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A report of 9 unrecorded radiation resistant bacterial species in Korea

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Five bacterial strains, ES10-3-3-1, KKM10-2-2-1, Ant11, JM10-4-1-3, and KMS4-11 assigned to the genus *Deinococcus* were isolated from soil samples collected from Namyangju-si in Gyeonggi-do, Gangnam-gu and Dongdaemun-gu in Seoul, Korea. In addition, four bacterial strains, KKM10-2-7-2, JM10-2-5, JM10-2-6-2, and KKM10-2-3 assigned to the genus *Hymenobacter* were isolated from soil samples collected from Gangnam-gu and Dongdaemun-gu in Seoul, in South Korea. The five *Deinococcus* species were Gram-stain positive, pink-pigmented, and short-rod or coccus shaped. The four *Hymenobacter* species were Gram-stain negative, red-pigmented, and short-rod shaped. Phylogenetic analysis based on 16S rRNA gene sequences revealed that strains ES10-3-3-1, KKM10-2-2-1, Ant11, JM10-4-1-3, and KMS4-11 were most closely related to *Deinococcus citri* NCCP-154^T (with 99.8% similarity), *Deinococcus grandis* DSM 12784^T (99.0%), *Deinococcus marmoris* DSM 12784^T (98.8%), *Deinococcus claudionis* PO-04-19-125^T (98.7%), and *Deinococcus radioresistens* 8A^T (99.8%), respectively. KKM10-2-7-2, JM10-2-5, JM10-2-6-2, and KKM10-2-3 were most closely related to *Hymenobacter algoricola* VUG-A23a^T (99.1% similarity), *Hymenobacter elongatus* VUG-A112^T (99.1% similarity), *Hymenobacter gelipurpurascens* Txg1^T (99.1% similarity), and *Hymenobacter psychrotolerans* Tibet-IIU11^T (99.3% similarity), respectively. These nine species have never been reported in Korea; thus, five *Deinococcus* species are reported in the family *Deinococcaceae*, order *Deinococcales*, class *Deinococci*, phylum *Deinococcus-Thermus* and four *Hymenobacter* species are reported in the family *Cytophagaceae*, order *Cytophagales*, class *Cytophagia*, phylum *Bacteroidetes*.

Keywords: 16S rRNA gene, *Bacteroidetes*, *Deinococcus*, *Deinococcaceae*, *Deinococcus-Thermus*, *Hymenobacter*, unrecorded species in Korea

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Introduction

In 2015, we collected diverse soil samples and isolated unrecorded bacterial species in Korea. The identified bacterial species belonged to the phyla *Deinococcus-Thermus* and *Bacteroidetes*. This report focuses on the isolation and description of unrecorded radiation-resistant species in the the genera *Deinococcus* and *Hymenobacter*.

The genus *Deinococcus* was proposed by Brooks and Murray (1981) and the type species *Deinococcus radiodurans* was isolated from gamma-ray-irradiated food. Currently, the genus *Deinococcus* comprises 57 species isolated from diverse environments such as air, hot springs, continental Antarctica, desert soil, fish, and water (http://www.bacterio.cict.fr/d/deinococcus.html). Members of the genus *Deinococcus* are Gram-positive (Brooks and Murray, 1981; Srinivasan *et al*., 2012a, 2012b), have red cell colors, and have L-ornithine as the di-amino acid in the cell-wall peptidoglycan.

The genus *Hymenobacter* was first proposed by Hirsch (1998) and the type species *Hymenobacter roseosalivarius* was isolated from continental Antarctic soils and sandstone (Hirsch *et al*., 1998). Currently, there are 36 species of the genus *Hymenobacter* with validly published names (http://www.bacterio.net/hymenobacter.html#r). Members of the genus *Hymenobacter* are pink or red, rod-shaped, and Gram-negative. The *Hymenobacter* species inhabit various environments, such as soil, glaciers,

marine and freshwater aquatic systems and air (Han *et al*., 2014).

