of lunching insures that no one group remain long, is also directly irradiated, also at considerable height.

[3] Hanovia *Safe-t-aire* tubes in Hanovia fixtures.

Epidemiological techniques

For an epidemiological study the school offered many advantages. Its pupils are drawn from a stable, homogeneous group, and a majority of them attend the school continuously throughout the 12 grades. Sixty-four per cent of the 1941 graduating class entered either the kindergarten or first grade. The immunity of the school, therefore, reflects the past incidence of contagious diseases in the school. The pupils, moreover, enjoy a certain social isolation, which limits the number of introductions of contagious diseases resulting from outside exposure, and which might therefore be expected to simplify further the patterns of spread. Among children of this social status, spread by physical contact might also be expected to be minimal.

Choice of an epidemiologic index of spread of infection requires: that the infection be manifested as disease, obscured neither by the occurrence of carriers nor by subclinical infections; that the disease be reliably recognizable clinically; that exposures to the infection outside the atmospheres under study shall not be so numerous as to mask the prevention of spread within the atmosphere; and that artificial immunization shall not so lower susceptible density as to prevent spread. Thus, measles, chicken pox and mumps were chosen as indices in the school, other childhood contagions seeming unsuited to the purpose. Ninety eight per cent of the children have been immunized against diphtheria; 43 per cent have received immunization against whooping cough, in addition to those who have had the disease; and scarlet

fever would require periodic Dick tests to trace the spread of infection. The common cold is discussed separately.

Very simple records have been kept:

(*a*) *Records of susceptibility.* The parents are requested to fill out, for each child, a report on the contagious diseases from which he has suffered in the past, and the artificial immunizations he has received. The aggregate of these records gives in readily available form, the number of susceptibles in each home room and the susceptible density, i.e., the interspacing with immunes. In tables 2, 4, 6, 8, and 13, the "number of susceptibles" to measles, chicken pox and mumps, therefore, signifies the number from whose parents was obtained a history of no previous attack.

(*b*) *Records of contagious diseases.* The date of onset for each contagious disease in the school is recorded. The board-of-health reports are not sufficiently reliable for the purposes of the study, and the date is checked with the parent. The diagnosis of the family physician is accepted, however.

(*c*) *Records of class exposure.* Together with the date of onset of each contagious disease there is recorded the date of last school attendance prior to the illness, the information coming from the teacher, and whether the case was contracted under quarantine from a prior case in the home. This careful check on the interval between latest school attendance and onset of symptoms is important in view of the Saturday-Sunday interval in attendance, and the fact that Friday attendance by a child who becomes ill on Sunday evening or Monday morning might be rated either as a probable class exposure, as in the case of measles, or not, as in the case of chicken pox. A child who develops the disease when under quarantine for a member of his family, or when absent for other reason during the prodromal stages, obviously does not expose his class.

A distinction is made in this paper between an "introduction" of a contagious disease into a class, and a "class exposure." An introduction indicates the occurrence among the children of one home room of a case not attributable to a prior case in that room and concerning which information is not available as to whether the child's last attendance occurred so shortly before the onset of symptoms as to make it probable he was infective, in which case he caused a "class exposure."

In the years prior to the beginning of the experiment, no record was kept of the "class exposure" except in the instances where cases were contracted under home quarantine. Through a misunderstanding, detailed records were likewise not kept of class exposure during the first year of the experiment, 1937–38, and it will be noted that in discussing this year, the noncommital word "introduction" is used.

In this study the term "secondary cases" refers, unless otherwise qualified, to cases following, after an interval corresponding to the incubation period of the disease in question, a "class exposure," that is, exposure in the home room. The incubation periods given by the American Public Health Association (7) have been adopted: measles, 10–12 days to the beginning of symptoms, 13–15 days to the rash; chicken pox, 14–21 days; mumps, 12–26 days. The term "secondary," therefore, indicates only the *possibility* that infection was incurred in the home room, and does not imply that any attempt was made to eliminate other sources of infection. It is obvious that the probability of a case being a "class secondary" decreases with increase in the number of introductions,

Except in the instances where outside exposure was to a case within the child's own family, and where presumably the exposure was heavier than a class or school exposure, and where the quarantine was a matter of definite record with the school and the health department (i.e., a "home secondary"), no account has been taken of possible exposure outside the school, though they are recorded when brought to our attention. Our greater familiarity with the teachers and staff of the primary department causes us to hear more often of outside exposures such as sharing transportation, visiting in homes, attendance at parties, in these departments than in the upper unirradiated grades.

The term "*secondary* attack rate among susceptibles" is used to refer to the percentage of the susceptibles in a given home room developing the disease following known class exposure; while the term "attack rate among susceptibles," if unqualified, refers to the percentage of recorded susceptibles in the various departments of the school who, during the year in question, developed the disease. This takes no account of the "density of susceptibles," i.e., the percentage of the total enrollment which these susceptibles form, the interspacing with immunes, and the rates are therefore not entirely comparable in the different departments.

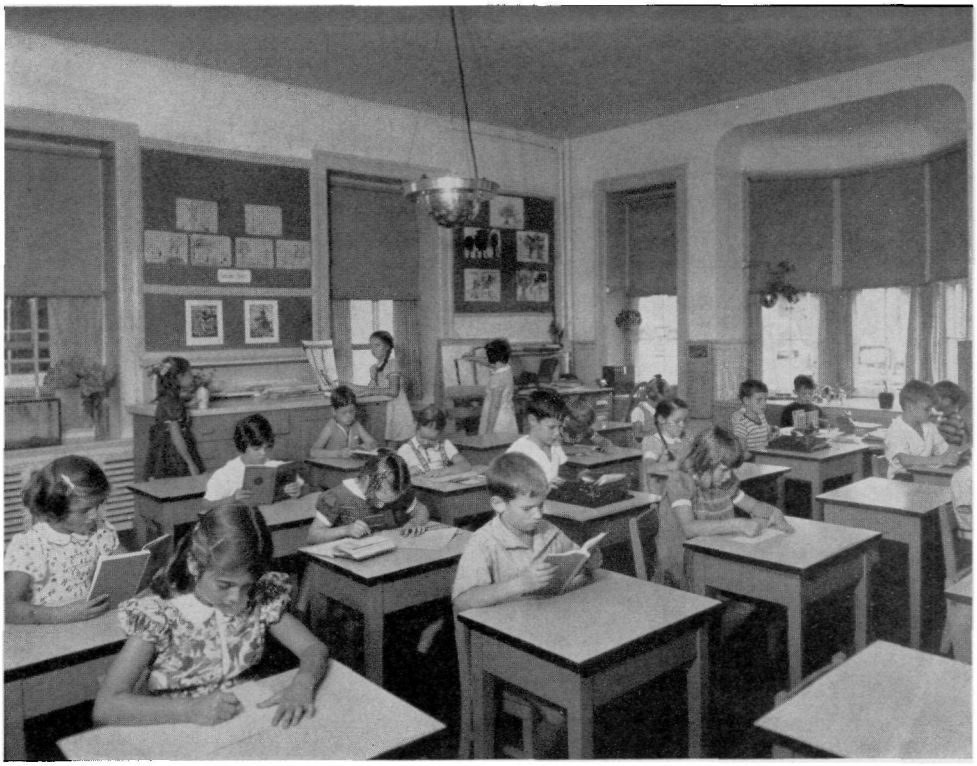

FIGURE 1. Classroom, Germantown Friends School, central radiant sources.

