Phage Typing Set for Group C₁ and C₂ *Salmonellae*

M. GERSHMAN

Departments of Microbiology and Animal and Veterinary Sciences, University of Maine, Orono, Maine 04473

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Fifteen common serotypes representative of group C₁ and C₂ *Salmonella* were characterized using a single set of phages.

Salmonellosis is a widespread disease affecting man, livestock, and companion animals. The incidence of *Salmonella* infections is in an ascendancy and the ubiquitous nature of these organisms appears to emphasize the futility of total eradication. Nevertheless, effective control measures can be applied through the early recognition of cases.

The multitude of *Salmonella* serotypes in existence is not particularly disturbing for diversity can be, and frequently is, epidemiologically useful. Many apparently unrelated cases have been linked through some unique characteristic possessed by an isolate.

Serological delineations are advantageous but may be inadequate for epidemiological purposes. Commonplace serotypes, for example, are difficult, if not impossible, to relate to a particular outbreak unless measures are first used to characterize the serotype involved. Among the methods available for differentiating *Salmonella*, phage typing has emerged as a technique providing both reliability and maximum strain differentiation (1).

Craigie and Yen (4) established a phage typing scheme for characterizing *Salmonella typhi* (4, 5). Its success led to the development of a number of schemes for other *Salmonella* serotypes. They include *S. paratyphi* A (2), *S. paratyphi* B (1), *S. typhimurium* (3, 8, 14), *S. braenderup* (12), *S. blockley* (13), *S. dublin* and *S. enteritidis* (9), *S. gallinarum*, and *S. pullorum* (10).

In keeping with our own immediate interests and circumstances, phage typing sets for *S. thompson* (6) and *S. newport* (7, 11) were developed in our laboratory. In the course of our research it was observed that these phage sets could be used to distinguish a number of other *Salmonella* serotypes also representative of serological groups C₁ and C₂.

Using a combined set of *S. thompson* and *S. newport* phages we were able to type 397 of the 400 cultures examined at random. The lytic pattern of these phages is noted in Table 1.

Isolates to be typed were lightly inoculated into 3 ml of nutrient broth and incubated at 37 C for 1.5 h or until turbidity was barely

TABLE 1. Lytic pattern of typing phages at routine test dilutions^a

Type strains	<i>Salmonella thompson</i> phages								<i>Salmonella newport</i> phages						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<i>S. thompson</i> 1	CL	—	CL	—	—	—	—	—	—	CL	CL	+++	—	OL	CL
<i>S. thompson</i> 2	—	CL	—	—	<SCL	++	—	CL	—	—	—	SCL	—	OL	—
<i>S. thompson</i> 3	+++	<SCL	CL	—	±	<SCL	CL	OL	—	++	OL	—	—	OL	—
<i>S. thompson</i> 4	+++	—	+++	CL	—	—	—	—	—	<SCL	+++	+++	++	—	CL
<i>S. thompson</i> 5	++	±	CL	—	CL	CL	CL	OL	—	±	OL	±	—	OL	±
<i>S. thompson</i> 6	<SCL	—	CL	—	SCL	CL	SCL	OL	—	—	OL	—	—	<SCL	—
<i>S. thompson</i> 7	+++	CL	CL	—	CL	CL	CL	CL	—	CL	CL	—	—	—	OL
<i>S. thompson</i> 8	—	—	—	—	SCL	+++	SCL	CL	—	—	—	—	—	—	—
<i>S. newport</i> 9	CL	—	SCL	—	—	—	—	—	CL	CL	CL	CL	CL	SCL	CL
<i>S. newport</i> 10	—	—	++	—	—	—	—	—	—	CL	SCL	—	+++	—	CL
<i>S. newport</i> 11	CL	CL	±	—	—	—	—	—	—	CL	CL	SCL	—	—	CL
<i>S. newport</i> 12	SCL	—	SCL	—	—	—	—	—	SCL	SCL	—	CL	CL	OL	CL
<i>S. newport</i> 13	SCL	—	—	—	—	—	—	—	—	SCL	—	CL	CL	OL	CL
<i>S. newport</i> 14	—	—	—	—	—	—	—	—	—	—	—	—	++	CL	OL
<i>S. newport</i> 15	+++	—	—	CL	—	—	—	—	—	CL	SCL	SCL	—	OL	CL

