Report on 31 unrecorded bacterial species in Korea that belong to the phylum Actinobacteria

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To discover and characterize indigenous species in Korea, a total of 31 bacterial strains that belong to the phylum Actinobacteria were isolated from various niches in Korea. Each strain showed the high sequence similarity (>99.1%) with the closest bacterial species, forming a robust phylogenetic clade. These strains have not been previously recorded in Korea. According to the recently updated taxonomy of the phylum Actinobacteria based upon 16S rRNA trees, we report 25 genera of 13 families within 5 orders of the class Actinobacteria as actinobacterial species found in Korea. Cellular morphology, Gram staining, basic biochemical characteristics are described in the species description.

Keywords: 16S rRNA gene, Actinobacteria, bacterial diversity, unrecorded species

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INTRODUCTION

Microorganisms are the most diverse and abundant groups of organisms on Earth, and they play important roles in various biogeochemical processes (Whitman et al., 1998; Fierer and Jackson, 2006). However, it was proposed that less than only 1% of total microbial cells were cultured on the planet (Amann et al., 1995). The diversity of uncultured microorganisms can offer the possibility of a vast number of novel microbial taxa to be still discovered. Thanks to innovative cultivation methods, increasing numbers of new names of prokaryotic species have been validly published (Oren and Garrity, 2014), and approximately 11,500 prokaryotic species have been validly published so far (Parte, 2014), although most of prokaryotic species have yet to be uncultured.

An increasing attention has been paid on the investigation of new or unrecorded prokaryotic species that are indigenous in Korea. A variety of novel bacterial species and unrecorded bacterial species were isolated from various environmental samples collected in Korea. As a result, the bacterial isolates were assigned to the phyla Actinobacteria, Bacteroidetes, Deinococci, Firmicutes, Proteobacteria and Verrucomicrobia.

The phylum Actinobacteria is comprised mainly of Gram-positive bacteria with a high G+C content (>55 mol% in genomic DNA), and constitutes one of the largest phyla within the Bacteria (Gao and Gupta, 2012). This phylum that contains >300 genera (Zhi et al., 2009) display enormous diversity in terms of their
morphology, physiology, and metabolic capabilities. The morphologies of actinobacterial species vary from coccoid to branched mycelia. Members of Actinobacteria are found in a wide range of environments such as soil, water, deep-sea, arctic ice, chemically contaminated sites, radioactive environments, gastrointestinal tracts of humans and animals, and plants (Gao and Gupta, 2012). Recently, the taxonomy of the phylum Actinobacteria based upon 16S rRNA trees was updated (Ludwig and Klenk, 2005.), which is the basis of the section on Actinobacteria in the Bergey's Manual of Systematic Bacteriology. Previously, the phylum Actinobacteria consisted of one class, 5 subclasses, and 9 orders. In the revised taxonomy, subclasses and suborders were eliminated, and elevated to the ranks of classes and orders, respectively; the phylum Actinobacteria is now divided into 6 classes and 22 orders. The largest class Actinobacteria, which accounts for >80% of all known actinobacterial families/genera, now contains a total of 15 orders, including both previously proposed orders Actinomycetales and Bifidobacteriales (Zhi et al., 2009). However, the order Actinomycetales is now restricted to the members of the family Actinomycetaceae, and the other suborders that were previously part of this order are now designated as distinct orders.

The species of this group also display tremendous physiological diversity, as revealed by their production of numerous extracellular enzymes (Chater et al., 2010) and secondary metabolites, many of which are antibiotics (Hopwood, 2007). The most extensively studied representatives of this group include soil-dwelling Streptomyces spp., which are the major producers of antibiotics (Chater, 2006; Ventura et al., 2007); the genus Mycobacterium, which are important human pathogens and responsible for the largest number of human deaths from bacterial infections; and the genus Rhodococcus, which possesses a high potential for industrial and environmental applications (Martínková et al., 2009; Yam et al., 2011).

As a part of results obtained from the research program supported by NIBR, the present report focuses on the description of bacterial species belonging to the Actinobacteria which have not been previously isolated in Korea. Here, we report 31 unrecorded bacterial species that belong to the phylum Actinobacteria.

