

## Taxonomic Note

Correspondence  
B. J. Tindall  
bti@dsmz.de

# Nomenclature and taxonomy of the genus *Salmonella*

B. J. Tindall,<sup>1</sup> P. A. D. Grimont,<sup>2</sup> G. M. Garrity<sup>3</sup> and J. P. Euzéby<sup>4</sup>

<sup>1</sup>DSMZ – Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH, Mascheroder Weg 1b, D-38124 Braunschweig, Germany

<sup>2</sup>Unité de Biodiversité des Bactéries Pathogènes Emergentes, INSERM U389, Institut Pasteur, F-75724 Paris Cedex 15, France

<sup>3</sup>Bergey's Manual Trust, Department of Microbiology and Molecular Genetics, 6162 Biomedical Physical Sciences Bldg, Michigan State University, East Lansing, MI 48824-4320, USA

<sup>4</sup>Société de Bactériologie Systématique et Vétérinaire (SBSV) and Ecole Nationale Vétérinaire de Toulouse (ENVT), 23 Chemin des Capelles, BP 87614, F-31076 Toulouse Cedex 03, France

The nomenclature of the genus *Salmonella* has reached an unsatisfactory state of affairs, with two systems of nomenclature in circulation. One system, proposed in the 1980s by Le Minor and Popoff, has received wide acceptance, although it does not conform to the rules of the Bacteriological Code. The other system, which conforms to the rules of the Bacteriological Code, is being used by an ever-decreasing minority. As a result of a number of recent Requests for an Opinion, the Judicial Commission of the International Committee on the Systematics of Prokaryotes has issued an Opinion (Opinion 80) with the intention that it should solve these discrepancies. However, like all Opinions, it is limited to matters of nomenclature and does not help to interpret the taxonomic consequences. The Judicial Commission has therefore asked experts in the field of nomenclature and taxonomy to write a commentary on the nomenclatural and taxonomic consequences of Opinion 80. The present article explains the nomenclatural consequences of Opinion 80, together with a clear presentation of the taxonomy that results when applying the currently widely accepted interpretation that the genus *Salmonella* currently includes only two species.

The current taxonomy and nomenclature of the genus *Salmonella* have been the subject of debate since Le Minor & Popoff (1987) proposed changes in the 1980s. In their Request for an Opinion, these authors not only proposed changes in the nomenclature of the species of this genus, but also requested that formal taxonomic interpretations be taken into consideration. Their request to recognize a single species could not be dealt with by the Judicial Commission because the Commission may only act on matters of nomenclature. Taxonomic opinion is not governed by the Bacteriological Code (the Code).

The nomenclatural changes that were proposed dealt with important human and animal pathogens. At the time, the Judicial Commission could not predict whether these changes would have severe consequences for the reporting of disease caused by pathogens such as *Salmonella typhi*. Following careful deliberations, the Judicial Commission recommended that the authors reformulate their Request for an Opinion to conform to the Code, but this did not happen (Wayne, 1994). In the intervening years, the nomenclature of Le Minor & Popoff (1987) has become

widely accepted in certain countries, despite the fact that those names have not been validly published and have no standing in nomenclature. In addition, their proposed taxonomy is also now in common usage. Euzéby (1999), Ezaki *et al.* (2000a, b) and Ezaki & Yabuuchi (2000) submitted proposals to deal with the problem of the serious discrepancies between the nomenclature of Le Minor & Popoff (1987) and that which is recognized under the Code. The major problem at present is that two systems of nomenclature are in use for members of the genus *Salmonella* and that great care must be taken when attempts are made to unify these systems. It was generally agreed during the meeting of the Judicial Commission held in 2002 that a solution must be sought that provides a link between the two nomenclatural systems while causing as little confusion as possible. Recognizing that the average microbiologist was not familiar with the Code, the commissioners believed that it would be necessary to deal with the nomenclatural problem and to provide a guide as to how the taxonomic consequences could be illustrated. In publishing Opinion 80, the Judicial Commission (2005) has sought to provide a solution to the problem of

nomenclature in this genus. However, the Judicial Commission does not have the power to rule on how these nomenclatural changes will affect the taxonomy of this group. In order to avoid confusion, it is the purpose of the present article to provide a clear interpretation of the nomenclature and taxonomy of members of the genus *Salmonella*.

