

Pursuit of the *Corynebacterium striatum* Type Strain

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The description of *Corynebacterium striatum* (Chester 1901) Ebersson 1918^{AL} in *Bergey's Manual of Systematic Bacteriology* has many inconsistencies with the identification scheme from the Centers for Disease Control and Prevention. We have studied the four *C. striatum* reference strains available from the American Type Culture Collection and the National Collection of Type Cultures and found that they fit the Centers for Disease Control and Prevention description of this species. However, it appears that the wrong strains were deposited for this species, because none of the reference strains fits the descriptions in the original publications. This is a substantial case for declaring it a nomen dubium, but the name could be rescued if a careful search reveals a strain that was used in making the original description. It is hoped that some readers may have the missing strains labeled with the early names *Bacillus striatus*, *Bacillus flavidus*, or *Corynebacterium flavidum*.

Two major resources for identification of *Corynebacterium striatum* (Chester 1901) Ebersson 1918^{AL} (20) have substantial disagreements in their descriptions of this species (11, 15). The purpose of this study was to analyze the original descriptions of organisms presumed by subsequent authors to be *C. striatum* and compare them with all reference strains of this species currently available from the American Type Culture Collection (ATCC) and the National Collection of Type Cultures (NCTC). We have found that none of the four available reference strains of *C. striatum* (ATCC 43735, ATCC 43751, and the type strains, ATCC 6940 and NCTC 764) fits any of the three original descriptions which authors have cited for this species (17, 18, 21).

The nomenclature of *C. striatum* has had an unusually complex history since it was first described as *Bacillus striatus* by vonBesser in 1889 (21). Table 1 summarizes the various names attributed to *C. striatum* and shows all publications cited in the various editions of *Bergey's manual of determinative bacteriology*. In *Bergey's manual of systematic bacteriology*, *C. striatum* stands as an accepted species and is presented with the complete morphological and biochemical details that were first compiled for the seventh edition of *Bergey's manual* (9, 11). Such agreement on *C. striatum* has not been a consistent feature of past editions of *Bergey's manual*. The eighth edition (19) listed *C. striatum* under *species incertae sedis*, and the sixth edition placed it in an appendix of incompletely described organisms while making no attempt to present a description of the species (8). Interestingly, the descriptions of *Corynebacterium flavidum* found in the first five editions of *Bergey's manual* (2-6) contained more biochemical details than were presented in their cited source, which was Morse's description of *Bacillus flavidus* (17). Subsequent *Bergey* editions (9, 11, 19) supplemented their description of *C. striatum* with details from Munch-Petersen's characterization of *C. flavidum* (18).

Table 2 summarizes the characteristics of *C. striatum* strains described by vonBesser, Morse, *Bergey's manuals*, Munch-Petersen, and the Centers for Disease Control (CDC). VonBesser's description of *B. striatus albus* and *B. striatus flavus* contained detailed descriptions of morpholog-

ical features but none of biochemical reactions (21). In 1912, Morse reported that *B. flavidus* was able to produce acid from glucose and maltose but not sucrose and presented a photomicrograph depicting thick cells with distinct bars (17). Ebersson concluded that Morse's *B. flavidus* was identical to vonBesser's *B. striatus*, a single species with the two varieties, *albus* and *flavus* (13). The next original paper describing *C. striatum* was not published until 1954, when Munch-Petersen isolated bovine coryneforms (*C. flavidum*) that produced an inhibitor of the beta-hemolysin of *Staphylococcus aureus* (18). Presumably because of glucose, maltose, and sucrose reactions, Munch-Petersen believed that his isolates matched the *B. flavidus* strains described by Morse fairly well.

The authors of the *C. striatum* sections in recent editions of *Bergey's manual* made the point that detailed comparisons between human and bovine strains have not been made and that there is considerable doubt whether more than one group of strains is being described under the name *C.*

TABLE 1. Summary of citations in references thought to be describing *C. striatum*^a

Reference	Yr	Name(s) of organism	References cited
21 ^b	1889	<i>B. striatus albus</i> and <i>B. striatus flavus</i>	None
10	1901	<i>B. striatum</i>	21
17 ^b	1912	<i>B. flavidus</i>	None
13 ^c	1918	<i>C. striatum</i>	10, 17, 21
14	1920	<i>C. flavidum</i>	17
2	1923	<i>C. flavidum</i>	17
5	1925	<i>C. flavidum</i>	17
6	1930	<i>C. flavidum</i>	17
3	1934	<i>C. flavidum</i>	2, 17
4	1939	<i>C. flavidum</i>	2, 17
8	1948	<i>C. striatum</i>	10, 13, 17, 21
18	1954	<i>C. flavidum</i>	4, 17
9	1957	<i>C. striatum</i>	10, 13, 17, 18, 21
19	1974	<i>C. striatum</i>	10, 13, 17, 18
11	1986	<i>C. striatum</i>	10, 13, 18

^a The table only includes references mentioned in various editions of *Bergey's manual*.

