

Prevalence of Serotypes of *Salmonella*

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The distribution of species and serotypes of *Salmonella* among 2,498 cultures which were isolated in the United States and its territories is presented. These isolates were received for examination during the 12-month period between October 1, 1966 and September 30, 1967. These and other data obtained from the *Salmonella* Surveillance Summaries for the past five years indicate that a relatively small number of species and serotypes of *Salmonella* are regularly isolated from diagnostic specimens. Of approximately 1,300 presently known *Salmonella* species and serotypes, 33 account for almost 90% of the isolates reported from humans and approximately 80% of the isolates from nonhuman sources. The 50 most prevalent species and serotypes account for 97% of the isolates from humans. An abbreviated antigenic schema based on these 50 species and serotypes of *Salmonella*, in conjunction with adequate biochemical tests, permits complete bacteriological characterization of the common *Salmonella*.

The great diversity of somatic (O) and flagellar (H) antigens among the various serotypes of *Salmonella* accounts for approximately 1,300 serotypes. The continual addition of new types to the antigenic schema has created a certain amount of controversy among bacteriologists. Some of them long have felt that complete serological identification of *Salmonella* was impractical except in specialized laboratories. However, from all *Salmonella* cultures recovered from diagnostic specimens, only a relatively small number of serotypes are regularly isolated using currently accepted techniques. This was shown by the work of Edwards (2) and more recently by Ewing (8).

This report summarizes the distribution of the various species and serotypes of the genus *Salmonella* submitted to the National Salmonella Center during the period October 1, 1966 through September 30, 1967. During this period, 2,498 isolates of *Salmonella* were examined. Although about 10% of the strains of *Salmonella* came from many parts of the world, this report is based primarily on cultures isolated in the United States and its territories. The data concerning the distribution of these particular serotypes among the various O antigen groups have been reported in a series of Quarterly Reports by Martin et al. (15-18). These and other data obtained from the *Salmonella* Surveillance Summaries for the past 5 years indicate that a relatively small number of species and serotypes of *Salmonella* are regularly isolated from diagnostic specimens.

MATERIALS AND METHODS

The biochemical and serological methods employed were similar to those reported by Edwards and Ewing (3), Ewing (5, 7), Ewing and Ball (10), and Martin et al. (*in press*). The nomenclature and definitions used in this report were adopted by Ewing (6, 9). This nomenclature is based upon the three species concept employed by Kauffmann and Edwards (13). This system and the definitions were adopted by the Subcommittee on Enterobacteriaceae of the American Society for Microbiology (ASM News 30:22, 1964; ASM News 34:30-31, 1968).

RESULTS

The 33 most prevalent salmonellae, recovered from human and other sources among 2,498 cultures examined during the 12-month period, are listed in Table 1. The human isolants are from individuals of all age groups and states of infection (case, convalescent carrier, contact carrier, and unknown). Sources other than human include animals, food, water, unknown, and miscellaneous. Of the 2,498 *Salmonella* cultures examined during the 12-month period, 2,009 (80.4%) belonged to 33 serotypes. Each serotype has been ranked (in parentheses) according to its prevalence (Table 1). Of the 2,009 strains, 1,459 (72.6%) were from humans and 550 (27.4%) were from sources other than human. Of the total number (2,498) received during the year, 58.4% were isolated from humans and belonged to the above-mentioned 33 serotypes. As will be discussed below, this comparatively low percentage does not reflect the true prevalence of com-

monly occurring serotypes of *Salmonella* isolated in diagnostic laboratories.

The most prevalent *Salmonella* in the United States during the years 1963 through 1967 are listed in Table 2. The data in Table 2 are from Salmonella Surveillance Summaries (19-23). With the exception of one or two serotypes, most sero-

types of *Salmonella* listed in Table 2 also appear in Table 1. Moreover, the ranks in the two tables are generally similar. The subtotal percentage for each of the 5 years indicates the percentage of the total number of *Salmonella* that belong to the 25 serotypes. Over a 5-year period, these 25 serotypes accounted for 88.8% of the strains isolated

TABLE 1. Distribution of species and serotypes of *Salmonella* by source among 2,498 cultures received in the Enteric Bacteriology Unit, NCDC, from October 1, 1966 to September 30, 1967

