Waterborne Infectious Hepatitis Epidemic From a Chlorinated Municipal Supply

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IN DECEMBER 1956 the bureau of epidemiology and communicable disease control of the New York State Department of Health was informed that a number of cases of jaundice had occurred in the township of Rhinebeck, N.Y. Preliminary investigation suggested that transmission of infection might have occurred through the chlorinated municipal water supply. Although spread of hepatitis by chlorinated water systems has been reported twice before (*1*, *2*), additional documentation of an outbreak presumably caused in this manner seems indicated.

Within Rhinebeck Township lies the incorporated village of Rhinebeck, with an estimated population of 2,300, situated about 2 miles from the Hudson River. Along the river in the same township and connected to Rhinebeck by a road is a smaller community, Rhinecliff, with a population of 660 (fig. 1).

The two communities are served by three physicians, Dr. Martin J. Poppo, Dr. William G. Thompson, and Dr. Frederick C. Cohn. All three cooperated in the study. These physicians live in Rhinebeck and practice in a wide surrounding rural area. They stated that, prior to the present episode, they could recall only rare cases of jaundice, and these were, in their opinion, obstructive rather than infectious.

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Methods

Patients with cases of jaundice reported by the physicians and by the nurses of Rhinebeck Central Schools were interviewed shortly after illness occurred. The interviews were conducted by medical students under the supervision of the authors. Inquiry was made about clinical symptoms, illness in other members of the household, milk supply, water supply, sources of food, contact with other persons who had had jaundice, public gatherings attended, meals taken outside the home, and exposure to hepatotoxins and inoculations. Only clinical jaundice was accepted in defining a case for epidemiologic analysis. While this criterion excluded a few reported cases, the exclusion would not be expected to obscure the mode of spread of the infection. It was impractical in this outbreak to attempt to locate and diagnose persons with nonicteric hepatitis who were not under medical care.

In order to determine whether reporting by physicians and by the school nurses had revealed most of the jaundiced cases in the area, additional inquiry was made by means of a community survey. Seventeen members of the class of 1957 of Albany Medical College visited every fifth house in the village and surrounding rural area. Visits were made to 57 households in all.

Results

The first case of infectious hepatitis with jaundice was reported on November 21, 1956.

Within 30 days, 70 cases had been reported, 41 in females and 29 in males. The community survey failed to uncover any additional cases not previously reported. In all, 83 cases were reported during the epidemic.

In most instances, the illness described began with anorexia, fever, and malaise, followed by nausea, vomiting, excretion of dark urine, and the development of jaundice. With the onset of jaundice, general improvement occurred. About 20 patients were hospitalized, usually for short periods, but in general the disease was mild. Conjunctivitis, hematuria, and aseptic meningitis were not encountered, and none of 12 blood examinations showed leukocytosis. No preceding wave of gastroenteritis was observed, such as has been reported in several other hepatitis outbreaks considered to be waterborne (*3–6*).

Gamma globulin supplied by the American National Red Cross through the State department of health or obtained through commercial sources was used extensively by the physicians for treating family contacts. The families of all patients with reported cases of jaundice received this prophylaxis. This may have limited the number of jaundiced cases. Two cases occurred in each of three families. Intervals between first and second cases were 3, 13, and 15 days, respectively, indicating that the cases were probably co-primary. In these second cases in three families, one patient had received no gamma globulin, one received it the day after onset of symptoms, the third received it 11 days prior to onset.

Age distribution of infectious hepatitis with jaundice, Rhinebeck Township, N.Y.,[1] 1956–57

Ages (years)	Cases through—					
	Dec. 7, 1956 [2]		Dec. 19, 1956 [3]		Feb. 1, 1957 [4]	
	Number	Percent	Number	Percent	Number	Percent
0–4	0	0	1	1.4	1	1.2
5–14	9	22.5	[5] 22	31.4	27	32.5
15–24	6	15.0	10	14.3	11	13.3
25–34	13	32.5	[6] 16	22.9	18	21.7
35–44	5	12.5	10	14.3	12	14.5
45–54	5	12.5	6	8.5	7	8.4
55–64	0	0	0	0	0	0
65 and over	2	5.0	5	7.2	7	8.4
Total	40	100.0	70	100.0	83	100.0

[1] Including Rhinecliff and village of Rhinebeck.
[2] 17 days after onset of initial case.
[3] 30 days after onset of initial case.
[4] 72 days after onset of initial case.
[5] 1 patient resided within village water supply limits, but used well water.
[6] 1 patient resided outside village water supply limits.