^b VonBesser and Morse did not cite references for *B. striatus* and *B. flavidus*, respectively.

^c On the basis of his own studies, Ebersson agreed with Morse that vonBesser was dealing with one organism that is capable of producing pigment varying from white to yellow.

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TABLE 2. Comparison of three original descriptions with Bergey's and CDC's summaries of organisms believed to be *C. striatum*

Trait	vonBesser (1889)	Morse (1912)	Bergey (1923 to 1939)	Munch-Petersen (1954)	Bergey (1986)	CDC ^a
Name	<i>B. striatus albus</i> and <i>B. striatus flavus</i>	<i>B. flavidus</i>	<i>C. flavidum</i>	<i>C. flavidum</i>	<i>C. striatum</i>	<i>C. striatum</i> ATCC 6940
Microscopic appearance						
Growth medium	NS ^b	24-h serum	NS	24-h broth	NS	NS
Shape	Often curved	Thick forms	Varies considerably	Pleomorphic	Pleomorphic, often club shaped	NS (Curved cells on agar)
Size	<i>B. striatus albus</i> small, approx. the size of diphtheria bacillus; <i>B. striatus flavus</i> larger	Large	0.75–1.0 × 3.0–5.0 μm	0.25–0.5 × 2–3 μm	0.25–0.5 × 2.0–3.0 μm	Short to slightly long
Barring and/or granulation	Conspicuous beaded staining with methylene blue	Clear-cut bars; predominant very large, irregular Neisser's granules	Barred	Fairly large metachromatic granules	Metachromatic granules often regularly arranged to give segmented effect	Beaded
Clubbing	Club forms seen in older cultures	Photomicrograph shows no club forms ^c	Club shaped	Many club shaped	Often clubbed	Club and dumbbell forms
Colonies on agar	Convex, ~0.5 mm diam, large brown center surrounded by a brownish zone seen with ×60 magnification	NS ^d	Spreading, adherent, wrinkled, or corrugated radially	Growth only visible after 48 h; day 5: 1–1.4 mm diam, white, smooth, entire, heaped up	Rather slow growth; white, smooth, entire; diam, ~1 mm at 48 h	NS (convex, smooth; 2 mm in 48 h)
Pigment on agar	<i>B. striatus albus</i> , milky colored; <i>B. striatus flavus</i> , sulfur yellow after several days	NS	Yellowish	Yellowish-green pigment, soluble in medium, produced by 8 strains ^e	Some produce yellowish-green pigment soluble in medium	NS (gray-white)
Pigment in liquid culture	NS	Yellowish or yellow-white	NS	White	White	NS (white)
Growth in broth	Little turbidity but significant sediment	In serum, heavy growth, often noticeably dry and granular	Thin pellicle	Already visible after 24 h; excellent growth, clear supernatant, finely granular sediment, easily suspended; no growth on surface	Clear supernatant, no pellicle, finely granular sediment	NS (heavy turbidity)
Hemolysis on blood agar	NS	NS	May show slight hemolysis	Slight hemolysis around deep but not surface colonies	Slight hemolysis around deep colonies	Lysis (not hemolytic)
Litmus milk reaction	NS	NS	Slightly acid, becoming slightly alkaline	No change in 5 days; may be reduced in 3 wk	NS	Indicator reduced
Gelatin liquefaction	NS	NS	– ^b	d (11/19 weak in 2 wk) ^b	(~50%)	–
Indole reaction	NS	NS	–	–	–	–
NO ₃ to NO ₂	NS	NS	–	–	–	+

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TABLE 2—Continued

Trait	vonBesser (1889)	Morse (1912)	Bergey (1923 to 1939)	Munch-Petersen (1954)	Bergey (1986)	CDC ^a
Carbohydrate acidified						
Glucose	NS	+ (always)	+	+ (19/19)	+	+ (100%)
Maltose	NS	+ (usually)	+	d (15/26)	+ (usually)	— (0%)
Glycerol	NS	+ (usually)	+	d (7/23)	NS	NS
Xylose	NS	NS	NS	— (0/11)	NS	— (0%)
Mannitol	NS	NS	NS	d (2/14)	NS	— (0%)
Lactose	NS	NS	NS	+ (13/14)	+ (usually)	— (0%)
Sucrose	NS	—	NS	— (1/14)	— (occasionally)	+ (100%)
Methyl red/ Voges-Proskauer	NS	NS	NS	d (2/19)/—	—/NS	d (80%)/— (6%)
Metabolism	NS	NS	Aerobic, facultative	Aerobic, facultative ^f	Aerobic, facultative	A/A on TSI ^g
Catalase reaction	NS	NS	NS	+	+	+
Inhibition of beta-hemolysin of <i>S. aureus</i>	NS	NS	NS	+	NS	NS (—)
Virulence in laboratory animals						
Mice	None	NS	NS ^h	Lethal in 6–13 days ⁱ	Fatal	NS
Guinea pigs	NS	None ^j	NS	Lethal in 1–3 days ⁱ	Fatal	NS
Rabbits	None ^k	NS	NS	NS	NS	NS
Habitat	Normal respiratory tract	Throat	Nose and throat, udders of cows with mastitis ^l	Infected cow udders	Human nasopharynx, milk of cows with mastitis	NS