Since irradiation of room atmospheres is directed primarily toward prevention of infection from infective nuclei rather than from direct hits by Flügge droplets, it might seem that room charts

TABLE 1

Contagious diseases, Germantown Friends School.
Records for 5 years prior to installation of ultra-violet lights

Year	Total enrollment	Cases, measles			Cases, chicken-pox			Cases, mumps		
		Senior	Interm.	Primary	Senior	Interm.	Primary	Senior	Interm.	Primary
1932–33	596	3	24	26	0	8	17	0	0	0
1933–34	589	7	16	44	0	4	4	11	25	14
1934–35	579	2	1	1	2	16	58	0	1	3
1935–36	596	0	4	5	0	3	3	0	0	0
1936–37	612	0	0	1	0	1	14	0	0	1
Total, five years prior to irradiation		12	45	77	2	32	96	11	26	18

showing the desk locations of the children would be informative. This has not proved to be the case in the primary grades of the schools studied, however, since desks, tables and chairs are movable, children move freely about the rooms and arrange their chairs at pleasure.

Contagious disease record prior to the use of ultraviolet lights

The incidence, during the 5-year period preceding the experimental introduction of radiant disinfection, of the diseases which were chosen as indices is shown in table 1. It will be seen that at the commencement of the experiment, the school had already been free from epidemic spread of disease for 2 years.

A. The first experimental year: 1937–38

Susceptibility. During the fall of 1937, ultraviolet lights in indirect fixtures were installed in the home rooms of one section of each of the first 4 grades, the plan being for the corresponding sections to remain as controls. All common classrooms, such as the music room, nature room, art room, rest room and library were indirectly irradiated, and direct radiation was used in hallways and lunchroom. Table 2

TABLE 2

Susceptibility, Germantown Friends School.
Fall, 1937

Group	Number	No report	Measles—susceptible		Chicken-pox—susceptible		Mumps—susceptible	
			Number	Per cent	Number	Per cent	Number	Per cent
Unirradiated								
Senior dept., Grades 9–12....	188	9	21	11.7	30	16.8	87	48.6
Interm. dept., Grades 5–8...	184	7	46	26.0	31	17.5	133	75.1
Primary dept., Grades 1–4...	89	1	55	62.5	37	42.0	70	79.5
Irradiated								
Primary dept., Grades 1–4...	89	6	58	69.9	29	34.9	70	84.3

TABLE 3

Mumps, Germantown Friends School, 1937–1938.
Class introductions and cases possibly secondary to them

	Grade, section	Susceptibles		Date, class introduction	Date, following cases
		Number	Per cent		
Irradiated Primary dept.	I, 1	21	100.0	Jan. 4 Apr. 18	
	III, 1	13	68.4	Mch. 7 Apr. 25	
	IV, 1	18	75.0	Jan. 31 Apr. 4, 7	Apr. 22; May 16
Unirradiated Primary dept.	I, 2	17	80.9	Feb. 18	Mch. 14; Apr. 5, 5, 5, 6; 18, 18, 18; May 9
	II, 2	17	73.9	Jan. 4 Apr. 7	
	III, 2	18	90.0	Jan. 31 Apr. 26	May 16
	IV, 2	18	75.0	Feb. 18 Apr. 19	May 4, 9
Unirradiated Upper classes	V	38	84.4	Jan. 4 Jan. 4 Jan. 10 Feb. 10 Mch. 28	Apr. 13; May 2, 3
	VI	33	71.7	Mch. 2 Apr. 11	
	VII	31	70.5	Jan. 31	Feb. 14, 17; Mch. 3, 7, 14
	X	29	60.4	Feb. 8 Apr. 19	

shows the susceptibility, as defined under *Epidemiological Techniques,* of the groups to the contagion indices in the fall of 1937.

Contagious diseases. Although the spring of 1938 was "measles year" in the city of Philadelphia, the school remained free except for scattered cases. The year was marked, however, by an outbreak of mumps (46 cases). As may be seen from table 3, there occurred 7 introductions (class exposures not recorded) into the irradiated and 7 introductions into the unirradiated primary classes. Following these there were 2 cases which were possible secondaries in the irradiated; 12 in the unirradiated rooms. In the upper unirradiated classes, there occurred 10 introductions, followed by 8 cases which were possibly secondaries.

B. The second experimental year: 1938–39

As stated above, the large number of introductions into the classes and their dates seemed to indicate interclass infections (see table 3) and, therefore *all* classrooms of the primary department were irradiated prior to the session of 1938–39.

Susceptibility. Table 4 shows the state of susceptibility in the school at the beginning of the year.

TABLE 4

Susceptibility, Germantown Friends School. Fall, 1938

Group	Number	No report	Measles—susceptible		Chicken-pox—susceptible		Mumps—susceptible	
			Number	Per cent	Number	Per cent	Number	Per cent
Unirradiated								
Senior dept., Grades 9–12....	180	0	28	15.5	25	13.9	101	56.1
Interm. dept., Grades 5–8...	199	1	66	33.3	40	20.2	128	64.7
Irradiated								
Primary dept., Grades 1–4...	171	2	117	69.2	83	49.1	125	74.0

Contagious diseases. The year 1938–39 was marked by another outbreak (33 cases) of mumps which reached a peak during November, and an isolated group of 3 cases the following April. These cases are summarized in table 5. It will be noticed that whereas the unirradiated upper classes suffered 32 cases during the fall epidemic, the irradiated primary department escaped with only one case which did not expose the class. Later in the year, however, a missed case exposed the same class on 3 successive days resulting in two secondary cases.

C. The third experimental year: 1939–40

Susceptibility. The state of susceptibility of the school at the beginning of the third year of the experiment is shown in table 6.

Contagious diseases. Probably no contagious disease is more volatile than chicken pox, and even those investigators who are reluctant to accept a general hypothesis of air-borne contagion concede the probability that this disease is spread through the medium of air. During the school year of 1939–40, various classes of the primary department were exposed to children in the prodromal (i.e., within 24 hours of the appearance of symptoms) or early stages of chicken pox 21 times within the *irradiated* atmospheres, as is shown in table 7. Only 7 secondary cases can be ascribed to these 21 exposures of classes in irradiated rooms; certainly not a record indicating facility of spread.

The volatility characteristic of chicken pox was, however, demonstrated in an explosive outbreak following the exposure of one of these classes on 4 successive days in an unirradiated atmosphere. It is customary for a class to be singled out each year to give a school play, and this particular third-grade class was rehearsed in the unirradiated auditorium for about an hour on each of 4 successive days with a missed case.