Materials and Methods

Various soil samples were suspended on distilled water and serially diluted. The aliquot was inoculated onto R2A agar and incubated at 25°C for 3 days (Table 1). The designated strain IDs, sources, culture media, and incubation conditions are summarized in Table 1. All strains were purified as single colonies and stored in 20% glycerol suspension at −80°C as well as lyophilized ampoules.

Colony morphology and cell size of the strains were observed on R2A agar after cells were grown for 3 days at 25°C by using transmission electron microscopy (LIBRA 120, Carl Zeiss). Transmission electron micrographs of the strains are shown in Fig. 1. Gram reaction was performed according to the classic Gram procedure described by Doetsch (1981). Biochemical characteristics were tested by using Biolog Microstation with GEN III microplate system. A single colony was selected and emulsified into 'inoculating fluid A' (Biolog) for subsequent inoculation on to the MicroPlate test plate (Biolog). More fastidious organisms, including capnophilic strains, were cultured on alternative media, according to the manufacturer's instructions, and inocula prepared to a specified transmittance using a turbidimeter, as specified in the user's guide. For each isolate, 100 µL of the cell suspension was inoculated into each well of the MicroPlate, using a multichannel pipette and incubated at 37°C for 24 h, according to growth characteristics. MicroPlates were read in a MicroStation semi-automated reader after 24 h and results interpreted by the identification system's software (GEN III database, version 5.2.1). The system indicated which isolates could not be identified after 20 h and required further incubation. Such isolates were re-incubated and re-read 3 to 6 h later. (Wragg *et al*., 2014) Genomic DNA was extracted and 16S rRNA gene was amplified by PCR with 9F and 1492R universal bacterial primers (Weisburg *et al*., 1991). The 16SrRNA gene sequences of the related taxa were obtained from EzTaxon-e (http://eztaxon-e.ezbiocloud.net) (Kim *et al*., 2012) and edited using the BioEdit program (Hall, 1999). Multiple alignments were performed with the MUSCLE program (Edgar, 2004). Evolutionary distances were calculated using the two-parameter model (Kimura, 1983). Phylogenetic trees were constructed using the neighbor-joining method (Saitou and Nei, 1987) in the MEGA5 program (Tamura, 2011) with bootstrap values based on 1,000 replications (Felsenstein, 1985).

Results and Discussion

Based on the comparative 16S rRNA gene sequence analyses and phylogenies, nine strains, designated ES10-3-3-1, KKM10-2-2-1, Ant11, JM10-4-1-3, KMS4-11, KKM10-2-7-2, JM10-2-5, JM10-2-6-2, and KKM10-2-3 were assigned to the species level. Morphology and physiological characteristics are shown in the species description section.

Strains ES10-3-3-1, KKM10-2-2-1, Ant11, JM10-4-1-3, and KMS4-11 were most closely related to *Deinococcus citri* NCCP-154^T (AB558498; 99.85% 16S rRNA gene sequence similarity), *Deinococcus grandis* DSM 12784^T (Y11329; 99.00% similarity), *Deinococcus marmoris* DSM 12784^T (JNIV01000230; 98.81% similarity), *Deinococcus claudionis* PO-04-19-125^T (EF635406; 98.80% similarity), and *Deinococcus radioresistens* 8A^T (KJ123751; 99.82% similarity), respectively (Table 1).

Strains KKM10-2-7-2, JM10-2-5, JM10-2-6-2, and KKM10-2-3 were most closely related to *Hymenobacter algoricola* VUG-A23a^T (EU155009; 99.18% 16S rRNA gene sequence similarity), *Hymenobacter elongatus* VUG-A112^T (GQ454797; 99.10% similarity), *Hymenobacter gelipurpurascens* Txg1^T (Y18836; 99.13% similarity), and *Hymenobacter psychrotolerans* Tibet-IIU11^T (DQ177475; 99.37% similarity), respectively (Table 2).