Age and Residence

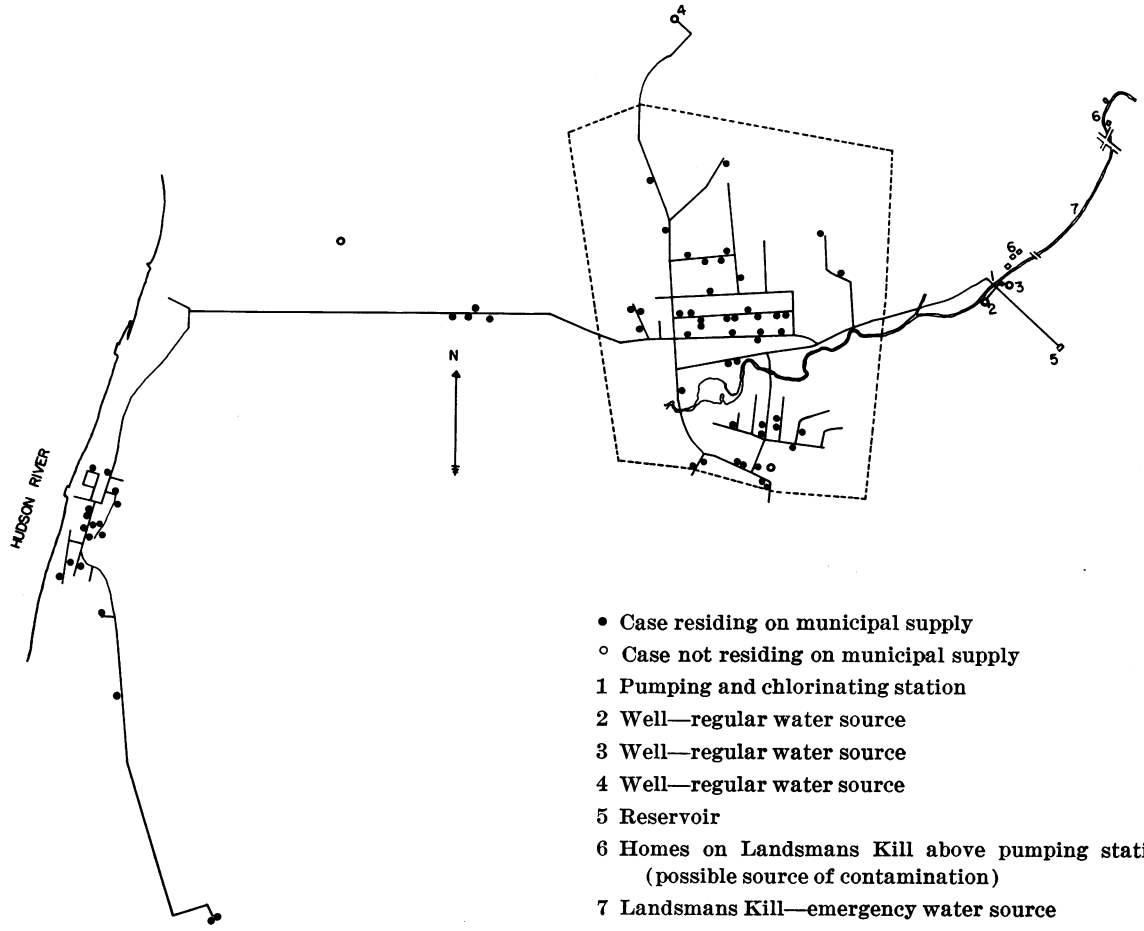
The age distribution of the patients is given in the table. The initial cases were not school centered. A tabulation of age distributions through December 7, 17 days from the initial case, shows the largest number of cases at this stage to be in the 25- to 34-year age group. However, the highest proportion of cases in the epidemic as a whole occurred in the 5- to 14-year age group, a finding consistent with the usual age distribution of cases reported in other epidemics of infectious hepatitis in New York State. Only one case was reported in the age group under 5 years, possibly because the disease in younger children tends to be milder and without clinical jaundice.

Twenty-nine of the first 70 cases reported were in children attending the Rhinebeck Central Schools. Only one of these children resided off the village water supply, although half the children attending the schools resided outside the village and off the village supply.

