
Request for an Opinion *

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Abstract

A recent taxonomic study confirmed the synonymy of *Rhodococcus equi* (Magnusson 1923) Goodfellow and Alderson 1977 and *Corynebacterium hoagii* (Morse 1912) Eberson 1918. As a result of these studies, both *R. equi* and *C. hoagii* were reclassified to *Rhodococcus hoagii* comb. nov. in application of the principle of priority of the Prokaryotic Code. Being *R. equi* a well-known animal and zoonotic human pathogen, and the name solidly established in the veterinary and medical literature, we and others argued that the nomenclatural change may cause error and confusion and be potentially perilous. We additionally have now found that the nomenclatural type of the basionym *C. hoagii*, ATCC 7005⁷, does not correspond with the original description of *C. hoagii* in the early literature. Its inclusion as the *C. hoagii* type on the Approved Lists 1980 results in a change in the characters of the taxon and in *C. hoagii* likely designating different bacteria. Moreover, ATCC 7005, the only strain in circulation under the name *C. hoagii*, does not have a well documented history; it is unclear why it was deposited as *C. hoagii* and a possible mixup with a *Corynebacterium* (*Rhodococcus*) *equi* isolate is a reasonable assumption. We therefore request the rejection of *Rhodococcus hoagii* as a nomen ambiguum, nomen dubium and nomen perplexum in addition to nomen periculosum, and conservation of the name *Rhodococcus equi*, according to Rules 56ab of the Code.

* Requests for an Opinion are a type of specialist article considered by the International Journal of Systematic and Evolutionary Microbiology (IJSEM), an official publication of the International Committee on Systematics of Prokaryotes (ICSP) and the International Union of Microbiological Societies. A Request for an Opinion formally engages the Judicial Commission of the ICSP to deliver a verdict regarding the adequacy of the nomenclature of a microorganism when strict adherence to the Rules of bacteriological nomenclature would produce chaos, or would result in nomenclatural instability.
A re-examination of the nomenclature of the animal and human pathogen *Rhodococcus equi* in the wake of its recently proposed transfer to a new genus “*Prescotella*” as “*Prescotella equi*” comb. nov. [1, 2] brought back to light the issue of the potential synonymy with *Corynebacterium hoagii* (Morse 1912) Eberson 1918 [3]. We refer for details to the expert analysis by B. Tindall [3], but a brief factual account is as follows. The first evidence that *Corynebacterium equi* (Magnusson 1923) (the basionym of *R. equi* until its transfer to the genus *Rhodococcus* [4]) and *Corynebacterium hoagii* might be heterotypic synonyms came from DNA-DNA hybridization studies reported in 1981 which found that the corresponding types were highly homologous (>88%) [5]. Subsequent numerical taxonomic [6, 7] and mycolic acid composition [8] studies also suggested a close similarity between *R. equi* and the *C. hoagii* type. As a result, *Rhodococcus equi* (Magnusson 1923) Goodfellow and Alderson 1977 and *Corynebacterium hoagii* (Morse 1912) Eberson 1918 were explicitly treated as synonyms in successive editions of *Bergey’s Manual of Systematic Bacteriology* [9-11].

Despite the above, the formal nomenclatural implications of the possibility of *Corynebacterium hoagii* (Morse 1912) Eberson 1918 being an earlier heterotypic synonym of *Rhodococcus equi* (Magnusson 1923) Goodfellow and Alderson 1977 remained unaddressed until very recently. This was in 2014 on the occasion of the description of *Rhodococcus defluvii* sp. nov. by Kämpfer et al. [12], which involved polyphasic taxonomic analyses that included the type strains of *C. hoagii* (DSM 20295T) and *R. equi* (DSM 20307T = ATCC 6939T). These studies (i) confirmed the identity of *R. equi* DSM 20307T and *C. hoagii* DSM 20295T as the same species while (ii) they did not find distinct chemotaxonomic differences or 16S rDNA-based phylogenetic separation with other rhodococci to justify the reclassification of *R. equi* into a new genus “*Prescotella*” [12] (consistent with recent compelling phylogenomic evidence [13, 14]). In application of the principle of priority of the International Code of Nomenclature of Prokaryotes, aka the “Prokaryotic code” [15], Kämpfer et al. proposed to reclassify *Corynebacterium hoagii* and *Rhodococcus equi* as *Rhodococcus hoagii* comb. nov., with DSM 20295T (= ATCC 7005T =
NCTC 10673\(^T\) as the nomenclatural type [12].

