

St. Louis Encephalitis in 1933

observations on epidemiological features

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L. L. Lumsden, 1875–1946, a self-styled “shoe-leather” epidemiologist, was a pioneer in indicting the mosquito as a vector of encephalitis. A Public Health Service officer from 1898 to 1939, Lumsden blended rugged realism with an imagination that conceived of the Public Health Service as a logical nucleus for national coordination of State, county, and municipal health activities. He also organized at Yakima, Wash., a full-time county health service, setting a national pattern for local health departments.

THESE OBSERVATIONS on the epidemiology of epidemic encephalitis lethargica are based on findings in the course of studies authorized in a letter dated September 14, 1933, from the Surgeon General of the Public Health Service. The studies included field surveys in St. Louis City, St. Louis County, Independence, Jackson County, Kansas City, Sedalia, Jefferson City, and Columbia in Missouri, East St. Louis, Collinsville, and Chicago in Illinois, and Louisville and Jefferson County in Kentucky.

Intensive studies, including home visits and collection of individual epidemiological case histories, were made in Independence and in Blue Township in Jackson County. In the collection of detailed data in that city and township able assistance was furnished by Dr. W. F. Lunsford, statistician, Missouri State Board of Health, and by the staff of the Jackson County Health Unit. In the other places visited the studies made by the writer were of a general rather than an intensive detailed character. In

the St. Louis region, where next after the Independence region the incidence of the disease in proportion to population was highest and where the large majority of the cases in the epidemic occurred, the intensive detailed studies were made by other officers of the Public Health Service, and their findings, presumably, will be the subject of an exhaustive detailed report.

Chronology and Geographic Distribution

From such evidence as has been obtainable, it appears that the earliest cases of encephalitis lethargica definitely diagnosed in the Missouri epidemic of 1933 had their onset of pronounced symptoms in the last day or two of July and were in a few persons residing in widely separated homes in rural parts of St. Louis County, 10 to 15 miles out from the limits of St. Louis City. Soon thereafter, the disease developed in epidemic rate among the residents of the thickly built-up zone ranging from 1 to 5 miles

Historical Note

In 1933 an unprecedented outbreak of human encephalitis occurred near St. Louis, Mo. When investigations were started by local, State, Federal, and other research workers, it was not known whether a virus, bacterium, or toxic chemical agent was involved. The mode of transmission was equally obscure. During the course of the epidemic, a virus was isolated and characterized—the first time that the etiological agent of any acute epidemic encephalitis of man had been identified. The virus of western equine encephalitis had been under study in the laboratory only since 1930; the virus of eastern equine encephalitis was being studied concurrently with the St. Louis virus and its isolation was also reported in 1933. These were known only as equine diseases. The role of mosquitoes in spreading any of these viruses was not known.

Into this abyss of ignorance and into the midst of a raging epidemic, the Surgeon General of the Public Health Service assigned Medical Director L. L. Lumsden for epidemiological studies. Two conflicting views developed as to the mode of spread of the St. Louis agent. A majority group, influenced by previous epidemiological studies on poliomyelitis and lethargic encephalitis, favored human to human

transmission, while a minority viewpoint, vigorously presented by Lumsden, favored insect transmission.

It is to Lumsden's credit that, after a careful survey of the situation, he reached a sound hypothesis as to the mode of transmission of St. Louis encephalitis, a hypothesis which has proved applicable to other virus encephalitides in North America. This has been abundantly proved by later work. For this reason, Lumsden's unpublished report of 1933, with its sound conclusions as well as its deficiencies, is printed in full at this time.

The ease and frequency with which the viruses of St. Louis, western equine, and eastern equine encephalitis are now isolated from nature and manipulated in the laboratory indicate progress in this field which must be credited largely to a small group of devoted workers who have continued inquiries when there were no epidemics and when there was little interest or support for such research. However, if we were today confronted with another episode of encephalitis lethargica such as the 1933 St. Louis epidemic, it is debatable if its course could be materially altered, the mortality rates suppressed, or the sequelae ameliorated.

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in width in St. Louis County and adjacent to and to the west, north, and south of the city, and also among residents of the outskirts of the city of St. Louis lying next to the affected county zone.

Senior Surgeon J. P. Leake states, "during the early part of the epidemic, the rate of incidence in St. Louis County was 11 times that in St. Louis City." Eventually cases of the disease were reported from every ward of the city, but for the whole period of the epidemic (approximately August 5 to October 14) the rate of incidence was very much higher among residents of the outlying western wards next to the county line than among residents of the "downtown" wards, although the latter include some of the most densely populated areas of the city. According to reports as of October

10, the rate of incidence in the two large wards adjacent to the Mississippi River and farthest downtown from the heavily affected county zone was only about one-fifth of that in some of the outlying wards adjacent to the county zone. For the whole period of the epidemic, the rate of incidence, according to official reports, in St. Louis County was nearly four times that in St. Louis City.

If the rates of incidence of encephalitis in the different areas of St. Louis City were, as appears probable, even roughly or generally in inverse proportion to the distance from the St. Louis County zone of high prevalence, such occurrence taken alone would appear to be of some epidemiological significance, and, perhaps, would become of more epidemiological significance if considered in connection with

the direction of prevailing winds, with main currents of travel by persons, and with other possible factors in the spread of disease.

According to records of the State board of health, the reports of cases of encephalitis lethargica, by weeks, in the cities and counties of Missouri in the period August 1 to October 21, 1933, were as indicated in table 1 (1).

