

# A report of 39 unrecorded bacterial species in Korea belonging to the classes *Betaproteobacteria* and *Gammaproteobacteria* isolated in 2018

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In the project of a comprehensive investigation of indigenous prokaryotic species in Korea, a total of 39 bacterial strains phylogenetically belonging to the classes *Betaproteobacteria* and *Gammaproteobacteria* were isolated from various environmental sources such as soil, cultivated soil, sludge, seawater, marine sediment, algae, human, tree, moss, tidal flat, beach sand and lagoon. Phylogenetic analysis based on 16S rRNA gene sequences revealed that 39 strains showed the high sequence similarities ( $\geq 98.7\%$ ) to the closest type strains and formed robust phylogenetic clades with closely related species in the classes *Betaproteobacteria* and *Gammaproteobacteria*. In the present study, we report 14 species of 9 genera of four families of two orders in the class *Betaproteobacteria* and 25 species of 21 genera of 15 families of eight orders in the class *Gammaproteobacteria*, which have not been reported in Korea. Morphological, biochemical, and physiological characteristics, isolation sources, and NIBR deposit numbers are described in the species descriptions.

Keywords: 16S rRNA, *Betaproteobacteria*, *Gammaproteobacteria*, indigenous Korean prokaryotic species, unrecorded species

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## INTRODUCTION

*Proteobacteria* (Stackebrandt *et al.*, 1988; Garrity *et al.*, 2005) is the largest phylum of gram-negative bacteria group and most diverse phylogenetic lineage in the domain *Bacteria*. At the time of writing, based on 16S rRNA gene sequences, the phylum *Proteobacteria* includes eight classes: *Alphaproteobacteria*, *Betaproteobacteria*, *Gammaproteobacteria*, *Deltaproteobacteria*, *Epsilonproteobacteria*, *Oligoflexia*, *Acidithiobacillia*, and *Hydrogenophilalia*. The class *Betaproteobacteria* and *Gammaproteobacteria* are the largest bacterial groups

within the phylum. The class *Betaproteobacteria* is divided into seven orders: *Burkholderiales*, *Ferritrophicales*, *Ferrovales*, *Gallionellales*, *Methylophilales*, *Neisseriales*, and *Sulfuricellales* (Boden *et al.*, 2017). The class *Gammaproteobacteria* is divided into 20 orders: *Acidiferrobactales*, *Aeromonadales*, *Alteromonadales*, *Arenicellales*, *Cardiobacteriales*, *Cellvibrionales*, *Chromatiales*, *Enterobacteriales*, *Immundisolibacterales*, *Legionellales*, *Lysobacterales*, *Methylococcales*, *Nevskiales*, *Oceanospirillales*, *Orbales*, *Pasteurellales*, *Pseudomonadales*, *Salinisphaerales*, *Thiotrichales* and *Vibrionales*. The order *Xanthomonadales* belonged to the class *Gammaproteo-*

*bacteria* is a basonym for *Lysobacterales* (Williams and Kelly, 2013).

In this study, bacterial strains belonging to the classes *Betaproteobacteria* and *Gammaproteobacteria* were isolated from various environments during the investigation of indigenous bacterial species in Korea by the research program supported by the National Institute of Biological Resource (NIBR) in 2018. As a result, 43 strains are proposed to represent unrecorded species of Korea.

## MATERIALS AND METHODS

A total of 43 bacterial strains were isolated from various environmental samples such as soil, cultivated soil, sludge, seawater, marine sediment, algae, human, tree, moss, tidal flat, beach sand and lagoon. Treatment of environmental samples and bacterial isolation were handled independently in several laboratories. Pure cultures of isolated bacteria were grown on various culture media including R2A agar (BD), marine agar (MA; BD), yeast malt agar (ISP 2; BD), trypticase soy yeast agar (TSYA; BD), mueller hinton agar (MHA; BD) and glucose yeast extract agar (GYEA; Himedia) at 15–30°C for 2–5 days, depending on strains. The designated strain ID, isolation source, culture media and incubation conditions are summarized in Table 1. All pure cultures were maintained as 10–20% glycerol suspension at –80°C and lyophilized ampoules.

*Bacterial* genomic DNA extraction, PCR amplification and sequencing of 16S rRNA genes were performed using the standard procedures as described previously (Kim and Cha, 2018). The 16S rRNA gene sequences were compared with those of the type strains of validly published bacterial species collected from the EzBiocloud (Yoon *et al.*, 2017). Multiple alignments of the 16S rRNA gene sequences of the isolates and those of the related type strains were carried out using the Clustal\_X program (Thompson *et al.*, 1997) for the phylogenetic analysis. Phylogenetic trees were reconstructed by maximum-likelihood (ML) (Felsenstein, 1981) and neighbour-joining (NJ) (Saitou and Nei, 1987) algorithms using MEGA7 software (Kumar *et al.*, 2016). The best substitution model for the ML tree was determined by model test in the software. Both tree topologies were evaluated on the basis of bootstrap analysis of 1000 datasets (Felsenstein, 1985).

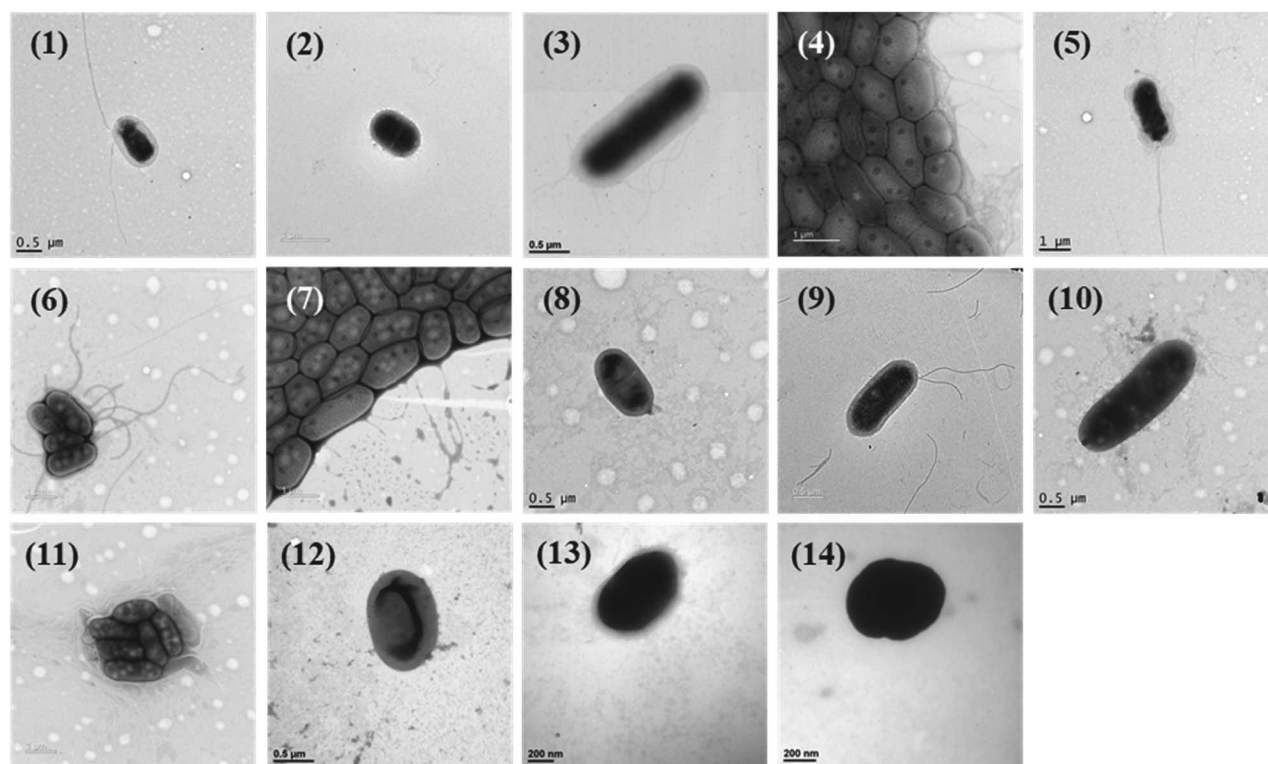
Cellular morphology and cell size were examined using either transmission electron microscope (TEM) or scanning electron microscope (SEM). Gram staining was performed using the standard procedures. Biochemical characteristics were tested using API 20NE galleries (bioMérieux) according to the manufacturer's instructions.

