Revised *Salmonella* nomenclature: designation of *Salmonella enterica* (ex Kauffmann and Edwards 1952) Le Minor and Popoff 1987 sp. nov., nom. rev. as the neotype species of the genus *Salmonella* Lignieres 1900 (Approved Lists 1980), rejection of the name *Salmonella choleraesuis* (Smith 1894) Weldin 1927 (Approved Lists 1980), and conservation of the name *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 (Approved Lists 1980). Request for an Opinion

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The Request for an Opinion by Le Minor and Popoff 1987, proposing designation of '*Salmonella enterica*' (ex Kauffmann and Edwards 1952) Le Minor and Popoff 1987 as the type and only species of the genus *Salmonella* Lignieres 1900 (Approved Lists 1980), has not been positively decided upon by the Judicial Commission. However, many bacteriologists use the name '*Salmonella enterica*'. To avoid further confusion, it is requested to reject the name *Salmonella choleraesuis* (Smith 1894) Weldin 1927 (Approved Lists 1980), to recognize the species *Salmonella enterica*, to conserve the name *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 (Approved Lists 1980), and to emend the genus *Salmonella* with the establishment of a neotype species, *Salmonella enterica*.

Keywords: *Salmonella*, *Salmonella enterica*, *Salmonella choleraesuis*, nomenclatural changes, *epitheta specifica conservanda*

Salmonella strains have been isolated from humans and almost all animals throughout the world, and they cause many types of infection (self-limited gastroenteritis, severe gastroenteritis, typhoid fever, bacteraemia, abortion, meningitis, respiratory disease, cardiac disease, osteomyelitis and other local infections) (Gray, 1995).

The nomenclature of these bacteria has changed many times and is still not stable (Euzéby, 1997; Farmer, III & Kelly, 1991; Gray, 1995; Le Minor *et al.*, 1970, 1982b; Le Minor & Popoff, 1987).

Five species are listed on the Approved Lists (Skerman *et al.*, 1980, 1989): *Salmonella arizonae* (Borman 1957) Kauffmann 1964, *Salmonella choleraesuis* corrig. (Smith 1894) Weldin 1927 (type species of the genus),

Salmonella enteritidis (Gaertner 1888) Castellani and Chalmers 1919, *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 and *Salmonella typhimurium* (Loeffler 1892) Castellani and Chalmers 1919.

The DNA relatedness studies demonstrate that all *Salmonella* strains form a single DNA hybridization group with seven sub-groups (Le Minor *et al.*, 1982a, 1986; Stoleru *et al.*, 1976). So, according to the phylogenetic definition of a species (Wayne *et al.*, 1987), all five species listed in the Approved Lists (Skerman *et al.*, 1980, 1989) are members of a single genomospecies. All seven sub-groups can be differentiated by phenotypic properties (Le Minor *et al.*, 1986), and Le Minor *et al.* (1982b, 1986) propose the name *Salmonella choleraesuis* (Smith 1894) Weldin 1927 for

the single *Salmonella* species with the following seven subspecies: *Salmonella choleraesuis* subsp. *arizonae* (Borman 1957) Le Minor *et al.* 1985, *Salmonella choleraesuis* subsp. *bongori* Le Minor *et al.* 1985, *Salmonella choleraesuis* subsp. *choleraesuis* (Smith 1894) Weldin 1927, *Salmonella choleraesuis* subsp. *diarizonae* Le Minor *et al.* 1985, *Salmonella choleraesuis* subsp. *houtenae* Le Minor *et al.* 1985, *Salmonella choleraesuis* subsp. *indica* Le Minor *et al.* 1987, and *Salmonella choleraesuis* subsp. *salamae* Le Minor *et al.* 1985.

The names *Salmonella choleraesuis* subsp. *arizonae*, *Salmonella choleraesuis* subsp. *bongori*, *Salmonella choleraesuis* subsp. *choleraesuis*, *Salmonella choleraesuis* subsp. *diarizonae*, *Salmonella choleraesuis* subsp. *houtenae* and *Salmonella choleraesuis* subsp. *salamae* were validly published in 1985 (*International Journal of Systematic Bacteriology*, 1985). The name *Salmonella choleraesuis* subsp. *indica* was validly published in 1987 (*International Journal of Systematic Bacteriology*, 1987).