As expected from the high 16S rRNA gene sequence similarities of the nine strains with their closest relatives, each strain formed a robust phylogenetic clade with the most closely related species (Fig. 2). From the high 16S rRNA gene sequence similarity and robust formation of phylogenetic clades, it is concluded that strains ES10-3-3-1, KKM10-2-2-1, Ant11, JM10-4-1-3, and KMS4-11

Table 1. 16S rRNA gene sequence similarity, isolation source, medium, and incubation conditions of unrecorded strains belonging to the genus *Deinococcus*.

Strain ID	Most closely related species	Similarity (%)	Isolation source	Medium	Incubation conditions
ES10-3-3-1	*Deinococcus citri*	99.3	soil of Namyangju-si	R2A	25°C, 3 d
KKM10-2-2-1	*Deinococcus grandis*	99.0	soil of Gangnam-gu	R2A	25°C, 3 d
Ant11	*Deinococcus marmoris*	99.1	soil of Dongdaemun-gu	R2A	25°C, 3 d
JM10-4-1-3	*Deinococcus claudionis*	98.8	soil of Dongdaemun-gu	R2A	25°C, 3 d
KMS4-11	*Deinococcus radioresistens*	99.8	soil of Gangnam-gu	R2A	25°C, 3 d

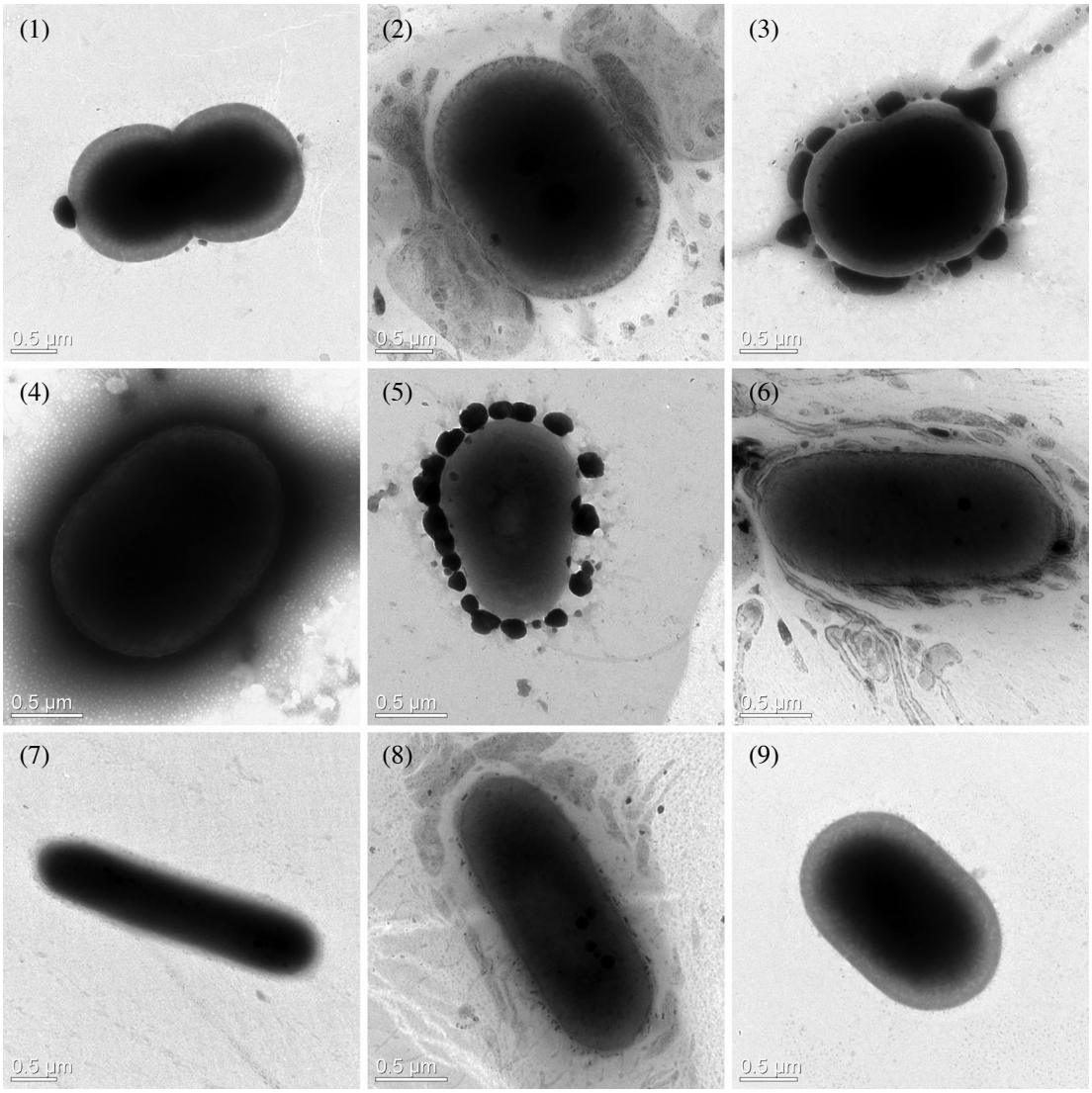


Fig. 1. Transmission electron micrographs of the strains isolated in this study. Bar: 0.5 μm substitutions per cell size. Strains: 1, ES10-3-3-10; 2, KKM10-2-2-1; 3, Ant11; 4, JM10-4-1-3; 5, KMS4-11; 6, KKM10-2-7-2; 7, JM10-2-5; 8, JM10-2-6-2; 9, KKM10-2-3.