From these records it appears that the epidemic began and also reached its height in the St. Louis region about a week or two before it did in the Independence (Jackson County) region, but that the marked decline in the epidemic occurred somewhat sooner in the Independence region than it did in the St. Louis region. It is interesting to note that of the two

Table 1. Number of cases of encephalitis reported, by weeks, and case incidence, 1933

Location	Week ended—											Total cases	Popula- tion ¹	Case rate, 100,000 population	
	August			September					October						
	12	19	26	2	9	16	23	30	7	14	21				
<i>City</i>															
St. Louis.....	3	15	40	104	107	104	62	45	41	14	13	548	821, 960	66	
Independence ²												(63)	15, 296	421	
Kansas City.....	0	1	2	5	4	0	0	0	0	0	4	16	399, 746	4	
St. Joseph.....	0	0	4	10	8	9	2	3	5	3	0	44	80, 935	54	
Jefferson City.....	0	0	0	0	0	0	0	0	0	0	0	0	21, 596	0	
Sedalia.....	0	0	0	0	0	0	0	0	0	0	0	0	20, 806	0	
Springfield.....	0	0	0	0	0	0	0	0	0	0	0	0	57, 527	0	
Joplin.....	0	0	0	0	0	0	0	0	0	1		1	33, 454	2	
Columbia ³												(?)	14, 967	46	
<i>County</i>															
St. Louis ⁴	33	67	95	96	91	78	33	22	10	7	3	535	211, 593	252	
Jackson ⁵	0	0	9	28	42	15	8	13	5	2	2	124	70, 708	175	
Boone ⁶	0	0	0	0	1	1	2	0	2	1	2	9	30, 995	29	
Audrain.....	0	0	0	0	0	0	0	0	0	0	0	1	22, 077	4	
Bates.....	0	0	0	0	0	0	1	0	0	0	0	1	22, 068	4	
Buchanan.....	0	0	0	0	0	2	0	0	0	0	0	2	98, 633	2	
Carroll.....	0	0	0	0	0	0	0	0	1	0	0	1	19, 940	5	
Cass.....	0	0	0	0	0	0	0	0	0	1	0	1	20, 962	4	
Clay.....	0	0	0	1	0	0	0	0	0	0	0	1	26, 811	3	
Clark.....	0	0	0	0	0	2	1	0	0	0	0	3	10, 254	29	
De Kalb.....	0	0	0	0	1	0	0	0	0	0	0	1	10, 270	9	
Dunklin.....	0	0	0	0	0	0	0	0	0	1	0	1	35, 799	2	
Franklin.....	0	0	1	0	0	0	0	0	0	0	0	1	30, 519	3	
Greene.....	0	0	0	0	0	2	0	0	0	0	0	2	82, 929	2	
Henry.....	0	0	0	0	0	0	0	0	0	1	0	1	23, 931	4	
Hickory.....	0	0	0	0	0	0	1	0	0	0	0	1	6, 430	15	
Jefferson.....	0	0	0	0	0	1	2	0	0	0	0	3	27, 563	10	
Knox.....	0	0	0	0	1	0	0	0	0	0	0	1	9, 658	10	
LaFayette.....	0	0	0	0	1	0	0	0	0	0	0	1	29, 259	3	
Lawrence.....	0	0	0	0	0	0	0	0	1	0	0	1	23, 774	4	
Montgomery.....	0	0	0	1	0	0	0	0	0	0	0	1	13, 011	7	
Morgan.....	0	0	0	0	0	0	0	0	1	0	0	1	10, 968	9	
Nodaway.....	0	0	1	0	0	0	0	0	0	0	0	1	26, 371	3	
Phelps.....	0	0	0	0	0	1	0	0	0	0	0	1	15, 308	6	
Polk.....	0	0	0	0	1	0	0	0	0	0	0	1	17, 803	5	
St. Charles.....	0	0	0	0	0	0	1	2	0	1	0	4	24, 354	16	
Saline.....	0	0	0	0	0	0	1	0	0	0	0	1	30, 598	3	
Shelby.....	0	0	0	0	1	2	0	0	0	1	0	4	11, 983	33	
Stoddard.....	0	0	0	0	0	1	0	0	0	0	0	1	27, 452	3	
Total for State.....	36	83	152	245	258	219	114	85	66	33	24	1, 315	2, 458, 308	736	

¹ United States census, 1930.

² Number of cases comprised in figures for Jackson County.

³ Number of cases comprised in figures for Boone County.

⁴ Outside St. Louis City.

⁵ Excluding Kansas City, including Independence.

⁶ Including Columbia.

⁷ For whole State, including counties for which no cases were reported.

regions of the State which were most heavily affected, one (St. Louis) is on the east border of the State and the other (Independence) is near the west border about 300 miles from St. Louis and that, with the exception of Columbia in Boone County, there were very few cases reported in the cities and the 7 counties along the main lines of travel between St. Louis County and Jackson County. In the three counties adjacent to St. Louis County, with a total population of 82,436, only 8 cases were reported—4 in St. Charles, 1 in Franklin, and 3 in Jefferson—and in none of the 7 counties along the main line of travel between St. Louis and Jackson County was a case reported.

Within the period August 1 to October 21, not a case was reported in either Jefferson City, with a population of 21,596, or in Sedalia, with a population of 20,806. Both of these cities are on the main current of travel between St. Louis and Kansas City. The State Fair, which was attended by many persons from the St. Louis and Independence regions, was held at Sedalia August 12 to 19, inclusive, when the period of causation of the disease in the St. Louis region was, presumably, at its height. Columbia and Independence, which cities are somewhat offside from the main current of travel between St. Louis and Kansas City, were stricken—the former moderately and the latter very severely. The incidence in Independence and in the zone about 6 miles wide (in Blue Township, Jackson County) between that city and Kansas City was much higher than the rate in St. Louis City and County. As nearly as the population can be estimated, the incidence in the area (of Blue Township) lying between Independence and the northeast section of Kansas City was 1 case to about 125 of population. In Jackson County outside Independence, Blue Township, and Kansas City, not a case was reported.

In Kansas City, with a population of 399,746, only 16 cases were reported to the State board of health between August 1 and October 21. The records of the Kansas City Health Department, however, showed on September 28 that 33 cases developing in the city had been reported to that department since August 1. It is exceedingly doubtful that as many as 100 cases actually occurred among residents of Kansas

City during the epidemic. At even such liberal estimate the case incidence in that city would have been only 1 to about 4,000 of population. It appears that a large proportion of the cases developing in Kansas City were in persons residing in the northeastern section of the city near the Jackson County (Blue Township) line.

In East St. Louis, Ill., with a population of 74,347, directly across the river from St. Louis, Mo., and connected therewith by bridges over which there is a constant current of traffic, only 3 local cases were reported between August 1 and September 25, but in Collinsville, Ill., a scattering village of 9,235 population located about 6 miles east of the city limits of East St. Louis, 4 local cases were reported within that period.

In Chicago, Ill., with a population of about 3,500,000, only 3 cases of encephalitis lethargica among residents were reported between August 1 and September 29. The number of cases reported in 1932 was 21 and the number reported in the period January 1 to August 1, 1933, was 6. In view of the tremendous amount of traffic between Chicago and St. Louis and Kansas City, the fact that Chicago was not reached by the epidemic is significant.