Materials and Methods

A total of 31 bacterial strains were isolated from various environmental samples collected from soil, tidal flat, freshwater, seawater, wetland, and plant roots using various culture media (Table 1). The strains were isolated from each environmental sample by using the standard dilution plating technique on various culture media including R2A (BD), marine agar (MA; BD), nutrient agar (NA; BD), 1/10 PCA (BD), and minimal medium (MM; 30 g D-glucose, 1 g yeast extract, 0.5 g K2HPO4, 0.5 g KH2PO4, 2.2 g (NH4)2SO4, 0.2 g MgSO4·7H2O, 0.01 g MnSO4·7H2O, 0.01 g FeSO4·7H2O and 0.01 g NaCl in 1 L of water). The agar plates were incubated at 25-37°C for 2-10 days (Table 1). All isolates were sub-cultured, purified and stored as a stock culture in the same medium supplemented with 10-30% (v/v) glycerol. The designated strain IDs, sources, culture media, and incubation conditions are presented in Table 1.

Genomic DNA extraction, PCR amplification and 16S rRNA gene sequencing were carried out using standard procedures; the 16S rRNA gene of the isolates was amplified using the universal bacterial primer pair (27F and 1492R). The 16S rRNA gene sequences were compared with sequences in the EzTaxon-e server (http://eztaxon-e.ezbiocloud.net/) (Kim et al., 2012) and aligned with closely related species by using the CLUSTAL X program (Thompson et al., 1997). The phylogenetic relationships were evaluated by using neighbor-joining (Saitou and Nei, 1987) and maximum-likelihood (Felsenstein, 1981) algorithms, and the trees were constructed using the Mega 6 program (Tamura et al., 2013). Evolutionary distances were calculated by the model of Jukes and Cantor (1969) and tree topologies were evaluated based on bootstrap analyses of 1,000 data sets.

Colony morphology was observed on agar plates after cells grew up to stationary phase, and cellular morphology and cell size were determined by either transmission electron microscopy or scanning electron microscopy using cells grown on various agar plates for 2-10 days. The Gram staining was carried out using the Gram-staining kit (Sigma-Aldrich), and enzyme activities and utilization of different carbon sources were assessed using API 20NE galleries (bioMérieux) according to the manufacturer’s instructions.

Results and Discussion

Assignment of unrecorded strains to the validly published species of Actinobacteria

On the basis of 16S rRNA gene sequence comparisons and phylogenetic analyses, a total of 31 strains, which have not been previously isolated in Korea, were assigned to the phylum Actinobacteria. All of the 31 strains belonged to the class Actinobacteria and were distributed to 13 families of 5 orders; 8 strains of 7 genera in the family Microbacteriaceae, 4 strains of the genus Rhodococcus in the family Nocardiaceae, 4 strains of 3 genera in the family Micrococccaceae, 3 strains of 3 genera in the family Intrasporangiaceae, 3 strains of the

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Table 1. List of strains belonging to the phylum **Actinobacteria** and their taxonomic assignment based on 16S rRNA gene analysis.