Table 2. 16S rRNA gene sequence similarity, isolation source, medium, and incubation conditions of unrecorded strains belonging to the genus *Hymenobacter*.

Strain ID	Most closely related species	Similarity (%)	Isolation source	Medium	Incubation conditions
KKM10-2-7-2	*Hymenobacter algoricola*	99.1	soil of Gangnam-gu	R2A	25°C, 3 d
JM10-2-5	*Hymenobacter elongatus*	99.2	soil of Dongdaemun-gu	R2A	25°C, 3 d
JM10-2-6-2	*Hymenobacter gelipurpurascens*	99.3	soil of Dongdaemun-gu	R2A	25°C, 3 d
KKM10-2-3	*Hymenobacter psychrotolerans*	98.8	soil of Gangnam-gu	R2A	25°C, 3 d

are members of the species *Deinococcus citri* (Ahmed *et al*., 2014), *Deinococcus grandis* (Oyaizu *et al*., 1987), *Deinococcus marmoris* (Hirsch *et al*., 2004), *Deinococcus claudionis* (Callegan *et al*., 2008), and *Deinococcus radioresistens* (Srinivasan *et al*., 2015), respectively. KKM10-2-7-2, JM10-2-5, JM10-2-6-2, and KKM10-2-3 are members of the species *Hymenobacter algoricola* (Klassen and Foght, 2011), *Hymenobacter elongatus* (Klassen and Foght, 2011), *Hymenobacter gelipurpurascens* (Buczolits *et al*., 2006), and *Hymenobacter psychrotolerans* (Zhang *et al*., 2008), respectively.