If encephalitis lethargica has an incubation period of 1 or 2 weeks, or more, as is assumed—apparently without definite reasons—by some observers, it is remarkable that a considerable number of persons while incubating the “infection” did not go from the epidemic areas to Chicago and have the onset of the disease while there. If the disease is caused by an infection which is transmitted either through personal contact or by flying insects, such as mosquitoes, which will travel by train, Chicago’s complete escape from the epidemic would be difficult to understand, unless the incubation period (if any) of the disease is very short and the “infection,” if conveyed by insects, is harbored by the “carrier-insects” for only a short period—less than 12 or 24 hours.

In Louisville, Ky., with a population of 307,745, located about the same distance by automobile or train travel from St. Louis as is Chicago, 28 cases of, with 9 deaths from, encephalitis lethargica were reported among residents of the city between August 1 and Septem-

ber 21, 1933. In addition to these, about 20 suspected cases were reported. Judging by the records of the city health department and the findings in the survey of the situation, the probability is that approximately 60 cases of the disease developed among the residents of Louisville in the period August 10 to October 10. A large majority of the cases were among persons residing in one or the other of two outskirts of the city about 6 miles apart.

Why was there such a distribution of the disease in the epidemic? Why did the incidence become less as the densest centers of population farthest away from the affected suburban zones were approached in St. Louis City and Kansas City and Louisville? Why did not the disease follow the main currents of human travel? Why did Jefferson City, Sedalia, and Chicago entirely escape? Why did Columbia have a fairly high prevalence? Why did Collinsville have a rate of incidence of the disease 10 times that of East St. Louis? Why were the cases in Louisville mainly in persons residing in one or the other of two outlying sections of the city about 6 miles apart? The answers to these questions should lead to sound epidemiological conclusions as to the mode of spread of the disease.

Judging by the reports recently received, it appears that with the advent of cool or cold weather in each of the heavily affected areas, the disease promptly ceased to prevail in epidemic proportions—in the Independence region somewhat before it did in the St. Louis region, although the epidemic began in the former region 2 weeks or more later than it did in the latter. The decline or the practical termination of the epidemic with the advent of cool or cold weather may be, of course, entirely coincidental and present no relationship of cause and effect; but to our elder epidemiologists it is somewhat remindful of the observations on yellow fever incidence in the days prior to 1900 when that disease, too, was a “mysterious malady.”

General Considerations

The high rate of incidence of encephalitis lethargica in persons in the older age groups, the rapid spread of the disease over large areas in the regions affected, and all of the other gen-

eral epidemiological features suggest that in this epidemic in Missouri we were dealing with a new or a comparatively new disease or a new type of an old disease. At the beginning of these studies the nature of the causative agent of the disease was entirely unknown.

So far as the writer was informed, it has not been definitely determined whether the causative agent is a microscopically visible organism, a filtrable virus, or a toxin. Therefore, it seems right throughout the course of the studies to try to keep entirely open-minded, to be not overly influenced by superficial appearance of analogy with any other disease, to consider constantly the possibility that in this epidemic of encephalitis we were dealing with a disease or a type of disease different from any other which previously had prevailed in this country or, perhaps, in any other country, to collect facts carefully and thoroughly, and to consider every possible factor which might operate in the causation and spread of this disease.

The geographic distribution of the epidemic appeared to furnish a lead. There must have been some definite difference between the communities which were heavily affected and those which were lightly affected or not affected at all. The determination of these differences and whether they were consistent seemed highly important. In the areas heavily affected, the disease appeared to attack in about the same proportion rich and poor, white and Negro, and persons of different national descents. Difference in sources of water supplies for drinking and culinary purposes in two or more adjacent areas did not appear to affect the prevalence of the disease. Difference in food habits did not appear to affect prevalence. No evidence was found of a disproportionately high prevalence of the disease among users of milk, ice cream, or any other food from any one source. Therefore, it seems that if either water supplies or food supplies had operated in the spread of the disease all of the supplies in the large areas affected would have to have been about equally involved.

The first 2 days of these studies (September 18 and 19) were spent by the writer in the St. Louis region for conference and observation with other officers engaged in intensive studies in that region. We made repeated trips back

and forth over the St. Louis City line through different parts of the then heavily affected, thickly built-up suburban zone in St. Louis County.

As the city line was crossed going into the suburban zone, one difference was striking and very apparent. In the city area there were both sewage and sewerage. In the suburban area there was sewage but no adequate sewerage. In the city the sewage is carried away by trunk sewers to the disposal plants and eventually to the river. In the suburban zone, which is a section of hills and dales, there is no general sewerage system and the sewage from the small municipalities and from the thousands of dwellings and places of business is carried by small municipal sewers or by private or individual sewers direct from toilets or from cesspools or septic tanks to nearby creeks or streams. These heavily polluted open streams are very offensive to sight and smell. Even if they had nothing to do with the causation or spread of any disease, they are bad. They should not be tolerated in any community.

Since the rainfall in this region in the summer of 1933 was less than that for any of many previous summers, sewage was concentrated to an unusual degree in these creeks in the summer and early fall of this year. Mosquitoes, mainly (or almost solely) *Culex pipiens*, were breeding in myriads in these heavily sewage-polluted creeks. The citizens generally in these areas stated that mosquitoes were much more numerous and much more of a pest this season than they had been for many years before. Surgeon L. L. Williams, Jr., stated that *C. pipiens* and *Culex quinquefasciatus* mosquitoes bred under such conditions are capable of and addicted to long flights—2 miles or more. Anyhow, in September of this year, *C. pipiens* mosquitoes were observed from time to time in rooms in some of the farthest downtown leading hotels of St. Louis. The probability is that they were present more or less in all parts of the city, but most abundant in the outlying western areas.

Mosquito breeding in open sewage-polluted creeks was kept in mind in the course of the observations in other communities. East St. Louis is located in a flat, river bottom area instead of in one of hills and dales, and there

was comparatively little, if any, mosquito breeding in exposed heavily sewage-polluted streams or other waters. Collinsville, Ill., however, is located in an area of hills and dales—very similar to that of the St. Louis County zone—and there was observed on each of the two sides of the village a heavily sewage-polluted creek in which in September mosquitoes (*C. quinquefasciatus*, mainly) were breeding in myriads. In the Independence and Blue Township region between Independence and Kansas City creeks were heavily sewage-polluted and *C. pipiens* were breeding therein to a much greater degree apparently than in the St. Louis County region as a whole. Columbia, Mo., presented this condition to a considerable degree. Kansas City, Jefferson City, Sedalia, and Chicago appeared free from it. Louisville, Ky., presented it to a marked degree in the immediate vicinity of each of the two areas in which encephalitis was highly prevalent.

