

## THE NOMENCLATURE AND CLASSIFICATION OF THE ACTINOMYCETES<sup>1</sup>

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Since the publication by one of us (Waksman, 1940) of a system of classification of actinomycetes, considerable criticism was expressed in regard to the designation and position of the anaerobic pathogenic species, the cause of common actinomycosis in man and "lumpy jaw" in cattle. This type of organism was placed in the genus *Cohnistreptothrix* Pinoy, the generic name *Actinomyces* being reserved for the aerobic species forming aerial mycelium-bearing spores. This could be justified on the ground that the organism seen by Harz was so poorly described and illustrated that it is unrecognizable by present day standards, and that therefore a new name could well be applied to the organism of actinomycosis in cattle; that further the name *Actinomyces* was the first one applied to cultivated, aerobic, spore-forming species which can be recognized by present day standards. This has been the attitude of a number of recent medical mycologists, especially the Italian workers (Ciferri and Redaelli, 1929; Baldacci, 1939).

Critics of Waksman's classification have, however, maintained that while Harz' description of his organism is perhaps vague, there is no question concerning the nature of the disease he studied, and that the chances are overwhelmingly in favor of his having actually observed the anaerobic pathogenic filamentous organism first described by Israel. Further, under the Botanical Code, the name *Actinomyces* must be applied either to the organism of "lumpy jaw" or not used at all.

This problem became particularly significant in view of the need for the revision of the *Actinomycetales* for the sixth edition of Bergey's Manual which is being undertaken by the authors of this paper. We have been reluctant to deviate from Waksman's classification because we have felt that to abandon the name *Actinomyces* for the large group of aerobic spore-forming species would cause more confusion than to adopt the name *Cohnistreptothrix*, already in wide usage, for the anaerobic, pathogenic species. It appears, however, that under the code we have no such choice open to us. We believe that, to avoid similar dilemmas in the future, the code should be modified to permit generic names in wide usage based upon *type cultures* to have priority over names based merely upon morphologic descriptions.

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<sup>2</sup> The Editor desires to record with the deepest regret the death of Dr. Henrici some ten days after this paper was submitted.

It is our desire in this paper to present a classification of these organisms which will retain the morphological subdivisions presented by Waksman (1940), as seems to be considered desirable by most workers in this field, but to apply to these subdivisions names which will be acceptable under the Microbiological Code, and which we hope will become permanent, thus ending the intolerable confusion now existing.

If the name *Actinomyces* is to be restricted to the anaerobic, pathogenic species, a new generic name must be found for the aerobic, saprophytic spore-forming species. We have carefully reconsidered all of the names previously applied to organisms of this type. It is not necessary here to discuss the non-validity of such names as *Streptothrix*, *Cladothrix*, *Actinocladothrix*, *Discomyces*, *Oospora*, etc. which must be rejected either because they were first applied as synonyms of *Actinomyces* or were previously applied to entirely different sorts of organisms. The name *Nocardia*, however, requires special consideration.

This name, introduced by Trevisan in 1888, has been widely applied, sometimes to all of the actinomycetes, sometimes to the saprophytic aerobic species only. Breed and Conn (1919) clearly state the status of this name as follows:

In the original paper, as in the paper by DeToni and Trevisan, five species are given in the genus, the first of these being *N. farcinica* Trevisan, the species described, but not named, by Nocard (1888). While this species is not definitely named as the type species, there is not the slightest question but that Trevisan regarded it as the type species of the new genus. *N. actinomyces* Trevisan (Syn. *Actinomyces bovis* Harz) is given as the second species followed by *N. foersteri* (Cohn) Trevisan (Syn. *Streptothrix foersteri* Cohn).

The species *N. farcinica* must therefore stand as the type species if the term *Nocardia* is used no matter what limits are set for the genus.

Breed and Conn further concluded that:

There appears to be no justification for the use of the term *Nocardia* Trevisan for the entire group of organisms included in the Actinomycetaceae. It may however be properly used for a subdivision of the genus *Actinomyces*, provided however *N. farcinica* is retained in the genus *Nocardia* and is established as the type of the genus.

Now just such a situation has arisen. It has become increasingly apparent through the work of several people, but especially that of Ørskov (1923) and Jensen (1931), that the organisms which have been grouped together as actinomycetes can be rather sharply subdivided into a group which multiplies by fragmentation of the mycelium into oidia and a group which multiplies by the production of spores in aerial hyphae. To the former group Jensen gave the generic name of *Proactinomyces*.

If, however, the position of Breed and Conn is sound (and it seems so to us), the name *Nocardia* must have precedence over *Proactinomyces*, for there is no doubt that the species described by Nocard is a typical *Proactinomyces* in the sense of Jensen.

In addition to Nocard's original description, the characteristics of the organism which he isolated from "farcin du boeuf" have been studied from authentic subcultures by Musgrave, Clegg and Polk (1908), Ørskov (1923), and Lieske (1921), all of whose descriptions are in essential agreement. The multiplication

by fragmentation of the mycelium and the lack of aerial hyphae-forming spores is clear in nearly all of these descriptions. Acidfastness, a character common to a number of species of the genus *Proactinomyces* Jensen, was described by Feistmantel (1902). Apparently subcultures of this organism were distributed for some time from the Pasteur Institute and from the Kral collection, and authentic cultures are possibly still extant, though it is questionable whether the culture listed as *Actinomyces farcinicus* in the American Type Culture Collection is this species.