There are no reports of these nine species in the gen-

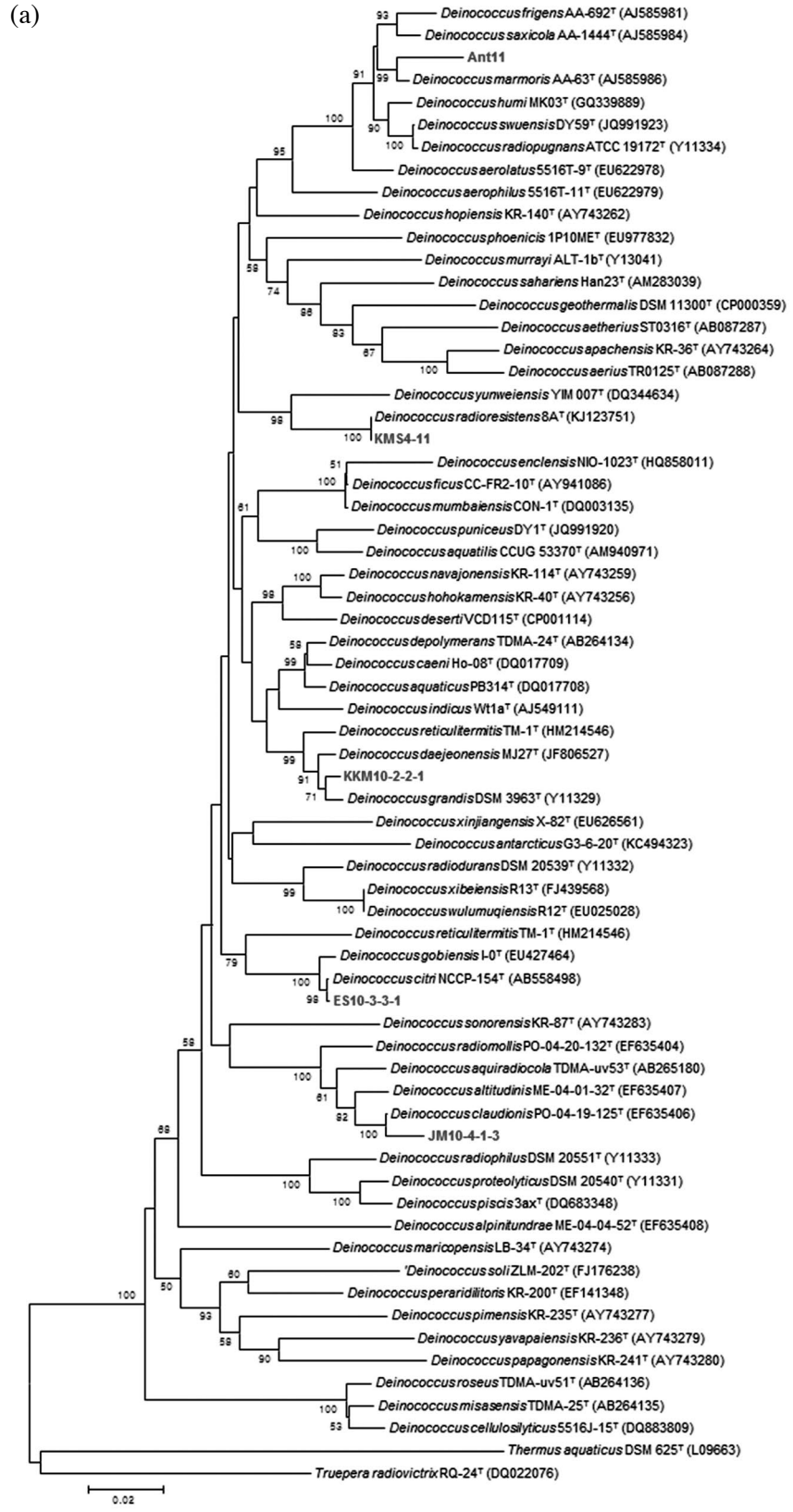


Fig. 2. Neighbor-joining phylogenetic tree based on 16S rRNA gene sequences shows the relationship between the strains isolated in this study and their relatives of the genus *Deinococcus* (a) and *Hymenobacter* (b). Bootstrap values (>70%) are shown above nodes for the neighbor-joining methods. Bar: 0.02 substitutions per nucleotide position.

