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Cytophaga-like bacteria)**

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► **To cite this version:**

John P Bowman, Jean-Francois Bernardet, Ellen Frandsen Lau. International Committee on Systematics of Prokaryotes: Subcommittee on the Taxonomy of Aerobic Bacteroidetes (formerly Flavobacterium and Cytophaga-like bacteria). International Journal of Systematic and Evolutionary Microbiology, 2020, 70 (11), pp.6017-6020. 10.1099/ijsem.0.004243 . hal-04494673

**HAL Id: hal-04494673**

**<https://hal.uvsq.fr/hal-04494673>**

Submitted on 7 Mar 2024

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# International Committee on Systematics of Prokaryotes: Subcommittee on the Taxonomy of Aerobic *Bacteroidetes* (formerly *Flavobacterium* and *Cytophaga*-like bacteria)

John P. Bowman<sup>1,\*</sup>, Jean-Francois Bernardet<sup>2</sup> and Ellen Frandsen Lau<sup>3</sup>

## Abstract

Minutes of the meeting: 15 November 2017 (Skype meeting).

## MINUTE 1. CALL TO ORDER

The meeting was called to order by the Chairman, J.-F. Bernardet, on 15 November 2017. The meeting was performed online via Skype with participants present in their home countries.

## MINUTE 2. RECORD OF ATTENDANCE

The members present were J.-F. Bernardet (Chairman), J. P. Bowman (Secretary) and E. Frandsen Lau. Apologies were received from J. Chun, C. Hugo, Y. Nakagawa and O. Nedashkovskaya.

## MINUTE 3. APPROVAL OF AGENDA

Separate closed and open meetings were not held due to availability of members and due to the nature of the meeting. Only the one meeting session was held. The proposed agenda was approved. No additional points to the agenda were made.

## MINUTE 4. MINUTES OF THE PREVIOUS MEETINGS

The minutes of the previous meetings, held in Montreal, Canada, on 30 July 2014, had been approved by mail and published [Bowman, Bernardet and Hugo, *Int J Syst Evol Microbiol* 2017;67:507–509].

## MINUTE 5. CHANGES IN MEMBERS AND OFFICERS

Proposed new members of the Subcommittee include Ainsley Nicholson (Special Bacteriology Reference Laboratory,

Bacterial Special Pathogens Branch, Division of High Consequence Pathogens and Pathology, Centers for Disease Control and Prevention, Atlanta, GA, USA) and Richard Hahnke (Leibniz Institute DSMZ-German Collection of Microorganisms and Cell Cultures, Braunschweig, Germany). Their nomination was subsequently formally endorsed soon after by Daniel R. Brown, the ICSP secretary for Subcommittees.

## MINUTE 6. CURRENT MEMBERSHIP

The current voting membership of the Subcommittee is as follows: J.-F. Bernardet (Chairman; Jouy-en-Josas, France); J. P. Bowman (Secretary; Hobart, Tasmania, Australia); J. Chun (Seoul, Korea); B. Holmes (Stanmore, UK), E. Frandsen Lau (Aarhus, Denmark); R. Hahnke (Braunschweig, Germany); C. Hugo (Bloemfontein, South Africa); A. Nicholson (Atlanta, GA, USA); Y. Nakagawa (Kisarazu, Japan); O. Nedashkovskaya (Vladivostok, Russia). Members are listed on the Subcommittee website, which includes reference to current affiliation and contact information ([www.the-icsp.org/taxonomic-subcommittees](http://www.the-icsp.org/taxonomic-subcommittees)).

## MINUTE 7. PLANS FOR FUTURE ACTIVITIES

### Minimal Standards

Minimal standards have been published successfully for developing a quality body of knowledge for taxa of the family *Flavobacteriaceae*. The *Flavobacteriaceae* Minimal Standards paper is highly cited. It was considered that Minimal Standards could be extended to other taxonomic groups. It was discussed that the Minimal Standards are not requirements for description of new taxa rather they exist as a guide for describing new taxa such that they have a consistent body of

**Author affiliations:** <sup>1</sup>University of Tasmania, School of Agricultural Science, Private Bag 54, Hobart, Australia; <sup>2</sup>INRAE, UVSQ, VIM, Université Paris-Saclay, Jouy-en-Josas, France; <sup>3</sup>Department of Dentistry and Oral Health, Aarhus University, Denmark.

