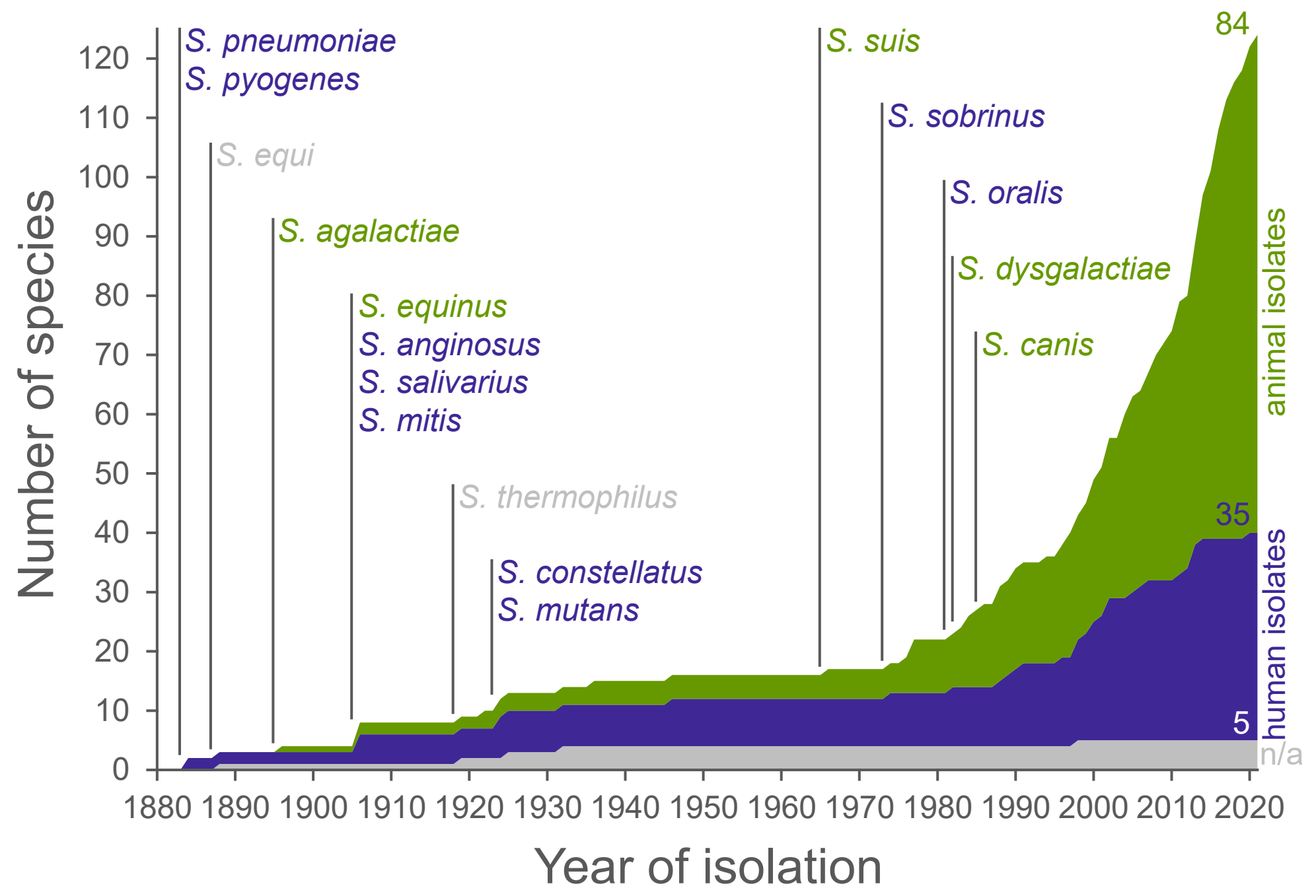


TYPICAL STREPTOCOCCUS A JOURNEY THROUGH THE GENUS

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HISTORY OF SPECIES DESCRIPTION



BACKGROUND

The German National Reference Center for Streptococci (GNRCS) has monitored invasive streptococcal disease in Germany since 1992. This includes important human pathogens like *S. pneumoniae*, *S. pyogenes*, *S. agalactiae* and *S. dysgalactiae*, but also all other streptococcal species. This is an attempt to provide an overview of the present 124 validly published streptococcal species and subspecies using the representative type-strains in combination with routine diagnostics and literature studies.

METHODS

Official type-strains of all species and subspecies of the genus *streptococcus* mentioned in the list of prokaryotic names with standing in nomenclature (LPSN) in 2021 have been analysed using haemolysis- and colony-size-assessment, leucine-aminopeptidase- (lap), pyrrolidonyl-arylamidase- (pyr), catalase- and optochine-susceptibility-test, Lancefield-typing and MALDI-Biotyper®-analysis.