Half the school children live within walking distance of the schools and half live in an area which extends 16 miles east, 6 miles south, 3 miles north, and to the river on the west. The school district encompasses all of the township of Rhinebeck and substantial portions of four adjacent townships. The children are divided between an elementary school (kindergarten through fourth grade) in the center of the village and a larger school on the outskirts (grades 5 through 12). Nine cases of jaundice were reported among 394 students in the elementary school, while 20 cases occurred among the 500 students attending the upper school. Two additional cases were reported from a military academy on the outskirts of Rhinecliff, the last station on the water supply.

After the first few cases were noted, the illness rapidly became the major topic of con-

Figure 1. Water system of village of Rhinebeck and Rhinecliff, N.Y., and location of 70 cases of infectious hepatitis with jaundice occurring in the first 30 days of the epidemic, 1956–57



versation in the village, and cases which might not ordinarily have been seen by physicians came to their attention. Children who lived outside the village, but attended school in Rhinebeck would have been seen immediately by a physician or a school nurse had they become jaundiced.

Possible Modes of Spread

Milk. The milk supply of the families in which cases of hepatitis occurred came from four different commercial dairies. In four families the milk was either evaporated, dried, or fresh unpasteurized.

Food. Family food supplies came from at least 12 different stores, including 3 large chain markets. Five families purchased most of their food outside Rhinebeck.

Insects. The epidemic occurred in December so that flies and mosquitoes were not considered to be important possible carriers.

Contact. Seven churches and a dozen restaurants were mentioned by various families. No history of a common meeting place other than at school over the 2 months preceding the outbreak could be elicited. As is indicated above, the age distribution of patients with early cases of hepatitis is not consistent with a contact-spread school-centered epidemic (*7*).

Hepatotoxins and injections. No unusual incidence of insecticide spraying or general use of chemicals or medications was found. Histories of injections were largely limited to poliomyelitis vaccine in children. These were given in the offices of all three physicians who serve the community.

Water. The water supply of Rhinebeck and Rhinecliff normally is obtained from three

wells; two are situated to the east of the village, a third to the north. In recent years, however, this water supply has become inadequate in the summer, and an emergency unapproved supply has been taken from Landsmans Kill which flows through the village close to two of the wells (fig. 1). Attempts to dig additional wells were unsuccessful through the fall of 1956, and the emergency water supply was continued to meet the demand. This supply was subjected to chlorination, but not to other water purification techniques. The water from the two wells close to the pumping station was chlorinated. The third well, to the north of the village, was sealed, was in good condition, and though not chlorinated, had been found to be free of bacteriological contamination.

Records of the water chlorination plant for the month of November 1956 revealed that residual free chlorine levels tested daily ranged from 0.35 ppm to 0.6 ppm by the orthotolidine test using the "flash" method. The orthotolidine test used in this fashion is said to be inferior to the orthotolidine-arsenite determination (*8*), but it is adequate if read within 15 seconds of the addition of orthotolidine to the specimens. There is no significant manganese in the water supply which might interfere with the validity of this determination. The New York State Department of Health recommends a minimum concentration of free residual chlorine for a disinfecting period of at least 10 minutes ranging from 0.2 ppm at a pH of 6.0 to 0.8 ppm at a pH of 10.0. These levels had been achieved at Rhinebeck, according to plant records.

Samples of water taken on December 12, 1956, a month after probable contamination of the supply of the two communities, revealed a coliform count of 15 MPN per 100 ml. at one sink tap in a greenhouse in Rhinecliff. (MPN indicates the most probable number of coliform organisms and is a standard determination based on a statistical analysis of the laboratory procedure.) Other specimens taken at the same time from scattered taps in the village, however, showed counts of less than 2.2 MPN. The significance of this one contaminated specimen cannot be ascertained, but no other specimen taken from the supply in the year preceding or 6 months following has shown a coliform count greater than 2.2 MPN per 100 ml.

Coliform counts are taken from four to six taps on the municipal supply each month. Specimens of raw water taken from Landsmans Kill above the intake of the chlorinating system have shown coliform counts from 240 to 930 MPN and indicate gross contamination of the raw water supply. Though no cases of infectious hepatitis were located in dwellings close by the stream above the intake point, the supply could readily have been contaminated by these dwellings which emptied their cesspool overflow into the stream.