Thus, throughout the limited observations made by the writer, the abundance of sewage-bred mosquitoes (*C. pipiens* or *C. quinquefasciatus*) appeared to be the only consistent factor of difference between communities which were heavily affected by encephalitis in this epidemic and those which were not affected or only slightly affected.

This one fact is not conclusive but it is suggestive and, therefore, seems worthy of careful consideration and further study. It is possible, of course, that some other insect, such as the sandfly or buffalo gnat (*Simuliidae*), or some unusual large fly or one not yet even thought of is the vector; but the evidence obtained in the course of these studies points to the mosquito as the most likely conveyor—if the disease is conveyed by insects. Every fact observed in the places visited by the writer seems in line with the hypothesis of mosquito conveyance and not one fact observed is in conflict with it. Thus, hypothesis passes into theory.

The geographic distribution and most other general features of the epidemic appear definitely out of line with the other much discussed hypothesis—and the one yet favored by some of the observers—that the disease is caused by an infection discharged in the secretions from the upper respiratory passages of patients and “carriers” and is transmitted

from person to person through direct and indirect personal contact. In the outbreak of malignant smallpox in Kansas City and vicinity in 1921 and in the influenza epidemic of 1918, the epidemiological pictures were very different from that of this encephalitis epidemic.

In view of the fact that only one person in about a thousand in the St. Louis region developed encephalitis in the course of the epidemic, negative results from human experimentation evidently would have to be produced on a large scale—involving hundreds of persons—to tend to nullify the mosquito conveyance hypothesis or any other reasonable hypothesis.

In considering the hypothesis that encephalitis is caused by a micro-organism, a virus, or a toxin conveyed to susceptible persons by mosquitoes, a number of interesting questions arise, such as the following:

1. Do the mosquitoes before becoming capable of conveying the causative agent have to feed on the blood of a person ill with the disease, or of one harboring the causative agent without being ill, and carry the agent through a developmental cycle as is the case with yellow fever and malaria?

2. May adult mosquitoes become capable of conveying the causative agent mechanically—as appears to be the case with some of the insects which convey the infections of some of the trypanosomiasis—after feeding on the blood or some of the secretions or excretions of a person (ill with the disease or before, after, or without illness) harboring the causative agent?

3. May mosquitoes while in the larval stage acquire the causative agent in their feeding on matter polluted with human excretions or secretions or on other matter and continue to harbor the agent and be capable after reaching adult life of conveying the agent to persons by biting or otherwise?

4. If mosquitoes become loaded with the agent before leaving their breeding places (as appears to be the case with the mites which convey the infection of tsutsugamushi fever) is it one out of many—thousands or millions—or a considerable proportion of them which becomes loaded?

5. Is the causative agent harbored by the

loaded mosquitoes for a period of days or weeks or for only a few hours after leaving their breeding places?

6. Is one loaded mosquito capable of conveying the causative agent to a susceptible person by one bite or are a number of bites by one or many loaded mosquitoes required?

7. Do other animals—such as poultry, birds, cows, horses, squirrels, rodents, or even fish or reptiles (dead or alive)—serve as sources of the causative agent from which mosquitoes may transmit the agent to man?

8. Are persons who “do not mind” mosquitoes, and who sit out in the open after dusk of evening and “take them,” more likely to contract encephalitis than are persons who are “poisoned” by mosquitoes and who try to get away from them?

9. Is it possible that the part of the body bitten is a determining factor, as is the case with rabies virus, tending to explain why elderly persons with well-clad bodies and whose faces and necks present the main field of attack for mosquitoes are more likely under comparable conditions of exposure to loaded mosquitoes to have the causative agent conveyed effectively to them than are lightly clad young persons whose legs and arms present the main area of attack?

10. Are persons with foul mouths and offensive breaths or with otitis more likely while sleeping under cover at night to attract *C. pipiens* mosquitoes to their heads and necks than are persons with clean mouths sleeping in the same rooms or houses?

Most of these questions, presumably, will have to be answered, if at all, by the findings from future studies; but if in the meanwhile the spread of encephalitis is not proved to be due to some agent or agency other than mosquitoes, these questions are and will be serious practical ones.

The sudden spread of the disease over large areas, the very unusual occurrence of more than one case in one family, and the other general features of the epidemic seem to suggest that if the causative agent is conveyed by mosquitoes, it is conveyed by filth-breeding and filth-liking mosquitoes (*C. pipiens*) which, in rare exception or in considerable proportion, come “loaded” from some of their breeding places and are capable for a short time of conveying

the causative agent without previously having fed on the blood of a person or other living animal.

Incidence in Institutions

Institutions, of which there are quite a number in the outskirts and suburbs of St. Louis City, seemed to furnish especially strategic situations for studies of encephalitis. Four institutions were visited. The first one, an institution for mental cases administered by Sisters of Charity, had a population, including personnel and inmates, of about 400. It is located on a hill about 2 miles from Clayton in St. Louis County and in a zone in which encephalitis was highly prevalent. All parts of the building were found to be well screened and otherwise in excellent hygienic condition. Not a case of encephalitis developed at that institution during the epidemic.

On a hill in one of the outskirts of the city in the vicinity of a section of the St. Louis County zone which was quite heavily affected are three city institutions, the Hospital for the Insane, the Isolation Hospital, and the Infirmary (Almshouse). They face north on the same street and are in adjacent grounds. The Isolation Hospital is in the middle. The prevailing winds are from the south. All three are supplied with milk, meat, vegetables, and other foods purchased by the city from the same contractors. All three obtain their water supplies from the same source, the city public supply.

At the time of the survey, on September 25, the Isolation Hospital and the Hospital for the Insane were found to be well screened and otherwise in excellent structural condition, but the Infirmary was found to be poorly screened and in some parts in need of structural repair. Doctors, nurses, and other persons in each of these institutions were queried regarding mosquitoes in wards and other sleeping quarters at night. The report for the Isolation Hospital and the Hospital for the Insane was that very rarely was a mosquito noticed in the sleeping quarters, but the report for the Infirmary was that mosquitoes were abundant and very troublesome in the sleeping quarters. At the Isolation Hospital, in which over 300 cases of

encephalitis had been treated during the epidemic, not a case had occurred among the personnel. At the Hospital for the Insane with a population, including personnel and inmates, of about 4,000, not a case had occurred.