\*Correspondence: John P. Bowman, [john.bowman@utas.edu.au](mailto:john.bowman@utas.edu.au)

information. Minimal Standards would need to be updated to include new requirements for describing taxa, including genomic data. The Minimal Standards would also incorporate available orthologous phenotypic data and attempts should be made to include data from multiple strains, especially for host-associated taxa.

## MINUTE 8. BERGEY'S MANUAL OF SYSTEMATICS OF ARCHAEA AND BACTERIA

J.-F. Bernardet indicated members of the committee have and were writing genus sections of the online Bergey's Manual for taxa that falls under overview by the Subcommittee for Aerobic *Bacteroidetes*. Sections related to the largely anaerobic *Bacteroidetes* (class *Bacteroidia*, order *Bacteroidales*) are not covered, however it should be noted that the Taxonomic Subcommittee 'Gram-Negative Anaerobic Rods' covers in principle these taxa but has not furnished any minute's activity since 2011. Some of these taxa can grow facultatively anaerobically and tend to be more recently described or relatively recently reclassified taxa, e.g. various members of families *Marinilabiliaceae*, *Marinifilaceae* and *Prolixibacteraceae*. Discussions have not covered these taxa to date.

Bergey's Manual as it currently stands includes several sections that are relevant to the Subcommittee's taxonomic overview. These chapter sections are listed below have been fully published and available online (<https://onlinelibrary.wiley.com/doi/book/10.1002/9781118960608>). The list below indicates whether a Subcommittee member was an author (if no authors are listed the author is not a member of the subcommittee). It should be noted there is a several year time lag between Bergey's Manual outputs and taxonomic changes occurring through standard publication and the list of taxa reviewed is far from complete.

*Bacteroidetes* phyl. nov.

*Cytophagia* classis. nov. (Y. Nakagawa), *Cytophagales*, (Y. Nakagawa)

*Cyclobacteriaceae* fam. nov. (O. Nedashkovskaya), *Algoriphagus* (O. Nedashkovskaya), *Aquiflexum*, *Belliella*, *Cyclobacterium*, *Echinicola* (O. Nedashkovskaya), *Rhodonellum*.

*Cytophagaceae* (Y. Nakagawa), *Adhaeribacter*, *Arcicella*, *Cytophaga* (Y. Nakagawa), *Dyadobacter*, *Efluviibacter*, *Emticicia*, *Flectobacillus*, *Flexibacter* (Y. Nakagawa), *Hymenobacter*, *Larkinella*, *Leadbetterella*, *Meniscus*, *Microscilla* (Y. Nakagawa), *Pontibacter* (O. Nedashkovskaya), *Runella*, *Spirosoma*, *Sporocytophaga*.

*Flammeovirgaceae* fam. nov. (O. Nedashkovskaya), *Fabibacter*, *Flammeovirga* (Y. Nakagawa),

*Flexithrix* (Y. Nakagawa), *Persicobacter* (Y. Nakagawa), *Reichenbachiella* (O. Nedashkovskaya), *Roseivirga* (O. Nedashkovskaya).

*Sphingobacteriia* classis. nov., *Sphingobacteriales* ord. nov.

*Chitinophagaceae*, *Chitinophaga*, *Terrimonas*

*Saprospiraceae*, *Aureispira*, *Haliscomenobacter*, *Lewinella*, *Saprospira*

*Sphingobacteriaceae*, *Sphingobacterium*, *Pedobacter*

*Flavobacteriia* classis nov. (J.-F. Bernardet), *Flavobacteriales* ord. nov. (J.-F. Bernardet)

*Blattabacteriaceae*, *Blattabacterium*

*Cryomorpaceae* (J.P. Bowman), *Brumimicrobium* (J.P. Bowman), *Crocinitomix* (J. P. Bowman),

*Cryomorpha* (J.P. Bowman), *Fluviicola*, *Lishizhenia*, *Owenweeksia* (J.P. Bowman)

*Flavobacteriaceae* (J.-F. Bernardet), *Aequorivita* (J.P. Bowman), *Algibacter* (O. Nedashkovskaya),

*Aquimarina* (O. Nedashkovskaya), *Arenibacter* (O.