**Table 1.** Summary of strains isolated belonged to the *Betaproteobacteria* and *Gammaproteobacteria* and their taxonomic affiliations.

Phylum	Order	Genus	Strain ID	NIBR ID	Most closely related species	Similarity (%)	Isolation source	Medium	Incubation conditions
<i>Betaproteobacteria</i>	<i>Burkholderiales</i>	<i>Achromobacter</i>	MMS18-G 109	NIBRBAC000502558	<i>A. insuavis</i>	100	Soil	ISP2	30°C, 5d
		<i>Advenella</i>	MS25	NIBRBAC000502453	<i>A. kashmirensis</i> subsp. <i>kashmirensis</i>	100	Sludge	R2A	30°C, 2d
		<i>Burkholderia</i>	LPB0241	NIBRBAC000502431	<i>B. multivorans</i>	99.7	Human	TSYA	37°C, 3d
		<i>Caballeronia</i>	HMF7542	NIBRBAC000502515	<i>C. humi</i>	99.7	Tree	R2A	30°C, 3d
		<i>Caballeronia</i>	MMS18-M_91	NIBRBAC000502573	<i>C. pedi</i>	99.2	Soil	ISP2	30°C, 5d
		<i>Caballeronia</i>	HMF7541	NIBRBAC000502514	<i>C. pterocochthonis</i>	99.3	Tree	R2A	30°C, 3d
		<i>Caballeronia</i>	HMF7531	NIBRBAC000502513	<i>C. tudeis</i>	99.7	Tree	R2A	30°C, 3d
		<i>Candidimonas</i>	BO221	NIBRBAC000502394	<i>C. nitroreducens</i>	99.3	Cultivated soil	R2A	25°C, 3d
		<i>Castellanella</i>	dNF-3	NIBRBAC000502456	<i>C. denitrificans</i>	100	Sludge	R2A	30°C, 2d
		<i>Cupriavidus</i>	GA039	NIBRBAC000502568	<i>C. pinatubonensis</i>	98.8	Soil	R2A	30°C, 3d
		<i>Massilia</i>	GA051	NIBRBAC000502566	<i>M. buxica</i>	99.5	Soil	R2A	30°C, 3d
		<i>Massilia</i>	HMF7122	NIBRBAC000502510	<i>M. violaceinigra</i>	99.6	Moss	R2A	30°C, 3d
		<i>Paraburkholderia</i>	CAU 1510	NIBRBAC000502376	<i>P. caribensis</i>	99.4	Marine sediment	GYEA	30°C, 2–3d
		<i>Paraburkholderia</i>	17G39-22	NIBRBAC000502346	<i>P. metrostideri</i>	98.9	Soil	R2A	25°C, 4d
		<i>Neisseriales</i>		<i>Neisseria</i>	18H6F1	NIBRBAC000502546	<i>N. subflava</i>	99.6	Soil

Table 1. Continued.

Phylum	Order	Genus	Strain ID	NIBR ID	Most closely related species	Similarity (%)	Isolation source	Medium	Incubation conditions
Aeromonadales	Aeromonas	Aeromonas	18N2A1	NIBRBA000502543	<i>A. finlandensis</i>	99.3	Soil	MHA	30°C, 2d
			18H4A15	NIBRBA000502548	<i>A. fluvialis</i>	99.6	Soil	MHA	30°C, 2d
Alteromonadales	Alteromonas	Alteromonas	HMF9091	NIBRBA000502518	<i>A. genovensis</i>	99.4	Sea water	MA	30°C, 3d
			KYW1522	NIBRBA000502397	<i>L. sediminis</i>	99.9	Sea water	MA	25°C, 3d
			Gri212	NIBRBA000502481	<i>M. atgicola</i>	100	Brid	MA	30°C, 3d
			CAU 1501	NIBRBA000502367	<i>M. hydrocarbonoclasticus</i>	99.8	Marine sediment	MA	30°C, 2-3d
			CAU 1507	NIBRBA000502375	<i>S. loihica</i>	98.7	Marine sediment	MA	30°C, 2-3d
Cellvibrionales	Microbulbifer	Microbulbifer	SC100	NIBRBA000502390	<i>M. yueqingensis</i>	100	Tidal flat	MA	25°C, 3d
			dN13-1	NIBRBA000502457	<i>E. muelleri</i>	99.5	Sludge	R2A	30°C, 2d
Enterobacteriales	Enterobacter	Enterobacter	18N3A9	NIBRBA000502539	<i>P. carotovorum</i> subsp. <i>carotovorum</i>	99.5	Soil	MHA	30°C, 2d
			18S2E14	NIBRBA000502552	<i>R. victoriana</i>	98.8	Soil	MHA	30°C, 2d
			BO208	NIBRBA000502393	<i>D. immobilis</i>	99.8	Cultivated soil	R2A	25°C, 2d
Lysobacteriales	Luteimonas	Luteimonas	BO171	NIBRBA000502391	<i>L. nephitis</i>	99.8	Cultivated soil	R2A	25°C, 3d
			HMF9224	NIBRBA000502526	<i>L. bugensis</i>	99	Beach sand	MA	30°C, 3d
			H-2	NIBRBA000502469	<i>L. defluvi</i>	100	Sludge	R2A	30°C, 2d
			18S2F3	NIBRBA000502533	<i>S. indicatrix</i>	99.1	Soil	MHA	30°C, 2d
			BT5	NIBRBA000502336	<i>X. maliensis</i>	99.4	Soil	R2A	25°C, 4d
Oceanospirillales	Marinobacterium	Marinobacterium	KYW1450	NIBRBA000502395	<i>M. coralli</i>	99.9	Sea water	MA	25°C, 3d
			HMF9105	NIBRBA000502519	<i>M. rhizomae</i>	98.9	Lagoon	MA	30°C, 3d
			SC76	NIBRBA000502389	<i>S. halophilus</i>	99.3	Tidal flat	MA	25°C, 3d
Pseudomonadales	Acinetobacter	Acinetobacter	LPB0223	NIBRBA000502420	<i>A. pittii</i>	99.9	Human	TSYA	37°C, 3d
			18S4A7	NIBRBA000502550	<i>P. baetica</i>	99.4	Soil	MHA	30°C, 2d
			BT57	NIBRBA000502335	<i>P. brassicaearum</i> subsp. <i>neourantitaca</i>	99.7	Soil	R2A	25°C, 4d
			Hyper-1	NIBRBA000502459	<i>P. chengduensis</i>	99.9	Sludge	R2A	30°C, 2d
			BO274	NIBRBA000502401	<i>P. coleopterorum</i>	99.9	Cultivated soil	R2A	25°C, 3d
Pseudomonadales	Pseudomonas	Pseudomonas	18H1S12	NIBRBA000502532	<i>P. taiwanensis</i>	99	Soil	MHA	30°C, 2d
			LPB0247	NIBRBA000502434	<i>P. oceanii</i>	99.7	Sea water	MA	25°C, 3d
Vibrionales	Vibrio	Vibrio	LPB0246	NIBRBA000502433	<i>V. gigantus</i>	99.7	Sea water	MA	25°C, 3d

