STUDIES ON THE MODE OF SPREAD OF B. ENTERITIDIS
MOUSE TYPHOID INFECTION.

I. NATIVE EPIDEMICITY.

BY LESLIE T. WEBSTER, M.D., AND IDA W. PRITCHETT, Sc.D.

(From the Laboratories of The Rockefeller Institute for Medical Research.)

(Received for publication, July 9, 1927.)

GENERAL INTRODUCTION.

Our experimental studies of epidemics have been confined thus far to two native animal diseases: mouse typhoid, caused by an organism of the animal paratyphoid B group, *B. pestis caviae,* and a respiratory infection of rabbits, *Bact. lepisepticum* snuffles and pneumonia. Mouse typhoid, being readily adapted to laboratory manipulations, has yielded data bearing upon its prevalence and mode of spread; rabbit snuffles, notwithstanding the technical difficulties encountered, has been of use in confirming the data and extending their application (1, a).

The scope of experimental epidemiology may be enlarged by extending the investigations to still other animal diseases. With this end in view, we have turned our attention to a third native infection, a variety of mouse typhoid induced by a bacillus of the enteritidis group. This infection is wide-spread among rodents (2), and occurs also in man as a form of food poisoning (3). Mice affected show gross and microscopic lesions resembling those occurring in the paratyphoid B infection (4). Indeed, the major features of these two diseases in mice are similar.

However, two rather special characteristics of the enteritidis infection in mice make a study of the disease of special interest from the point of view of experimental epidemiology. The first of these is the fact that a high titre bacteriophage may be obtained readily from a large per cent of infected animals; the second is that under relatively

---

1 This organism is also designated *B. aertrycke* and *B. paratyphi.*
simple conditions, the typical smooth colony forms of *B. enteritidis* change to mucoid and rough colony variants. Similar bacteriophage and transformation processes have been considered, of late, to play such an important part in determining the prevalence of other diseases, that it seemed desirable to study the phenomena as they occur in *B. enteritidis* mouse typhoid infection and determine, if possible, the extent to which they influence its spread.

The studies to be described are divided as follows: (1) Bacteriological tests on mice from various scattered populations to determine the prevailing colony types of paratyphoid-enteritidis bacilli. The results of these tests are summarized in this paper. (2) Attempts were made to determine the conditions under which "spontaneous" transformations of colony types occurred. These experiments are described in the next paper. (3) In Papers III and IV of the series, comparative studies of bacilli from the various colony types were carried out with special attention to differences in virulence. From these results, a working hypothesis was formulated to explain the mechanism of colony transformation. (4) Finally, an elaborate study of several populations involving several thousand mice spontaneously infected with *B. enteritidis* and a Friedländer-like organism has been carried on over a period of 2 years, to determine at various interepidemic, preepidemic, and epidemic periods, the colony types and relative virulence of the specific bacteria, and the effect of changes in carrier rate, season, and experimental alteration in population resistance on the spread of disease. These results are to be published later.

*Types of B. enteritidis Recovered from "Spontaneously" Infected Mice.*

Apparently there is general agreement among recent investigators that in native paratyphoid-enteritidis infection, the smooth colony type of organism predominates at all times.

Thus Topley encountered only smooth types of *B. gaertner* and *B. aertrycke* during his observations of experimental mouse typhoid epidemics. Thomas describes paratyphoid-enteritidis bacilli isolated from guinea pigs as forming, in general, the smooth type of colony, although one strain of *B. enteritidis* appeared rough (2, c). Savage and White, in an extensive investigation of the Salmonella group, state that "in direct platings from pathological material, colonies of
Salmonella bacilli are, as a rule, wholly smooth. On occasion, however, roughness may be detected in these first cultures" (3, d). Nelson, describing a typhoid epidemic among guineas pigs, states that smooth colony types predominated; occasionally, a few mucoid variants were encountered.