Species	Serotype	Group	Source		
			Human	Other	Total
<i>S. enteritidis</i>	<i>anatum</i>	E ₁	19 (13) ^a	37	56 (8) ^a
	<i>bareilly</i>	C ₁	4 (23)		4
	<i>binza</i>	E ₂	3 (24)	17	20 (19)
	<i>blockley</i>	C ₂	27 (11)	14	41 (13)
	<i>bredeney</i>	B	4 (23)	13	17 (21)
	<i>chester</i>	B	9 (19)	4	13 (23)
	<i>cubana</i>	G	8 (20)	14	22 (17)
	<i>derby</i>	B	21 (12)	27	48 (11)
	<i>enteritidis</i>	D	62 (5)	5	67 (6)
	<i>give</i>	E ₁	6 (22)	12	18 (20)
	<i>heidelberg</i>	B	51 (6)	50	101 (5)
	<i>infantis</i>	C ₁	41 (9)	15	56 (8)
	<i>javiana</i>	D	42 (8)	7	49 (10)
	<i>litchfield</i>	C ₂	7 (21)		7
	<i>manhattan</i>	C ₂	18 (14)	9	27 (15)
	<i>meleagridis</i>	E ₁	2 (25)		2
	<i>montevideo</i>	C ₁	16 (16)	23	39 (14)
	<i>muenchen</i>	C ₂	12 (18)	8	20 (19)
	<i>newport</i>	C ₂	97 (4)	23	120 (4)
	<i>oranienburg</i>	C ₁	17 (15)	28	45 (12)
	<i>panama</i>	D	18 (14)	7	25 (16)
	<i>paratyphi B</i>	B	14 (17)		14 (22)
	<i>java</i> ^b	B	44 (7)	10	54 (9)
	<i>saint paul</i>	B	40 (10)	14	54 (9)
	<i>san diego</i>	B	12 (18)	9	21 (18)
<i>schwarzengrund</i>	B		10	10 (24)	
<i>senftenberg</i>	E ₄	2 (25)	5	7 (25)	
<i>tennessee</i>	C ₁	8 (20)	10	18 (20)	
<i>thompson</i>	C ₁	162 (3)	49	211 (3)	
<i>S. typhi</i>		D	223 (2) ^c		223 (2) ^c
<i>S. enteritidis</i>	<i>typhimurium</i>	B	416 (1)	112	528 (1)
	<i>typhimurium</i> <i>copenhagen</i>	B	51 (6)	15	66 (7)
	<i>worthington</i>	G	3 (24)	3	6
Subtotal			1,459	550	2,009
Others					489 ^d
Total					2,498

^a Number in parenthesis indicates rank with regard to frequency of occurrence.

^b Bioserotype.

^c The figures for *S. typhi* are weighted because of repeat examinations of cultures from both cases and carriers.

^d This total represents those cultures of *Salmonella* submitted having one or more of the following criteria: belonged to one of the higher O antigen groups, possessed unusual characteristics, an undescribed serotype, received from sources other than the United States and its territories.

TABLE 2. Twenty-five most commonly occurring species and serotypes of *Salmonella* in humans (ranked 1 to 25) compared with numbers isolated from other sources (from Annual Summaries, NCDC Salmonella Surveillance)