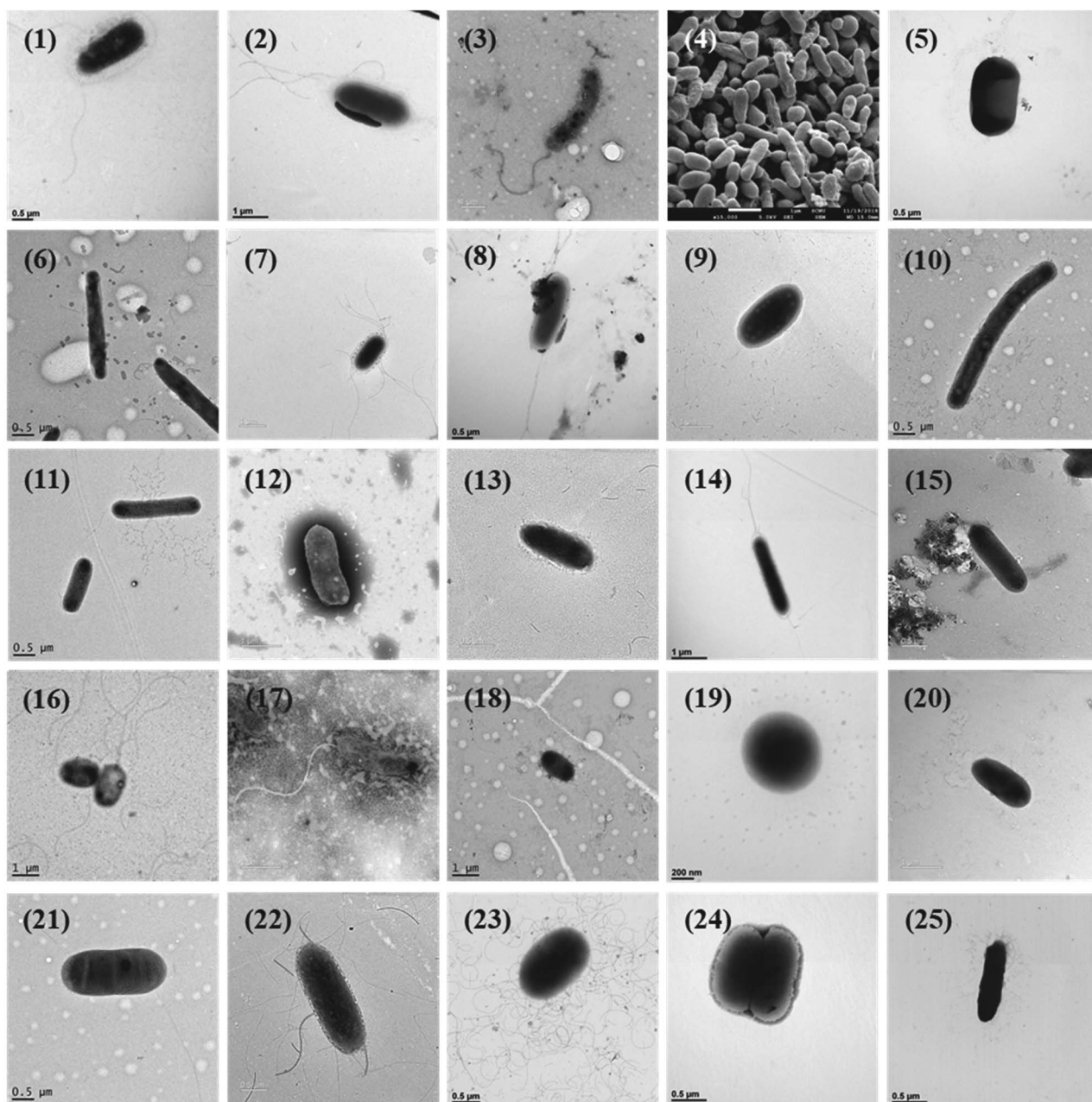


**Fig. 1.** Transmission electron micrographs of cells of the species belonging to the *Betaproteobacteria* isolated in this study. Strains: 1. MMS18-G 109; 2. MS25; 3. LPB0241; 4. HMF7542; 5. MMS18-M\_91; 6. HMF7541; 7. HMF7531; 8. BO221; 9. dNF-3; 10. GA051; 11. HMF7122; 12. CAU 1510; 13. 17G39-22; 14. 18H6F1.

## RESULTS AND DISCUSSION

Fourteen strains were classified into two orders in the class *Betaproteobacteria*; 13 strains in the order *Burkholderiales* and one strain in the order *Neisseriales* (Table 1). These strains were Gram-staining-negative except for the strain LPB0241 and rod-shaped except for the strains MS25, BO221, and 18H6F1. Three strains were oval-shaped, coccobacilli-shaped and coccus-shaped, respectively (Fig. 1). Colony morphology and physiological characteristics are presented in the species description section. In the order *Burkholderiales*, seven strains were assigned to the family *Burkholderiaceae* which included the genera *Burkholderia*, *Caballeronia* and *Paraburkholderia*, four strains belonged to the family *Alcaligenaceae* which included the genera *Achromobacter*, *Advenella*, *Candidimonas* and *Castellaniella*, two strains belonged to the genus *Massilia* in the family *Oxalobacteraceae*. In the order *Neisseriales*, one strain was assigned to the genus *Neisseria* within the family *Neisseriaceae*. Phylogenetic relationship between the isolates and those of the related type strains are presented in Fig. 3. Here we report 14 bacterial species which have been unrecorded in Korea, belonging to four families in two orders of the class *Betaproteobacteria*.