| Class      | Order         | Family          | Genus       | Strain ID      | NIBR ID            | Most closely related species             | Similarity (%) | Isolation source | Medium | Incubation conditions |
|------------|---------------|-----------------|-------------|----------------|--------------------|------------------------------------------|----------------|-------------------|--------|----------------------|
|            | Actinobacteria| Dietziaceae     | Dietzia     | KYW853         | NIBR BA00000114113 | Dietzia cinnamome                         | 99.9           | Sea water         | MA     | 25°C, 2d             |
|            |               | Mycobacteriales | Mycobacterium | SPE-2          | NIBR BA00000113880 | Mycobacterium frederisbergense            | 99.4           | Plant root        | R2A    | 30°C, 2d             |
|            |               | Nocardiaceae    | Rhodococcus | U KS-28        | NIBR BA00000113883 | Rhodococcus equin                     | 99.9           | Wetland           | R2A    | 25°C, 2d             |
|            |               |                 | Rhodococcus | IK56           | NIBR BA00000113918 | Rhodococcus canchipeptinex            | 99.2           | Fresh water       | 1/10 PCA | 25°C, 10d            |
|            |               |                 | Rhodococcus | MK5-14         | NIBR BA00000113950 | Rhodococcus jostil                | 99.7           | Soil              | MA     | 30°C, 2d             |
|            |               |                 | Rhodococcus | RS5-4          | NIBR BA00000113951 | Rhodococcus maanushanensis           | 99.3           | Soil              | R2A    | 30°C, 2d             |
|            |               | Tsukamurellaceae| Tsukamurella | mNW17          | NIBR BA00000113963 | Tsukamurella tyrosinosolvens        | 99.8           | Soil              | MM     | 25°C, 3d             |
|            | Cellulomonadaceae | Cellulomonas   | Cellulomonas | UKS-33         | NIBR BA0000011382 | Cellulomonas xylanilytica         | 99.6           | Wetland           | R2A    | 25°C, 2d             |
|            | Dermabacteraceae | Brachybacterium | Brachybacterium | HME8794       | NIBR BA00000114094 | Brachybacterium multis           | 99.6           | Tidal flat        | MA     | 30°C, 2d             |
|            | Intrasporangiaceae | Humibacillus   | Humibacillus | mNW13          | NIBR BA00000113978 | Humibacillus xanthopallidus        | 99.3           | Soil              | MM     | 25°C, 5d             |
|            | Micrococcales  | Plantibacter    | Plantibacter | SPE-06         | NIBR BA00000113879 | Plantibacter flavus        | 99.4           | Plant root        | R2A    | 30°C, 2d             |
|            |               | Curtobacterium | Curtobacterium | MIC10         | NIBR BA0000011384 | Curtobacterium citreum             | 99.9           | Fresh water       | R2A    | 25°C, 2d             |
|            | Microbacteriaceae | Microbacterium | Microbacterium | MSS-22        | NIBR BA00000113944 | Microbacterium esteromatieum      | 99.3           | Soil              | MA     | 30°C, 2d             |
|            |               | Leifsonia      | Leifsonia    | MA9            | NIBR BA00000113962 | Leifsonia soli              | 99.3           | Soil              | MA     | 25°C, 2d             |
|            |               | Microbacterium | Microbacterium | MAT14        | NIBR BA00000113972 | Microbacterium pumilum         | 99.9           | Soil              | MA     | 25°C, 2d             |
|            | Microbacteriaceae | Microbacterium | Microbacterium | WR-M1Y        | NIBR BA00000113997 | Microbacterium oxydans         | 99.7           | Soil              | MA     | 25°C, 3d             |
|            |               | Agrococcus     | Agrococcus   | WT-RY7         | NIBR BA00000114009 | Agrococcus baldri          | 99.4           | Plant             | R2A    | 25°C, 3d             |
|            | Micrococcaceae | Aquiluna       | Aquiluna     | HME8543        | NIBR BA00000114076 | Aquiluna rubra               | 99.4           | Fresh water       | R2A    | 37°C, 2d             |
|            | Arthrobacter   | Arthrobacter    | Arthrobacter | RK 4 Y 5-1    | NIBR BA00000113945 | Arthrobacter globiformis       | 99.7           | Soil              | R2A    | 30°C, 2d             |
|            | Arthrobacter   | Arthrobacter    | Arthrobacter | mNW18         | NIBR BA00000113977 | Arthrobacter seiteroma        | 99.1           | Soil              | MM     | 25°C, 3d             |
Table 1. Continued.

| Class          | Order            | Family                   | Genus               | Strain ID      | NIBR ID         | Most closely related species                      | Similarity (%) | Isolation source | Medium | Incubation conditions |
|----------------|------------------|--------------------------|---------------------|----------------|----------------|---------------------------------------------------|----------------|----------------------|--------|-----------------------|
| Actinobacteria |                  | Micrococcaceae           | Micrococcus         | HR39           | NIBRB A0000113993 | *Kocuria rosea*                                    | 99.6           | Tidal flat          | R2A    | 25°C, 3d               |
|                |                  |                         | *Micrococcus*       | HME8781        | NIBRB A0000114092 | *Micrococcus flava*                                | 99.1           | Tidal flat          | MA     | 30°C, 2d              |
|                |                  | Pseudomonosporaceae     | Isoptericola        | RS5-5_B        | NIBRB A0000113943 | *Isoptericola nanjingensis*                         | 100            | Soil                | R2A    | 30°C, 2d              |
|                |                  |                         | Cellulosimicrobium  | NS3-4_B        | NIBRB A0000113954 | *Cellulosimicrobium flavitolens*                    | 99.9           | Soil                | NA     | 30°C, 2d              |
|                | Propionibacteriales | Streptomycetales       | Streptomycetes      | UKS-24         | NIBRB A0000113885 | *Streptomycetes avellaneus*                         | 100            | Wetland             | R2A    | 25°C, 2d              |
|                |                  | Streptomycetales        | Streptomycetes      | MS5-13         | NIBRB A0000113953 | *Streptomycetes omiyaensis*                         | 100            | Soil                | MA     | 30°C, 2d              |
|                |                  | Streptomycetales        | Streptomycetes      | MA10           | NIBRB A0000113970 | *Streptomycetes atratus*                            | 100            | Soil                | MA     | 25°C, 2d              |
|                | Streptosporangiaceae | Microbispom              | Microbispora        | UKS-23         | NIBRB A0000113868 | *Microbispora rosea*                                | 99.6           | Wetland             | R2A    | 25°C, 2d              |
of the family Streptosporangiaceae, respectively (Fig. 2).