^aAbbreviations: CL, confluent lysis; OL, opaque lysis (opacity due to secondary growth); SCL, semiconfluent lysis; <SCL, less than semiconfluent lysis; +++, 120 plaques; ++, 81 to 120 plaques; +, 61 to 80 plaques; ±, 41 to 60 plaques; +, 21 to 40 plaques; ±, 6 to 20 plaques; —, 0 to 5 plaques.

TABLE 2. Reactions of test strains at routine test dilutions^a

Salmonella group C ₁ type strains	Culture no.	Patterns	Salmonella group C ₁ type strains	Culture no.	Patterns
<i>S. bareilly</i>	1	3/11	<i>S. montevideo</i>	16	3/11/12/14
<i>S. bareilly</i>	2	2/3	<i>S. montevideo</i>	17	2/9/14
<i>S. bareilly</i>	3	3	<i>S. montevideo</i>	18	2
<i>S. bareilly</i> ^b	4	2/3/9/10/11	<i>S. montevideo</i>	19	1/3/10/11/12/14/15
<i>S. bareilly</i> ^b	5	2/3/9/10/11	<i>S. montevideo</i>	20	2/3/5/6/7/8/11/14
<i>S. bareilly</i> ^b	6	2/3/9/10/11	<i>S. montevideo</i>	21	3/8
<i>S. bareilly</i> ^b	7	2/3/9/10/11	<i>S. montevideo</i>	22	2/8/14
<i>S. bareilly</i> ^b	8	2/3/9/10/11	<i>S. montevideo</i>	23	3/10/15
<i>S. bareilly</i>	9	2/3/11	<i>S. oranienburg</i>	1	14
<i>S. braenderup</i>	1	3	<i>S. oranienburg</i>	2	3/11
<i>S. braenderup</i>	2	10/15	<i>S. oranienburg</i>	3	2/3/11
<i>S. braenderup</i>	3	14	<i>S. oranienburg</i>	4	3/15
<i>S. cholerae</i> -Suis	1	14	<i>S. oranienburg</i>	5	3/5/11/12/14
var. kunzen-			<i>S. oranienburg</i>	6	3/11/14
dorf			<i>S. tennessee</i>	1	1/2/10
<i>S. eimsbuettel</i>	1	2/3/8/11/14	<i>S. tennessee</i>	2	2/4/7/10/12/13/14
<i>S. eimsbuettel</i>	2	1/3/10	<i>S. tennessee</i>	3	10/14
<i>S. eimsbuettel</i>	3	1/3/10/11/14/15	<i>S. tennessee</i>	4	2
<i>S. eimsbuettel</i>	4	2/3	<i>S. tennessee</i>	5	1/10
<i>S. eimsbuettel</i>	5	3/10/14	<i>S. tennessee</i>	6	1/3/12/14
<i>S. eimsbuettel</i>	6	3/11/15	<i>S. tennessee</i>	7	14
<i>S. eimsbuettel</i>	7	3			
<i>S. eimsbuettel</i>	8	2/3/11	<i>S. thompson</i>	9	3/5/6/7/8/10/11/14/15
<i>S. eimsbuettel</i>	9	3/11/14	<i>S. thompson</i>	10	5/6/7/10/11/14
<i>S. eimsbuettel</i>	10	3/14	<i>S. thompson</i>	11	3/5/6/7/8/10/11/12/13/14
<i>S. eimsbuettel</i>	11	2/3/11/14	<i>S. thompson</i>	12	3/5/6/7/8/11/12/14/15
<i>S. eimsbuettel</i>	12	14	<i>S. thompson</i> ^c	13	3/5/6/7/8/11/14