TABLE 5

Mumps, Germantown Friends School, 1938–1939.
Class exposures and secondary infections

	Grade	Susceptibles		Date of onset	Class exposure	Cases, secondary	Cases, tertiary
		Number	Per cent				
Irradiated	IV, 2	14	66.7	Nov. 28	No		
Primary dept				Apr. 10	Apr. 10, 11, 12 (missed case)	Apr. 30, May 1	
Unirradiated	V	31	63.3	Nov. 2	Yes		
Upper classes				Nov. 2	Yes		
				Nov. 7	No		
				Nov. 7	No		
				Nov. 8	Yes	Nov. 28	
				Jan. 3	No		
				Jan. 3	No		
	VI	35	70.0	Oct. 3	Yes	Oct. 17, 18, 18, 20, 20.24, 26	Nov. 1, 7, 7, 7, 8
				Jan. 19	Yes		
	VII	33	64.7	Nov. 7	No		
				Nov. 7	No		
				Nov. 7	No		
	VIII	29	60.4	Nov. 26	No		
	XI	28	58.3	Dec. 2	Yes		
				Jan. 17	No (home sec.)		
				Jan. 26	Yes		
	XII	21	44.7	Nov. 27	No		
				Nov. 28	No		

TABLE 6

Susceptibility, Germantown Friends School.
Fall, 1939

Group	Number	No report	Measles—susceptible		Chicken-pox—susceptible		Mumps—susceptible	
			Number	Per cent	Number	Per cent	Number	Per cent
Unirradiated								
Senior dept., Grades 9–12....	175	3	28	21.7	20	11.6	101	58.7
Interm. dept., Grades 5–8...	199	3	78	39.8	34	17.7	104	53.1
Irradiated								
Primary dept., Grades 1–4...	169	0	121	71.6	101	59.8	127	75.1

Children from other classes were known to have been in the auditorium at the same time, but there was no record of those so exposed. When, on the evening of May 9th, the day before the play, this child, sole secondary to a previous class exposure on April 24th under the lights, was diagnosed, it was realized that he had first shown vesicles on May 6th. Between the 14th and 20th day follow-

TABLE 7

Secondary cases of chicken-pox, primary department, following exposure in irradiated and unirradiated atmospheres, Germantown Friends School, 1939–1940

Class, section	Date, onset of cases	Class last exposed	Children exposed		Secondary cases. Date of onset
			Immune	Susceptible	
Exposures in *irradiated* atmospheres					
II, 2	Dec. 9	Dec. 8	9	13	0
IV, 1	Jan. 4	Jan. 3	12	10	0
IV, 1	Jan. 13	Jan. 12	13	9	0
II, 2	Feb. 2	Feb. 1	10	12	0
I, 1	Feb. 25	Feb. 23 (exposure?)	5	8	0
II, 1	Mch. 11	Home sec., not exposed	—	—	—
IV, 2	Apr. 4	Apr. 3	15	7	0
II, 1	Apr. 5	Apr. 4	9	14	1 case, Apr. 24
I, 2	Apr. 8	Apr. 8	2	12	0
II, 2	Apr. 9	Apr. 9	11	11	1 case, Apr. 26
II, 1	Apr. 24*	Apr. 23	10	13	0
III, 1	Apr. 24	Apr. 24	6	17	1 case, May 6
II, 2	Apr. 26*	Apr. 26	12	10	0
I, 2	May 20	May 20–24 (missed case)	3	11	1 case, June 5
III, 2	May 20	Home sec., not exposed	—	—	—
II, 2	May 22	May 22 and 23 (missed case)	13	9	1 case, June 8†
IV, 2	May 25	May 24	16	5	0
IV, 2	May 25	May 24			
I, 2	May 26	May 24	4	10	0
II, 1	May 26	May 24	11	12	2 cases, June 7 and 8†
III, 2	May 30	May 30	11	11	0
I, 2	June 5*	June 4	5	9	0
IV, 1	June 6	June 5	14	8	0
Exposure in *unirradiated* atmospheres					
III, 1	May 6*	May 6–9 (missed case)	7	16	15 cases, May 20, 21, 21, 21, 22, 22, 22, 22, 23, 23, 23, 23, 24, 24, 26 (also one teacher)

* These cases were themselves secondary to class exposure.
† Last day of school, June 6th.

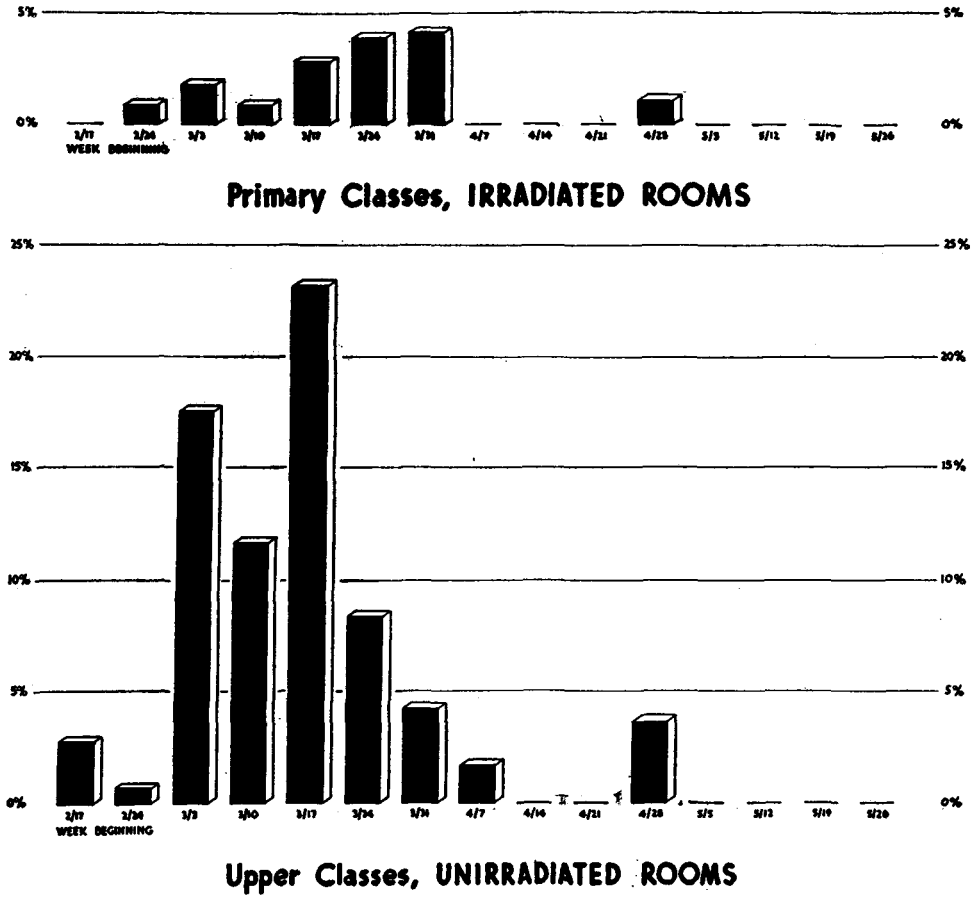

FIGURE 2. Measles, 1941, Germantown Friends School. Weekly attack rate among susceptibles in irradiated and unirradiated rooms, not including home secondary cases. Data in table 10.

ing the first day of known exposure (May 6th), 15 of the 16 children in the class recorded as susceptible developed chicken pox in a typical static type epidemic, a result indicative of intense common-source exposure. Seven cases in other primary classes are so grouped in time as to make it probable that they too were secondary to this case.

Among the unirradiated upper classes there were 11 cases during the year. Of these, 4 children exposed their classes: the seventh grade (5 susceptibles, 19 immunes) was exposed to two cases on May 23rd; the eighth grade (2 susceptibles, 24 immunes) was exposed May 24th; the eleventh grade (3 susceptibles, 34 immunes) was exposed to a missed case May 22nd–24th. None of these 10 exposed susceptibles developed the disease.