**Description of Dietzia cinnamenea KYW853**

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are opaque, round, smooth, convex and orange-colored after 2 days of incubation on R2A at 25°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and β-galactosidase in API 20NE. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetylglucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain KYW853 (= NIBRBA0000114113) was isolated from a sea water sample, Gwangyang Bay, Gwangyang, Korea.

**Description of Mycobacterium frederikbergense SPE2-2**

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are round, smooth and yellow-colored after 2 days of incubation on R2A at 30°C. Positive reactions are obtained for nitrate reduction, glucose fermentation, esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for indole production, arginine dihydrolase, urease and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetylglucosamine, potassium gluconate, adipic acid, malic acid, trisodium citrate and phenylacetic acid are utilized. Does not utilize D-maltose and capric acid. Strain SPE2-2 (= NIBRBA0000113880) was isolated from a plant root sample, Chungnam National University, Daejeon, Korea.

**Description of Rhodococcus equi UKS-28**

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular, raised, entire and yellow-colored after 2 days of incubation on R2A at 25°C. Positive reaction is obtained for nitrate reduction in API 20NE, and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and β-galactosidase. Malic acid is utilized. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetylglucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain UKS-28 (= NIBRBA0000113883) was isolated from a wetland sample, Ungok-ri, Gochang, Chonbuk, Korea.

**Description of Rhodococcus canchipurensis IK56**

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are smooth, circular, convex, opaque and pallid pink-colored after 10 days of incubation on 1/10 PCA at 25°C. Positive reactions are obtained for nitrate reduction, esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase. Malic acid is utilized. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetylglucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain IK56 (= NIBRBA0000113918) was isolated from a freshwater sample, Ingeyeong lake, Incheon, Korea.

**Description of Rhodococcus jostii MK5-14**

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular, entire, smooth and beige colored after 2 days on MA at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and β-galactosidase in API 20NE. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetylglucosamine, potassium gluconate, adipic acid, malic acid, trisodium citrate and phenylacetic acid are utilized. Does not utilize D-maltose and capric acid. Strain MK5-14 (= NIBRBA0000113950) was isolated from a sample of ginseng field, Iljuk, Anseong, Korea.

**Description of Rhodococcus maanshanensis RS5-4**

Cells are Gram-staining-positive, non-flagellated, non-pigmented and rod-shaped. Colonies are circular, entire, smooth and white-colored after 2 days on R2A at 30°C. Positive reactions are obtained for nitrate reduction, urease, esculin hydrolysis, and β-galactosidase in API 20NE and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetylglucosamine, D-maltose, potassium gluconate, adipic acid, malic acid and trisodium citrate are utilized. Does not utilize capric acid and phenylacetic acid. Strain RS5-4 (= NIBRBA0000113951) was isolated from a sample of ginseng field, Iljuk, Anseong, Korea.

**Description of Tsukamuraella tyrosinosolvens mNW17**

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular and beige-colored after 3 days on minimal medium at 25°C. Positive reactions are obtained for glucose fermentation, urease, esculin hydrolysis, gelatinase and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production and arginine dihydrolase. L-arabinose,
Fig. 1. Transmission electron micrographs or scanning electron micrographs of cells of the strains isolated in this study. Strains: 1, KYW853; 2, SPE2-2; 3, UKS-28; 4, IK56; 5, MK5-14; 6, RS5-4; 7, mNW17; 8, UKS-33; 9, HME8794; 10, mNW13; 11, HWR24; 12, AB7; 13, SPE-06; 14, MIC10; 15, MS5-22; 16, MA9; 17, MAT14; 18, WR-M1Y; 19, WT-RY7; 20, HME8543; 21, RK 4 Y 5-1; 22, mNW18; 23, HR39; 24, HME8781; 25, RS5-5_B; 26, NS3-4_B; 27, Gsoil 950; 28, UKS-24; 29, MS5-13; 30, MA10; 31, UKS-23.
Fig. 2. 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 phylum Actinobacteria. The numbers at nodes represent bootstrap values (>50%) obtained by neighbor-joining and maximum-likelihood methods, respectively. Closed circles indicate the nodes recovered by maximum-likelihood algorithm. The GenBank accession number of each species is enclosed in parentheses. Bar, 0.02 substitutions per nucleotide position.
D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, trisodium citrate and phenylacetic acid are utilized. Does not utilize D-glucose, D-mannose, capric acid, adipic acid and malic acid. Strain mNW17 (= NIBRBA0000113963) was isolated from a forest soil sample, Gwanak Mountain, Seoul, Korea.