RESULTS

The first streptococcal type-strains, isolated in 1884, were *S. pneumoniae* SV1 and *S. pyogenes* SF130, followed by other important pathogenic species like *S. equi* in 1888, *S. agalactiae* in 1896 and *S. mutans* in 1924. Later on, driven by technical innovations like PCR and NGS, more and more animal pathogens and commensal species were identified (**HISTORY OF SPECIES DESCRIPTION**). Only one third of the type-strains were isolated in association with human anatomical structures, while half of these human isolates are supposed to be commensals. The type-strains of most streptococcal species originated from a wide spectrum of wild and domestic animals (**ORIGIN OF SPECIES DESCRIPTION**).

With an increasing number of streptococcal species, the phylogenetic relationships within the genus gain more and more complexity, leading to the disappearance of distinct clusters which were the basis for the traditional species grouping (**PHYLOGENETIC RELATIONSHIP**). This grouping, initially introduced to combine streptococcal species by phylogenetic, pathogenic and habitat similarity is still a valuable tool for the classification of important members of the genus, but with an increasing number of species and new techniques, this system needs constant and careful evaluation (**TAXONOMIC GROUPING**).

MALDI-TOF approaches are widely used for the rapid identification of bacterial isolates, especially in medical diagnostic settings. The MALDI-Biotyper®, was able to correctly assign the species for 69 (≈56%) type-strains, including all important pathogens, while 35 (28%) were wrongly identified and 19 (15%) received no species assignment (**MALDI BIOTYPER**).

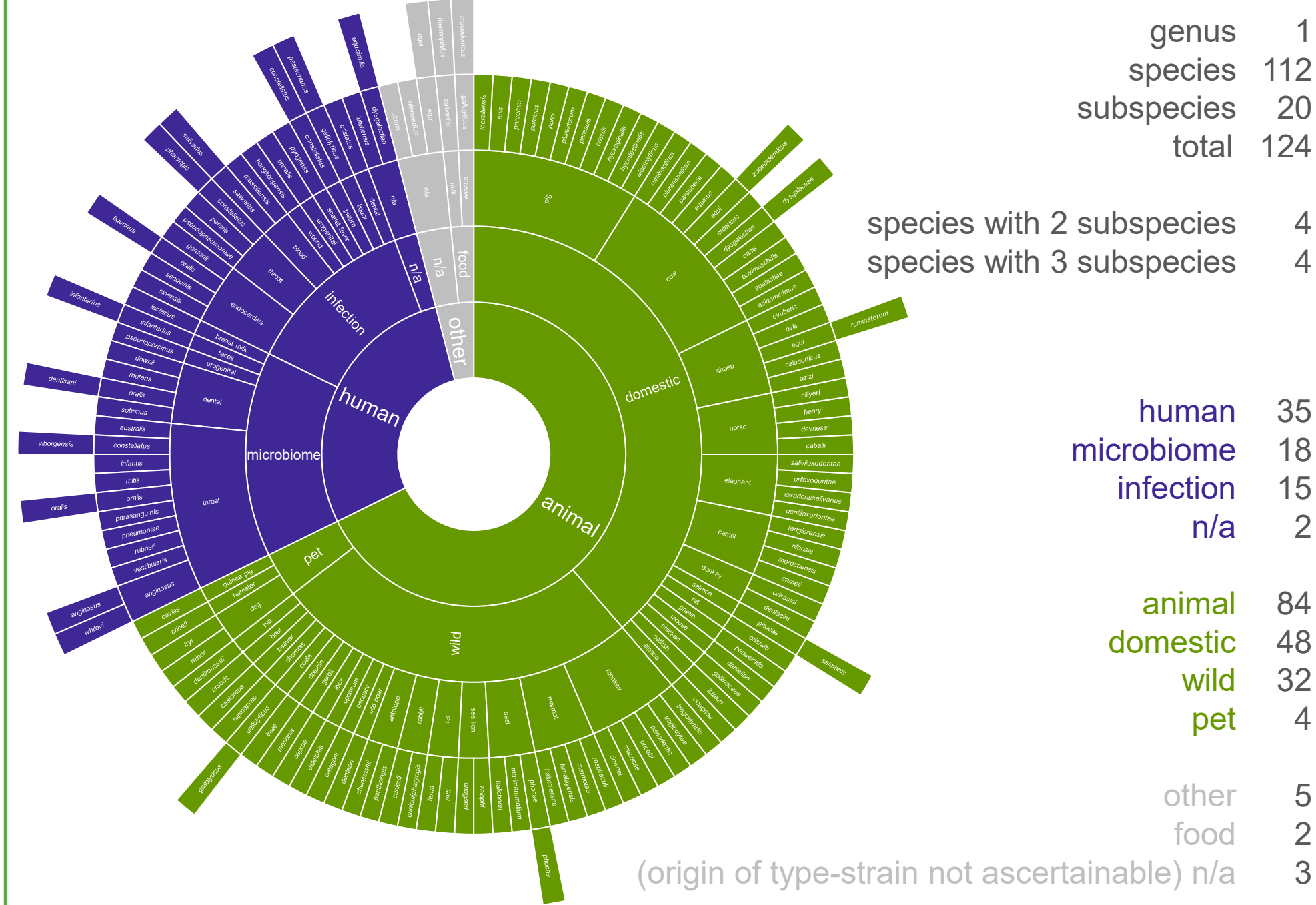
All type-strains showed a positive lap-reaction and only two strains (*S. catagoni*, *S. didelphis*) appeared to be positive in the catalase-test. All strains were optochin-resistant except for *S. pneumoniae*, while the pyr-test, to discriminate *S. pyogenes* showed positive reactions for nine other strains. 69 of the type-strains showed α -hemolysis, 19 β -hemolysis and 35 γ -hemolysis with 13% of the α -hemolytic, 63% of the β -hemolytic and 23% of the γ -hemolytic strains positive for a Lancefield-antigen, leading to attribute combinations with potential risk of confusion (**MICROBIOLOGICAL TYPING**).