Nedashkovskaya), *Bergeyella*, *Bizionia* (O. Nedashkovskaya),

*Capnocytophaga*, *Cellulophaga* (J.P. Bowman),

*Chryseobacterium* (J.-F. Bernardet, C. Hugo), *Cloacibacterium*,

*Coenonia*, *Costertonia*, *Croceibacter*, *Dokdonia*,

*Donghaeana*, *Elizabethkingia* (B. Bruun, J.-F. Bernardet),

*Empedobacter*, *Epilithonomomas*, *Flaviramulus*, *Flavobacterium* (J.-F. Bernardet, J.P. Bowman),

*Formosa*, *Gaetbulibacter*, *Gelidibacter* (J.P. Bowman), *Gillisia*, *Gramella*

(O. Nedashkovskaya), *Kaistella*, *Kordia*, *Krokinobacter*,

*Lacinutrix*, *Leeuwenhoekella* (O. Nedashkovskaya), *Lutibacter*,

*Maribacter* (O. Nedashkovskaya), *Mariniflexile*,

*Mesononia* (O. Nedashkovskaya), *Muricauda* (J.P. Bowman),

*Myroides*, *Nonlabens*, *Olleya*, *Ornithobacterium*, *Persicivirga*,

*Polaribacter* (J. P. Bowman), *Psychroserpens* (J.P. Bowman),

*Psychroflexus* (J.P. Bowman), *Riemerella*, *Robiginitalea*,

*Salegentibacter* (J.P. Bowman), *Sandarakinotalea*,

*Sediminicola*, *Sejongia*, *Stenothermobacter*, *Subsaxibacter*

(J.P. Bowman), *Subsaximicrobium* (J.P. Bowman), *Tenacibaculum*,

*Ulvibacter* (O. Nedashkovskaya), *Vitellibacter*

(O. Nedashkovskaya), *Wautersiella*, *Weeksella*, *Winogradskyella*

(O. Nedashkovskaya), *Yeosuana*

*Incertae Sedis taxa: Rhodothermaceae, Rhodothermus, Salinibacter, Thermonema, Toxothrix* (see discussion below on some of these taxa).

## MINUTE 9. RECENT TAXONOMY DEVELOPMENTS

J.-F. Bernardet provided a list of new taxa and reclassifications. Most species description-based activity was focused in the family *Flavobacteriaceae*, but new taxa are increasingly appearing in many other sections of the phylum as reported in the previous minutes. Two important papers were published where comparisons of concatenated conserved protein sequences were used to revise several of the higher taxonomic ranks within the *Bacteroidetes* (Hahnke et al. *Front Microbiol.* 2016;7:2003; Munoz et al. *Syst Appl Microbiol* 2016;39:281–296.) with subsequent corrigenda (Munoz et al. *Syst Appl Microbiol* 2016;39:491–492; Munoz et al. *Syst Appl Microbiol* 2017;40:190, Hahnke et al. *Front Microbiol* 2018;9:304). Furthermore, many taxa were emended (mainly by Hahnke et al.) to show more accurate data concerning mol% G+C ratios and some other details. The use of average nucleotide identity (ANI) as a useful means for classification was discussed as

well as its limits. Special strain aspects, such as plasmids, were also discussed but it was recognised that much more data was needed before such genomic features could ever be applied usefully to taxonomy. J.-F. Bernardet related his experiences in the study of the fish pathogen *Flavobacterium columnare* where ANI and *in silico* DNA–DNA hybridization (DDH) analyses of strains revealed evidence for new species and even potentially new genera. However, this was also accompanied by the limitation of no useful phenotypes differentiating the groups. E. Frandsen Lau also related her experiences studying *Capnocytophaga* strains and species that show similar patterns where ANI and DDH groups that fulfil the concept of separate species lack distinguishing phenotypes. She opined that this has led to some researchers losing interest in a species concept or speciation. More research on how genome-informed taxonomy can be aligned to phenotypic and traditional microbiology seems necessary. This is evidenced by the downstream impacts it can have for bacterial identification in diagnostic laboratories.