Description of *Cellulomonas xylanilytica* UKS-33

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular, raised, entire and yellow-colored after 2 days on R2A at 25°C. Positive reactions are obtained for esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase. Does not utilize D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid and trisodium citrate and phenylacetic acid. Strain UKS-33 (= NIBRBA0000113882) was isolated from a tidal flat sample, Ungok-ri, Gochang, Korea.

Description of *Humibacillus xanthopallidu* mNW13

Cells are flagellated and rod-shaped. Colonies are circular and orange-colored after 5 days on minimal medium at 25°C. Positive reactions are obtained for glucose fermentation, urease, esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, arginine dihydrolase and gelatinase. D-mannose, D-mannitol, D-maltose and malic acid are utilized. Does not utilize D-glucose, L-arabinose, N-acetyl-glucosamine, potassium gluconate, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain mNW13 (= NIBRBA0000113978) was isolated from a forest soil sample, Gwanak Mountain, Seoul, Korea.

Description of *Serinicoccus profundi* HWR24

Cells are Gram-staining-positive, non-flagellated and cocoid-shaped. Colonies are circular, convex, glistening and yellow-colored after 3 days on R2A at 25°C. Positive reactions are obtained for nitrate reduction, esculin hydrolysis, gelatinase and β-galactosidase in API 20NE, and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase and urease. D-glucose, D-mannose, D-maltose, potassium gluconate and malic acid are utilized. Does not utilize L-arabinose, D-mannitol, N-acetyl-glucosamine, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain HWR24 (= NIBRBA0000113995) was isolated from a tidal flat sample, Hwango-ri, Amnyeon-eup, Taean, Korea.

Description of *Janibacter anopheles* AB7

Cells are Gram-staining-positive, non-flagellated and short-rod-shaped. Colonies are circular, raised, entire and ivory-colored after 2 days on MA at 25°C. Positive reactions are obtained for nitrate reduction, esculin hydrolysis and β-galactosidase in API 20NE and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, malic acid and trisodium citrate are utilized. Does not utilize capric acid, adipic acid and phenylacetic acid. Strain AB7 (= NIBRBA0000114044) was isolated from a tidal flat sample, Uihang-ri, Sowon-myeon, Taean, Korea.

Description of *Plantibacter flavus* SPE-06

Cells are Gram-staining-positive, non-flagellated and rod and spiral-shaped. Colonies are round, convex and yellow-colored after 2 days on R2A at 30°C. Positive reactions are obtained for glucose fermentation, esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, arginine dihydrolase, urease and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate and malic acid are utilized. Does not utilize capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain SPE-06 (= NIBRBA0000113879) was isolated from a plant root sample, Chungnam National University, Daejeon, Korea.

Description of *Curtobacterium citreum* MIC10

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular and yellow-colored after 2 days on R2A at 25°C. Positive reactions are obtained for nitrate reduction, esculin hydrolysis, gelati-
nase and β-galactosidase in API 20NE, and negative re-
actions are obtained for indole production, glucose fer-
mentation, arginine dihydrolase and urease. D-glucose,
L-arabinose, D-mannose, D-mannitol, N-acetyl-glucos-
amine, D-maltose, and potassium gluconate are utilized.
Does not utilize capric acid, adipic acid, malic acid, tri-
sodium citrate and phenylacetic acid. Strain MAT14 (= NIBRBA0000113972) was isolated from a forest soil sample, Gwanak Mountain, Seoul, Korea.

Description of Microbacterium esteraromaticum

MS5-22

Cells are Gram-staining-negative, flagellated and rod-
shaped. Colonies are circular, entire, smooth and yel-
low-colored after 2 days on MA at 30°C. Positive re-
actions are obtained for nitrate reduction and β-galactosi-
dase in API 20NE, and negative reactions are obtained
for indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose and potassium gluconate utilized. Does not utilize capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain MS5-22 (= NIBRBA0000113944) was isolated from a sample of ginseng field, Iljuk, Anseong, Korea.