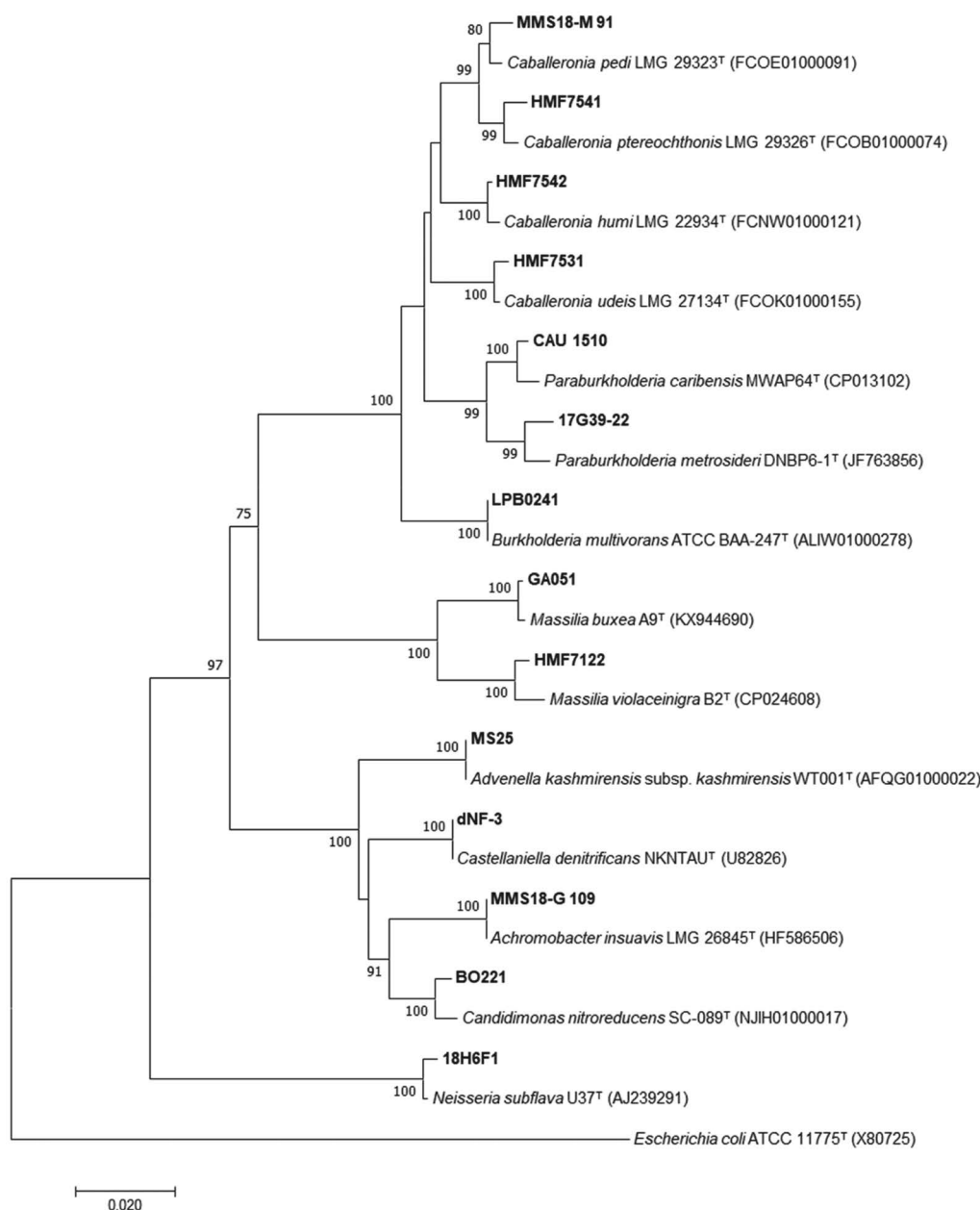
Twenty five strains were classified into eight orders in the class *Gammaproteobacteria*: two strains in the order *Aeromonadales*, three strains in the order *Alteromonadales*, one strain in the order *Cellvibrionales*, three strains in the order *Enterobacterales*, six strains in the order *Lysobacterales*, three strains in the order *Oceanospirillales*, six strains in the order *Pseudomonadales*, and one strain in the order *Vibrionales* (Table 1). In order the *Aeromonadales*, two strains were assigned to the genus *Aeromonas* in the family *Aeromonadaceae*. In the order *Alteromonadales*, one strain belonged to the genus *Alteromonas* within the family *Alteromonadaceae*, one strain belonged to the genus *Litorilittus* within the family *Colwelliaceae* and one strain belonged to the genus *Shewanella* within the family *Shewanellaceae*. In the order *Cellvibrionales*, one strain was assigned to the genus *Microbulbifer* within the family *Microbulbiferaceae*. In the order *Enterobacterales*, one strain was assigned to the genus *Enterobacter* in the family *Enterobacteriaceae*, another strain belonged to the genus *Pectobacterium* in the family *Pectobacteriaceae*, and the other strain belonged to the genus *Rahnella* in the family *Yersiniaceae* (Fig. 4). In the order *Lysobacterales*, one strain was assigned to the genera *Dokdonella* in the family *Rhodanobacteraceae* and the other strains belonged to the family



**Fig. 2.** Transmission electron micrographs or scanning electron micrographs of cells of the species belonging to the *Gammaproteobacteria* isolated in this study. Strains: 1. 18N2A1; 2. 18H4A15; 3. HMF9091; 4. KYW1522; 5. CAU 1507; 6. SC100; 7. dN13-1; 8. 18N3A9; 9. 18S2E14; 10. BO208; 11. BO171; 12. HMF9224; 13. H-2; 14. 18S2F3; 15. BT5; 16. KYW1450; 17. HMF9105; 18. SC76; 19. LPB0223; 20. BT57; 21. Hyper-1; 22. BO274; 23. LPB0247; 24. 18H1S12; 25. LPB0246.