Prior to the publication of Opinion 80, the Code recognized the following names as being validly published within the genus *Salmonella*:

*Salmonella choleraesuis* (Smith 1894) Weldin 1927 (type species of the genus), type strain ATCC 13312 = CIP 55.133 = NCTC 5735 = DSM 14846 = JCM 1651 (serovar Choleraesuis),

*Salmonella bongori* (Le Minor *et al.* 1985) Reeves *et al.* 1989, type strain ATCC 43975 = CCUG 30042 = CIP 82.33 = DSM 13772 = NCTC 12419,

*Salmonella choleraesuis* subsp. *bongori* Le Minor *et al.* 1985, type strain ATCC 43975 = CCUG 30042 = CIP 82.33 = DSM 13772 = NCTC 12419,

*Salmonella enteritidis* (Gaertner 1888) Castellani and Chalmers 1919, type strain ATCC 13076 = NCTC 12694,

*Salmonella paratyphi* (*ex* Kayser 1902) Ezaki *et al.* 2000, type strain NCTC 5702 = KI 1015,

*Salmonella typhi* (Schroeter 1886) Warren and Scott 1930, type strain ATCC 19430 = CUETM 79.394 = HAMB1 1306 = NCTC 8385,

*Salmonella typhimurium* (Loeffler 1892) Castellani and Chalmers 1919, type strain ATCC 13311 = NCTC 74 = CIP 58.58 = JCM 1652 (serovar Typhimurium),

*Salmonella choleraesuis* subsp. *choleraesuis* (Smith 1894) Weldin 1927, type strain ATCC 13312 = CIP 55.133 = NCTC 5735 = DSM 14846 = JCM 1651 (serovar Choleraesuis),

*Salmonella arizonae* (Borman 1957) Kauffmann 1964, type strain ATCC 13314 = CCUG 6322 = CIP 82.30 = DSM 9386 = NCTC 8297,

*Salmonella choleraesuis* subsp. *arizonae* (Borman 1957) Le Minor *et al.* 1985, type strain ATCC 13314 = CCUG 6322 = CIP 82.30 = DSM 9386 = NCTC 8297,

*Salmonella choleraesuis* subsp. *diarizonae* Le Minor *et al.* 1985, type strain ATCC 43973 = CCUG 30040 = CIP 82.31 = NCTC 10060 = DSM 14847,

*Salmonella choleraesuis* subsp. *houtenae* Le Minor *et al.* 1985, type strain ATCC 43974 = CCUG 30041 = CIP 82.32 = DSM 9221 = NCTC 12418,

*Salmonella choleraesuis* subsp. *indica* Le Minor *et al.* 1987, type strain K1240 = ATCC 43976 = CCUG 30038 = CIP 102501 = NCTC 12420 = DSM 14848, and

*Salmonella choleraesuis* subsp. *salamae* Le Minor *et al.* 1985, type strain ATCC 43972 = CCUG 30039 = CIP 8229 = DSM 9220 = NCTC 5773.

Le Minor & Popoff (1987) proposed that the type species of the genus *Salmonella* should be changed to *Salmonella enterica*, with the type strain of that species being strain LT2. The authors did not exclude the fact that other authors may wish to retain other names that were validly published: 'Since we recognize the right of other bacteriologists to believe that the genus *Salmonella* should be composed of several species, including *S. choleraesuis*, we shall refrain from requesting the rejection of that name.'

In reacting to the Requests for an Opinion by Ezaki *et al.* (2000a, b) and Euzéby (1999), the Judicial Commission has also taken the request of Le Minor & Popoff (1987) into consideration and decided that *Salmonella enterica* becomes the type species of the genus, replacing *Salmonella choleraesuis* (Judicial Commission, 2005). The type strain of *Salmonella enterica* is CIP 60.62 = NCIMB 11450 = LT2 = ATCC 43971 = NCTC 12416. Furthermore, to avoid any ambiguities in interpreting the Code, the epithet *enterica* in *Salmonella enterica* is conserved over all earlier epithets that may be applied to this species. The Judicial Commission has also ruled that the subspecies combinations proposed by these authors should also be considered to be validly published, with the dates and authorship being assigned to these authors. In proposing these subspecies, *Salmonella enterica* subsp. *enterica* is automatically created (Rule 40d/46). The circumscription of *Salmonella enterica* is given by Le Minor & Popoff (1987) and also applies to *Salmonella enterica* subsp. *enterica*. However, this also means that the following names are validly published:

*Salmonella enterica* Le Minor and Popoff 1987 (type species of the genus), type strain CIP 60.62 = NCIMB 11450 = LT2 = ATCC 43971 = NCTC 12416 (serovar Typhimurium),

*Salmonella bongori* (Le Minor *et al.* 1985) Reeves *et al.* 1989, type strain ATCC 43975 = CCUG 30042 = CIP 82.33 = DSM 13772 = NCTC 12419,

*Salmonella enterica* subsp. *bongori* (Le Minor *et al.* 1985) Le Minor and Popoff 1987, type strain ATCC 43975 = CCUG 30042 = CIP 82.33 = DSM 13772 = NCTC 12419,

