

What's in a Name? The Genus *Citrobacter*

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The ability to reliably identify bacterial pathogens in clinical specimens is a major function for the clinical microbiologist. Working with a biological system however does not always make this an easy task. Additionally, the classification of bacteria into species is an artificial process where boundaries are set by humans and thus the identification of a bacterium becomes a subjective process.

Currently, the most accurate method for species identification involves a polyphasic approach to classification including the integration of genotypic, phenotypic, and chemotaxonomic features of an organism. Complete genomic sequencing is considered the standard for species delineation but complete sequences are not available for most bacterial species. Therefore, techniques such as DNA-DNA hybridization analysis and direct sequence analysis of various target genes have been a reliable standard for species identification in the interim. Results show that the phenotypic and chemotaxonomic features generally agree with the genomic information for most bacterial species.

Classification of bacteria to species also includes the process of naming new species. In this recent period of genomic sequencing, the variety and number of new and reclassified species has become a challenge for the laboratorians. When new species are named or when old species are re-named, the naming must follow the rules of the *Bacteriological Code*. To be validated, a species name that is published in any peer-reviewed journal must subsequently be placed on a validation list in the *International Journal of Evolutionary and Systematic Bacteriology* (formerly *International Journal of Systematic Bacteriology*) (IJSEM) or the new species name must be published as a full report in the IJSEM.

Prior to the availability of genomic methods to identify species, many bacterial species unknowingly had multiple validated names published in the IJSEM for what eventually turned out to be the same species. Thus each name is valid according to the rules of bacterial nomenclature. One example of multiple names for the same species would be the names of *Pseudomonas maltophilia*, *Xanthomonas maltophilia*, and *Stentrophomonas maltophilia*, all species names considered valid for the same organism. This certainly adds to the confusion for the identification and reporting of bacterial species.

The new genomic techniques now available for species identification also lead to problems for the clinical microbiologists in the ability to differentiate and identify completely a microbial pathogen. The routine phenotypic methods are not sensitive enough for species identification in many cases, thus requiring genotypic methods not available in most laboratories. This has resulted in the use of “group” or “complex” names to include multiple species in a report. This article will be a part of an ongoing series to provide guidance for the clinical microbiologist in how to most accurately report the identity of a bacterial pathogen.

The Genus *Citrobacter*. The genus *Citrobacter* within the family *Enterobacteriaceae* is composed of 11 unique species that includes 12 valid names organized into 3 major subgroups (**Table**). Subgroup A consists of 8 species which have similar phenotypic and genotypic characteristics. These species in most cases cannot be reliably identified using the standard phenotypic methods employed in the laboratory. Therefore, the identification for any one of these species is most accurately reported as “*Citrobacter freundii* complex”.

Table Current species within the genus <i>Citrobacter</i> .	
Subcategory	<i>Citrobacter</i> species
A ^a	<i>braakii</i> <i>freundii</i> <i>gillanii</i> <i>murlinae</i> <i>rodenticum</i> <i>sedlakii</i> <i>werkmanii</i> <i>youngae</i>
B	<i>amalonaticus</i> <i>farmeri</i>
C	<i>koseri/diversus</i> ^b
^a Collectively identified as the <i>Citrobacter freundii</i> complex.	
^b Both <i>C. koseri</i> and <i>C. diversus</i> are valid scientific names.	

Subgroup B consists of 2 species, *C. amalonaticus* and *C. farmeri* (formerly called *C. amalonaticus* biogroup 1). These two species can generally be separated by phenotypic methods commonly used in the laboratory

however, in some cases where atypical strains are encountered, these species cannot be separated. When this occurs, the more accurate identification may be a combination of both species such as *C. amalonaticus/farmeri*.

Subgroup C also consists of two valid species *C. diversus* and *C. koseri*. Both of these species were originally published as valid names by the *IJSB* in 1980 [3]. Recent genotypic analysis of these two species now recognizes both as representing the same species. In 1993, a request was made to the *Judicial Commission on the International Committee on Systematic Bacteriology* to determine which species was correct and thus should be used to identify this species [1]. This Commission subsequently rejected *C. diversus* and elevated the name *C. koseri* as the accepted species [2]. This opinion has unfortunately caused some controversy within the scientific community. The rules of the *Bacteriological Code* say that the older name has precedence and should be the accepted valid name. Therefore, *C. diversus*, which was originally published as a name in 1932, should have precedence as the accepted name since *C. koseri* was not published until 1970. Based on the opinion from the Judicial Commission, most automated systems now use *C. koseri* as the accepted name for this organism. Until the controversy surrounding these two names can be settled some automated systems suggest that the most accurate reporting should use both names i.e., *C. diversus/koseri* or *C. koseri/diversus*.

In conclusion, reference laboratories are available to provide sequence comparison analysis testing to validate the identification of the *Citrobacter* species or other microbial pathogens when necessary. Although the NPHL does not provide this service, molecular tools are available at UNMC to identify microbial pathogens for research purposes. Contact Dr. Iwen at 402-559-7774 for additional information on the availability of this service.

References

1. Frederiksen, W. 1990. Correct names of the species *Citrobacter koseri*, *Levinea malonatica*, and *Citrobacter diversus*: request for an opinion. *Int. J. Syst. Bacteriol.* 40: 107-108.
2. Judicial Commission on the International Committee on Systematic Bacteriology. 1993. Rejection of the name *Citrobacter diversus*. Werkman and Gillen. *Int. J. Syst. Bacteriol.* 43: 392.
3. Skerman, V.B.D., V. McGowan, and P.H.A. Sneath. 1980. Approved lists of bacterial names. *Int. J. Syst. Bacteriol.* 30: 225-420.