*Lysobacteraceae*, including the genera *Luteimonas*, *Lysobacter*, *Stenotrophomonas*, and *Xanthomonas*. In the order *Oceanospirillales*, one strain was assigned to the genus *Salinicola* in the family *Halomonadaceae* and the other strains belonged to the family *Oceanospirillaceae*, including the genera *Marinobacterium* and *Marinomonas* (Fig. 5). In the order *Pseudomonadales*, two strains were assigned to the family *Moraxellaceae*, including the ge-

nus *Acinetobacter* and *Psychrobacter* and the other strains belonged to the genus *Pseudomonas* within the family *Pseudomonadaceae*. In the order *Vibrionales*, one strain was assigned to the genus *Vibrio* in the family *Vibrionaceae* (Fig. 6). *Lysobacteraceae* was the family where the largest number of isolates were assigned (5 species), followed by *Pseudomonadaceae* (4 species). These strains were Gram-staining-negative and rod-shaped except

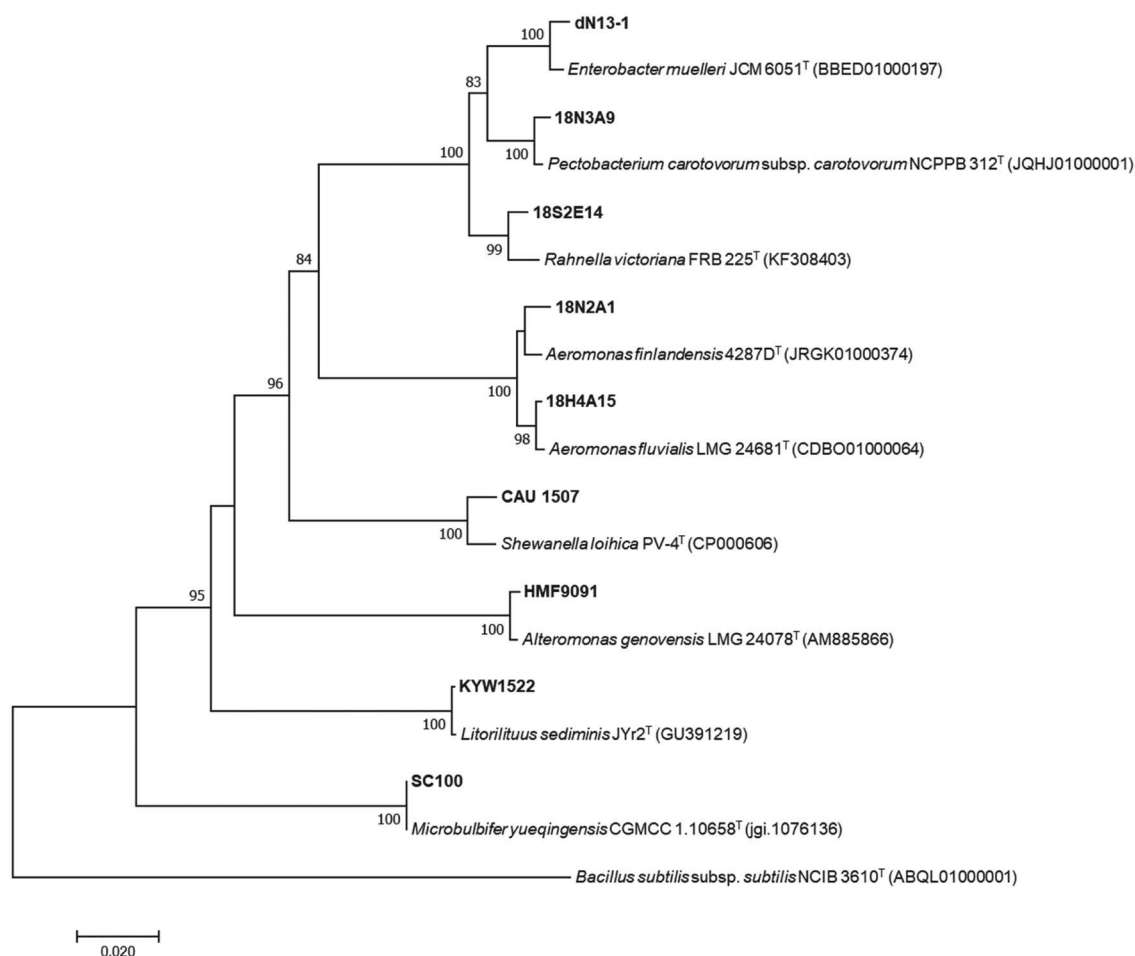


**Fig. 3.** Neighbor-joining phylogenetic tree, based on 16S rRNA gene sequences, showing the relationship between the strains isolated in this study and their relatives of the class *Betaproteobacteria*. Numbers at the nodes are levels of bootstrap value (%) based on 1000 replicated datasets; only values above 70% are shown. *Escherichia coli* ATCC 11775<sup>T</sup> (X80725) was used as an outgroup. Bar, 0.02 substitutions per nucleotide position.

for the strain LPB0223 and LPB0246. Two strains were coccus-shaped and comma-shaped, respectively (Fig. 2). Colony morphology and physiological characteristics are presented in the species description section. Phylogenetic relationship between the isolates and those of the related type strains are presented in Figs. 4–6. Here, we report 25 bacterial species which have been unrecorded in Korea, belonging to 15 families within eight orders of the class *Gammaproteobacteria*.

#### Description of *Achromobacter insuavis* MMS18-G 109

Cells are Gram-staining-negative, flagellated and rod-shaped. Colonies are circular, convex, smooth and cream-colored after 5 days of incubation on ISP2 at 30°C. Negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, *N*-acetyl-glucos-



**Fig. 4.** Neighbor-joining phylogenetic tree, based on 16S rRNA gene sequences, showing the relationship between the strains isolated in this study and their relatives of the orders *Aeromonadales*, *Alteromonadales*, *Cellvibrionales* and *Enterobacteriales* in the class *Gammaproteobacteria*. Numbers at the nodes are levels of bootstrap value (%) based on 1000 replicated datasets; only values above 70% are shown. *Bacillus subtilis* subsp. *subtilis* NCIB 3610<sup>T</sup> (ABQL01000001) was used as an outgroup. Bar, 0.02 substitutions per nucleotide position.

amine, D-maltose, capric acid, trisodium citrate, and phenylacetic acid. Strain MMS18-G 109 (= NIBRBAC000502558) was isolated from a soil sample, Daejeon, Korea.