D. The fourth experimental year, 1940–41

The season 1940–41 has been marked by the largest epidemic of measles from which the city of Philadelphia has ever suffered. As early as October an increased incidence was reported and an epidemic anticipated. During the 8

months October 1940 through May 1941, 25,463 cases were reported. The year has brought to the Germantown Friends School also the largest epidemic (112 cases) which the school has experienced during the 9 years for which records are available.

Susceptibility. Table 8 shows the

TABLE 8

Susceptibility, Germantown Friends School. Fall, 1940

Group	Number	No report*	Measles—susceptible†		Chicken-pox—susceptible		Mumps—susceptible	
			Number	Per cent	Number	Per cent	Number	Per cent
Unirradiated								
Senior dept., Grades 9–12....	184	6	41	23.0	16	9.0	111	62.4
Interm. dept., Grades 5–8...	202	4	97	48.9	41	20.7	112	56.5
Irradiated								
Primary dept., Grades 1–4...	149	6	108	75.5	63	44.0	109	86.1

* Five children in these groups who later developed measles are classed as susceptibles in tables 9, 10, and 16.

† Four children who, in the fall, gave a history of having had measles later developed the disease. For simplicity, these children were classified in the tables as susceptible.

TABLE 9

Measles, 1941. Germantown Friends School

	Grade, section	Susceptibles		Dates of cases*
		Number	Per cent	
Irradiated	I, 1	10	76.9	No cases
Primary	I, 2	10	71.4	No cases
department	II, 1	13	76.5	Mch. *20*, *26;* Apr. *3*
	II, 2	14	100.0	Mch. 25
	III, 1	17	73.9	Mch. 6, 7; Apr. 1, 5, *12;* May 1
	III, 2	19	82.6	Mch. 22, 23, 26; Apr. *3*, *7*
	IV, 1	17	73.9	Feb. 24; Mch. 10, 21, *21*; Apr. 3
	IV, 2	13	56.5	Mch. *4*, 19, 25, 28
Unirradiated	V	29	60.4	Feb. 23; Mch. 6, 10, 10, 10, 16, *17*, 22; Apr. *2*, *3*, 3, 29
Upper classes	VI	26	55.3	Feb. 21, 22, 28; Mch. 9, 20, 21, 24, 26, *28*, 30; Apr. 3, 7, *8*, *9*
	VII	30	56.6	Mch. 4, 4, 4, 5, 5, 7, 8, 8, 10, 11, 11, 19, 20, 21, 21, 21, 22, 22, 22, 23, *24*, 24; May 5
	VIII	14	26.9	Feb. 21; Mch. 6, 6, 6, 7, 7, 7, 8, 8, 8, 18, 20
	IX	14	28.0	Mch. 5, 8, 9, 10, 10, 12, 18, 18, *19*, 19, 20, 24, 29; Apr. 3
	X	13	28.9	Mch. 7, 8, 10, 10, 16, 19, 20
	XI	10	22.7	Mch. *18*, 20, *21*
	XII	4	10.3	Mch. 18, 23; May 4

* Italicized figures indicate the date of a home secondary.

state of susceptibility at the beginning of the school year. Comparison of the susceptibility to measles in the fall of 1940 with that in the fall of 1937, the first year of the experiment and the last epidemic year in the city of Philadelphia, shows that in each department an increased density of susceptible children had been built up, the increase being: in the senior department, from 11.7 to 23.0 per cent of the total; in the intermediate department, from 26.0 to 48.9 per cent; and in the primary department, from 66.1 to 75.5 per cent.

Contagious diseases. On November 19th, 1940, a child in the fourth grade exposed his class, within the irradiated atmosphere, to measles, developing a rash the following day. No secondary cases followed in the class, although the child's younger brother in the third grade developed measles under quarantine; and on December 4th, a child in the second grade developed the disease, presumably from an outside exposure since no connection between the cases could be discovered. No further cases followed these 3 and, in spite of the epidemic surrounding them, the school remained free until February 21st.

The epidemic began with the occurrence of 4 cases in the intermediate department during the week of February 17th. Its course is shown in tables 9 and 10 and the weekly attack rate among susceptibles (omitting home secondary cases, contracted under quarantine) of the irradiated and unirradiated atmospheres is plotted in figure 2.

It will be seen from tables 9, 10 and 16 that in the upper unirradiated classes (i.e., the senior and intermediate departments), which contained 141 susceptible children (37.2 per cent of the total), 88 cases occurred during the epidemic, of which 10 were home secondaries, contracted under quarantine. These 88 cases represent an attack rate

TABLE 10

Measles, Germantown Friends School, 1941.
Weekly attack rate among susceptibles

Week of	Unirradiated, Senior and interm. depts.					Irradiated, Primary dept.				
	Susceptibles (Cases deducted weekly)	Total cases	Home secondaries, dev. under quar.	Cases, not incl. home secondaries	Weekly attack rate among suscept., not incl. home second.	Susceptibles (Cases deducted weekly)	Total cases	Home secondaries, dev. under quar.	Cases, not incl. home secondaries	Weekly attack rate among suscept., not incl. home second.
2/17	141	4	0	4	2.8	110	0	0	0	0
2/24	137	1	0	1	0.7	110	1	0	1	0.9
3/3	136	24	0	24	17.6	109	3	1	2	1.8
3/10	112	13	0	13	11.6	106	1	0	1	0.9
3/17	99	27	4	23	23.2	105	6	2	4	3.8
3/24	72	8	2	6	8.3	99	5	1	4	4.0
3/31	64	5	2	3	4.7	94	5	2	3	3.2
4/7	59	3	2	1	1.7	89	2	2	0	0
4/14	56	0	0	0	0	87	0	0	0	0
4/21	56	0	0	0	0	87	0	0	0	0
4/28	56	2	0	2	3.6	87	1	0	1	1.1
5/5	54	1	0	1	1.9	86	0	0	0	0
5/12	53	0	0	0	0	86	0	0	0	0

among the 141 susceptibles of 62.4 per cent; if the home secondary cases are excluded, the remaining 78 cases represent an attack rate among the 141 susceptibles of 55.3 per cent. At the end of the epidemic there remained 53 children (13.9 per cent of the total enrollment) still recorded as susceptible.

In the irradiated primary department, on the other hand, there were at the beginning of the epidemic 110 susceptible children (75.9 per cent of the total enrollment). There occurred 24 cases of which 8 were home secondaries, an attack rate of 21.8 per cent of the 110 susceptible children if the home secondaries are included, or of 14.5 per cent if they are excluded. At the end of the epidemic there remained 86 susceptible children, 59.3 per cent of the total.

It will be seen in Table 10 and figure 2 that the cases in the primary department, both those possibly contracted in the school and those probably contracted under home quarantine, followed the epidemic wave of the upper classes by a 2-week interval and were apparently an infiltration of infection from those classes.