Species	Serotype	Group	1963		1964		1965		1966		1967	
			Human	Other sources	Human	Other sources	Human	Other sources	Human	Other sources	Human	Other sources
<i>S. enteritidis</i>	<i>anatum</i>	E ₁	224(14) ^a	270	279(14)	250	300(14)	269	333(14)	441	297(15)	521
	<i>bareilly</i>	C ₁	59	23	99	26	104	33	78	30	81(25)	51
	<i>blockley</i>	C ₂	360(11)	125	427(11)	114	401(12)	213	603(8)	194	519(8)	115
	<i>braenderup</i>	C ₁	56	6	102	20	85	25	111(25)	38	83(24)	84
	<i>bredeney</i>	B	153(22)	116	220(18)	109	160(21)	110	159(19)	86	120(22)	174
	<i>chester</i>	B	190(16)	96	75	181	115	184	109	153	100(23)	52
	<i>cubana</i>	G	40	28	63	32	145(22)	25	131(23)	219	66	243
	<i>derby</i>	B	1610(2)	114	2360(2)	213	632(8)	106	404(10)	266	326(13)	458
	<i>enteritidis</i>	D	801(6)	70	801(6)	89	1065(5)	53	1237(5)	87	1277(3)	128
	<i>give</i>	E ₁	65	48	79	38	116(25)	95	78	55	61	55
	<i>heidelberg</i>	B	1533(3)	365	1717(3)	483	1621(2)	831	1622(2)	786	1648(2)	665
	<i>infantis</i>	C ₁	970(5)	347	1523(4)	362	1145(4)	385	1315(4)	368	980(5)	424
	<i>javiana</i>	D	168(19)	5	256(16)	1	361(13)	11	312(15)	8	373(12)	32
	<i>litchfield</i>	C ₂	67	22	69	16	96	18	97	19	81(25)	4
	<i>manhattan</i>	C ₂	192(15)	32	181(21)	47	125(24)	47	134(21)	42	284(16)	38
	<i>meleagridis</i>	E ₁	82	18	48	47	140(23)	80	8	25	7	53
	<i>montevideo</i>	C ₁	490(10)	253	524(10)	215	458(11)	213	337(13)	346	398(11)	335
	<i>muenchen</i>	C ₂	265(13)	74	261(15)	86	219(16)	50	229(17)	69	217(18)	96
	<i>newport</i>	C ₂	1080(4)	203	1036(5)	161	1257(3)	203	1319(3)	159	1263(4)	154
	<i>orantienburg</i>	C ₁	539(9)	99	550(9)	149	591(9)	190	399(11)	183	406(10)	260
	<i>panama</i>	D	141(24)	12	189(20)	27	229(15)	32	274(16)	23	182(19)	62
	<i>paratyphi B</i>	B	175(17)	4	175(23)	1	177(19)	7	153(20)	9	173(20)	
	<i>java^b</i>	B	155(21)	3	231(17)	5	199(18)	25	367(12)	51	309(14)	381
	<i>saint paul</i>	B	586(8)	206	645(8)	194	767(6)	273	737(6)	334	907(6)	91
	<i>san diego</i>	B	120(25)	69	178(22)	85	229(15)	158	122(24)	110	149(21)	152
<i>schwarzengrund</i>	B	147(23)	191	155(24)	106	114	162	71	276	72	274	
<i>senftenberg</i>	E ₄	33	39	108(25)	86	74	127	72	188	58	322	
<i>tennessee</i>	C ₁	164(20)	88	332(13)	119	173(20)	117	133(22)	206	63	322	
<i>thompson</i>	C ₁	321(12)	90	421(12)	133	562(10)	198	579(9)	203	508(9)	209	
<i>S. typhi^c</i>		D	706(7)	2	703(7)		719(7)		654(7)		690(7)	
		B	5435(1)	1065	5656(1)	942	6526(1)	978	5744(1)	884	5530(1)	896
<i>S. enteritidis</i>	<i>typhimurium</i>	B	173(18)	260	206(19)	153	203(17)	282	178(18)	203	273(17)	250
	<i>copenhagen</i>	B										
Subtotal (ranks 1 to 25)			16,698	4,343	19,134	4,490	18,520	5,501	17,586	6,062	17,174	6,579
Per cent			89.5	80.6	91.0	82.2	88.8	80.5	87.8	78.6	87.1	74.8
Total of all serotypes (100%)			81,649	5,389	21,113	5,461	20,865	6,834	20,040	7,709	19,723	8,794

^a Number in parenthesis indicates rank with regard to frequency of occurrence in humans (ranks 1 to 25).

^b Bioserotype.

^c The figures for *S. typhi* are weighted because of repeat examinations of cultures from both cases and carriers.