#### **Description of *Advenella kashmirensis* subsp. *Kashmirensis* MS25**

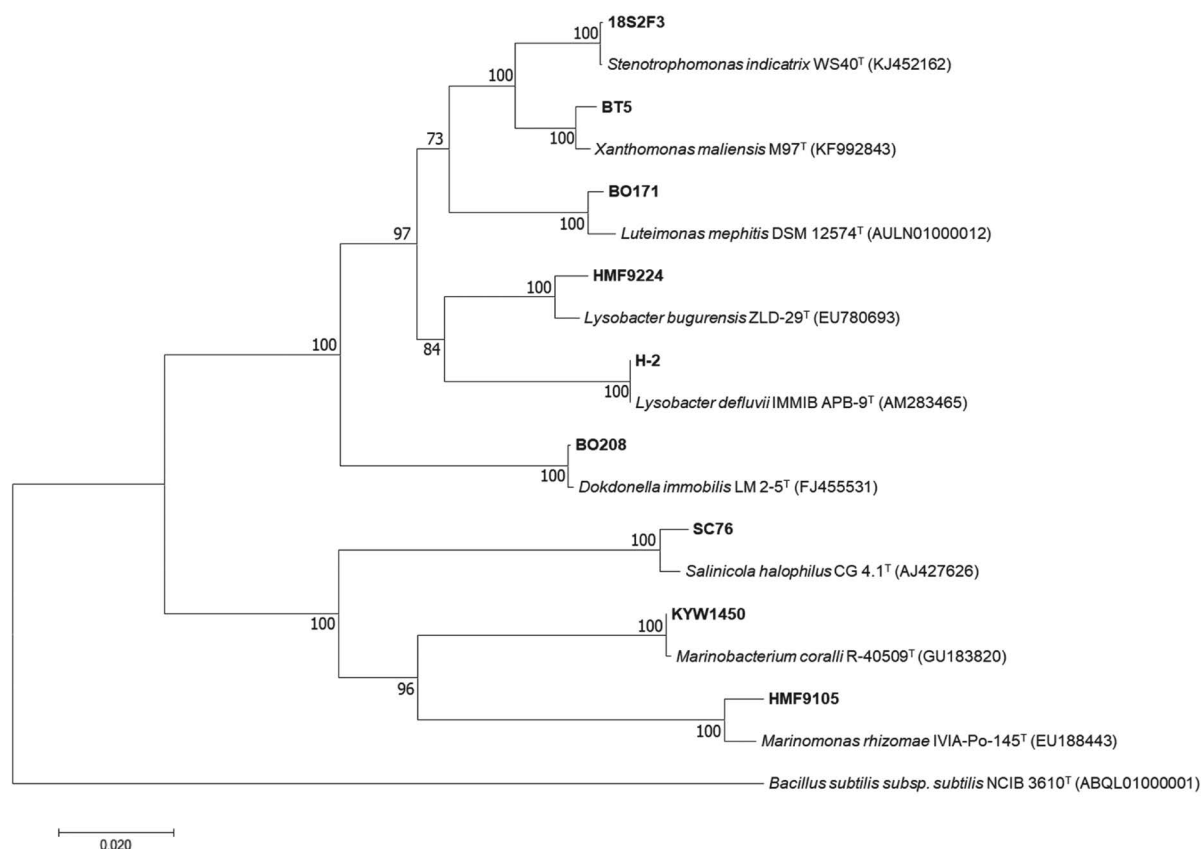
Cells are Gram-staining-negative, non-flagellated and oval-shaped. Colonies are circular, convex, smooth and pale yellow-colored after 2 days of incubation on R2A at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, capric acid and phenylacetic acid. Strain MS25 (= NIBRBAC000502453) was isolated from a sludge sample, Suwon, Gyeonggi-do, Korea.

#### **Description of *Burkholderia multivorans* LPB0241**

Cells are Gram-staining-positive, non-flagellated, non-pigmented and rod-shaped. Colonies are circular, convex, smooth, glistening and beige-colored after 3 days of incubation on TSY at 37°C. Negative reactions are obtained for cytochrome oxidase, indole production, glucose fermentation, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain LPB0241 (= NIBRBAC000502431) was isolated from a human sample, Seoul National University Hospital, Seoul, Korea.

#### **Description of *Caballeronia humi* HMF7542**

Cells are Gram-staining-negative, non-flagellated and



**Fig. 5.** Neighbor-joining phylogenetic tree, based on 16S rRNA gene sequences, showing the relationship between the strains isolated in this study and their relatives of the orders *Lysobacterales* and *Oceanospirillales* in the class *Gammaproteobacteria*. Numbers at the nodes are levels of bootstrap value (%) based on 1000 replicated datasets; only values above 70% are shown. *Bacillus subtilis* subsp. *subtilis* NCIB 3610<sup>T</sup> (ABQL01000001) was used as an outgroup. Bar, 0.02 substitutions per nucleotide position.

rod-shaped. Colonies are circular, convex, smooth and white-colored after 3 days of incubation on R2A at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-maltose. Strain HMF7542 (= NIBRBAC000 502573) was isolated from a wooden post surface sample, Yongin, Gyeonggi-do, Korea.

#### Description of *Caballeronia pedi* MMS18-M\_91

Cells are Gram-staining-negative, flagellated and rod-shaped. Colonies are circular, convex, entire, smooth, and yellowish white-colored after 5 days of incubation on ISP2 at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis and gelatinase in API 20NE. Does not utilize L-arabinose, D-maltose, capric acid, adipic acid and trisodium citrate. Strain MMS18-M\_91 (= NIBRBAC000502573) was isolated from a soil sample, Daejeon, Korea.

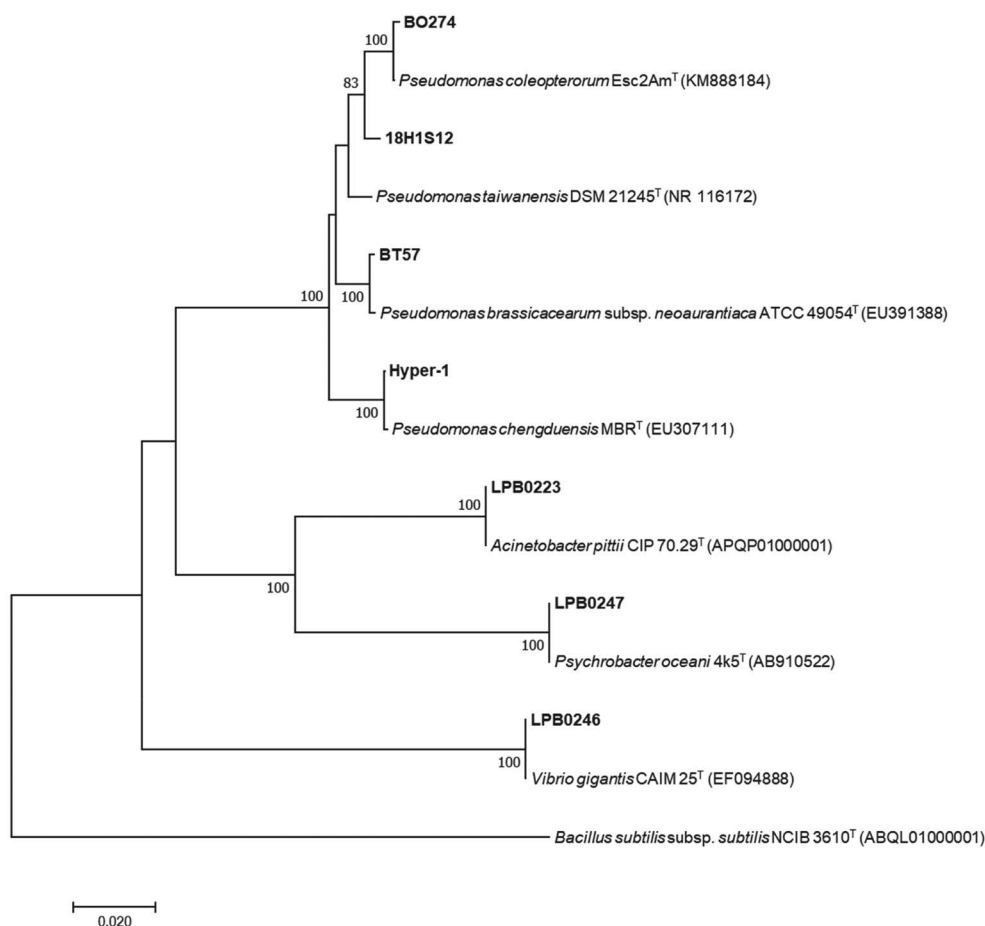
#### Description of *Caballeronia ptereochthonis* HMF7541

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and white-colored after 3 days of incubation on R2A at 30°C. Negative reactions are obtained for indole production, glucose fermentation, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-maltose and adipic acid. Strain HMF7541 (= NIBRBAC000 502514) was isolated from a wooden post surface sample, Yongin, Gyeonggi-do, Korea.