At the Infirmary, with a population, including personnel and inmates, of about 1,200, 13 cases of encephalitis had developed during the epidemic. Two of these were in female attendants who were domiciled with six other female attendants in a large ward on the second floor of the south side of the building. The first case was in an attendant who slept in a bed directly in front of the door leading from an open porch into the ward. The screen on this door had sagged and furnished little protection against mosquito invasion. The second case, developing 6 or 7 days after the first, was in an attendant whose bed was at the same end of the ward and located a few feet toward the wall from that of the attendant who developed the first case. The other six attendants who were domiciled in this ward and who were not stricken with the disease slept in beds located at the other end of the ward in the part of the quarters farthest away from the door. The space of about 40 feet between the set of 2 beds and the set of 6 beds was used as a lounge.

At both the Hospital for the Insane and the Infirmary, contact through visitors and otherwise with the outside world was free during the epidemic; but, for obvious reasons, there was more restriction at the Hospital for the Insane than at the Infirmary with respect to permitting inmates to visit homes in the community and go out into and sit around in the institutional grounds after sundown.

Intensive Studies in the Independence Region

The encephalitis studies in the region of Independence were begun on September 19 and were terminated on September 28. They comprised (a) a survey of sanitary and other general conditions in the community, (b) examination of the morbidity and mortality records of the health office of Independence City and of the Jackson County Health Department, (c) a search for mosquito breeding places in the vicinity, (d) visits to homes and collection of detailed epidemiological histories

of 19 cases of encephalitis among residents of Independence City and of 28 cases among residents of Blue Township in Jackson County.

Independence is the seat of government of Jackson County. It is an attractive little city with rolling topography, wide, clean streets and well-kept homes, and without serious overcrowding in any part. Economic conditions generally appear considerably above average for cities of its size. The land area is about 3 square miles and the population in 1930 was 15,296, 14,450 whites and 846 Negroes (U. S. Census). Of the whites, only 488 are foreign-born.

Independence is located east of the northeast section of Kansas City, the distance by road between the limits of the two cities being about 6 miles. The public water supply, furnishing over 90 percent of water used for drinking and culinary purposes in the city, is obtained from the Kansas City supply. The milk supplies and other dairy products distributed in the city are from Kansas City and from local dairies and nearby dairy farms. About 50 percent is said to be pasteurized and most of the remainder to be grade A raw. Practically all meats sold in the city are distributed by Kansas City dealers. Vegetables are mainly from Kansas City markets and nearby farms.

About 80 percent of the private dwellings and public places are connected with the city sewers and the remainder are provided with septic tanks, cesspools, or privies. The main trunk sewer, carrying about two-thirds of the city's sewage, discharges into Rock Creek, a shallow stream ranging in width from 3 to 10 feet, meandering in and out along the southern outskirts of the city, and finally discharging into a lake in Mount Washington Cemetery about 1 mile from the eastern limit of Kansas City. The sewage before discharge into the creek (in the south central outskirts of the city) goes through some sort of sedimentation treatment which evidently is inadequate because the sewage was found highly putrescible after it entered the creek. Samples of water dipped from Rock Creek and from other heavily sewage-polluted creeks in the other outskirts or suburbs of the city were found, on September 22, to be literally teeming with mosquito larvae, which on examination proved to be *C. pipiens*.

The locally prevailing winds are from the south.

Local Prevalence of Encephalitis

Independence was severely affected by the encephalitis epidemic. From August 19 to October 21, 1933, 63 cases with 14 deaths were reported among the residents of the city. Sixty cases were in white persons and 3 were in Negroes. The case incidence for the whole period of the epidemic in Independence was 1 to about 250 of population.

Blue Township in Jackson County, especially that part lying between Independence and Kansas City, was also severely affected. In that intercity zone the case incidence was 1 to about 125 of population. The population of Jackson County, exclusive of Independence and Kansas City is 55,406. Of them, 27,356 reside in Blue Township outside Independence. In this total rural population of Blue Township there were reported from August 19 to October 14, 1933, 61 cases of encephalitis with 8 deaths, a case incidence of 1 to about 450 of population.

In the total population of 28,056 in the other rural townships of Jackson County not a case was reported within that period. All cases

Table 2. Distribution of cases of encephalitis lethargica in Independence and Blue Township, Mo., by age and sex, 1933

Age (years)	Independence			Blue Township			Total
	Male	Female	Total	Male	Female	Total	
0-4	0	0	0	0	0	0	0
5-9	0	0	0	3	0	3	3
10-14	2	0	2	4	1	5	7
15-19	1	1	2	1	1	2	4
20-24	0	0	0	0	2	2	2
25-29	5	2	7	1	2	3	10
30-34	0	1	1	4	3	7	8
35-39	3	2	5	5	4	9	14
40-44	0	2	2	1	4	5	7
45-49	0	4	4	1	0	1	5
50-54	3	2	5	2	3	5	10
55-59	5	2	7	1	1	2	9
60-64	0	1	1	1	1	2	3
65-69	5	2	7	1	2	3	10
70-74	2	2	4	0	1	1	5
75-79	0	0	0	3	4	7	7
80-84	3	2	5	0	1	1	6
85-89	1	0	1	0	0	0	1
Total	30	23	53	28	30	58	111

Table 3. Incidence of encephalitis lethargica in Independence, Mo., by age and sex, 1933

Age (years)	Population			Cases	Incidence of cases to persons
	Total	Male	Female		
Under 5.....	1, 170	607	563	0	0-1, 170
5-9.....	1, 367	726	641	0	0-1, 367
10-14.....	1, 326	636	690	2	1-663
15-19.....	1, 308	656	652	2	1-654
20-24.....	1, 533	736	797	0	1-1, 533
25-29.....	1, 339	635	704	7	1-191
30-34.....	1, 061	503	558	1	1-1, 061
35-44.....	2, 045	962	1, 083	7	1-292
45-54.....	1, 728	824	904	9	1-192
55-64.....	1, 256	611	645	8	1-157
65-74.....	768	346	422	11	1-69
75 and over...	388	194	194	6	1-64
Unknown.....	7	4	3	5	-----
Total..	15, 296	7, 440	7, 856	58	1-264

reported in Blue Township outside Independence were in white persons. In the rural part of the township, only 60 Negroes reside. The area of Blue Township west of Independence, which probably was more heavily stricken by the epidemic than any other area of considerable population, is hilly. In the dales between the hills are numerous creeks. Most of these creeks are polluted with sewage and are heavily polluted in periods of drought such as that of the summer of 1933. Samples of water dipped from a number of places in those creeks on September 22 were found to contain myriads of *C. pipiens* larvae. The report from the residents generally was that mosquitoes were much more abundant in July, August, and September of this year than in the corresponding months of any previous year within their recollection. The opportunity for the breeding of mosquitoes in heavily sewage-polluted water in this region, in proportion to population, seemed several times as great as that furnished in the St. Louis County region.