The major classification-based changes to the taxonomy to the aerobic *Bacteroidetes* are summarized below. This represents the taxonomic situation of November 2017 except for one corrigendum connected to the study of Hahnke *et al.* 2016. Note these changes partly solve the *incertae sedis* status for Bergey's Manual entries (*Thermonema*, *Rhodothermaceae*) as designated in the online edition of Bergey's Manual.

Within the class *Cytophagia* Munoz *et al.* (see above) proposed three new families including *Hymenobacteraceae*, *Persicobacteraceae* and *Thermonemataceae*. Hahnke *et al.* also proposed the family *Microscillaceae* and family *Bernardetiaceae*. *Hymenobacteraceae* has *Hymenobacter* as its type genus and also includes the genera *Adhaeribacter*, *Nibrifactor*, *Pontifactor* and *Rufifactor*. *Thermonemataceae* includes *Thermonema* as the type genus while *Persicobacteraceae* includes *Persicobacter* (type genus), *Aureibacter* and *Fulvitalia*. *Microscillaceae* includes *Microscilla* as type genus as well as the new genus *Eisenibacter* (formerly *Flexibacter elegans*). *Bernardetiaceae* includes the newly described genera *Bernardetia* (formerly *Flexibacter litoralis*) and *Hugenholtzia* (formerly *Flexibacter roseolus*). The new genus *Garritya* (formerly *Flexibacter polymorphus*) is a tentative member of *Bernardetiaceae* as defined in Hahnke *et al.* Another new genus called *Thermoflexibacter* (formerly *Flexibacter ruber*) described by Hahnke *et al.* was not classified at the family level due to uncertainties related to its position but is firmly located within order *Cytophagales*. Other changes in class *Cytophagia* included one genus being added to the family *Cyclobacteriaceae* (*Negadavirga*), three genera added to family *Cytophagaceae* (*Fluviimonas*, *Lacihabitans* and *Rufifactor*) and one genus to *Flammeovirgaceae* (*Imperialibacter*). The genus *Flexibacter* after reclassification by Hahnke *et al.* retains only *Flexibacter flexilis*.

Munoz *et al.* also proposed that taxa within *Rhodothermaceae* be elevated to phylum level designated *Rhodothermaeota*. Hahnke further emended the description due to *Balneola* and its relatives no longer being grouped in this new taxon. Munoz *et al.* indicated *Rhodothermaeota* includes *Rhodothermaceae*

and the new families *Rubricoccaceae* (type genera *Rubricoccus* and *Rubrivirga*) and *Salinibacteraceae*. *Salinibacteraceae* includes *Salinibacter* as type genus (the description of which was emended), *Salinisaeta* and a new genus called *Salinivenus*.

Within the class *Sphingobacteriia*, the family *Balneolaceae* was promoted to the rank of class (*Balneolia*) by Munoz *et al.* while Hahnke *et al.* proposed a new phylum for this family, designating it *Balneolaeta*. This taxon contains four genera *Aliifonibius*, *Balneola*, *Gracilimonas* and *Fodinibius* with *Balneola* as the type genus. Both studies also created the order *Balneolales*. Another change affecting class *Sphingobacteriia* included elevation of the family *Chitinophagaceae* to the status of class, designated *Chitinophagia* (Munoz *et al.* 2016). This was accompanied by the description of the order *Chitinophagales*. This group also acquired 11 new genera (*Arachidiococcus*, *Asinibacterium*, *Cnuella*, *Crenotalea*, *Flaviaestuariatibacter*, *Heliimonas*, *Hydrobacter*, *Parasedimini-bacterium*, *Taibaiella*, *Thermoflavifilum* and *Vibrionimonas*). Furthermore, a new family was described called *Filobacteriaceae* containing *Filobacterium* as type genus. Another major change to class *Sphingobacteriia* was elevation of the family *Sapropiraceae* to the rank of class by Hahnke *et al.* This change resulted in the description of *Saprospirales* and *Saprospiria* as the order and class designations. Two new family level ranks were created including *Lewinellaceae* and *Haliscomenobacteraceae*. *Lewinellaceae* contains *Lewinella* as type genus while *Haliscomenobacteraceae* includes *Haliscomenobacter* as type genus, *Portibacter* and the new genus *Phaeodactylibacter*. The taxonomic issue surrounding the species *Sphingobacterium composti* is resolved with the description of Ten *et al.* 2007 having precedence over the description of Yoo *et al.* 2007 (the description becoming a later homonym)