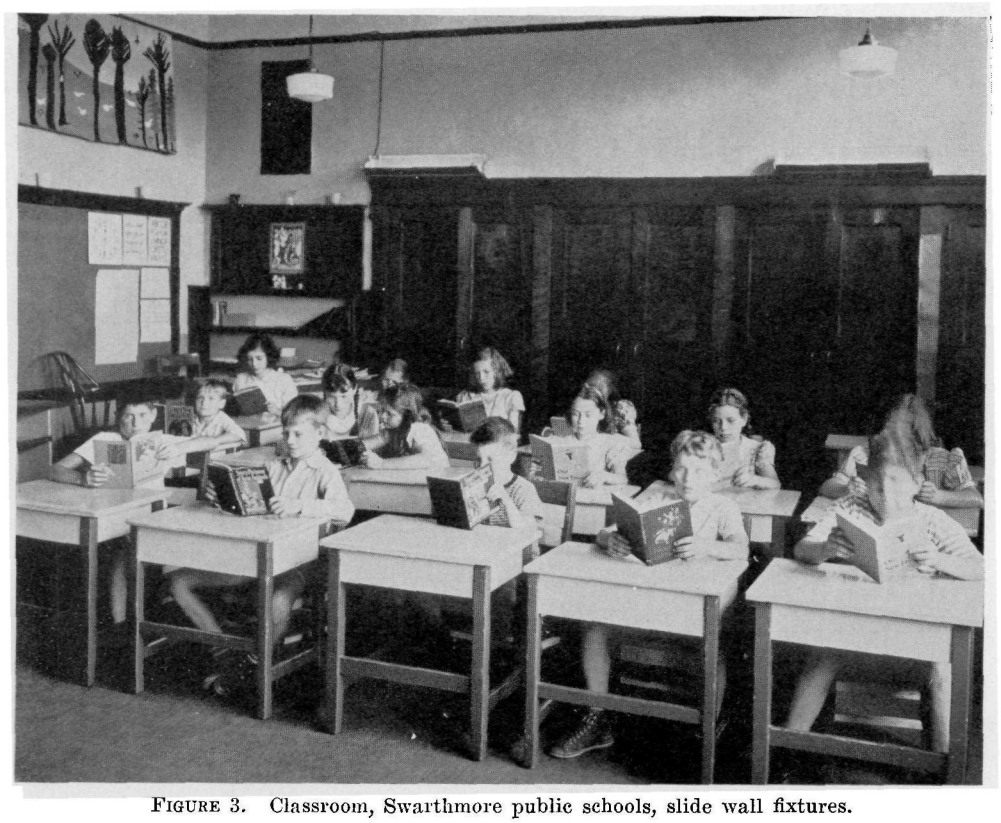

FIGURE 3. Classroom, Swarthmore public schools, slide wall fixtures.

The frequency of colds before and after the use of lights

In contrast to childhood contagions, the total numbers of colds after installation of the lights has shown no detectable reduction. The question arises: are colds actually spread within the irradiated rooms, or can the results be interpreted to mean that children are subjected both within and without the school

to such repeated exposure that the incidence of the disease is determined by susceptibility rather than by exposure? In the case of the common cold, where lasting immunity is not conferred, where several attacks per child per season may occur, and where adults as well as children harbor the virus, do home and random infections occur so frequently as to mask any reduction accomplished in the school?

Analysis of the absences for colds before and after installation of the lights There has been no marked shift in this distribution since the lights were installed, nor has there been any reduction in the total number of colds. In table 11, colds, before and after the lights were installed, are classified according to the first day of absence which they caused.

Experiment II. Swarthmore public schools

Prior to the 1940–41 session, the experiment was extended to include the

TABLE 11

Incidence of colds by days of the week *
Primary department, Germantown Friends School, 1933-34—1939-40

	Monday	Tuesday	Wednesday	Thursday	Friday	Total
Unirradiated rooms 1933–34—1937–38						
Number	871	368	295	286	302	2122
Per cent	41.0	17.3	13.9	13.5	13.7	..
Wed. Thurs. and Fri. 883 cases, 41.6 per cent.						
Irradiated rooms 1937–38—1940–41						
Number	710	292	263	258	215	1738
Per cent	40.9	16.8	15.1	14.8	12.4	..
Wed. Thurs. and Fri. 736 cases, 42.3 per cent.						

* The colds in this table are classified according to the first day of absence which they caused.

carries conviction that the incidence is not determined, at least in the Germantown Friends School, by school exposure. If a cold is indeed an infection, and if an incubation period of from 36 to 48 hours is assumed, the absences beginning on Wednesdays, Thursdays, and Fridays might be expected to amount to more than their proportionate share of the weekly total if school were the chief source of infection. As a matter of fact, however, absences beginning on those days constitute, both before and after the installation of the lights, just slightly less than three-sevenths of the total.

public schools of Swarthmore, Pa. The town of Swarthmore (pop. 3,405) is a small college community suburban to Philadelphia. The two primary schools and high school constitute almost the entire school system of the community, there being no parochial school and only one small private school (a nursery department and a college preparatory—no primary school grades) drawing largely from outside the Borough of Swarthmore.

These schools, while public, differ less from the Germantown Friends School than would most public schools, as the

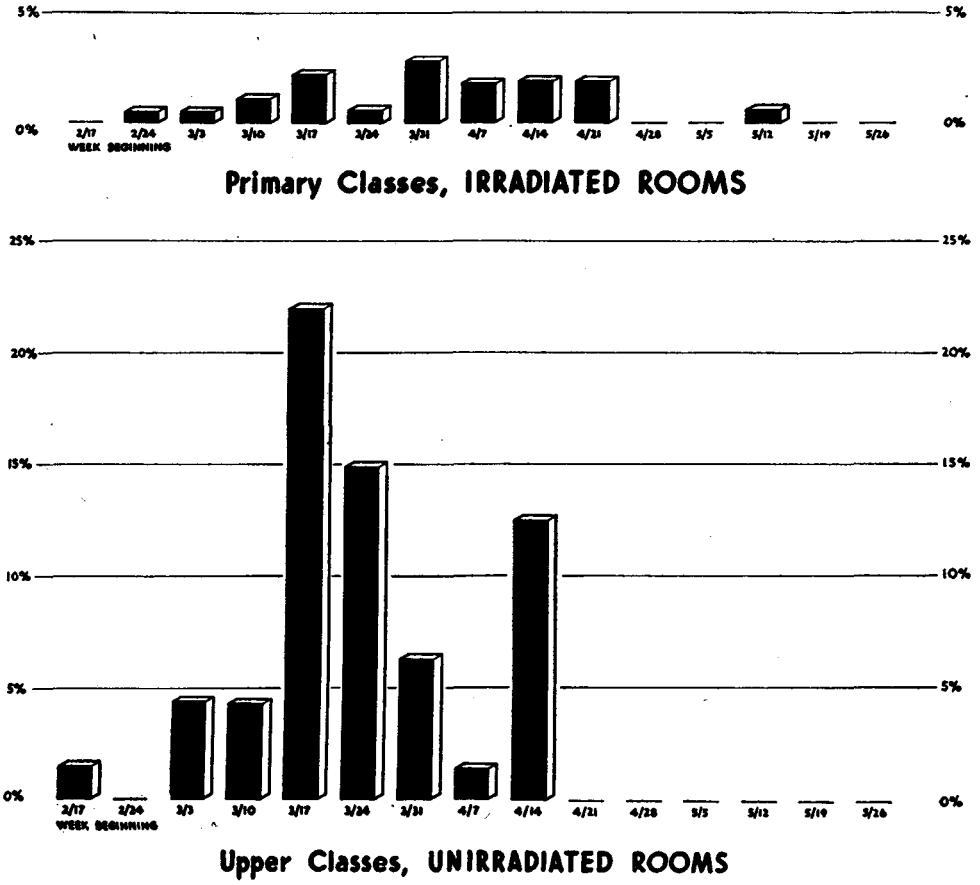

FIGURE 4. Measles, 1941, Swarthmore public schools. Weekly attack rate among susceptibles in irradiated and unirradiated rooms, not including home secondary cases. Data in table 15.

dominant influence of Swarthmore College results in the maintenance of standards comparable to those of the Germantown Friends School. Due to these high standards there is a number of children who live outside the school district who pay tuition to attend the schools, especially the high school. The school population is less continuous than at Germantown, and the immunity is less a reflection of past contagion.