The zone between Independence and Kansas City is quite thickly built up, resembling for the most part a scattering village. The majority of the residents appear to be in good or fair economic circumstances. Most of the water used for drinking and culinary purposes in this zone is piped from the Kansas City supply. The large majority of the homes seem well constructed and well kept. It was surprising to

find among the streets at the front of some of the rows of those attractive homes gutters filled with and flowing with highly offensive sewage.

Dates of Onset of Cases

In a large majority of the cases especially investigated, the onset of definite illness was sudden or after a prodromal period of only a day or two. The dates of onset (usually those upon which the patient took to bed) of 51 cases in Independence and of 59 cases in Blue Township (outside Independence), whose histories on this point were obtained, were evenly distributed throughout August and September. [Tabulation omitted.—EDITOR.]

Age and Sex

The occurrence of cases of encephalitis among 111 persons in different age-sex groups is shown in table 2. It is interesting to note that in persons under 15 years of age the case incidence was much higher among males than among females.

The case incidence among persons in different age groups among 15,296 residents of Independence is shown in table 3.

Table 4 presents the number of persons in the different age groups in the rural farm and the rural nonfarm population of Jackson County, the number of cases of encephalitis in each of

Table 4. Incidence of encephalitis lethargica in Jackson County, Mo., by age and population group, 1933

Age (years)	Population		Number of cases	Relative but not actual case incidence
	Rural farm	Rural non-farm		
Under 5.....	1, 292	4, 042	0	0-4, 042
5-9.....	1, 559	4, 384	3	1-1, 461
10-14.....	1, 645	3, 706	5	1-741
15-19.....	1, 415	3, 177	2	1-1, 588
20-24.....	1, 042	3, 017	2	1-1, 508
25-29.....	917	3, 396	3	1-1, 132
30-34.....	1, 006	3, 322	7	1-474
35-44.....	2, 215	5, 724	13	1-440
45-54.....	1, 971	3, 696	5	1-739
55-64.....	1, 450	2, 524	4	1-631
65-74.....	918	1, 697	4	1-424
75 and over...	326	923	8	1-115
Unknown.....	22	22	5	-----
Total.....	15, 778	39, 630	61	1-640

the age groups, and, since the large majority of the cases were in the nonfarm residents, the case incidence based on the nonfarm groups of the population.

Findings at Affected Homes

In the course of epidemiological studies, the ascertainment of definite information as to the possibly salient conditions to which the persons affected with encephalitis have been exposed prior to illness is of primary and fundamental importance. Therefore, visits to the homes of persons in which cases of encephalitis had developed in the Independence region were begun with interest and with an effort toward complete openmindedness.

Of the affected homes, 18 in the city and 27 in the township (outside Independence) were visited. At the second home visited, a history was obtained that within the 3 weeks prior to the onset of the patient's illness, 25 of about 100 chickens kept in the yard had died of some sort of convulsive disease. At the fourth and fifth homes, a history was obtained that within several weeks prior to the development of each case, goldfish kept in a bowl in the house or in a rock garden in the yard had been dying. At the seventh home visited, the wife had captured three strange insects in the bedroom of her husband the day he became ill with encephalitis. These insects, resembling somewhat the drones of honey bees, were later identified at the St. Louis headquarters of the studies as moths of unusual occurrence in that part of the world. The convulsive chickens, the sick goldfish, and the strange moth tales, however, did not continue, no history of any of them being obtained at any of the other stricken homes visited.

Especial consideration was given to the possibility of the encephalitis epidemic having been caused by a toxin—comparable to that of botulism—conveyed in some widely distributed canned or otherwise prepared food, but the histories of the cases definitely eliminated such etiological possibility. Attention also was given to the possibility of unhealed wounds, sores, bad tonsils, and diseased gums serving as a nidus of infection. The proportion of cases among persons with diseased gums was found to be quite interesting.

Possible Susceptibility Factors. No evidence was obtained to suggest that hay fever, asthma, hives, herpes, previous attack of any infectious disease, vaccination against smallpox, or immunization against diphtheria or typhoid fever tended to make one especially susceptible to the disease.

Of the 47 cases of encephalitis intensively studied in the Independence region, only 4 were in persons who gave a history of frequent colds or sore throat prior to onset of the illness, only 6 were in persons who had bad tonsils, 3 were in persons who were subject to fever blisters, 12 were in persons who during the 2 weeks or more prior to illness had unhealed wounds or sores, and 24 were in persons who had diseased gums and/or badly decayed teeth. Definite histories of mouth conditions were obtained for 18 city cases and 22 township cases. The 18 city cases were in persons who during the 2 weeks or more prior to their onsets of encephalitis had mouth conditions as follows: 10 with Riggs' disease, 2 with Vincent's angina severely affecting the gums, 4 with false teeth, and only 2 with healthy gums and sound natural teeth. The 22 township cases were in persons who during the 2 weeks or more prior to their onsets of encephalitis had mouth conditions as follows: 12 with Riggs' disease, 2 with false teeth, and 8 with healthy gums and sound natural teeth. In a sufficient proportion of instances to be somewhat impressive, the one member of a family who had a foul mouth was the one member who developed encephalitis.

Water and Foods

There was no evidence that any water supply used for drinking operated as a factor in the spread of encephalitis. The distribution of cases among users of the different water supplies was in close proportion to the numbers in the general population exposed to the different supplies.