TABLE 3. Antigenic formula and rank of *Salmonella* that occurred most frequently among 23,414 cultures received in the period from July 1, 1948 through June 30, 1958^a

Species	Serotype	Group	Antigenic formula			Human sources		Total no. (all sources)
			O Antigens	H antigens		No.	Rank	
				Phase 1	Phase 2			
<i>S. enteritidis</i>	<i>paratyphi A</i> ^b	A	1,2,12	a		33	37	35
	<i>paratyphi B</i>	B	1,4,5,12	b	1,2	267	8 ^c	322
	<i>paratyphi B, Odense</i>		1,4,12	b	1,2	4	47	4
	<i>java</i> ^b		1,4,5,12	b	[1,2]	211	11	279
	<i>stanley</i>		4,5,12	d	1,2	20	41	68
	<i>schwarzengrund</i>		1,4,12,27	d	1,7	52	30	133
	<i>saint paul</i>		1,4,5,12	e, h	1,2	108	22	225
	<i>reading</i>		4,5,12	e, h	1,5	216	10	239
	<i>chester</i>		4,5,12	e, h	e, n, x	87	24	172
	<i>san diego</i>		4,12	e, h	e, n, z ₁₅	182	15	408
	<i>derby</i>		1,4,5,12	f, g		157	19	555
	<i>california</i>		4,5,12	m, t		60	27	131
	<i>typhimurium</i>		1,4,5,12	i	1,2	1479	1	4013
	<i>typhimurium, copenhagen</i>		1,4,12	i	1,2	70	26	231
<i>bredeney</i>		1,4,12,27	l, v	1,7	91	23	239	
<i>heidelberg</i>		1,4,5,12	r	1,2	176	16	444	
<i>S. cholerae-suis</i>		C ₁	6,7	c	1,5	16	43	27
<i>S. cholerae-suis</i>	<i>kunzendorf</i> ^b		6,7	[c]	1,5	236	9	599
<i>S. enteritidis</i>	<i>braenderup</i>		6,7	eh	e, n, z ₁₅	26	38	39
	<i>montevideo</i>		6,7	g, m, s		554	4	856
	<i>oranienburg</i>		6,7	m, t		632	3	863
	<i>thompson</i>		6,7	k	1,5	153	20	231
	<i>infantis</i>		6,7	r	1,5	188	14	267
	<i>bareilly</i>		6,7	y	1,5	191	13	290
	<i>tennessee</i>		6,7	z ₂₉		296	7	450
	<i>muenchen</i>	C ₂	6,8	d	1,2	347	5	559
	<i>manhattan</i>		6,8	d	1,5	86	25	175
	<i>newport</i>		6,8	e, h	1,2	739	2	1162
	<i>blockley</i>		6,8	k	1,5	56	28	174
	<i>litchfield</i>		6,8	l, v	1,2	24	40	42
	<i>tallahassee</i>		6,8	z ₄ , z ₃₂		12	44	35
	<i>kentucky</i>		(8), 20	i	z ₆	46	31	137
	<i>miami</i> ^b	D	1,9,12	a	1,5	39	34	63
<i>S. typhi</i>			9,12, Vi	d		— ^d	— ^d	3502
<i>S. enteritidis</i>	<i>enteritidis</i>		1,9,12	g, m		174	17	540
	<i>berta</i>		9,12	f, g, t		25	39	30
	<i>dublin</i>		1,9,12	g, p		5	46	36
	<i>panama</i>		1,9,12	l, v	1,5	169	18	229
	<i>javiana</i>		1,9,12	l, z ₂₃	1,5	196	12	208
	<i>pullorum</i> ^b		9,12			38	35	1607

^a Modified from Edwards (2).^b Bioserotype.^c Italics in the "Rank" column indicate the 25 species and serotypes that occurred most frequently among cultures from human sources. Since a number of cultures that were untypable (e.g., O forms) were excluded, the figures in the "Total" column do not add to 23,414.^d The figures from *S. typhi* are weighted because of repeat examinations of cultures from both cases and carriers.