Description of Leifsonia soli MA9

Cells are flagellated and rod-shaped. Colonies are cir-
cular and yellow-colored after 2 days on MA at 25°C.
Positive reactions are obtained for esculin hydrolysis, gelatinase and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase and gelatinase. D-glucose and D-mannose are utilized. Does not utilize L-arabinose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain MA9 (= NIBRBA0000113962) was isolated from a forest soil sample, Gwanak Mountain, Seoul, Korea.

Description of Microbacterium pumilum MAT14

Cells are Gram-staining-positive, flagellated and rod-
shaped. Colonies are circular and orange-colored after
2 days on MA at 25°C. Positive reactions are obtained for glucose fermentation, urease, esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, arginine dihydrolase and gelatinase. 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 MAT14 (= NIBRBA0000113972) was isolated from a forest soil sample, Gwanak Mountain, Seoul, Korea.

Description of Microbacterium esteraromaticum

MS5-22

Cells are Gram-staining-negative, flagellated and rod-
shaped. Colonies are circular, entire, smooth and yel-
low-colored after 2 days on MA at 30°C. Positive re-
actions are obtained for nitrate reduction and β-galactosi-
dase in API 20NE, and negative reactions are obtained
for indole production, glucose fermentation, arginine dihydrolase and urease. D-glucose, D-mannose, D-mannitol, D-maltose and potassium gluconate are utilized. Does not utilize L-arabinose, N-acetyl-glucosamine, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain WR-M1Y (= NIBRBA0000113997) was isolated from a soil sample in field of reeds, Wando, Korea.

Description of Agrococcus baldri WT-RY7

Cells are Gram-staining-positive, flagellated and rod-
shaped. Colonies are circular, convex, glistening and vivid-yellow-colored after 3 days on R2A at 25°C. Positive reactions are obtained for esculin hydrolysis, gelatinase and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase and urease. 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 WT-RY7 (= NIBRBA0000114009) was isolated from a plant sample, Wando, Korea.

Description of Aquiluna rubra HME8543

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular, raised, entire and red-colored after 2 days on R2A at 37°C. Positive reaction is obtained for β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis and gelatinase. 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 HME8543 (= NIBRBA0000114076) was isolated from a freshwater sample, Geongan Stream, Yongin, Korea.

Description of Arthrobacter globiformis RK 4Y 5-1

Cells are Gram-staining-negative, flagellated, non-pig-
mented and rod-shaped. Colonies are circular, entire,
smooth and white-colored after 2 days on R2A at 30°C. Positive reactions are obtained for gelatinase and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease and esculin hydrolysis. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, adipic acid, malic acid, trisodium citrate and phenylacetic acid are utilized. Does not utilize capric acid. Strain HR39 (= NIBRBA0000113994) was isolated from a sample of ginseng field, Iljuk, Anseong, Korea.

Description of Arthrobacter scleromae mNW18

Cells are Gram-staining-positive, flagellated, non-pigmented and coccoid-shaped. Colonies are circular and cream-colored after 3 days on minimal medium at 25°C. Positive reactions are obtained for glucose fermentation, urease, esculin hydrolysis, gelatinase and β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production and arginine dihydrolase. L-arabinose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, trisodium citrate and phenylacetic acid are utilized. Does not utilize D-glucose, D-mannose, capric acid, adipic acid and malic acid. Strain mNW18 (= NIBRBA0000113977) was isolated from a forest soil sample, Gwanak Mountain, Seoul, Korea.

Description of Kocuria rosea HR39

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are irregular, convex, glistening and pale orange/yellow-colored after 3 days on R2A at 25°C. Positive reactions are obtained for nitrate reduction and β-galactosidase in API 20NE, and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, D-maltose, potassium gluconate, adipic acid and malic acid are utilized. Does not utilize D-mannose, N-acetyl-glucosamine, capric acid, trisodium citrate and phenylacetic acid. Strain HR39 (= NIBRBA0000113993) was isolated from a tidal flat sample, Hwango-ri, Anmyeon-eup, Taean, Korea.