The school system includes a high school (grades 7–12), and two primary schools (kindergarten to sixth grade): the College Avenue School, on the same grounds and in close proximity to the high school; and the Rutgers Avenue School, about a mile distant. The two primary schools were irradiated and the high school was left unirradiated. The experimental set up is, therefore, similar to the one at the Germantown Friends School, in that there is an irradiated lower group and an unirradiated upper group, with the difference, however, that the experimental group here includes two grades (fifth and sixth) above those in the Germantown group, and that the Rutgers Avenue School is at some distance from the unirradiated classes of the high school.

There is no school physician at Swarth-

TABLE 12

Contagious diseases, Swarthmore public schools. Nine years prior to installation of ultra-violet lights

Year	Measles			Chicken-pox			Mumps		
	Primary		High school	Primary		High school	Primary		High school
	College	Rutgers		College	Rutgers		College	Rutgers	
1931–32	4	0	0	1	1	1	0	1	0
1932–33	67	0	1	58	31	8	0	0	0
1933–34	13	2	3	0	2	0	6	17	1
1934–35	0	0	0	1	2	0	0	0	0
1935–36	1	0	2	5	3	1	2	2	0
1936–37	0	0	0	54	52	4	0	0	0
1937–38	14	52	10	6	2	2	8	2	17
1938–39	11	0	0	0	0	0	1	0	1
1939–40	0	2	0	0	0	0	0	0	1
Total, 9 years prior to irradiation	110	56	16	125	93	16	17	22	20

Primary schools, grades Kindergarten to sixth
High school, grades seventh to twelfth.

more, but there is a school nurse 3 days a week. Naturally, exclusion from school for contagious disease is not quite so prompt as at Germantown.

Design

(See figure 3)

The experiment at Swarthmore differs from that at Germantown in that only the "home rooms" are irradiated. The difference is, however, not so great as might at first appear, for the pupils spend relatively more time in the home rooms because the schools do not have special rooms for art, music, nature study, etc. The children of the various classes do, however, mingle with one another, and less often with the members of other groups in the unirradiated hallways, lunchroom and gymnasium.

Radiant disinfection of the air of the primary schools is accomplished with side-wall fixtures. Four 36-inch germicidal burners, mounted in suitable reflectors,[4] radiate from a 7-foot level through an approximately 5-foot distance to 12-foot nonreflecting ceilings in rooms of some 7,000 cubic feet capacity, ventilated by forced draft. Bacterial tests indicate the equivalent of approximately 100 changes of air per hour.

Contagious disease record prior to the use of ultraviolet lights

The incidence in the Swarthmore schools of the contagious diseases chosen as indices is shown in table 12 for the 9-year period prior to the installation of the lights.

A. The first experimental year: 1940–41

Susceptibility. In table 13 is shown the state of susceptibility of the pupils to the contagious diseases at the begin-

[4] General Electric Company 36-inch fluorescent type germicidal burners in Wheeler Company fixtures.

ning of the experiment. It will be noted, by comparing table 13 with table 8, that the susceptibility to measles was lower at Swarthmore than at Germantown both in the irradiated and in the unirradiated groups.

Contagious diseases. In the Swarthmore schools, as in the city of Philadelphia and in the Germantown Friends School, cases of measles reached a higher figure than in any year for which figures are available, a total of 122 cases having occurred, 76 in the undirradiated high school and 47 in the two irradiated primary schools.

In table 14 the dates of the cases are given by the grades in which they occurred.

In table 15 it may be seen that in the unirradiated high school classrooms there were, at the beginning of the epidemic, 137 children susceptible to measles (25.6 per cent of the total enrollment). There occurred during the epidemic 75 cases of the disease, of which 4 were home secondaries contracted under quarantine. These 75 cases represent an attack rate among the 137 susceptibles of 54.7 per cent. If the 4 home secondaries are excluded, the remaining 71 cases represent an attack rate of 51.8 per cent of the 137 susceptibles. At the end of the epidemic there remained 62 children still recorded as susceptible (11.1 per cent of the total enrollment).

In the irradiated College Avenue Primary School class-rooms (located on the same grounds as the high school) there were at the beginning of the experiment 102 children susceptible to measles, or 58.6 per cent of the total enrollment. There occurred during the epidemic 27 cases of the disease, of which 11 were home secondaries. These cases represent an attack rate among susceptibles of 26.5 per cent if home secondaries are included, 15.7 if they are omitted. At the end of the epidemic there remained 75 children still recorded as susceptible (43.1 per cent of the total enrollment).

In the Rutgers Avenue school there were, at the beginning of the epidemic, 89 susceptible children (53.9 per cent of the total enrollment). There occurred 20 cases of the disease, of which 12 were home secondaries. The 20 cases represent an attack rate among the 89 susceptibles of 22.5 per cent. If the home second-

TABLE 13

Susceptibility, Swarthmore public schools. Fall, 1940

Group	Number	Measles—susceptible*		Chicken-pox—susceptible		Mumps—susceptible	
		Number	Per cent	Number	Per cent	Number	Per cent
Unirradiated							
High school (Grades 7–12).....	535	137	25.6	114	21.3	291	54.4
Irradiated							
College Avenue (Grades Kdg.–6)..	174	102	58.6	74	42.5	148	85.1
Rutgers Avenue (Grades Kdg.–6)..	165	89	53.9	81	49.1	137	83.0

* Thirteen children who, in the fall, gave a history of having had measles (and one who was not sure) later developed the disease. For simplicity, these children were classified in the tables as susceptible.

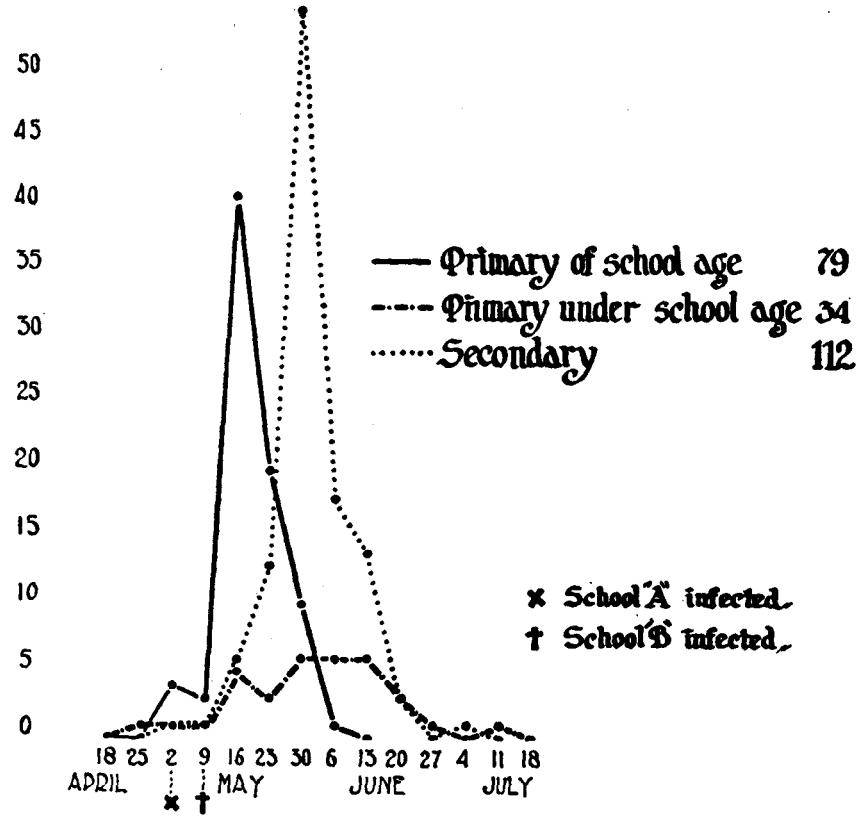

FIGURE 5. I. Renfrewshire—measles epidemic in an isolated village showing the weekly incidence of primary cases of school age, under school age and secondary cases.