The name *Salmonella choleraesuis* can lead to confusion since the specific epithet is also the name of a serovar, *Salmonella choleraesuis* subsp. *choleraesuis* serovar *Choleraesuis*. So, in 1987, Le Minor & Popoff (1987) requested that:

(1) The genus *Salmonella* consists of only one species and they proposed to use for this single species a name which has not been used previously for a serovar: '*Salmonella enterica*' (ex Kauffmann and Edwards 1952) Le Minor and Popoff 1987, sp. nov., nom. rev.

(2) This unique species encompasses seven subspecies: '*Salmonella enterica* subsp. *arizonae*', '*Salmonella enterica* subsp. *bongori*', '*Salmonella enterica* subsp. *diarizonae*', '*Salmonella enterica* subsp. *enterica*', '*Salmonella enterica* subsp. *houtenae*', '*Salmonella enterica* subsp. *indica*' and '*Salmonella enterica* subsp. *salamae*'.

(3) The names *Salmonella choleraesuis* corrig. (Smith 1894) Weldin 1927 (Approved Lists 1980), *Salmonella enteritidis* (Gaertner 1888) Castellani and Chalmers 1919 (Approved Lists 1980), *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 (Approved Lists 1980), and *Salmonella typhimurium* (Loeffler 1892) Castellani and Chalmers 1919 (Approved Lists 1980) are subjective synonyms of '*Salmonella enterica* subsp. *enterica*'.

(4) The type strain of '*Salmonella enterica*' (ex Kauffmann and Edwards 1952) Le Minor and Popoff 1987, is the new type strain LT2^T (Lillengen strain type 2) = CIP 6062^T.

Le Minor & Popoff (1987) recognized the right of other bacteriologists to believe that the genus *Salmonella* should be composed of several species including *Salmonella choleraesuis* (type strain ATCC 13312^T = NCTC 5735^T). So, to avoid an objective synonymy, they proposed that '*Salmonella enterica*' be represented by a new type strain.

These proposals received unanimous support from the members of the Subcommittee on *Enterobacteriaceae* (Penner, 1988).

After this Request for an Opinion, the name *Salmonella bongori* (Le Minor *et al.* 1985) Reeves *et al.* 1989, comb. nov. has been validly published for *Salmonella choleraesuis* subsp. *bongori* Le Minor *et al.* 1985 (Reeves *et al.*, 1989; *International Journal of Systematic Bacteriology*, 1989).

If the name *Salmonella bongori* is not a problem, there is a lot of confusion with the name '*Salmonella enterica*'.

On the one hand, this name is used by many working bacteriologists:

- it is used in reference documents such as the last revision of the *Antigenic Formulas of the Salmonella Serovars* (Popoff & Le Minor, 1997);
- it is used in reference books such as the 2nd edition of the *Escherichia coli and Salmonella, Cellular and Molecular Biology* (Neidhardt *et al.*, 1996);
- and it is used in many scientific publications [for example, a search in the bibliographic database PubMed (<http://www.ncbi.nlm.nih.gov/PubMed/>) for *Salmonella enterica* as keyword finds 21403 documents and a search for *Salmonella choleraesuis* as keyword finds only 165 documents].

On the other hand, the Judicial Commission did not decide positively upon the request by Le Minor and Popoff, despite considerable agreement on the scientific validity, because of a reluctance to let *Salmonella typhi* be reduced to a serovar ('*Salmonella enterica* subsp. *enterica*' serovar Typhi) for reasons involving safety (Judicial Commission, 1991, 1995; Wayne, 1994). However, the Commissioners expressed a desire to see an alternative proposal published as a Request for an Opinion (Wayne, 1994).

The nomenclature should reflect advances in the science of taxonomy and the Judicial Commission should not be indifferent to the opinion of a large majority of bacteriologists.

To avoid further confusion, I request:

(1) The rejection of the specific name *Salmonella choleraesuis* corrig. (Smith 1894) Weldin 1927 (Approved Lists 1980) as an ambiguous name [Rule 56a (1) of the International Code of Nomenclature of Bacteria (Lapage *et al.*, 1992)] because the specific epithet has been used with different meanings and thus has become a source of confusion.