The colony-size assessment of β -hemolytic streptococci, used in the classification of antimicrobial resistance guidelines, showed no significant breakpoint of the colony diameter in dependence of the phylogenetic background (**β -HEMOLYTIC COLONY SIZE**).

CONCLUSIONS

The genus *streptococcus* is constantly growing, and currently harbours 124 (sub)species. The widely used MALDI-Biotyper® is able to identify most streptococcal species associated with human infections. The combination of catalase- and lap-test reliably identifies streptococci, also recently described species. Optochin susceptibility is still a good marker to exclude pneumococci, but *S. pyogenes* isolates identified by the pyr-test need further confirmation. However, exceptions should be expected, as the presented study is limited to one strain per species.

ORIGIN OF SPECIES DESCRIPTION



TAXONOMIC GROUPING

	Kawamura et al. 1995 16S rRNA	Facklam et al. 2002 Literature review	Richards et al. 2014 130 core genes	Go et al. 2014 278 orthologous proteins	Potting et al. 2015 16S rRNA + 7 genes	combined + 16S rRNA
<i>S. pneumoniae</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. pseudopneumoniae</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. mitis</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. oralis</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. infantis</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. figuratus</i>	Mitis group	Sanguinis Group	Sanguinis Group	Mitis group	Mitis group	Mitis group
<i>S. sanguinis</i>	Mitis group	Sanguinis Group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. parvaquintus</i>	Mitis group	Sanguinis Group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. australis</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. constellatus</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group B	Mitis group
<i>S. gordonii</i>	Mitis group	Sanguinis Group	Sanguinis Group	Mitis group	Mitis group A	Mitis group
<i>S. penicillatus</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group A	Mitis group
<i>S. massiliensis</i>	Mitis group	Mitis group	Mitis group	Mitis group	Mitis group A	Mitis group
<i>S. salivarius ssp. salivarius</i>	Salivarius group	Salivarius group	Salivarius group	Salivarius group	Salivarius group	Salivarius group
<i>S. salivarius ssp. thermophilus</i>	Salivarius group	Salivarius group	Salivarius group	Salivarius group	Salivarius group	Salivarius group
<i>S. vestibularis</i>	Salivarius group	Salivarius group	Salivarius group	Salivarius group	Salivarius group	Salivarius group
<i>S. anginosus</i>	Anginosus group	Anginosus group	Anginosus group	Anginosus group	Mitis group A	Anginosus group
<i>S. constellatus</i>	Anginosus group	Anginosus group	Anginosus group	Anginosus group	Mitis group A	Anginosus group
<i>S. intermedius</i>	Anginosus group	Anginosus group	Anginosus group	Anginosus group	Mitis group A	Anginosus group
<i>S. sinensis</i>	None	None	None	None	Mitis group A	Anginosus group
<i>S. bovis</i>	None	None	None	None	None	None
<i>S. acidominimus</i>	None	None	None	None	None	None
<i>S. plauti</i>	None	None	None	None	None	None
<i>S. gallinarum</i>	None	None	None	None	None	None
<i>S. infantis</i>	None	None	None	None	None	None
<i>S. minor</i>	None	None	None	None	None	None
<i>S. canis</i>	None	None	None	None	None	None
<i>S. pharyngitis</i>	None	None	None	None	None	None
<i>S. agalactiae</i>	None	None	None	None	None	None
<i>S. canis</i>	None	None	None	None	None	None
<i>S. dysgalactiae</i>	None	None	None	None	None	None
<i>S. infantis</i>	None	None	None	None	None	None
<i>S. parvaquintus</i>	None	None	None	None	None	None
<i>S. constellatus</i>	None	None	None	None	None	None