During the past 5 years, one of us (Pritchett) has tested a number of batches of mice obtained from various sources to detect the presence of mouse typhoid bacilli. The results of these tests, which include the species and colony type of bacillus obtained, are summarized briefly in Table I and may be stated as follows:

**Group 1. Hagedoorn Albinos.**—10 mice received from Professor Hagedoorn of California in June, 1922. 1 was dead on arrival and at autopsy _B. enteritidis_ was recovered from the blood and feces. A year later a mouse of this strain, a descendant of the original 10, died and was found at autopsy to harbor the smooth colony type of _B. enteritidis_.

**Group 2. Baltimore Albinos.**—100 mice received from a dealer in Baltimore. These mice had been strain inbred for a year and a half. 1 mouse was dead on arrival and other mice died at intervals of a few days. The smooth type _B. enteritidis_ was cultured from the blood and feces of the 10 or 12 autopsied.

**Group 3. Annandale Hybrids.**—Composed of black, brown, yellow, and white mice. 51 of these mice were received from Annandale, New York, in November, 1922. 3 were dead on arrival, and 1 other died the next day; all were found to harbor _B. pestis caviae_ in the blood and feces. Of the 47 which lived, 12 were found to be fecal carriers of _B. pestis caviae_ so that of the entire group about 23 per cent were infected with this organism; smooth colony types alone were recovered.

**Group 4. Bagg Albinos.**—Of 45 mice sent from Cold Spring Harbor, New York, in December, 1922, 1 was dead on arrival and was found to harbor _B. pestis caviae_ in the blood, feces, and internal organs. Of the 44 which lived, 36 were fecal carriers of _B. pestis caviae_, so that 82 per cent of the original lot of 45 were shown to be infected with this organism; only smooth types were obtained.

**Group 5. Lathrop Blacks.**—45 mice sent from Cold Spring Harbor, New York, in December, 1922. Two separate fecal cultures of all the mice failed to show any mouse typhoid bacilli.

**Group 6. Lathrop Browns.**—100 mice sent from Cold Spring Harbor, New York, in the early spring of 1923. 1 mouse was dead on arrival and 10 or 12 succumbed during the 1st week; all showed the presence of smooth colonized _B. pestis caviae_ in the blood and feces.

**Group 7. Louvain Albinos.**—7 mice were received from the University of Louvain, Belgium, in May, 1924, of a stock bred in that laboratory for 3 or 4 years. By the end of May, all but 1 had died, and the single survivor died later. From three autopsies heavy growths of smooth type _B. enteritidis_ were obtained from the spleen and feces.
### TABLE I.

**Prevalence of Mouse Typhoid Bacilli in Different Mouse Populations.**

<table>
<thead>
<tr>
<th>Group</th>
<th>Description of mice examined</th>
<th>Source of mice and date of examination</th>
<th>No. in lot</th>
<th>Per cent negative for mouse typhoid</th>
<th>Mouse Typhoid I (B. enteritidis)</th>
<th>Mouse Typhoid II (B. pestis cauis)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. of positive</td>
<td>No. of smooth colonies</td>
</tr>
<tr>
<td>1</td>
<td>Hagedoorn albinos</td>
<td>California, 1922</td>
<td>10</td>
<td>?</td>
<td>1 mouse</td>
<td>1 mouse</td>
</tr>
<tr>
<td>2</td>
<td>Albinos</td>
<td>Baltimore, 1922</td>
<td>100</td>
<td>?</td>
<td>10 mice</td>
<td>10 mice</td>
</tr>
<tr>
<td>3</td>
<td>Hybrids, black, brown, yellow, and white</td>
<td>Annandale, N. Y., 1922</td>
<td>51</td>
<td>77</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Bagg strain albinos</td>
<td>Cold Spring Harbor, N. Y., 1922</td>
<td>45</td>
<td>18</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Lathrop strain black</td>
<td>Cold Spring Harbor, N. Y., 1922</td>
<td>55</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Lathrop strain brown</td>
<td>Cold Spring Harbor, N. Y., 1923</td>
<td>100</td>
<td>?</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Louvain&quot; albinos</td>
<td>Louvain, Belgium, 1924</td>
<td>7</td>
<td>3 mice</td>
<td>3 mice</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Rockefeller Institute farm albinos</td>
<td>Princeton, N. J., 1923</td>
<td>100</td>
<td>?</td>
<td>10 mice</td>
<td>10 mice</td>
</tr>
<tr>
<td>9</td>
<td>Rockefeller Institute &quot;Lynch&quot; black agoutis</td>
<td>New York, N. Y., 1922</td>
<td>50</td>
<td>76</td>
<td>22 per cent</td>
<td>All</td>
</tr>
<tr>
<td>10</td>
<td>Albinos</td>
<td>Pennsylvania, 1925</td>
<td>64</td>
<td>88</td>
<td>22 per cent</td>
<td>100 per cent</td>
</tr>
<tr>
<td>11</td>
<td>Rockefeller Institute breeding room albinos</td>
<td>1922-1926</td>
<td>Many thousands</td>
<td>?</td>
<td>Less than 0.01 per cent</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Pritchett experimental epidemic</td>
<td>1925</td>
<td>80</td>
<td>60</td>
<td>Spontaneous 37.5 per cent infection</td>
<td>96.4 per cent</td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------</td>
<td>------</td>
<td>------</td>
<td>----</td>
<td>-------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>12</td>
<td>Webster experimental epidemics</td>
<td>1925–1927</td>
<td>4000+</td>
<td>99+</td>
<td>Spontaneous M. T. I infection</td>
<td>1 per cent or less</td>
</tr>
</tbody>
</table>
Group 8. Princeton Albinos.—100 mice received from the Department of Animal Pathology in October, 1923. 1 mouse was dead on arrival, but autopsy cultures showed no mouse typhoid bacilli. Within 2 or 3 days others died and showed the presence of smooth *B. enteritidis* in the blood and feces.