(2) The recognition of the species *Salmonella enterica* (ex Kauffmann and Edwards 1952) Le Minor and Popoff 1987, sp. nov., nom. rev. The type strain is strain ATCC 13312^T = NCTC 5735^T.

This species is divided into six subspecies: (i) a new subspecies, *Salmonella enterica* subsp. *enterica* (ex Kauffmann and Edwards 1952) Le Minor and Popoff

1987 subsp. nov. (type strain ATCC 13312^T = NCTC 5735^T); and (ii) five subspecies which are new combinations [Rule 34a of the International Code of Nomenclature of Bacteria (Lapage *et al.*, 1992)]: *Salmonella enterica* subsp. *arizonae* (Borman 1957) Le Minor and Popoff 1987, comb. nov. (type strain ATCC 13314^T = CIP 8230^T = NCTC 8297^T); *Salmonella enterica* subsp. *diarizonae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987, comb. nov. (type strain NCTC 10060^T = CIP 8231^T); *Salmonella enterica* subsp. *houtenae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987, comb. nov. (type strain CIP 8232^T); *Salmonella enterica* subsp. *indica* (Le Minor *et al.* 1987) Le Minor and Popoff 1987, comb. nov. (type strain K1240^T = CIP 102501^T); and *Salmonella enterica* subsp. *salamae* (Le Minor *et al.* 1985) Le Minor and Popoff 1987, comb. nov. (type strain NCTC 5773^T = CIP 8229^T).

(3) The conservation of the name *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 (Approved Lists 1980).

Clearly, the names *Salmonella enteritidis*, *Salmonella typhi* and *Salmonella typhimurium*, included in the Approved Lists (Skerman *et al.*, 1980), were wrongly considered as species names. Historically, these species names were given to serovars by Kauffmann who defined the species as 'a group of related sero-fermentative phage types' (Kauffmann, 1961, cited by Le Minor & Popoff, 1987). According to Le Minor & Popoff (1987), this 'one serovar-one species' concept is untenable and the names *Salmonella enteritidis*, *Salmonella typhi* and *Salmonella typhimurium* are subjective synonyms of *Salmonella enterica* subsp. *enterica*. Actually, *Salmonella enteritidis*, *Salmonella typhi* and *Salmonella typhimurium* are no longer reported as species by the WHO International Collaborating Centre for *Salmonella* (Popoff & Le Minor, 1997) or by most other reference laboratories, such as the Centre National d'Études Vétérinaires et Alimentaires, Laboratoire Central d'Hygiène Alimentaire (Brisabois *et al.*, 1995).

However, the Judicial Commission is reluctant to let *Salmonella typhi* be reduced to a serovar because it is the causal agent of typhoid fever and because the use of the name *Salmonella enterica* subsp. *enterica* serovar Typhi could lead to accidents that may endanger health and life. The Judicial Commission can place a name on the list of conserved names without prejudice to the recognition or acceptance of its genetics relatedness to another taxon [for example, in spite of the scientific evidence which indicates the taxonomic relatedness of *Yersinia pestis* and *Yersinia pseudotuberculosis*, the name *Yersinia pestis* has been conserved for the plague bacillus (Judicial Commission, 1985)]. So, to reconcile the views of both the Judicial Commission and the working bacteriologists, it seems necessary to place the specific epithet *typhi* on the list of *epitheta specifica conservanda*.

On the other hand, the names *enteritidis* and *typhimurium* should apply only to serovar Enteritidis

(*Salmonella enterica* subsp. *enterica* serovar Enteritidis) and to serovar Typhimurium (*Salmonella enterica* subsp. *enterica* serovar Typhimurium), respectively.

(4) The emendation of the genus *Salmonella* Lignieres 1900 (Approved Lists 1980) with the establishment of a neotype species, *Salmonella enterica* (*ex* Kauffmann and Edwards 1952) Le Minor and Popoff 1987.

The genus *Salmonella* Lignieres 1900 (Approved Lists 1980) emend. Le Minor and Popoff 1987 consists of three species: (i) *Salmonella bongori* (Le Minor *et al.* 1985) Reeves *et al.* 1989; (ii) *Salmonella enterica* (*ex* Kauffmann and Edwards 1952) Le Minor and Popoff 1987, sp. nov., nom. rev. (type species of the genus); and (iii) *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 (Approved Lists 1980).

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