Description of Micrococcus flavus HME8781

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular, convex, entire and yellow-colored after 2 days on MA at 30°C. Negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis, gelatinase and β-galactosidase in API 20NE. D-glucose D-maltose and malic acid are utilized. Does not utilize L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, potassium gluconate, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain HME8781 (= NIBRBA0000114092) was isolated from a tidal flat sample, Sinan, Korea.

Description of Isoptericola nanjingensis RS5-5_B

Cells are Gram-staining-positive, non-flagellated and coccoid-shaped. Colonies are circular, entire, smooth and light yellow-colored after 2 days on R2A at 30°C. Positive reactions are obtained for nitrate reduction, esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose and potassium gluconate are utilized. Does not utilize capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain RS5-5_B (= NIBRBA0000113943) was isolated from a sample of ginseng field, Iljuk, Anseong, Korea.

Description of Cellulosimicrobium funkei NS3-4_B

Cells are Gram-staining-positive, non-flagellated and coccoid-shaped. Colonies are punctiform, entire, smooth and light yellow-colored after 2 days on NA at 30°C. Positive reactions are obtained for nitrate reduction, esculin hydrolysis and β-galactosidase in API 20NE, negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase. D-glucose, L-arabinose, D-mannose, N-acetyl-glucosamine, D-maltose and potassium gluconate are utilized. Does not utilize D-mannitol, capric acid, adipic acid, malic acid, trisodium citrate and phenylacetic acid. Strain NS3-4_B (= NIBRBA0000113954) was isolated from a sample of ginseng field, Iljuk, Anseong, Korea.

Description of Microlunatus soli Gsoil 950

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular, raised, entire and yellow-colored after 2 days on R2A at 25°C. Positive reactions are obtained for nitrate reduction, glucose fermentation, urease, esculin hydrolysis, gelatinase and β-galactosidase in API 20NE, and negative reactions are obtained for indole production and arginine dihydrolase. D-glucose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose and trisodium citrate are utilized. Does not utilize L-arabinose, potassium gluconate, capric acid, adipic acid, malic acid, and phenylacetic acid. Strain Gsoil 950 (= NIBRBA0000113889) was isolated from a sample of ginseng field, Pocheon, Korea.
Description of *Streptomyces avellaneus* UKS-24

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are circular, raised, entire and yellow-colored after 2 days on R2A at 25°C. Positive reaction is obtained for β-galactosidase in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, esculin hydrolysis and gelatinase. D-glucose, L-arabinose, N-acetyl-glucosamine, potassium gluconate and malic acid are utilized. Does not utilize D-mannose, D-mannitol, D-maltose, capric acid, adipic acid, trisodium citrate and phenylacetic acid. Strain UKS-24 (= NIBRBA0000113885) was isolated from a wetland sample, Ungok-ri, Gochang, Korea.

Description of *Streptomyces omiyaensis* MS5-13

Cells are Gram-staining-positive, non-flagellated and rod-shaped. Colonies are irregular, undulate, smooth and light yellow-colored after 2 days on MA at 30°C. Positive reactions are obtained for nitrate reduction, esculin hydrolysis and β-galactosidase in API 20NE, and negative reactions are obtained for indole production, glucose fermentation, arginine dihydrolase, urease and gelatinase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, adipic acid, malic acid and phenylacetic acid are utilized. Does not utilize capric acid and trisodium citrate. Strain MS5-13 (= NIBRBA0000113953) was isolated from a sample of ginseng field, Anseong, Korea.

Description of *Streptomyces atratus* MA10

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, raised, entire and yellow-colored after 2 days on MA at 25°C. Strain MA10 (= NIBRBA000113970) was isolated from a forest soil sample, Gwanak Mountain, Seoul, Korea.

Description of *Microbispora rosea* subsp. *rosea* UKS-23

Cells are Gram-staining-negative, non-flagellated and rod-shaped. Colonies are circular, raised, entire and yellow-colored after 2 day on R2A at 25°C. Positive reaction is obtained for esculin hydrolysis in API 20NE, and negative reactions are obtained for nitrate reduction, indole production, glucose fermentation, arginine dihydrolase, urease, gelatinase and β-galactosidase. D-glucose, L-arabinose, D-mannose, D-mannitol, N-acetyl-glucosamine, D-maltose, potassium gluconate, adipic acid and malic acid are utilized. Does not utilize capric acid, trisodium citrate and phenylacetic acid. Strain UKS-23 (= NIBRBA0000113886) was isolated from a wetland sample, Ungok-ri, Gochang, Korea.

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