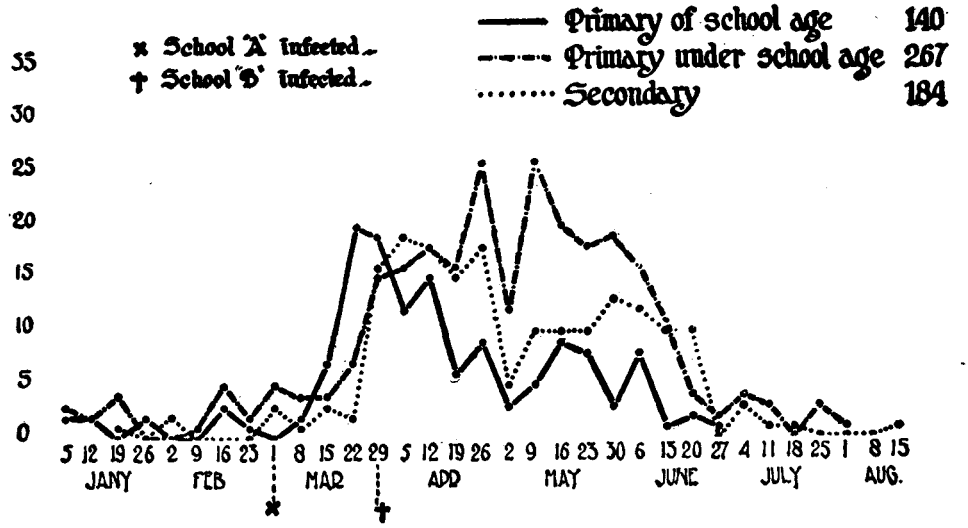

FIGURE 5. II. Renfrewshire—measles epidemic in a populous district showing the weekly incidence of primary cases of school age, under school age and secondary cases

Figure 5, I and II are taken from Picken (9) and are reproduced by permission of the Royal Society of Medicine.

TABLE 14

Measles, 1941.

Swarthmore public schools

School	Grade	Susceptibles		Dates of cases*
		Number	Per cent	
College Ave. (*Irradiated*)	Kind.	12	66.7	March 11, 22, 22; April 9
	1	20	83.3	April 15, *22*
	2	14	70.0	March 21, 31; April 2, 3, 3, 4, *30*
	3	12	75.0	April *3;* May *7*
	4	13	48.1	April 23, 23, *30*
	5	16	44.4	April *6, 14, 15,* 20, *27*
	6	15	45.4	March 24; April 17, *30;* May *5*
Rutgers Ave. (*Irradiated*)	Kind.	17	85.0	March 5, *26*
	1	22	88.0	March 19, *28, 30;* April *2, 10, 27*
	2	11	61.1	April 26
	3	8	38.1	April 13
	4	13	59.1	March 2, 10; April *2, 10,* 10, *26;* May 18
	5	13	43.3	March *18;* April *2, 10*
	6	5	17.2	No cases
High school (*Unirradiated*)	7	29	39.2	Feb. 22; March 10, 11, 17, 19, 21, 22, 22, 22, 23, 23, 24, 24, 24, 25, 26, 26; April 4, 13, 15, 15, 15
	8	28	35.0	Feb. 21; March 19, 21, 21, *22,* 22, 23, 24, 24, 25; April *3, 10,* 14, 15, *15,* 19
	9	34	27.6	March 6, 7, 7, 8, 15, 16, 17, 19, 21, 21, 22, 23, 24, 27, 31
	10	20	21.5	March 7, 7, 14, 15, 17, 17, 18, 19, 20, 20, 22, 23; April 17
	11	14	17.3	March 17, 25, 28; April 4, 17
	12	10	12.7	March 24; April 4, 6, 18

* Italicized figures indicate the date of a home secondary.

aries are omitted the remaining 8 cases represent an attack rate of 9.0 per cent. There were, at the end of the epidemic, 69 children still recorded as susceptible (40.2 per cent of the total).

DISCUSSION

During the 4-year study in the Germantown Friends School and the 1-year study in the Swarthmore public schools, there has been no *epidemic* spread of contagion among the highly susceptible groups of children of the primary schools within irradiated atmospheres, although epidemic spread has occurred among less susceptible groups of older children in the departments of the schools whose atmospheres were not irradiated.

During the first experimental year, 7 introductions of mumps into the irradiated and 7 into the unirradiated classrooms of the primary department at Germantown were followed by 2 and 12 cases, respectively. During the second year, an epidemic of 32 cases of mumps occurred in the upper unirradiated classrooms, with only one case appearing in the irradiated primary classes. While

mumps is a disease of lower incidence than measles or chicken pox and susceptibility, therefore, extends into the older age groups, there is no selective action for the older ages, the peak incidence in the United States being among the 7- and 8-year groups (8). In the 5 years at Germantown and the 9 years at Swarthmore prior to irradiation, the primary classes enjoyed no such exemption. If, as some believe, the total incidence of mumps is lower than that of measles or chicken pox because there are those who are naturally resistant, such persons would be included among the susceptibles in the tables and would gradually become an increasingly greater proportion of these "susceptibles" as this group became depleted in favor of the immune group.

During the third experimental year, 21 exposures to chicken pox of classes within the irradiated atmospheres resulted in only 7 secondary cases, but exposure of one class for a relatively short time on each of 4 successive days in an unirradiated atmosphere with a missed case resulted in a static type epidemic involving 15 of the 16 susceptibles in the class. The susceptibility to chicken pox in the upper grades was so low that spread could not have been expected.

The most convincing confirmation of the hypothesis comes from the results of the 1941 measles epidemics at Germantown and Swarthmore. Reference to table 16 shows that the attack rates among susceptibles (not including home secondaries) was: among the primary irradiated classes, 14.5 per cent at Germantown, 15.7 per cent at College Avenue, 9.0 per cent at Rutgers Avenue; among the upper unirradiated classes,

TABLE 15

Measles, Swarthmore public schools, 1941.