<i>S. eimsbuettel</i>	13	1/3/10/11/15	<i>S. thompson</i> ^c	14	3/5/6/7/8/11/14
<i>S. eimsbuettel</i>	14	3/11	<i>S. thompson</i> ^c	15	3/5/6/7/8/11/14
			<i>S. thompson</i> ^c	16	3/5/6/7/8/11/14
<i>S. infantis</i>	1	1/2/10/12/14/15	<i>S. thompson</i> ^c	17	3/5/6/7/8/11/14
<i>S. infantis</i>	2	1/3/14	<i>S. thompson</i> ^c	18	3/5/6/7/8/11/14
<i>S. infantis</i>	3	1	<i>S. thompson</i> ^c	19	3/5/6/7/8/11/14
<i>S. infantis</i>	4	3/11/12/14	<i>S. thompson</i>	20	3/5/6/7/8/11/12/14
<i>S. infantis</i>	5	12/14	<i>S. thompson</i> ^c	21	3/5/6/7/8/11/14
<i>S. infantis</i>	6	1/2/3/12/14	<i>S. thompson</i> ^c	22	3/5/6/7/8/11/14
<i>S. infantis</i>	7	3/12/14	<i>S. thompson</i> ^c	23	3/5/6/7/8/11/14
<i>S. infantis</i>	8	3	<i>S. thompson</i> ^c	24	3/5/6/7/8/11/14
<i>S. infantis</i>	9	1/3/10/11/14/15	<i>S. thompson</i> ^c	25	3/5/6/7/8/11/14
<i>S. infantis</i>	10	1/2/12/14/15	<i>S. thompson</i> ^c	26	3/5/6/7/8/11/14
<i>S. infantis</i>	11	1/4	<i>S. thompson</i>	27	5/7/8/9
<i>S. infantis</i>	12	1/10/14/15	<i>S. thompson</i>	28	1/3/5/6/7/8/11/14
<i>S. infantis</i>	13	14	<i>S. thompson</i>	29	3/5/6/7/8/11/14/15
<i>S. infantis</i>	14	3/14	<i>S. thompson</i>	30	1/3/5/6/7/10/11/15
<i>S. montevideo</i>	1	14	<i>S. thompson</i>	31	1/2/3/4/5/6/7/10/11/12/14/15
<i>S. montevideo</i>	2	2/12/14	<i>S. thompson</i>	32	3/5/6/7/8/11
<i>S. montevideo</i>	3	2/14	<i>S. thompson</i>	33	2/3/5/6/7/8/11
<i>S. montevideo</i>	4	12/14	<i>S. thompson</i>	34	1/3/5/6/7/8/10/11/12/14
<i>S. montevideo</i>	5	3/10/11/12/14/15	<i>S. thompson</i>	35	1/2/3/5/6/7/8/11/14
<i>S. montevideo</i>	6	11/15	<i>S. thompson</i>	36	1/2/3/5/6/7/8/11/13/14
<i>S. montevideo</i>	7	1/3/11/14	<i>S. blockley</i>	1	4/10/11/12/15
<i>S. montevideo</i>	8	1/2/3/14	<i>S. blockley</i>	2	3/4/10/11/15
<i>S. montevideo</i>	9	3/14	<i>S. blockley</i>	3	1/3/4/10/11/15
<i>S. montevideo</i>	10	2/3/8	<i>S. blockley</i>	4	4/10/12/15
<i>S. montevideo</i>	11	3/12/14	<i>S. blockley</i>	5	1/2/4/10/11/15
<i>S. montevideo</i>	12	2/3/8	<i>S. blockley</i>	6	4/10/11/12/13/15
<i>S. montevideo</i>	13	2/8	<i>S. blockley</i>	7	1/3/4/10/11/12/15
<i>S. montevideo</i>	14	3	<i>S. blockley</i>	8	1/3/4/10/11/14/15
<i>S. montevideo</i>	15	8/14			