<i>S. gordonii</i>	None	None	None	None	None	None
<i>S. penicillatus</i>	None	None	None	None	None	None
<i>S. massiliensis</i>	None	None	None	None	None	None
<i>S. salivarius ssp. salivarius</i>	None	None	None	None	None	None
<i>S. salivarius ssp. thermophilus</i>	None	None	None	None	None	None
<i>S. vestibularis</i>	None	None	None	None	None	None
<i>S. anginosus</i>	None	None	None	None	None	None
<i>S. constellatus</i>	None	None	None	None	None	None
<i>S. intermedius</i>	None	None	None	None	None	None
<i>S. sinensis</i>	None	None	None	None	None	None
<i>S. bovis</i>	None	None	None	None	None	None
<i>S. acidominimus</i>	None	None	None	None	None	None
<i>S. plauti</i>	None	None	None	None	None	None
<i>S. gallinarum</i>	None	None	None	None	None	None
<i>S. minor</i>	None	None	None	None	None	None
<i>S. canis</i>	None	None	None	None	None	None
<i>S. infantis</i>	None	None	None	None	None	None
<i>S. equi</i>	None	None	None	None	None	None
<i>S. pharyngitis</i>	None	None	None	None	None	None
<i>S. agalactiae</i>	None	None	None	None	None	None
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<i>S. parvaquintus</i>	None	None	None	None	None	None
<i>S. constellatus</i>	None	None	None	None	None	None
<i>S. gordonii</i>	None	None	None	None	None	None
<i>S. penicillatus</i>	None	None	None	None	None	None
<i>S. massiliensis</i>	None	None	None	None	None	None
<i>S. salivarius ssp. salivarius</i>	None	None	None	None	None	None
<i>S. salivarius ssp. thermophilus</i>	None	None	None	None	None	None
<i>S. vestibularis</i>	None	None	None	None	None	None
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<i>S. bovis</i>	None	None	None	None	None	None
<i>S. acidominimus</i>	None	None	None	None	None	None
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<i>S. gallinarum</i>	None	None	None	None	None	None
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<i>S. constellatus</i>	None	None	None	None	None	None
<i>S. intermedius</i>	None	None	None	None	None	None
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<i>S. bovis</i>	None	None	None	None	None	None
<i>S. acidominimus</i>	None	None	None	None	None	None
<i>S. plauti</i>	None	None	None	None	None	None
<i>S. gallinarum</i>	None	None	None	None	None	None
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<i>S. vestibularis</i>	None	None	None	None	None	None
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<i>S. constellatus</i>	None	None	None	None	None	None
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<i>S. bovis</i>	None	None	None	None	None	None
<i>S. acidominimus</i>	None	None	None	None	None	None
<i>S. plauti</i>	None	None	None	None	None	None
<i>S. gallinarum</i>	None	None	None	None	None	None
<i>S. minor</i>	None	None	None	None	None	None
<i>S. canis</i>	None	None	None	None	None	None
<i>S. infantis</i>	None	None	None	None	None	None
<i>S. equi</i>	None	None	None	None	None	None
<i>S. pharyngitis</i>	None	None	None	None	None	None
<i>S. agalactiae</i>	None	None	None	None	None	None
<i>S. canis</i>	None	None	None	None	None	None
<i>S. dysgalactiae</i>	None	None	None	None	None	None
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<i>S. salivarius ssp. thermophilus</i>	None	None	None	None	None	None
<i>S. vestibularis</i>	None	None	None	None	None	None
<i>S. anginosus</i>	None	None	None	None	None	None
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<i>S. intermedius</i>	None	None	None	None	None	None
<i>S. sinensis</i>	None	None	None	None	None	None
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<i>S. plauti</i>	None	None	None	None	None	None
<i>S. gallinarum</i>	None	None	None	None	None	None
<i>S. minor</i>	None	None	None	None	None	None
<i>S. canis</i>	None	None	None	None	None	None
<i>S. infantis</i>	None	None	None	None	None	None