*Salmonella choleraesuis* subsp. *bongori* Le Minor *et al.* 1985, type strain ATCC 43975 = CCUG 30042 = CIP 82.33 = DSM 13772 = NCTC 12419,

*Salmonella enterica* subsp. *enterica* Le Minor and Popoff 1987, type strain CIP 60.62 = NCIMB 11450 = LT2 = ATCC 43971 = NCTC 12416 (serovar Typhimurium),

*Salmonella enteritidis* (Gaertner 1888) Castellani and Chalmers 1919, type strain ATCC 13076 = NCTC 12694,

*Salmonella paratyphi* (*ex* Kayser 1902) Ezaki *et al.* 2000, type strain NCTC 5702 = KI 1015,

*Salmonella typhi* (Schroeter 1886) Warren and Scott 1930, type strain ATCC 19430 = CUETM 79.394 = HAMB1 1306 = NCTC 8385,

*Salmonella typhimurium* (Loeffler 1892) Castellani and Chalmers 1919 (type strain ATCC 13311 = NCTC 74 = CIP 58.58 = JCM 1652 (serovar Typhimurium),

*Salmonella choleraesuis* (Smith 1894) Weldin 1927, type strain ATCC 13312 = CIP 55.133 = NCTC 5735 = DSM 14846 = JCM 1651 (serovar Choleraesuis),

*Salmonella choleraesuis* subsp. *choleraesuis* (Smith 1894) Weldin 1927, type strain ATCC 13312 = CIP 55.133 = NCTC 5735 = DSM 14846 = JCM 1651 (serovar Choleraesuis),

*Salmonella enterica* subsp. *arizonae* (Borman 1957) Le Minor and Popoff 1987, type strain ATCC 13314 = CCUG 6322 = CIP 82.30 = DSM 9386 = NCTC 8297,

*Salmonella arizonae* (Borman 1957) Kauffmann 1964, type strain ATCC 13314 = CCUG 6322 = CIP 82.30 = DSM 9386 = NCTC 8297,

*Salmonella choleraesuis* subsp. *arizonae* (Borman 1957) Le Minor *et al.* 1985, type strain ATCC 13314 = CCUG 6322 = CIP 82.30 = DSM 9386 = NCTC 8297,

*Salmonella enterica* subsp. *diarizonae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987 1985, type strain ATCC 43973 = CCUG 30040 = CIP 82.31 = NCTC 10060 = DSM 14847,

*Salmonella choleraesuis* subsp. *diarizonae* Le Minor *et al.* 1985, type strain ATCC 43973 = CCUG 30040 = CIP 82.31 = NCTC 10060 = DSM 14847,

*Salmonella enterica* subsp. *houtenae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987, type strain ATCC 43974 = CCUG 30041 = CIP 82.32 = DSM 9221 = NCTC 12418,

*Salmonella choleraesuis* subsp. *houtenae* Le Minor *et al.* 1985, type strain ATCC 43974 = CCUG 30041 = CIP 82.32 = DSM 9221 = NCTC 12418,

*Salmonella enterica* subsp. *indica* (Le Minor *et al.* 1987) Le Minor and Popoff 1987, type strain K1240 = ATCC 43976 = CCUG 30038 = CIP 102501 = NCTC 12420 = DSM 14848,

*Salmonella choleraesuis* subsp. *indica* Le Minor *et al.* 1987, type strain K1240 = ATCC 43976 = CCUG 30038 = CIP 102501 = NCTC 12420 = DSM 14848,

*Salmonella enterica* subsp. *salamae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987 1985, type strain ATCC 43972 = CCUG 30039 = CIP 8229 = DSM 9220 = NCTC 5773, and

*Salmonella choleraesuis* subsp. *salamae* Le Minor *et al.* 1985, type strain ATCC 43972 = CCUG 30039 = CIP 8229 = DSM 9220 = NCTC 5773.

However, this does not appear to solve the current problems of nomenclature, nor the different taxonomic interpretations. This is primarily due to the fact that the Judicial Commission is not empowered by the Code as a taxonomic arbiter [see Principle 1 (4)]. However, it is evident that, if the taxonomic proposals of Le Minor & Popoff (1987) and Reeves *et al.* (1989) are followed, only two species are to be recognized. The Judicial Commission (2005) has ruled that the type species of the genus *Salmonella* Lignieres 1900 is *Salmonella enterica* Le Minor and Popoff 1987 and that the epithet *enterica* be conserved over all earlier epithets that may be applied to this species. At the same time, Le Minor & Popoff (1987) also recognized that the species *Salmonella enterica* be divided into several subspecies. Thus, by applying the recent ruling of the Judicial Commission (2005) together with the taxonomic interpretation of Le Minor & Popoff (1987) and Reeves *et al.* (1989), the taxonomy and resulting nomenclature that should be followed are listed below. Those names that are to be used within the resulting taxonomy are underlined.