TABLE 2—Continued

Salmonella group C ₁ type strains	Culture no.	Patterns	Salmonella group C ₁ type strains	Culture no.	Patterns
<i>S. blockley</i>	9	4/12	<i>S. muenchen</i>	1	1/10/12/13/14/15
<i>S. blockley</i>	10	1/11/13/14/15	<i>S. muenchen</i>	2	1/3/4/9/10/11/12/13/15
<i>S. kentucky</i>	1	3/10/11	<i>S. newport</i>	16	1/12/13/15
<i>S. kentucky</i>	2	9/10/11/13	<i>S. newport</i>	17	1/4/7/10/11/12/14/15
<i>S. kentucky</i>	3	10/11	<i>S. newport</i>	18	1/10/15
<i>S. kentucky</i>	4	11/14	<i>S. newport</i>	19	12/13/14
<i>S. kentucky</i>	5	3/11/12	<i>S. newport</i>	20	9/12/13/14/15
<i>S. kentucky</i>	6	3/9/11	<i>S. newport</i>	21	3/11
<i>S. kentucky</i>	7	10	<i>S. newport</i>	22	1/4/10/11/14/15
			<i>S. newport</i>	23	14
<i>S. kottbus</i>	1	1/4/10/12/13/15	<i>S. newport</i>	24	1/4/10/12/13/14/15
<i>S. kottbus</i>	2	1/9/10/15	<i>S. newport</i>	25	4/9/10/12/13/14/15
<i>S. kottbus</i>	3	1/4/9/14/15	<i>S. newport</i>	26	1/4/10/15
<i>S. kottbus</i> ^b	4	4/10/12/13/15	<i>S. newport</i>	27	12/13/14/15
<i>S. kottbus</i> ^b	5	4/10/12/13/15	<i>S. newport</i>	28	1/3/4/10/11/13/14/15
<i>S. kottbus</i> ^b	6	4/10/12/13/15	<i>S. newport</i>	29	10/14/15
<i>S. kottbus</i> ^b	7	4/10/12/13/15	<i>S. newport</i>	30	1/4/11/12/13/15
<i>S. kottbus</i> ^b	8	4/10/12/13/15	<i>S. newport</i>	31	10/12/13/14/15
<i>S. kottbus</i> ^b	9	4/10/12/13/15	<i>S. newport</i>	32	12/13
<i>S. kottbus</i> ^c	10	4/10/12/13/15	<i>S. newport</i>	33	15
<i>S. kottbus</i> ^c	11	4/10/12/13/15	<i>S. newport</i>	34	2/10/14/15
<i>S. kottbus</i> ^c	12	4/10/12/13/15	<i>S. newport</i>	35	10/14
<i>S. manhattan</i>	1	1/4/10/11/12/15	<i>S. newport</i>	36	3/10/12/13/15

^a Only strong reactions (+++ or above) are recorded.

^b Cultures were isolated from a hospital outbreak.

^c Cultures were isolated from a campus outbreak.

detectable. A small quantity of the broth culture was then flooded onto a nutrient agar plate, allowed to dry for approximately 15 min, and then spotted with phages using a 1-ml syringe with a 26-gauge needle. The plates were incubated overnight at 37 C and read the next day. The cultures were examined with the aid of an $\times 10$ aplanatic hand lens and viewed through the bottom of the plate. Phage activity was recorded on the basis of the reactions described in Table 2. The serotypes used in this study and the ensuing patterns are listed in Table 2.

It appears, from our initial results, that specific phage sets are not necessary to type individual serotypes. Indeed, a common well-developed set or two may be adequate to characterize most commonly encountered salmonellae.

Over 1,600 *Salmonella* serotypes have been identified to date. All share the potential for sudden, and unexpected, prominence. Under the circumstances it is inconceivable that a specific set of phages will always be available for any given serotype.

Given the universality of salmonellosis and the realization that a large variety of serotypes are routinely isolated, the convenience and availability of a single collection of phages, for typing *Salmonella* in general, assumes a significant dimension.

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