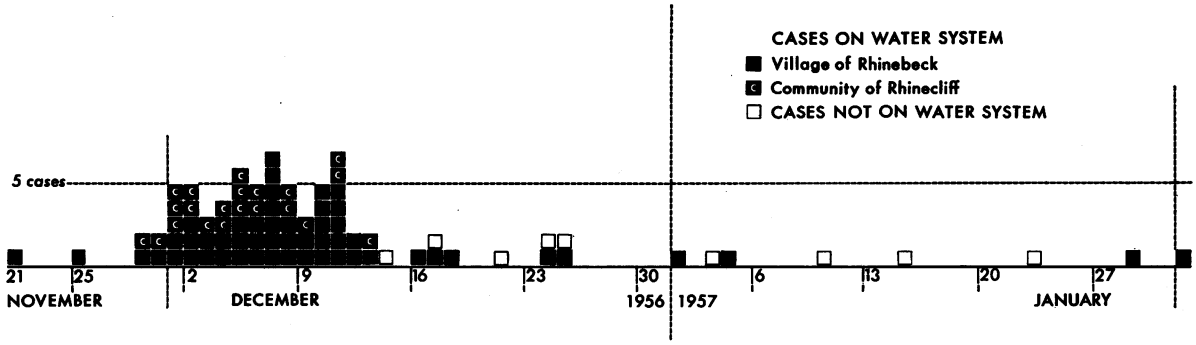
Discussion

The course of the hepatitis epidemic as illustrated in figure 2 appears to be consistent with a common source epidemic. The majority of the cases occurred within a period of time shorter than the recognized incubation period of infectious hepatitis. Few of the cases could therefore be considered secondary. In addition, the rise and fall of the epidemic curve itself suggests a common source of infection.

Though separated by 2 miles, Rhinebeck and Rhinecliff share a common water supply. The geographic distribution of cases, separated into two groups 2 miles apart, but connected by a common water supply, argues for the water supply acting as a common source of infection. It was first thought that the occurrence of two cases in students at a military academy mitigated against the waterborne hypothesis until it was found that the academy is the last drawing point on the village water supply.

When the 70 cases of infectious hepatitis occurring in the first 30 days of the epidemic were plotted on the spot map (fig. 1), it appeared that all but two of the individuals involved in the epidemic resided in houses on the municipal water supply and that the remaining population of the township, estimated at 1,400 individuals, was almost uninvolved. One of the two patients not on the water supply resided within the village but claimed to drink only well water; the other did not live on the municipal waterlines. Radial spread of the disease could not be demonstrated.

Figure 2. Infectious hepatitis with jaundice, Rhinebeck Township, 1956–57



Thirteen cases occurred in the township from December 21 through February 1, a period of nearly a month and a half following the first 30-day wave of the epidemic. Six cases were located on the municipal water system and seven were not (fig. 2). Only four cases were reported in the ensuing 6-month period.

Twenty-one of the 57 families interviewed in the community survey drank well water exclusively. Five families claimed that they boiled their water because they suspected that the water supply was contaminated. Thirty-one of the families interviewed drank municipal water. No previously unreported cases were discovered in these interviews.

It is interesting to speculate about the actual instance of contamination of the water supply. The first wave of 70 cases occurring within 30 days of the first case, or within the generally accepted incubation period for infectious hepatitis, can be readily separated from the cases which followed (fig. 2). If a common source is assumed for these 70 cases, then the midpoint of the epidemic curve for these cases is December 7. A mean incubation period of 25 days would indicate that contamination occurred about November 11 (Sunday). The first 70 cases had onset from 14 to 37 days from that date. Contamination of the water supply on a day when children were not in school could account for the absence of cases in children who attend the school but reside off the water system.

It might be inferred from the epidemic curve that contamination occurred in only one instance or over a short period. Rain may have increased the amount of organic matter in the stream over a short period, thus temporarily protecting the virus present in the water from the action of the chlorine, or the water may actually have been contaminated in only one instance with feces containing virus. It is also possible that chlorination was inadequate on a single day and that the insufficiency was not determined by the test for chlorine levels as recorded.