While validly published, the use of the new name *Rhodococcus hoagii* is problematic for a number of reasons. We discussed these in a recent review on *R. equi* [14] and below we summarise the main points and expand on some additional key arguments, for consideration by the Judicial Commission of the International Committee on Systematics of Prokaryotes (ICSP) for rejection of the name *R. hoagii* according to Rule 56a of the Prokaryotic Code [15]. It is beyond this RfO to address the issue of the potential illegitimacy of *Rhodococcus Zopf 1981* (bacterial genus) because a later homonym of the algal genus *Rhodococcus Hansgirg 1884*; for more information about this question we refer to ref. [16].

First, the *hoagii* epithet has remained largely in disuse, essentially restricted to an obscure type deposited in connection to biotransformative properties (https://www.lgcstandards-atcc.org/products/all/7005, see below), with no obvious link to the identity of *R. equi* as a well-known veterinary pathogen and human opportunistic pathogen [17-19]. The literature that mentions *C. hoagii* prior to its inclusion in the Approved Lists of Bacterial Names in 1980 [20] is limited to a few articles on human-associated “diphtheroids” published in the early 1900s [21-23], and to a few taxonomic studies on the “coryneforms” performed in Japan in the 1970’s where a subculture of the *C. hoagii* type ATCC 7005\(^T\) was included [24, 25].

In contrast, the *equi* epithet has been in widespread use and constantly associated with its cognate bacterial species since its discovery in 1923 by H. Magnusson as the causative agent of a severe infectious disease of foals [26, 27]. While *R. equi* can also cause opportunistic human infections and colonize other animal species [14, 17, 18, 28-30], it remains best known as a horse pathogen and thus the epithet is aptly descriptive of the species [31, 32]. Indeed, the name *R. equi* has a solid standing in human and veterinary medicine, animal science and the equine industry, and the change to *R. hoagii* is disconcerting and likely to hamper the traceability and interpretation of the medical, scientific and technical literature regarding this pathogen.

Second, the original descriptions of *C. hoagii* by M.E. Morse in 1912 [22] and F. Eberson...
in 1918 [2], and by L. Hoag himself in 1907 [21] for his “Organism X” bacillus (which Morse assumed it corresponded to a group of human “diphtheroids” she analyzed and for which she coined the epithet “hoagii”), report features that are difficult to reconcile with the known characteristics of \( R. \) equi (apart from the faint salmon-pink [21-23] to “buff” pigmentation [21], shared by a number of other bacteria). According to these early descriptions, “Organism X”/\( C. \) hoagii appears to be a relatively common human-associated coryneform/diphtheroid. Hoag found it “a number of times” in throat cultures [21] and Morse refers to these diphtheroids as the most abundant in the collection of human throat isolates she examined [21]. However, \( R. \) equi is not known to be a human commensal, only rarely infects people and, when found in human specimens, it is almost invariably associated with severe invasive infections (of suspected exogenous acquisition via exposure to livestock farming environments) [18, 29].