Group 9. Lynch Black Agoutis.—50 mice obtained from The Rockefeller Institute cancer stock in November, 1922. Three fecal cultures were made on the 50 mice between November 8th and December 4th. 11 (22 per cent) were found to be fecal carriers of smooth *B. enteritidis*, while 1 mouse carried smooth type *B. pestis caviae*.

Group 10. Pennsylvania Albinos.—64 mice obtained from a Pennsylvania breeder in October, 1925. The mice began to die immediately, about 50 per cent succumbing in the first 10 days after arrival. 22 per cent of these mice showed the presence of smooth *B. enteritidis*, either in the feces during life or in the blood and organs at autopsy.

Group 11.—The mouse breeding room at The Rockefeller Institute, New York, supplies 500 to 1000 mice a month. The population of this room is entirely free from *B. pestis caviae* infection, so called Mouse Typhoid II, but does yield an occasional carrier of the smooth type of *B. enteritidis*, Mouse Typhoid I. Estimates of one 6 month period showed the percentage incidence of carriers to be less than 0.01 (1, b).

Group 12.—A group of 80 mice which had survived a series of experimentally induced epidemics of *B. pestis caviae* was found at autopsy to be infected with both the paratyphoid (2½ per cent) and the enteritidis organisms (37½ per cent). All the *B. pestis caviae* colonies were smooth; while of the *B. enteritidis* infected animals, 14.2 per cent showed an occasional mucoid colony on the culture plates (1, b).

Group 13.—Finally, from groups of mice totalling over 4000 in number, among which *B. enteritidis* typhoid epidemics have been occurring, there have been recovered from autopsy cultures, with few exceptions, only smooth colony types (see introductory Paragraph 4, Division 4).

**SUMMARY.**

Thirteen batches of mice from nine different sources were tested for the presence of mouse typhoid bacilli. Individuals from nine of the groups were found to be infected with the *B. enteritidis* type, four with the paratyphoid B, one with both, and one with neither type. With two exceptions, smooth type colonies alone were found. These results are in conformity with similar observations

---

2 The population from which these mice were drawn is entirely separate from the regular Institute breeding room. Lynch has already reported the occurrence of two mouse typhoid epidemics among the cancer stock, that of 1918-19 being due to *B. enteritidis*, and that of 1920-21 to *B. pestis caviae* (2, e).
as reported by others and confirm the general belief that smooth colony types of paratyphoid-enteritidis bacilli prevail throughout the various stages of rodent typhoid infection.

BIBLIOGRAPHY.