For *Flavobacteriia* a new family was created called *Crocinitomiciaceae* which includes *Crocinitomix* as the type genus and five other genera (*Brumimicrobium*, *Fluviicola*, *Lishizhenia*, *Salinirepens* and *Wandonia*). Otherwise, the changes amounted to addition of new genera. In the reduced and still taxonomically ambiguous family *Cryomorphaceae*, the genus *Luteibaculum* was added. For the family *Flavobacteriaceae*, no less than a total of 26 genera were added including *Aestuariatibacter*, *Aesturivivens*, *Antarcticimonas*, *Aquibacter*, *Arcticiflavibacter*, *Arenitalea*, *Aurantiacicella*, *Aureisphaera*, *Chishuella*, *Citreitalea*, *Flavicella*, *Flavimarina*, *Flavirhabdus*, *Frondebacter*, *Geojedonia*, *Hanstrupera*, *Hwangdonia*, *Ichthyoenterobacterium*, *Jejudonia*, *Litoribaculum*, *Pustulibacterium*, *Sabulilitoribacter*, *Seonamhaeicola*, *Spongiimonas*, *Spongiivirga* and *Wenyngzhuangia*. It should be noted that the genus *Epilithonimonas* was reclassified as a species within *Chryseobacterium*.

## MINUTE 9. OTHER BUSINESS

### Research activities of subcommittee members relevant to taxonomy of aerobic *Bacteroidetes*

E. Frandsen Lau described her work on *Capnocytophaga* and other species and strains relevant to oral microbiology and clinical disease. She is keen to explore such strains

using genomic and phenotypic approaches. J.-F. Bernardet mentioned the work of his group with fish pathogenic strains of *Flavobacterium psychrophilus* and *Tenacibaculum maritimum*, with flavobacterial strains able to break down complex polysaccharides and related research. He mentioned some taxonomic issues with genus *Tenacibaculum* (and its relative *Polaribacter*) including strains of the *T. maritimum* type strain being different between some culture collections based on genome sequence data. J.P. Bowman indicated his intention to sequence genomes of type strains in his possession (e.g. *Cryomorpha ignava*) and to eventually disseminate these strains more widely.

### **Flavobacterium centric meetings**

Upcoming meetings with specialised focus on genus *Flavobacterium* were mentioned by J-F. Bernardet. These included the ‘First International Conference on Marine Flavobacteria’ organized by INRA for mid-2018 (was held in June 2018 in Corsica, France). The meeting focuses on marine flavobacteria and included many topics relevant to taxonomy, ecology,

biotechnology and microbiome research. Another meeting, specifically focussing on issues relevant to genus *Flavobacterium* – the ‘fifth International Conference of Members of the Genus *Flavobacterium*’ – was organized to be held in late 2018 (was held in Nara, Japan, November 2018). The main focus of this meeting was related to fish diseases caused by various *Flavobacterium* species but also included other topics.

### **MINUTE 10. ADJOURNMENT AND NEXT MEETING**

The meeting was adjourned after approximately 2h. The next meeting for the Subcommittee was decided to be held in Glasgow, Scotland, UK at the 2019 FEMS Microbiology Congress (<https://fems2019.org/>).

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#### **Funding information**

The authors received no specific grant from any funding agency.

#### **Conflicts of interest**

The authors declare that there are no conflicts of interest.

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