TABLE 3—Continued

Species	Serotype	Group	Antigenic formula			Human sources		Total no. (all sources)
			O Antigens	H antigens		No.	Rank	
				Phase 1	Phase 2			
<i>anatum</i> <i>meleagridis</i> <i>give</i>	E ₁	3,10	e, h	1,6	320	6	1066	
		3,10	e, h	1, w	45	32	212	
		3,10	1, v	1, 7	119	21	263	
<i>newington</i>	E ₂	3,15	e, h	1,6	41	33	138	
<i>illinois</i>	E ₃	(3), (15), 34	z ₁₀	1,5	2	48	31	
<i>senftenberg</i> <i>simsbury</i>	E ₄	1,13,19	g, s, t		52	30	191	
		1,13,19	z ₂₇		4	47	61	
<i>rubislaw</i>	F	11	r	e, n, x	26	38	41	
<i>poona</i> <i>worthington</i> <i>cubana</i>	G	13,22	z	1,6	33	37	52	
		1,13,23	z	1, w	53	29	174	
		1,13,23	z ₂₉		52	30	90	
<i>florida</i> <i>madelia</i>	H	1,6,14,25	d	1,7	6	45	43	
		1,6,14,25	y	1,7	16	43	41	
<i>cerro</i> <i>siegburg</i>	18	18	Z ₄ , Z ₂₈		12	44	31	
		6,14,18	Z ₄ , Z ₂₈		36	36	38	
<i>minnesota</i>	21	21	b	e, n, x	26	38	79	
<i>urbana</i>	30	30	b	e, n, x	19	42	32	

from human sources and 79.5% isolated from sources other than human.

Table 3 shows the antigenic formulas for the 50 or 57 most frequently occurring serotypes (including those in Tables 1 and 2). (The larger number depends upon whether bioserotypes and other variants are counted separately.) Also, each serotype has been ranked (in parentheses) according to its prevalence. Although the prevalence of a few serotypes fluctuates from year to year, the prevalence of the most frequently occurring serotype is relatively constant. The majority of serotypes of *Salmonella* listed in Table 3 belong in O antigen groups B through E₄ and G. The compilations shown in Tables 1 to 3 for *S. typhi* are weighted because of repeat examination of cultures from both cases and carriers.

In analyzing the data in the aforementioned tables, it became apparent that relatively few serotypes (and species) of *Salmonella* are being isolated from diagnostic material. This observation provided the impetus for an abbreviated antigenic schema based upon the most prevalent serotypes of *Salmonella*. Employing primarily

the data presented in Table 3, Table 4 lists the unabsorbed O and H antisera as well as the respective absorbed single-factor antisera (O and H) needed for complete serological typing of the above-mentioned salmonellae. Antisera for typing *S. enteritidis* bioserotype *paratyphi* A also are listed in Table 4. Even though this bioserotype is relatively uncommon in the United States, bacteriologists should be acquainted with it and aware that it can be imported at any time.

DISCUSSION

From an examination of the distribution of serotypes of *Salmonella* isolated from humans and sources other than human, two observations became apparent. First, relatively few species and serotypes of *Salmonella* were consistently recovered from diagnostic materials, and, second, the concept of an abbreviated antigenic schema based on the most prevalent species and serotypes of *Salmonella* that occur in the United States was confirmed.

Of approximately 1,300 known serotypes of *Salmonella*, only a small number are regularly isolated. In 1962, Edwards showed that, of ap-

TABLE 4. Antisera needed for typing the 50 commonly occurring *Salmonella* serotypes^{a, b}

O Antisera		H Antisera			
		Phase 1		Phase 2	
Unabsorbed	Absorbed	Unabsorbed	Absorbed	Unabsorbed	Absorbed
1,2,12	2	a		e, n, x	x
4,5,12	5	b		e, n, Z ₁₅	Z ₁₅
4,12,27	27	c		1,2	2
6,7	7	d		1,5	5
6,8		e, h	h	1,6	6
(8),20	20	f, g	f	1,7	7
9,12		g, m	m	Z ₆ (crosses with 1,5)	Z ₆
3,10	10	g, m, s	m and s		
3,15	15	g, p	p		
(3), (15), 34	34	g, s, t	s and t		
1,3,19	19	i			
11		k			
13,22	22	l, v	v		
1,13,23	23	l, w	w		
6,14,25	14 and 25	l, Z ₁₃	Z ₁₃		
18		l, Z ₂₈	Z ₂₈		
21		m, t	m and t		
30		r			
Vi		y			
		z			
		Z ₄ , Z ₄₃	Z ₄₃		
		Z ₄ , Z ₄₂	Z ₄₂		
		Z ₁₀			
		Z ₂₇			
		Z ₂₉			

^a Modified from Edwards (2).