Epidemics of infectious hepatitis, presumably waterborne, had been described by a number of authors (*3*, *4*, *9–12*) prior to the classic work of Neefe and Stokes (*13*), who demonstrated the transmission of the infection from a contaminated well and through water from the well to human volunteers. The largest number of such epidemics have been reported as a result of contamination of ground water supplies—both wells (*10–20*) and springs (*3*, *6*). Contaminated surface water supplies have also accounted for several epidemics: one involving a contaminated river supply where the purification and chlorination plant was not functioning (*4*), three due to contaminated streams (*9*, *21*, *22*), and one due to a contaminated lake supply (*5*). Rabe (*23*) and Warren (*24*) observed small epidemics which appear to have been borne through large disrupted municipal water supplies. In both instances, definite contamination with *Escherichia coli* was demonstrated frequently. The literature concerning waterborne infectious hepatitis has recently been thoroughly reviewed by Mosley (*25*).

The work of Neefe and his associates (*26*, *27*) demonstrated through human volunteer studies that the normal treatment of municipal water supplies may be inadequate to inactivate the hepatitis virus. They showed that inactivation was complete with free residual chlorine levels of 1.1 and 0.4 ppm after 30 minutes con-

tact in coagulated, settled, and filtered water, but that 1.08 ppm total residual chlorine after 30 minutes contact did not inactivate the virus in otherwise untreated water, as indicated by infection of two of five volunteers who drank it. The observation is similar to that reported by Trask, Melnick, and Wenner (*28*) working with poliomyelitis virus. They found that when extraneous organic matter was added to a suspension of poliomyelitis virus, though sufficient chlorine was added to meet the additional demand presented by the organic matter, the chlorine level then had to be further increased 10 to 18 times to inactivate the amount of virus in the original suspension. These authors pointed out that the inactivation of a virus in a water supply contaminated with organic matter is a very different problem from the inactivation in a laboratory.

Only three epidemics of hepatitis have been reported in connection with water supplies known to be chlorinated. The epidemic reported by Hayward (*29*) of at least 52 cases occurring in a Pennsylvania city of 60,000 might be explained on the basis of transmission by the water supply, but the evidence is inconclusive and the epidemic may have been contact spread. Sundell (*1*) reported a common-source epidemic from a lake supply which was filtered and chlorinated. The water was bacteria free after treatment. Of the 391 cases reported, 32 percent of the patients were icteric. The author felt that the number of nonjaundiced cases was greater than usually encountered because the virus was attenuated by partial chlorination. Originally 0.8 mg. of chlorine per liter was added to the water supply. This was later increased to 1.2 mg. per liter, but the epidemic continued. When the chlorine level was raised to a level of 0.4 mg. of free chlorine per liter, corresponding to total chlorine added of 6 mg. per liter, seven times the original amount of chlorine used, and the contact time increased to 60 minutes, the epidemic ceased within 30 days.

Perhaps the most spectacular epidemic is that of 29,000 cases in the city of Delhi, India, in 1955–56, described by Melnick (*2*) and Viswanathan (*30*). Because of a shift in the bed of the river from which the water supply was drawn, "the people of New Delhi were drinking half river water and half sewage from November 13 to November 17." Though the water is subjected to accepted procedures of settlement, coagulation, filtration, and disinfection in modern plants before it is delivered to Delhi consumers, additional amounts of chlorine were added to the water to secure adequate levels when the presence of gross sewage in the intake was noted. However, at least 29,000 cases of infectious hepatitis occurred in the community served by this water supply, even though by bacteriological analysis the efforts to increase disinfection were successful. It is interesting that no increase in the gastroenteritides including typhoid fever, was reported.

Summary

An epidemic of 83 cases of infectious hepatitis with jaundice occurred in two neighboring New York State communities between November 21, 1956, and February 1, 1957. Seventy of the cases occurred within the first 30 days of the epidemic. The two communities, although 2 miles apart, had a common water supply. As an emergency measure water was taken from a stream potentially subject to pollution. It was chlorinated but not otherwise treated. Only 2 of the first 70 patients did not reside on the water supply. The distribution in time of the cases is consistent with a common-source epidemic. Milk, food, contact, insects, hepatotoxins, and parenteral inoculations appeared very unlikely as common sources of infection. It is concluded that the epidemic of infectious hepatitis was waterborne through the emergency water supply, despite the fact that the water was chlorinated.

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Public Health Service Research Highlights in 1960

The following items were taken from "Research Highlights, National Institutes of Health," presented to the Congress of the United States.