#### Description of *Caballeronia udeis* HMF7531

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and white-colored after 3 days of incubation on R2A at 30°C. Negative reactions are obtained for indole production, glucose fermentation and gelatinase in API 20NE. Does not utilize D-maltose, capric acid, adipic acid and trisodium citrate. Strain HMF7531 (= NIBRBAC000502513) was isolated from a wooden post surface sample, Yongin, Gyeonggi-do, Korea.





**Fig. 6.** Neighbor-joining phylogenetic tree, based on 16S rRNA gene sequences, showing the relationship between the strains isolated in this study and their relatives of the orders *Pseudomonadales* and *Vibrionales* in the class *Gammaproteobacteria*. Numbers at the nodes are levels of bootstrap value (%) based on 1000 replicated datasets; only values above 70% are shown. *Bacillus subtilis* subsp. *subtilis* NCIB 3610<sup>T</sup> (ABQL01000001) was used as an outgroup. Bar, 0.02 substitutions per nucleotide position.

#### Description of *Candidimonas nitroreducens* BO221

Cells are Gram-staining-negative, non-flagellated and coccobacilli-shaped. Colonies are circular, convex, smooth and white-colored after 3 days of incubation on R2A at 25°C. Negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase in API 20NE. Does not utilize D-mannitol, *N*-acetyl-glucosamine, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain BO221 (= NIBRBAC000502394) was isolated from a cultivated soil sample, Suncheon, Jeollanam-do, Korea.

#### Description of *Castellaniella denitrificans* dNF-3

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex and cream-colored after 2 days of incubation on R2A at 30°C. Negative reactions are obtained for indole production, glucose fer-

mentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize L-arabinose, D-mannose, D-mannitol, *N*-acetyl-glucosamine, D-maltose and adipic acid. Strain dNF-3 (= NIBRBAC000502456) was isolated from a sludge sample, Suwon, Gyeonggi-do, Korea.

#### Description of *Massilia buxea* GA051

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth, glistening and yellow-colored after 3 days of incubation on R2A at 30°C. Negative reactions are obtained for nitrate reduction, indole production, arginine dihydrolase, urease and gelatinase in API 20NE. Does not utilize L-arabinose, D-mannose, D-mannitol, *N*-acetyl-glucosamine, potassium gluconate, capric acid, malic acid, trisodium citrate and phenylacetic acid. Strain GA051 (= NIBRBAC000502566) was isolated from a soil sample, Daejeon, Korea.

**Description of *Massilia violaceinigra* HMF7122**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and white-colored after 3 days of incubation on R2A at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain HMF7122 (=NIBRBAC000502510) was isolated from a moss sample, Yongin, Gyeonggi-do, Korea.

**Description of *Paraburkholderia caribensis* CAU 1510**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth, shiny, transparent and yellow-colored after 2–3 days of incubation on GYE at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize L-arabinose, D-maltose, potassium gluconate, capric acid, adipic acid and trisodium citrate. Strain CAU 1510 (=NIBRBAC000502376) was isolated from a marine sediment sample, Yeosu, Jeollanam-do, Korea.

**Description of *Paraburkholderia metrosideri* 17G39-22**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 4 days of incubation on R2A at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, esculin hydrolysis and gelatinase in API 20NE. Does not utilize D-maltose, adipic acid and trisodium citrate. Strain 17G39-22 (=NIBRBAC000502346) was isolated from a soil sample, Gwangneung forest, Namyangju, Gyeonggi-do, Korea.

**Description of *Neisseria subflava* 18H6F1**

Cells are Gram-staining-negative, non-flagellated and cocci-shaped. Colonies are circular, convex, smooth and yellow-colored after 2 days of incubation on MH at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain 18H6F1 (=NIBRBAC000502546) was isolated from a soil sample, Seoul, Korea.

**Description of *Aeromonas finlandiensis* 18N2A1**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, flat, smooth and white-colored after 2 days of incubation on MH at 30°C. Negative reactions are obtained for glucose fermentation, arginine dihydrolase, urease and gelatinase in API 20NE. Does not utilize L-arabinose, adipic acid, trisodium citrate and phenylacetic acid. Strain 18N2A1 (=NIBRBAC000502543) was isolated from a soil sample, Chuncheon, Gangwon-do, Korea.

**Description of *Aeromonas fluviialis* 18H4A15**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, flat, smooth and white-colored after 2 days of incubation on MH at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase in API 20NE. Does not utilize D-mannose, D-mannitol, capric acid, trisodium citrate and phenylacetic acid. Strain 18H4A15 (=NIBRBAC000502548) was isolated from a soil sample, Seoul, Korea.

**Description of *Alteromonas genovensis* HMF9091**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and beige-colored after 3 days of incubation on MA at 30°C. Negative reactions are obtained for nitrate reduction, indole production and arginine dihydrolase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain HMF9091 (=NIBRBAC000502518) was isolated from a sea water sample, Gangneung, Gangwon-do, Korea.

**Description of *Litorilittus sediminis* KYW1522**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and beige-colored after 3 days of incubation on MA at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase and urease in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain KYW1522 (=NIBRBAC000502397) was isolated from a sea water sample, Gwangyang, Jeollanam-do, Korea.

**Description of *Shewanella loihica* CAU 1507**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth, shiny,

opaque and pink-colored after 2 days of incubation on MA at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, potassium gluconate, capric acid, adipic acid and phenylacetic acid. Strain CAU 1507 (=NIBRBAC000502375) was isolated from a marine sediment sample, Yeosu, Jeollanam-do, Korea.

#### Description of *Microbulbifer yueqingensis* SC100

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and greyish-yellow-colored after 3 days of incubation on MA at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain SC100 (=NIBRBAC000502390) was isolated from a tidal flat sample, Suncheon, Jeollanam-do, Korea.

#### Description of *Enterobacter muelleri* dN13-1

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and pale yellow-colored after 2 days of incubation on R2A at 30°C. Negative reactions are obtained for cytochrome oxidase, nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis and gelatinase in API 20NE. Does not utilize L-arabinose, adipic acid, trisodium citrate and phenylacetic acid. Strain dN13-1 (=NIBRBAC000502457) was isolated from a sludge sample, Suwon, Gyeonggi-do, Korea.