^a Authors' results, when different from those of CDC, are given in parentheses.

^b Symbols and abbreviations: NS, not specified; +, 90% or more of strains positive; —, 10% or fewer strains positive; d, 11 to 89% of strains positive. Numbers in parentheses indicate number of strains positive out of the total number of strains.

^c Photomicrographs of other coryneform groups in Morse's paper did show wedge shapes or club shapes.

^d Morse omitted solid media to avoid the pitfalls of earlier methods that named diphtheroids on the basis of "slight peculiarities in morphology, etc."

^e Munch-Petersen did not clearly specify whether the total number of strains studied for pigment production was 19, 26, or 31.

^f Implied but not specifically stated.

^g Acid slant and butt on triple sugar iron agar.

^h These references stated that *C. flavidum* is pathogenic for unspecified types of laboratory animals.

ⁱ Intramuscular inoculations.

^j Subcutaneous inoculations of an unspecified small number of strains had no effect.

^k Hemorrhagic reddening at the subcutaneous injection site resolved after 2 days. Intraperitoneal and intravenous injections caused no reaction.

^l The paper states that "similar organisms have been found in udders of cows with mastitis."

striatum (11, 19). On the basis of the morphology and virulence descriptions from Munch-Petersen and Morse, it seems highly unlikely that the *C. flavidum* from the milk of cows with mastitis was the same as Morse's *B. flavidus* from human specimens submitted to rule out diphtheria. *C. flavidum* did not have the clear-cut bars of *B. flavidus*, whereas the club shapes that were reported to be common in *C. flavidum* cells are not apparent in Morse's photomicrographs of *B. flavidus* (17, 18). However, it is difficult to directly compare morphologic descriptions in the two studies, because Morse avoided the use of solid media. A comparison of the virulence studies of Morse and Munch-Petersen provides further evidence that they were dealing with two different organisms (Table 2).

The fact that Morse and Munch-Petersen probably were describing different organisms might not cause much concern if the type strain of *C. striatum* (ATCC 6940) actually conformed to either author's description. However, we have

studied the four *C. striatum* strains from both the ATCC and the NCTC and found that none of them fits the description by either Munch-Petersen or Morse. Surprisingly, molecular and biochemical comparisons of all ATCC and NCTC strains of *C. striatum* and *Corynebacterium xerosis* have revealed that all of the reference strains of *C. striatum* are closely related to three reference strains of *C. xerosis* (ATCC 7094, ATCC 9016, and NCTC 9755) (12).

The reactions of *C. striatum* in the CDC system and Bergey's differ for 4 of the 13 biochemical tests that they have in common (nitrate reduction, maltose, lactose, and sucrose) (11, 15). These discrepancies can be explained by the fact that the Bergey descriptions are based on the published description by Munch-Petersen (12a), whereas the CDC description is based on reactions of the currently available type strain, ATCC 6940. As summarized in Table 2, we have found that the *C. striatum* reference strains conform to the CDC description, with the single exception

that they are not hemolytic on sheep blood agar. We are not aware of recent isolations of organisms that fit the description of *C. striatum* found in reference 11.

In cases such as this, when there is no possibility of the type being a mutant of the original, the name would become a nomen dubium (rule 56a, Bacteriological code) and should be referred to the Judicial Commission for a formal rejection, justified by the lack of accord between the properties of the type and the description. However, if a careful search reveals a strain or strains used in the original description agreeing in its characteristics, then a neotype can be proposed (rule 18c). Therefore, this paper forms part of the careful search. It is hoped that some readers will recognize that they have old stock cultures labeled *B. striatus*, *B. flavidus*, *C. flavidum*, or *C. striatum* that actually fit an original description of any of these organisms as summarized in Table 2. Such strains could then be studied by modern taxonomic methods and assigned to the correct taxa. The English literature contains only three reports of infections due to *C. striatum* (1, 7) or *C. striatum*-like organisms (16). Although this may simply reflect the relatively low virulence of this species, it seems likely that many potential case reports were not written because the conflicting identification schemes for *C. striatum* precluded definitive identifications.

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