*Salmonella enterica* (ex Kauffmann and Edwards 1952) Le Minor and Popoff 1987 (type species of the genus), type strain CIP 60.62 = NCIMB 11450 = LT2 = ATCC 43971 = NCTC 12416 (serovar Typhimurium),

= *Salmonella choleraesuis* (Smith 1894) Weldin 1927 (heterotypic synonym), type strain ATCC 13312 = CIP 55.133 = NCTC 5735 = DSM 14846 = JCM 1651 (serovar Choleraesuis),

*Salmonella bongori* (Le Minor *et al.* 1985) Reeves *et al.* 1989,

= *Salmonella enterica* subsp. *bongori* (Le Minor *et al.* 1985) Le Minor and Popoff 1987 (homotypic synonym) = *Salmonella choleraesuis* subsp. *bongori* Le Minor *et al.* 1985 (homotypic synonym), type strain ATCC 43975 = CCUG 30042 = CIP 82.33 = DSM 13772 = NCTC 12419,

*Salmonella enterica* subsp. *enterica* (ex Kauffmann and Edwards 1952) Le Minor and Popoff 1987, type strain CIP 60.62 = NCIMB 11450 = LT2 = ATCC 43971 = NCTC 12416 (serovar Typhimurium),

= *Salmonella enteritidis* (Gaertner 1888) Castellani and Chalmers 1919 (heterotypic synonym), type strain ATCC 13076 = NCTC 12694,

= *Salmonella paratyphi* (ex Kayser 1902) Ezaki *et al.* 2000 (heterotypic synonym), type strain NCTC 5702 = KI 1015,

= *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 (heterotypic synonym), type strain ATCC 19430 = CUETM 79.394 = HAMB1 1306 = NCTC 8385,

= *Salmonella typhimurium* (Loeffler 1892) Castellani and Chalmers 1919 (heterotypic synonym), type strain ATCC 13311 = NCTC 74 = CIP 58.58 = JCM 1652 (serovar Typhimurium),

= *Salmonella choleraesuis* subsp. *choleraesuis* (Smith 1894) Weldin 1927 (heterotypic synonym), type strain ATCC 13312 = CIP 55.133 = NCTC 5735 = DSM 14846 = JCM 1651 (serovar Choleraesuis),

*Salmonella enterica* subsp. *arizonae* (Borman 1957) Le Minor and Popoff 1987,

= *Salmonella arizonae* (Borman 1957) Kauffmann 1964 (homotypic synonym) = *Salmonella choleraesuis* subsp. *arizonae* (Borman 1957) Le Minor *et al.* 1985 (homotypic synonym), type strain ATCC 13314 = CCUG 6322 = CIP 82.30 = DSM 9386 = NCTC 8297,

*Salmonella enterica* subsp. *diarizonae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987,

= *Salmonella choleraesuis* subsp. *diarizonae* Le Minor *et al.* 1985 (homotypic synonym), type strain ATCC 43973 = CCUG 30040 = CIP 82.31 = NCTC 10060 = DSM 14847,

*Salmonella enterica* subsp. *houtenae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987,

= *Salmonella choleraesuis* subsp. *houtenae* Le Minor *et al.* 1985 (homotypic synonym), type strain ATCC 43974 = CCUG 30041 = CIP 82.32 = DSM 9221 = NCTC 12418,

*Salmonella enterica* subsp. *indica* (Le Minor *et al.* 1987) Le Minor and Popoff 1987,

= *Salmonella choleraesuis* subsp. *indica* Le Minor *et al.* 1987 (homotypic synonym), type strain K1240 = ATCC 43976 = CCUG 30038 = CIP 102501 = NCTC 12420 = DSM 14848, and

*Salmonella enterica* subsp. *salamae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987,

= *Salmonella choleraesuis* subsp. *salamae* Le Minor *et al.* 1985 (homotypic synonym), type strain ATCC 43972 = CCUG 30039 = CIP 8229 = DSM 9220 = NCTC 5773.

It is hoped that the recent actions of the Judicial Commission (2005) have allowed the nomenclatural changes envisaged by Le Minor & Popoff (1987) to take effect. In addition, the taxonomic opinion of Le Minor *et al.* (1982), Le Minor & Popoff (1987) and Reeves *et al.* (1989), that the genus *Salmonella* should currently comprise two species and that the type species *Salmonella enterica* should be divided into six subspecies, results in the taxonomy and nomenclature currently in use by the WHO and other organizations. It is now hoped that the resulting taxonomy and nomenclature will find widespread usage.

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