#### Description of *Pectobacterium carotovorum* subsp. *Carotovorum* 18N3A9

Cells are Gram-staining-negative, flagellated and rod-shaped. Colonies are circular, raised, smooth, glistening and white-colored after 2 days of incubation on MH at 30°C. Negative reactions are obtained for indole production, arginine dihydrolase and urease in API 20NE. Does not utilize D-maltose, capric acid, adipic acid and phenylacetic acid. Strain 18N3A9 (=NIBRBAC000502539) was isolated from a soil sample, Gapyeong, Gyeonggi-do, Korea.

#### Description of *Rahnella victoriana* 18S2E14

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and

white-colored after 2 days of incubation on MH at 30°C. Negative reactions are obtained for cytochrome oxidase, indole production, arginine dihydrolase, urease and gelatinase in API 20NE. Does not utilize capric acid, adipic acid and phenylacetic acid. Strain 18S2E14 (=NIBRBAC000502552) was isolated from a soil sample, Chungju, Chungcheongbuk-do, Korea.

#### Description of *Dokdonella immobilis* BO208

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 3 days of incubation on R2A at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate and capric acid. Strain BO208 (=NIBRBAC000502393) was isolated from a cultivated soil sample, Suncheon, Jeollanam-do, Korea.

#### Description of *Luteimonas mephitis* BO171

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 3 days of incubation on R2A at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase and urease in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain BO171 (=NIBRBAC000502391) was isolated from a cultivated soil sample, Suncheon, Jeollanam-do, Korea.

#### Description of *Lysobacter bugurensis* HMF9224

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 3 days of incubation on MA at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain HMF9224 (=NIBRBAC000502526) was isolated from a beach sand sample, Pohang, Gyeongsangbuk-do, Korea.

#### Description of *Lysobacter defluvii* H-2

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth, glisten-

ing and orange-colored after 2 days of incubation on R2A at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain H-2 (=NIBRBAC000502469) was isolated from a sludge sample, Suwon, Gyeonggi-do, Korea.

#### **Description of *Stenotrophomonas indicatrix* 18S2F3**

Cells are Gram-staining-negative, flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 2 days of incubation on MH at 30°C. Negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase and urease in API 20NE. Does not utilize L-arabinose, D-mannitol, potassium gluconate, adipic acid and phenylacetic acid. Strain 18S2F3 (=NIBRBAC000502533) was isolated from a soil sample, Chungju, Chungcheongbuk-do, Korea.

#### **Description of *Xanthomonas maliensis* BT5**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 4 days of incubation on R2A at 25°C. Negative reactions are obtained for indole production, arginine dihydrolase, urease and gelatinase in API 20NE. Does not utilize capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain BT5 (=NIBRBAC000502336) was isolated from a soil sample, Jeju-si, Jeju-do, Korea.

#### **Description of *Marinobacterium coralli* KYW1450**

Cells are Gram-staining-negative, flagellated and rod-shaped. Colonies are circular, convex, smooth and beige-colored after 3 days of incubation on MA at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain KYW1450 (=NIBRBAC000502395) was isolated from a sea water sample, Gwangyang, Jeollanam-do, Korea.

#### **Description of *Marinomonas rhizomae* HMF9105**

Cells are Gram-staining-negative, flagellated and rod-

shaped. Colonies are circular, convex, smooth and white-colored after 3 days of incubation on MA at 30°C. Negative reactions are obtained for nitrate reduction, indole production and gelatinase in API 20NE. Does not utilize capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain HMF9105 (=NIBRBAC000502519) was isolated from a Lagoon sample, Gangneung, Gangwon-do, Korea.

#### **Description of *Salinicola halophilus* SC76**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 3 days of incubation on MA at 25°C. Negative reactions are obtained for cytochrome oxidase, nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-mannitol, N-acetyl-glucosamine, D-maltose, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain SC76 (=NIBRBAC000502389) was isolated from a tidal flat sample, Suncheon, Jeollanam-do, Korea.

#### **Description of *Acinetobacter pittii* LPB0223**

Cells are Gram-staining-negative, non-flagellated and cocci-shaped. Colonies are circular, entire, convex, smooth and cream-colored after 3 days of incubation on TSY at 37°C. Negative reactions are obtained for cytochrome oxidase, nitrate reduction, indole production, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose and potassium gluconate. Strain LPB0223 (=NIBRBAC000502420) was isolated from a human sample, Seoul National University Hospital, Seoul, Korea.

#### **Description of *Pseudomonas brassicacearum* subsp. *neaurantiaca* BT57**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and yellow-colored after 3 days of incubation on MA at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation and gelatinase in API 20NE. Does not utilize capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain BT57 (=NIBRBAC000502335) was isolated from a soil sample, Jeju-si, Jeju-do, Korea.

#### **Description of *Pseudomonas chengduensis* Hyper-1**

Cells are Gram-staining-negative, flagellated and rod-shaped. Colonies are circular, convex, smooth and pale

yellow-colored after 2 days of incubation on R2A at 30°C. Negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize L-arabinose, D-mannose, N-acetyl-glucosamine and capric acid. Strain Hyper-1 (=NIBRBAC 000502459) was isolated from a sludge sample, Suwon, Gyeonggi-do, Korea.

#### Description of *Pseudomonas coleopterorum* BO247

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, convex, smooth and pale yellow-colored after 3 days of incubation on R2A at 25°C. Negative reactions are obtained for cytochrome oxidase, nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize N-acetyl-glucosamine, D-maltose, adipic acid and phenylacetic acid. Strain BO247 (=NIBRBAC000502401) was isolated from a cultivated soil sample, Jeju-si, Jeju-do, Korea.

#### Description of *Pseudomonas taiwanensis* 18H1S12

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, flat and white-colored after 2 days of incubation on MH at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose and adipic acid. Strain 18H1S12 (=NIBRBAC000502532) was isolated from a soil sample, Hanam, Gyeonggi-do, Korea.

#### Description of *Psychrobacter oceani* LPB0247

Cells are Gram-staining-negative, flagellated and rod-shaped. Colonies are circular, entire, convex, smooth and cream-colored after 3 days of incubation on MA at 25°C. Negative reactions are obtained for glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain LPB0247 (=NIBRBAC000502434) was isolated from a sea water sample, Jukdo, Ulleungdo, Gyeongsangbuk-do, Korea.

#### Description of *Vibrio gigantis* LPB0246

Cells are Gram-staining-negative, non-flagellated and comma-shaped. Colonies are circular, entire, convex, smooth and cream-colored after 3 days of incubation on

MA at 25°C. Negative reactions are obtained for glucose fermentation, arginine dihydrolase and  $\beta$ -galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain LPB0246 (=NIBRBAC000502433) was isolated from a sea water sample, Jukdo, Ulleungdo, Gyeongsangbuk-do, Korea.

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