Weekly attack rate among susceptibles

Week of	*Unirradiated*, High school					*Irradiated*, College Avenue school					*Irradiated*, Rutgers Avenue school				
	Susceptibles (cases deducted weekly)	Total cases	Home secondaries, dev. under quar.	Cases, not incl. home secondaries	Weekly attack rate among suscept., not incl. home second.	Susceptibles (cases deducted weekly)	Total cases	Home secondaries, dev. under quar.	Cases, not incl. home secondaries	Weekly attack rate among suscept., not incl. home second.	Susceptibles (cases deducted weekly)	Total cases	Home secondaries, dev. under quar.	Cases, not incl. home secondaries	Weekly attack rate among suscept., not incl. home second.
2/17	137	2	0	2	1.5	102	0	0	0	0	89	0	0	0	0
2/24	135	0	0	0	0	102	0	0	0	0	89	1	0	1	1.1
3/3	135	6	0	6	4.4	102	0	0	0	0	88	1	0	1	1.1
3/10	129	6	0	6	4.7	102	1	0	1	1.0	87	1	0	1	1.1
3/17	123	29	1	28	22.8	101	3	0	3	3.0	86	2	1	1	1.2
3/24	94	14	0	14	14.9	98	1	0	1	1.0	84	3	3	0	0
3/31	80	6	1	5	6.3	97	7	2	5	5.2	81	3	3	0	0
4/7	74	2	1	1	1.4	90	1	0	1	1.1	78	5	3	2	2.6
4/14	72	10	1	9	12.5	89	5	2	3	3.4	73	0	0	0	0
4/21	62	0	0	0	0	84	4	2	2	2.4	73	3	2	1	1.4
4/28	62	0	0	0	0	80	3	3	0	0	70	0	0	0	0
5/5	62	0	0	0	0	77	2	2	0	0	70	0	0	0	0
5/12	62	0	0	0	0	75	0	0	0	0	70	1	0	1	1.4

55.3 per cent at Germantown, 51.8 per cent at Swarthmore. In tables 10 and 15 it will be seen that the time relationships of the epidemic are more indicative of an infiltration from the upper schools into the primary classes than of epidemic spread within the latter. Reference to table 16 also shows that in each of the 3 primary schools, the susceptibility was considerably higher at the end of the epidemic than it was in the upper classes at the beginning. Certainly the pat-

TABLE 16

Measles, 1941, Germantown and Swarthmore

	Pupils	Susceptibles before epidemic		Cases	Home second.	Attack rate among suscept.		Susceptibles at end of epidemic	
		Number	Per cent			Incl. home second.	Not incl. home second.	Number	Per cent
Irradiated lower									
Germantown grades 1–4.....	145	110	75.9	24	8	21.8	14.5	86	59.3
Swarthmore grades Kdg.–6									
College Avenue.....	174	102	58.6	27	11	26.5	15.7	75	43.1
Rutgers Avenue.....	165	89	53.9	20	12	22.5	9.0	69	40.2
Unirradiated upper									
Germantown grades 5–12....	379	141	37.2	88	10	62.4	55.3	53	13.9
Swarthmore grades 7–12....	535	137	25.6	75	4	54.7	51.8	62	11.6

terns of the epidemics in the two schools were strikingly different from any previous experience.

One might almost suspect a strain of virus with an affinity for older ages. The 6-year group in Philadelphia, however, showed as usual the highest incidence. Likewise, at the Penn Charter School, a private day school for boys several squares distant from the Germantown Friends School, whose pupils are drawn from the same social class, the primary classes suffered most heavily. Among 95 boys in the first 4 grades (susceptibility unknown), there were 47 cases (49.5 per cent) total; among 391 boys in the eight upper classes, there were 38 cases (9.7 per cent).[5] At the Germantown Friends School, 12.6 per cent of the pupils in the primary department were attacked, and 23.2 per cent of the pupils in the upper classes.

Equally favorable results would not necessarily follow radiant disinfection of schools chosen at random. The prevention of air-borne infection among "intermittent aggregations" necessitates both an effective means of control and the employment of that means within the particular atmosphere in which the infections actually were transferred. Picken (9) has previously emphasized that, so far as the administrative control of measles is concerned, "any measures for this purpose must have regard to the channels of infection. Children are infected in their homes or at school or at random"; and he has pointed out that in rural areas the school plays a relatively greater rôle in the dissemination of infection than in urban communities.

[5] These figures were kindly sent to us by Dr. T. C. Garrett, physician to the Penn Charter School.

In figure 5 (charts I and II taken from Picken), are shown two epidemics of measles: in a rural area, measles spread first in the school and was then carried home to the younger children, the curve of school cases and home cases following the same pattern with a time lag corresponding to the incubation period; in the urban district, on the other hand, opportunity for exposure was not thus limited to the home and the school, random infection playing a greater rôle. Picken comments: "Clearly it would be difficult to control an epidemic of the latter type by efforts directed at the school. Random infection plays too large a part. On the other hand, the epidemic traced in Chart I indicates that control through schools may be possible."

Multiple exposures are even more of an obstacle in the control of colds. The interlocking network of aggregations in which the children become infected with childhood contagions is largely restricted to those consisting of children. The epidemiological pattern of colds is, however, more complex; lasting immunity is not conferred. To the network of childhood aggregations in which infection may be spread must be added those shared with adults; and home aggregations especially become relatively more important. Incidence in diseases to which exposures are multiple within and without the school becomes a measure of susceptibility rather than exposure, and prevention will become manifest only when the last source of infection is eliminated.

It should again be emphasized that the primary objective of the experiments was not to postpone childhood contagions to high school ages (though this may be desirable in the poorer districts of large cities, where mortality is high among pre-school children to whom infection may be introduced by primary school children), but to test the hypothesis (1) that epidemic contagion is spread through the medium of confined atmospheres and can be prevented by radiant disinfection of air. The results obtained in the experiments described here lend support to this hypothesis, and point to the immediate application of methods described to prevent the occurrence of contagious diseases at unfavorable times, such as measles in midwinter when the danger of complicating streptococcal infections is highest, and in unfavorable situations, such as army barracks, where overcrowding aids spread and where facilities for care may be overtaxed by an avalanche of cases.

References

1. Wells, W. F., and Wells, M. W.
1936 Air-borne infection. J. A. M. A., *107:* 1698 and 1805.
Wells, W. F.
1940 Droplet nuclei as vehicles of contagion. Proc., Third Internat. Cong. for Microbiology, p. 266.
Wells, W. F.
1940 Studies on air-borne infection. Science, *92:* 457.
2. Hart, D.
1936 Sterilization of the air in the operating room by special bactericidal radiant energy. J. Thor. Surg., *6:* 45.
3. Overholt, R. H., and Betts, R. H.
1940 A comparative report on infections of thoracoplasty wounds. J. Thor. Surg., *9:* 520.

4. Wells, W. F.
1939 Sanitary ventilation in wards. Heating and Ventilating, *36:* 26.
5. delMundo, F., and McKhann, C. F.
1941 Ultraviolet radiations in control of hospital infections. Am. J. Dis. Child., *61:* 213.
6. Wells, W. F., and Green, R.
The environmental control of epidemic contagion. II. A bacteriologic study of radiant disinfection of air in schools. Paper in preparation.
7. Com. Amer. Public Health Ass'n.
1940 The control of communicable diseases. Pub. Health. Reports, Reprint No. 1697.
8. Collins, S. D.
1929 Age incidence of the common communicable diseases of children. U. S. Pub. Health Reports, *44:* 763 (see Figure 8).
9. Picken, R. M. F.
1921 The epidemiology of measles in a rural and residential area. Proc. Royal Soc. Med., *14:* 75.