More importantly, furthermore, Hoag [21] and Morse [22] indicate, and Eberson relays [23], that the diphtheroid bacilli that correspond to the description of “Organism X”/\( C. \) hoagii have as a distinctive characteristic the ability to “rapidly ferment dextrose (glucose) and saccharose (sucrose)” with “marked acid formation”. Similarly, Yamada and Komagata report in 1972 that a \( C. \) hoagii isolate (AJ 1374) had the ability to produce acid from a variety of sugars (hexoses or disaccharides thereof such as glucose, fructose, mannose, sucrose, or maltose plus rhamnose, lactose and dextrin) [24]. This is at odds with the known oxidative and eminently asaccharolytic metabolism of \( R. \) equi [13, 24, 33, 34], the latter linked to the absence of phosphoenolpyruvate:carbohydrate transport system (PTS) components due to gene loss in the \( R. \) equi/\( R. \) defluvii monophyletic line of descent [13].

Third, the origin of the \( C. \) hoagii type kept in several bacterial collections, and its identity with the bacteria described by Morse, is uncertain. The strain history at the ATCC repository (https://www.lgestandards-atcc.org/) indicates that ATCC 7005 was deposited by a F.S. Orcutt at an undisclosed date (affiliation and country of origin also unknown). It refers to a patent granted in 1958 to Merk Sharp and Dohme on production of diene-steroids by certain corynebacteria, in
which ATCC 7005 was applied (Nobile A. Process for production of dienes by corynebacteria. US Patent 2,837,464), but there is no background as to why that particular strain was labeled *C. hoagii*. The ATCC entry also refers to Nesemann G. et al. German Federal Republic Patent 2,302,772 and Canadian Patent 1,022,867 by Hoechst AG from 1973/1974 in relation to a microbiological process of preparation of oxoalkylxanthines, but this seems to be an error because *C. hoagii* ATCC 7005 is not mentioned at any point in this patent (only *Flavobacterium dehydrogenans* ATCC 13930, *Arthrobacter simplex* ATCC 6946, *Mucor griseocyanus* ATCC 1207a and *Pseudomonas testosteroni* ATCC 11996 are referred to, https://register.dpma.de/DPMAregister/pat/register). The types deposited as DSM 20295T and NCTC 10673T (accession date only specified for the latter, 01/01/1969) are, like the other *C. hoagii* isolates available from other major international repositories (NBRC, JCM, CIP, CCUG), all derivatives of the original F.S. Orcutt’s ATCC 7005, the primary source and history of which, as mentioned, is not documented.

It would therefore appear that the epithet *hoagii* might have been used to designate two different types of bacteria. (i) An undefined sugar fermentative coryneform/diphtheroid commensal, as originally described by Hoag, Morse and Eberson [21-23] (and Yamada and Komagata for their AJ 1374 isolate [24]). Intriguingly, despite being described by Morse as the “largest numerically” among her collection of human-associated diphtheroids [22], this organism disappears from the medical literature after the 1920’s, possibly because recognized under a different name by others. And (ii) a *C. equi* isolate probably mistakenly deposited (likely in the 1950’s and in any case before 1969) as *C. hoagii* ATCC 7005, which then became the type strain—and only isolate in circulation— of the species [20]. Given the notorious difficulties in differentiating coryneforms in the 1950/60’s and even later, a possible mixup between two similarly looking cultures is indeed not an implausible scenario. Such mistakes are not uncommon, as illustrated e.g. by the whole genome sequence of the type strain of *Rhodococcus rhodnii* NRRL B-16535T (GenBank acc. no. GCA_000720375.1), which phylogenetically does
not belong to the rhodococci but to an unknown, distant actinobacterium [13, 14].

Taken together all the above, we believe there are sufficient grounds to consider that the name *R. hoagii* under which both *C. hoagii* and *R. equi* have been reclassified meets three of the provisions allowing the Judicial Commission to reject a name according to Rule 56a, namely:

(reason 1) an **ambiguous name** (*nomen ambiguum*), i.e. “a name which has been used with different meanings and thus has become a source of error”; (reason 2) a **doubtful name** (*nomen dubium*), i.e. “a name whose application is uncertain”; and (reason 4) a **perplexing name** (*nomen perplexum*), i.e. “a name whose application is known but which causes uncertainty in bacteriology” [15].