A survey of cancer in New York State for 1949–51 found that incidence was generally higher in urban than in rural populations. The urban-rural ratio was higher for males than for females. The incidence pattern was in substantial agreement with those for Connecticut and Iowa (p. 11).

Scientists in more than 150 hospitals in the United States and Western Europe were evaluating 159 drugs in some 200 clinical studies of cancer treatment (p. 20).

In experiments with hamster cells propagated in tissue culture the vast majority of cells surviving sublethal doses of X-rays repaired radiation damage before division and did not transmit damage to daughter cells. Cells underwent repeated cycles of damage and repair with no apparent weakening of the repair process (p. 32).

Eastern encephalitis virus was isolated from the *Aedes vexans* mosquito for the first time by Yale scientists. Less than 5 percent of the specimens collected were of the *Aedes vexans* species, but the only virus isolation was made from members of that species (p. 107).

Monkey malaria was transmitted by mosquitoes to two workers in an NIH laboratory in Memphis, Tenn. The accidental infections have caused investigators to plan reexamination of the entire question of host-specificity of primate malarias (p. 116).

Studies of rheumatic fever cases found that patients who eventually suffer from rheumatic heart disease usually show heart valve damage during their first attack of rheumatic fever, and that patients whose first attack does not produce valve damage usually remain free from rheumatic heart disease, even after subsequent attacks (p. 82).

Preliminary work with a fluorescent antibody technique for detecting the malaria parasite in blood smears indicated that the method, when fully developed, may enable technicians to screen many more suspects for malaria in a day than is possible with present methods (p. 118).

Concentrations of sodium pentachlorophenate (NaPCP) as low as 0.05 ppm in the water habitats of *Australorbis glabratus*, a snail vector of schistosomiasis, were found to greatly reduce the fecundity of the snails and to decrease the viability of the eggs produced (p. 121).

The report of a 3-year study designed to determine the possible relationship between high incidence of intestinal parasitism in mental hospital patients and housing facilities stated that greatly improved sanitation had little effect on transmission of intestinal protozoa. There was a small reduction in the incidence of helminthic infection (p. 126).

A timesaving new test, based on tellurite reduction, for differentiating pathogenic staphylococci from harmless strains was developed in Salt Lake City and reported in the *Journal of Laboratory and Clinical Medicine*. Isolates are streaked on a tellurite-glycine agar plate; after overnight incubation, pathogenic isolates show jet black colonies indicative of growth with reduction of tellurite (p. 134).

The value of a diet low in the amino acid phenylalanine in preventing or delaying severe mental deficiency from phenylketonuria (PKU) was established. PKU victims are unable to convert phenylalanine into tyrosine, resulting in abnormal accumulations of it in the blood. A child's IQ drops 5 points every 10 weeks after birth that the diet is delayed. A relatively simple diagnostic blood test for PKU was developed in 1959 at NIH (p. 161).

A pilot project for screening infants for phenylketonuria, galactosuria, and other forms of aminoaciduria that may cause mental retardation was begun in Cincinnati. Squares of filter paper are given to mothers of newly born children. The paper is placed in diapers when the babies are 4 to 6 weeks old. The dried squares are returned to the hospital, where the urine is analyzed (p. 259).

A simple and rapid test was found for detecting children who may develop Wilson's disease (progressively fatal degeneration of the liver caused by abnormal copper metabolism). The test measures the amount of the plasma copper protein, ceruloplasmin, in the blood. Early detection is important since symptoms rarely occur before age 7, although the metabolic defect is present from birth. If latent disease is found, measures can be taken to minimize absorption of copper from the diet and to promote excretion of copper already absorbed (p. 163).

A long-term study established that the caries-preventing effect of taking daily a fluoride tablet (containing 2.21 mg. of NaF) is comparable to the effect of drinking fluoridated water. However, the investigators concluded that the method is not as practical as water fluoridation (p. 209).

The findings of a long-term study intended to uncover the causes of alcoholism were reported in *Origin of Alcoholism* (Stanford University Press). A group of 225 boys selected in the 1930's were traced to adulthood. Of these, 29 became alcoholics. By statistical comparison, the investigators found traits that typified alcoholics even in childhood. The alcoholic subjects had undergone a variety of frustrating experiences; they were more likely to have suffered neurological disorders and more likely to have come from a home disrupted by severe conflict and basic disagreement (p. 264).