We conclude therefore that *Nocardia* Trevisan is the valid name for the aerobic, fragmenting non-sporulating types of actinomycetes, having priority over *Proactinomyces* Jensen.

There remains the consideration of valid names for the aerobic sporulating species. We have not found in previous literature any valid generic name which can be applied to those species which produce spores in chains, spores that are apparently formed within the hyphae, and which are characteristic of the large group of saprophytic soil actinomycetes. It is true that Wollenweber (1921) proposed to divide the genus *Actinomyces* into two subgenera, *Pionnothrix* lacking aerial mycelium, and *Aerothrix* with aerial mycelium, and it might be argued that the latter is a valid generic name for the spore-forming species. But the species listed under these two subgenera indicate that Wollenweber missed the essential differential character, which is not the production of aerial hyphae, but the production of spores. After surveying this situation we have with reluctance concluded that the only solution for this problem is to coin a new generic name for the aerobic, saprophytic actinomycetes which form catenulate spores, and we propose the name *Streptomyces*, which, so far as we can learn has never been used before and which indicates the essential character of the group. Since the Botanical Code recommends that family names be derived from generic names, the new family name for the spore-forming actinomycetes is proposed as *Streptomycetaceae*.

**Family Streptomycetaceae.** Actinomycetes with branched slender mycelium, rarely or not septate, forming spores on aerial hyphae, not fragmenting into oidia. There are two genera, *Streptomyces* and *Micromonospora*.

**Genus *Streptomyces*.** *Streptomycetaceae* forming spores in chains on aerial hyphae. Spores are apparently endogenous in origin, formed by a segregation of protoplasm within the hypha into a series of round, oval or cylindrical bodies. Chains of spores are often spirally coiled. Sporophores may be simple or branched.

We have selected as the type species of this newly-named genus, *Streptomyces albus* (Rossi-Doria emend Krainsky) comb. nov. This species was formerly known as *Actinomyces albus* Krainsky and first described as *Streptothrix alba* Rossi-Doria. This is one of the commonest and best known species of the group, and while it may later be subdivided into further species, it is at present as definite as any others. It has been recently studied intensively by Duché (1934) and by Baldacci (1939). It is colorless with white aerial mycelium, forming ovoidal spores in coiled chains on lateral branches of the aerial hyphae. It is

proteolytic, liquefying gelatin and peptonizing milk with the production of an alkaline reaction in the latter. It does not produce any soluble pigment either on an organic or synthetic medium, but does produce a characteristic earthy or musty odor.

The name *Micromonospora* Ørskov, applied to those forms which produce single conidia on lateral branches, is apparently still valid. It is true that Tsiklinsky (1899) had previously applied the name *Thermoactinomyces* to species of this group, whose identity is clear from photomicrographs. But in her description of the genus she also included thermophilic species with catenulate spores, basing the genus on temperature relations rather on morphology.

Finally we wish to remark on the proposal by Stanier and van Niel (1941) that the genus *Mycobacterium* be transferred from the *Actinomycetales* to the *Eubacteriales*. We believe that those who have extensively studied microorganisms within this group, especially the pathogenic actinomycetes, will agree that such a separation is too violent and unnatural. One frequently finds strains which require much careful study before it can be decided whether they are to be considered as mycobacteria or actinomycetes. Strains may form mycelium for only a few hours, then fragment into bacillary forms; or may form mycelium for a few transfers when freshly isolated, and appear forever afterwards only as acidfast rods. There are also known organisms transitional between the actinomycetes and the staphylococci. It is possible that Badian's cytological studies may eventually show a relationship between the endospores of the *Bacillaceae* and those of the group we have designated as *Streptomyces*. All of these considerations lead us to believe that a more natural system would be arrived at by transferring the gram-positive bacteria from the *Eubacteriales* to the *Actinomycetales* than to transfer *Mycobacterium* to the *Eubacteriales*. Present knowledge however does not justify so drastic a change, but we prefer to retain the acidfast bacteria in the *Actinomycetales*. We do agree with Stanier and van Niel that the gram-negative genus *Mycoplana* should not be retained within this order. We also agree with Stanier and van Niel as well as with Breed that the genus *Corynebacterium* be transferred to the *Lactobacteriaceae*.

In view of the above considerations we propose the following nomenclature and classification of the *Actinomycetales* which we hope will satisfy both the Microbiological and Botanical Codes and the taxonomic data:

- A. Mycelium rudimentary or absent. Family *Mycobacteriaceae* Chester
  - I. Acidfast organisms. *Mycobacterium* Lehmann and Neumann.
- B. True mycelium produced.
  - I. Vegetative mycelium fragments into bacillary or coccoid elements.
    - a. Anaerobic or microaerophilic, parasitic, not acidfast. Family *Actinomycetaceae* Buchanan.
    - b. Aerobic, partially acidfast or non-acidfast. *Actinomyces* Harz.  
*Nocardia* Trevisan.
  - II. Vegetative mycelium not fragmenting into bacillary or coccoid elements.
    - a. Multiplication by conidia in chains from aerial hyphae. Family *Streptomycetaceae* Waksman and Henrici.
    - b. Multiplication by single terminal spores on short sporophores. *Streptomyces* Waksman and Henrici.  
*Micromonospora* Ørskov.

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