^b Totals: unabsorbed O antisera, 18 plus Vi; absorbed O antisera, 13; unabsorbed, phase 1, H antisera, 25; absorbed, phase 1, H antisera, 12; unabsorbed, phase 2, H antisera, 7; absorbed, phase 2, H antisera, 7.

proximately 800 serotypes of *Salmonella* known at that time, only 201 (25%) were identified among 23,414 cultures submitted in a 10-year period. Of this number, 55 occurred 30 or more times and comprised 97.7% of the total. In his studies, Ewing (8) compared data from the *Salmonella* Surveillance Summaries (19-23) with those reported by Edwards (2) and noted that the most common serotypes of *Salmonella* recorded in the surveillance reports were among the above-mentioned 55 in frequency of occurrence. The results of a worldwide survey of more than 500,000 cultures and their distribution were recently reported by Kelterborn (14). He substantiated the findings of previous workers (2, 8, 10) by showing that the majority of serotypes that frequently occur in man and animals belong to the first few *Salmonella* O antigen groups. Among more than 500,000 cultures, 95.6% of the strains were distributed as follows: group B, 47.1%; group C₁, 13.3%; group C₂, 7.1%; group

D₁, 23.7%; group E₂, 4.4%. However, this percentage (95.6%) represented only about 38% of all the known serotypes. The remaining serotypes of the schema constituted only 4.4% of the total number of cultures analyzed. The data cited by Kelterborn (14) agree with the results of this study. Hence, the large number of known serotypes of *Salmonella* should not be a cause for alarm or dismay.

The percentages calculated from the data in Table 2 relative to the prevalent serotypes are somewhat higher than those derived from the numbers of cultures received by the National *Salmonella* Center. This apparent discrepancy is caused by the comparatively large number of strains of *Salmonella* sent to the National *Salmonella* Center which belonged to the higher O antigen groups, possessed unusual characteristics, or were undescribed serotypes.

The second observation concerns the concept of an abbreviated antigenic schema based on the

most prevalent species and serotypes of *Salmonella* that occur in the United States. "Simplified" methods for the diagnosis of cultures of *Salmonella* have been proposed by several investigators (1, 4, 11, 12, 24). However, comparatively little has been reported concerning the epidemiological adequacy of these methods or their effectiveness when applied to large numbers of cultures. The antigenic formulas of the most prevalent serotypes of *Salmonella* which occurred in a 10-year period are presented in Table 3. The 50 species and serotypes (including variants) shown have accounted for 96.7% of all of the salmonellae isolated from human sources. Thus, these (and other) data suggest that the formulas given in Table 3 constitute an abbreviated antigenic schema comprising the most common *Salmonella* species and serotypes found in humans and to a lesser extent in other materials. With this in mind, a list is given in Table 4 showing the antisera needed by a laboratory interested in complete typing of the most common serotypes of *Salmonella*. A set containing 51 unabsorbed and 32 absorbed O and H antisera, respectively, will permit complete serological typing of about 95% of cultures encountered in daily practice. Also many additional serotypes, not listed in Table 3, may be completely or partially characterized with these antisera (Table 4). For example, a serotype of *Salmonella* that is relatively uncommon, such as *S. enteritidis* serotype *new brunswick* (3,15:1,v:1,7) can be identified. Many other examples could be cited. This is brought about by the community of O and H antigens among salmonellae.

Although the above-mentioned abbreviated antigenic schema (Table 3), based on the most prevalent serotypes of *Salmonella*, is recommended for many laboratories, determination of the biochemical characteristics of these bacteria should not be neglected. On the contrary, these should always be determined. By employing selected minimal biochemical tests (Martin et al., *in press*) and complete serological analysis based on frequency of serotypes, exact identification of a large number of *Salmonella* becomes a distinct possibility. Since many of the antisera listed in Table 4 are now becoming available commercially, complete serotyping of the most commonly occurring salmonellae should become a reality.

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LITERATURE CITED

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