Furthermore, and most importantly, the application of an unfamiliar epithet such as *hoagii* to the well-known animal and human pathogen *R. equi* we believe meets the definition of Rule 56a (reason 5) for rejection: a **perilous name** (*nomen periculosum*), i.e. “a name whose application is likely to lead to accidents endangering health or life or both or of serious economic consequences” [15]. There are indeed real chances of potential misdiagnoses or inaccurate risk assessments, with significant consequences to health and the economy, as a result of the introduction of the new name *R. hoagii* to designate a pathogenic microbe and zoonotic agent with a previously well-established, highly visible and recognizable name.

In an accompanying note to Rule 56a (5) it is stated that if the Judicial Commission recognizes a high order of risk to health, or of serious economic consequences, an Opinion may be issued that the taxon be maintained as a separate nomenspecies, without prejudice to the recognition or acceptance of its genetic relatedness to another taxon [15]. It is obvious that this note had in mind the example used to illustrate the application of Rule 56a (5), i.e. *Yersinia pseudotuberculosis* subsp. *pestis*, whereby Opinion 60 [35] places this name in the list of **nomen rejicienda** (rejected) and maintains de facto both *Y. pseudotuberculosis* and *Yersinia pestis* as two separate nomenspecies. The strict application of this interpretation may imply that the names *R. equi* and *R. hoagii* should be maintained as independent nomenspecies. We believe there is no
justification for this in the case of *R. equi*/*hoagii*, and can even lead to further uncertainty and
(dangerous) confusion. While *R. hoagii* clearly falls under the definition of *nomen periculosum*
as given in the Code, the situation is very different from that of *Y. pseudotuberculosis* and *Y.
pestis* for a number of reasons.

Thus, despite *Y. pseudotuberculosis* and *Y. pestis* being genetically closely related and
the latter having derived clonally from the former in relatively recent evolutionary times
(≈4,000-10,000 years ago), both form genomically distinct groups with a clearly distinguishable
differential pathogenicity [36-39] and therefore they warrant being treated as independent
species. In contrast, *R. hoagii* and *R. equi* are genomically the same biological entity, as can be
readily appreciated by a simple comparative analysis of the whole-genome sequences of *R.
hoagii* DSM 20295$^\text{T}$ = ATCC 7005$^\text{T}$ (GenBank acc. no. GCA_001646645.1) and the *R. equi* type
strain ATCC 6939$^\text{T}$ (Fig. 1) (or any other sequenced *R. equi* isolate; all are remarkably
genetically homogeneous [13]). It could be argued that *R. equi* might be applied as a
nomenspecies to the equine isolates only, and *R. hoagii* to the rest of the strains, including all
isolates from other animal species and humans. However, this possibility cannot be contemplated
because the same *R. equi* strain can be found associated with different animal hosts depending on
the type of virulence plasmid they carry, or as an environmental saprophyte where the virulence
plasmid is often lost (see next). Indeed, recent evidence indicates that three host-adapted
conjugative virulence plasmids, designated pVAPA, pVAPB and pVAPN, each carrying a host-
specific variant of the same *vap* pathogenicity island, determine *R. equi* host tropism for,
respectively, equines, porcines and ruminants [29, 40, 41]. These virulence plasmids are not
linked to a specific *R. equi* genomic type but are horizontally exchangeable across the species’
population structure (associated with corresponding host jumps) [13, 29], and the three plasmid
types can be indistinctly found in isolates recovered from non-adapted (opportunistic) animal
hosts (e.g. humans) [14, 28]. The virulence plasmids are also easily lost in the absence of host
selection (i.e. upon *in vitro* growth or in the environment [28, 29, 42]; this is the case of the *R.*
equi type strain ATCC 6939T, which lacks the pVAPA virulence plasmid despite originally being an equine clinical isolate [13, 29]). In addition, regarding the epithet hoagii, before the new combination bearing it was established in 2014 to encompass both \textit{C. hoagii} and \textit{R. equi} [12], the taxon with the basionym \textit{C. hoagii} was virtually restricted to a sole recognized isolate, the nomenclatural type ATCC 7005T. Moreover, the origin of this strain is uncertain, in contrast to the \textit{R. equi} type ATCC 6939T, which has an earlier deposition number and a well-documented history (derives from NCTC 1621, in turn an original isolate from H. Magnusson who discovered the species in 1923). Furthermore, as discussed above, there are also powerful reasons to believe that the name \textit{C. hoagii} might have been arbitrarily or accidentally coopted to deposit under ATCC 7005 a bacterium that does not correspond to the glucose- and sucrose-fermenting diphtheroid described by Morse in 2012 [22] and F. Eberson in 1918 [23], but which actually was a \textit{C. equi} isolate, in those times already commonly represented in bacterial collections.