No evidence was obtained pointing to milk or any milk product as a factor in the spread of the disease. The number of cases among the users of milk from the different milk supplies of the community was as nearly proportionate to the amount of the milk distributed by the different dealers as could be expected with such a limited number of cases. There

was no disproportionately large number of cases among consumers of milk or any other dairy product from any one source. The heavier milk drinkers and ice cream consumers of the affected families generally escaped the disease. A large majority of the cases were in persons who used milk sparingly (in coffee or on cereals) or not at all.

No evidence was obtained to suggest that meat, vegetables, or fruit, or any other food supplies were a considerable factor in the spread of the disease. Only 5 of 18 cases in the Independence group and only 4 of the 24 cases in the Blue Township group—whose histories on this point were obtained—were in persons who, within the 3 weeks prior to onset of illness, ate any food or drank any beverage of an unusual nature either at or away from home to which other members of their families were not also exposed. The incidence of the disease appeared less among beer drinkers than among nonbeer drinkers in the community, and there was no suggestively large proportion of cases among those who habitually drank beer of any one particular brand.

Sanitary and Hygienic Conditions. The large majority of the encephalitis cases were in persons residing in dwellings with apparently good sanitary and hygienic conditions, excepting that with respect to exposed sewage in the street gutters and nearby creeks.

Animals on Premises. The presence of animals at the 18 affected homes visited in the city and in 27 affected homes visited in the township was determined.

Unusual Insects. In 18 of the affected city homes visited, large gray flies of an unusual kind were reported to have been present in large numbers at 4 and small black flies at 2. In 27 of the affected township homes visited, large black flies of an unusual kind were reported to have been present at 1, bottle flies (in large numbers) at 1, and small black flies at 1.

Personal Contact. Among the 122 homes in which cases were reported in the encephalitis epidemic in the Independence region there were only two instances of more than one case in a home. Two cases occurred in one of the homes in the city and two in one of the homes in Blue Township. The interval between the on-

sets of the two cases in the city homes was 25 days and that between the onsets of the two cases in the township home was 7 days. The affected households in the zone averaged 4.5 persons. Therefore, the total number of persons who did not develop the disease in those 122 households was about 425. The case incidence in the Independence region was 1 to about 200 of population. In view of these data, it seems that residence in a home with a case of encephalitis did not increase the risk of contracting the disease.

Of the 47 cases specially studied, only 3 gave a history of direct association and only 1 of indirect association (through another member of the family) with previous cases of encephalitis, and among these 3 are included the 2 cases developing in previously affected households. Thus, it appears that if personal contact operated as a considerable factor in the spread of the disease, it must have done so in a very quiet, mysterious, and obscure manner.

The persons not developing the disease in the stricken households of the Independence region were, according to the histories obtained, remarkably free during the period of the epidemic from ailments of a sort to suggest the possibility of a mild case of encephalitis. In only 2 of the 45 households visited were histories obtained of such ailments in other members of the household. In one a son of the patient suffered with a "cold" during the 2 weeks prior to onset of the encephalitis case, and in the other the wife of the patient had an "intestinal upset" for 2 days about 1 week before the development of the encephalitis case.

Two instances were discovered of the occurrence of more than one case of encephalitis among persons at place of occupation—one at a public school in the city, where a librarian and a janitor had their onsets of illness 5 days apart, and the other at a printing office in the city, where the cashier had her onset of illness on August 22, and her successor at the desk, on August 29, 6 days after going on the job.

Biting Insects. Of the encephalitis cases especially studied, 19 city cases and 28 township cases, 9 had a history of having been bitten by insects other than mosquitoes 2 or 3 weeks prior to the onset of illness. In the city, 4 persons

had been bitten by small black flies or gnats and 1 by large black flies. In the township, 2 persons had been bitten by fleas, 1 by large black flies, and 1 by small black flies.

Every one of the persons who developed the disease gave a definite history of having been bitten by mosquitoes frequently and many times during the period of 3 or 4 weeks immediately prior to, and extending to a time within a few hours of, onset of illness. Thus, mosquitoes appeared to be the only biting insect to serve as the epidemiological common denominator to all the cases.

At each of the homes visited, the one member of the family who "did not mind" mosquitoes and who was not "poisoned" by them was the one who developed the case of encephalitis.

Discussion

The observations and reports on the encephalitis epidemic in Missouri in 1933 indicate that the flight of mosquitoes in the regions in which the disease was highly prevalent began to diminish about September 15, and by the end of that month was probably less than 10 percent of that of the period of maximum flight. Following a heavy rain and a pronounced drop in temperature in the night of September 26, both the flight and the larval life of mosquitoes suddenly decreased very much in the Independence region. Twenty-five dippings on September 28 from places in Rock Creek and in other polluted creeks in the vicinity showed only two live larvae. Every dipperful of water from those same places on September 22 had shown scores or hundreds of live larvae. Thus, it appears that the epidemic in each of the most heavily affected regions began and reached its height when and where mosquitoes (*C. pipiens*) were unusually and tremendously prevalent, decreased as the mosquito flight decreased, and ceased to prevail (in epidemic rate) when adult mosquitoes in the vicinity became scarce or ceased to travel. Such coincidences are significant.

The epidemic in Missouri this year seemed to present many epidemiological features similar to those of the epidemic in the Inland Sea

region of Japan in the summer of 1924. Mosquitoes found in the vicinity of Osaka have been identified as *C. quinquefasciatus* and/or *C. pipiens* (2). It would be interesting to ascertain whether they were unusually abundant in the Inland Sea region in the summer of 1924.

Conclusions

1. The preponderance of epidemiological evidence supports the hypothesis that encephalitis lethargica of the epidemic type which prevailed in Missouri and neighboring States in the summer and autumn of 1933 is caused by an agent (micro-organism, virus, or toxin) which is conveyed to persons by mosquitoes (*C. pipiens* and/or *C. quinquefasciatus*) which have bred under some set of unusual conditions in waters heavily polluted with human sewage, thereby becoming capable for a short period—perhaps only a few hours—of conveying the causative agent to persons by biting or otherwise without previously having fed upon the blood of a person or other living animal harboring the causative agent.

2. The installation of sewerage systems and other appropriate measures should be carried out as promptly and as thoroughly as may be practicable, before the summer of 1934, in every city, town, village, and suburban and other thickly settled community to prevent the breeding of *C. pipiens* and/or *C. quinquefasciatus* mosquitoes in surface streams, creeks, rivers, ponds, lakes, or other exposed collections of water which are or which are likely to become heavily polluted with human sewage.