Some of the points put forward here have been previously raised by G. Garrity [43] in his well-argued Request for an Opinion (RfO) to ICSP’s Judicial Commission for the conservation of the name \textit{R. equi} and rejection of \textit{Corynebacterium hoagii}. However, since then \textit{Corynebacterium hoagii} and \textit{R. equi} have been officially reclassified as \textit{Rhodococcus hoagii} comb. nov. by Kämpfer et al. [12] and this nomenclatural act included in a Notification List [44]. We have also identified significant additional issues regarding the \textit{R. hoagii} type 7005T which cast reasonable doubts as to whether it indeed corresponds to the same organism which Morse and Eberson described as \textit{C. hoagii} in 1912/1918 [22, 23] formally setting the priority of the name. We are therefore hereby submitting a request for an opinion to the Judicial Commission for the conservation of \textit{Rhodococcus equi} (Magnusson 1923) Goodfellow and Alderson 1977 as the correct name of the species, and rejection of \textit{Rhodococcus hoagii} (Morse 1912) Kämpfer et al. 2014.

If the Judicial Commission takes into consideration this request and declares \textit{R. hoagii} as
a rejected name, a simple and practical solution to resolve the nomenclatural conundrum around

*R. equi* would be to recognize the lack of proper documented evidence, and potential mistake

and permanent source of error, with the ATCC 7005 deposition, and reclassify the nomenclatural

type originally bearing the epithet *hoagii* as *R. equi* ATCC 7005. Since the type of the basonym,

*C. equi* ATCC 6939<sup>T</sup> was deposited earlier, the *R. equi* type should revert to this strain.

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**Conflict of interest**

The authors declare no conflict of interest.

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FIGURES

**Fig. 1.** Whole genome sequences of strains DSM 20307$^T$ ( = ATCC 6939$^T$, type strain of *Rhodococcus equi*; GenBank assembly accession GCA_002094305.1) and DSM 20295$^T$ ( = ATCC 7005$^T$, type strain of *C. hoagii*; GenBank assembly accession GCA_001646645.1) compared to the reference (complete) genome sequence of *R. equi* (*hoagii*) isolate 103S (NCBI RefSeq NC_014659.1) [14]. Alignment constructed with Mauve software (http://asap.ahabs.wisc.edu/mauve/). Similarity plot is in pink, height indicates level of similarity; plot pointing downwards indicates similarity to the reverse strand of the genome. White regions represent fragments that were not aligned or contain genome-specific sequences. Red vertical divisions indicate contigs. Note the dominant solid pink sequence segments which denote near complete conservation between the genomes, consistent with the high degree of genomic relatedness between *R. equi* (*hoagii*) isolates [13]. Pairwise Average Nucleotide Identity (ANI): 103S/DSM 20295 = 98.85%, 103S/DSM 20307 = 99.14% (calculated with FastANI 1.3).
Figure 1