3. From all the evidence obtained in the course of these studies, it appears improbable that water used for drinking and culinary purposes, milk or other foods, insects other than mosquitoes, or personal contact, either separately or together operated as very considerable factors in the spread of the disease.

4. Persons generally, and especially those over 50 years of age, in communities in which encephalitis prevails or is likely to prevail in epidemic rate should hasten to secure needed corrective work to put their gums and teeth in hygienic condition.

5. Encephalitis lethargica should be made a reportable disease by Federal, State, and local health agencies.

6. Studies of the cause and mode of spread of encephalitis should be continued unceasingly and adequately until complete practical knowledge of the subject becomes available.

REFERENCES

(1) Leake, J. P.: Encephalitis in St. Louis. J. A. M. A. 101: 928-929, Sept. 16, 1933.

(2) Howard, L. O., Dyar, H. G., and Knab, F.: The mosquitoes of North and Central America and the West Indies. Washington, D. C., Carnegie Institution of Washington, 1915, vol. 3, pt. 1, pp. 345-382.

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EDITOR'S NOTE: *The theory of mosquito transmission of encephalitis, detailed in the foregoing paper, was touched upon briefly in a paper read by Dr. Lumsden at the 29th annual meeting of the Southern Medical Association in St. Louis, Mo., in November 1935 and published in the March 1936 issue of the Southern Medical Association Journal, vol. 29, pp. 303-308.*

Air Pollution

Wagner College. The sixth annual symposium on air pollution and its control will be held at Wagner College, Staten Island, N. Y., on Saturday, April 26, from 9 a. m. to 4 p. m.

Participating in the symposium will be air pollution control officials from government and industry, and specialists in the fields of engineering agriculture and public health.

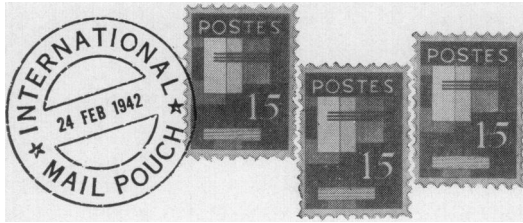
This year's program will emphasize the legal, technical, and legislative aspects of interstate air pollution control, and the contribution of industry to the abatement of atmospheric contamination.

The symposium is sponsored by Wagner's department of bacteriology and public health. Dr. Natale Colosi, chairman of the department, is in charge of the symposium.

University of North Carolina. Concentration of course work in air pollution, offered in fulfillment of the master's degree, has been announced by the School of Public Health of the University of North Carolina, Chapel Hill. Courses are open to sanitary scientists and sanitary engineers.

The department of sanitary engineering, which has a grant from the Community Air Pollution Program of the Public Health Service, will direct the studies.

University of Minnesota. Specialized graduate courses in air pollution will be offered in the spring quarter of 1958. This summer, from August 4-15, a workshop in air pollution will be open to qualified physicians, engineers, chemists, and other sanitation personnel. Inquiries should be addressed to Dr. Gaylord W. Anderson, Director, School of Public Health, College of Medical Sciences, University of Minnesota, Minneapolis 14.



Tax Victory

The health center in Concepción, Paraguay, won a victory when the municipality dropped its building tax on latrines. The levy of 250 guaranies equaled the total construction cost of the latrine, and made the price prohibitive to many families.

—M. A. TAFF, JR., *chief, health, welfare and housing field party, U. S. Operations Mission, Paraguay.*

Second Try

The paramount chief, two clan chiefs, district commission members, and the director of public health nursing spoke at the first graduation of a class of four unlettered midwives in Gbarnga, Liberia. Only the three midwives who failed to pass did not enjoy the festive occasion. Two of them remain undaunted, however, and are enrolled in the next class of 10 pupils. Recruiting for the midwives course goes on in all important clan areas. Classes are scheduled for 8 different locations, including the Gbarnga clinic.

—E. L. MASTHOFF, M.D., *medical officer, U. S. Operations Mission, Liberia.*

Pilgrims and Smallpox

After pilgrims returning from Kerbella, Iraq, introduced 21 smallpox infections in Iran, Iranian and Iraqi public health officers of the provinces along the common border met to develop a control plan. Dr. Franz Rosa, U. S. Operations Mission, Iran, visited Iraq for 5 days to help work out a joint and coordinated plan of action by the two countries to combat the disease.

Opportunities for the introduction of smallpox into Iran by Kerbella pilgrims resulted from several factors. Some travelers were not vaccinated as they left or reentered Iran. Nor were they immunized in Kerbella, where the disease has not been effectively controlled. Police and quarantine authori-

ties overlooked vaccinating or examining infants, who were regarded as "baggage."

Infected ailing pilgrims were carried all the way across the country on buses; some were not even identified when they crossed through quarantine posts. Ineffective vaccination, illegal border crossings, false vaccination certificates, concealment of infected travelers, and failure to check certificates or to isolate cases also contributed to transmission of the virus.

Vaccination and quarantine measures have since been strengthened. Now only 10 percent of the pilgrims leaving the country are unvaccinated as they reach the border. Previously, a third of those returning from Iraq, having left Iran several months earlier, were not vaccinated. Every unvaccinated person that is seen at the border station is being immunized.

—GLEN W. McDONALD, M.D., M.P.H., *chief, Public Health Division, U. S. Operations Mission, Iran.*

Thai Promoter

The headman of Bang Tao, Thailand, is the strongest advocate of the privy program. After a trip to Bangkok he came back determined to promote in his own village the progress he'd seen in other parts of the country. As a result, enthusiastic participants in Bang Tao's health project have bought 300 privy slabs.

The villagers at first objected to the privies on the religious principle which forbids more than one human fecal deposit in the same place. Now installing a privy is the popular thing to do in Bang Tao. Slabs are sold at cost and the money put into a revolving fund to make additional slabs. Health department sanitarians assist in selecting sites and installing slabs.

Interest in health education and community organization ran as high in the 7 villages of Tambol Gattoo, our first demonstration area. Villagers as well as community health council members joined in the self-help project. Privy slabs have been selling almost as fast as they are produced; 500 have been installed.

Other phases of this project include protection of private and public water supplies, premise sanitation, and improvement of preventive and medical care facilities of the local health centers.

—ANDREW P. HAYNAL, *deputy chief, public health adviser, U. S. Operations Mission, Thailand.*