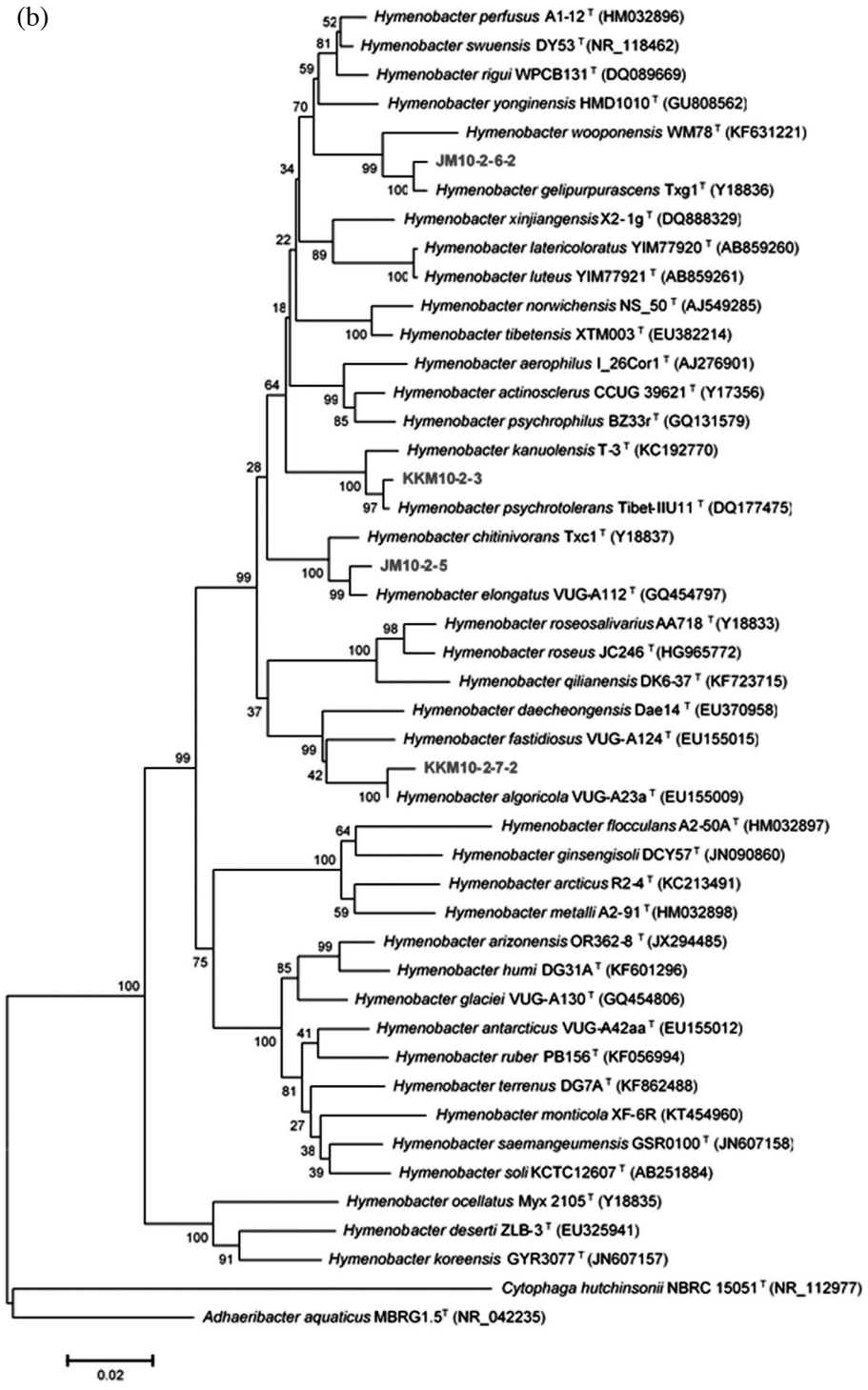


Fig. 2. Continued.

era *Deinococcus* or *Hymenobacter* having been isolated in Korea. The strains ES10-3-3-1, KKM10-2-2-1 Ant11, JM10-4-1-3, KMS4-11 KKM10-2-7-2, JM10-2-5, JM10-2-6-2, and KKM10-2-3 are unreported strains of *Deinococcus citri*, *Deinococcus grandis*, *Deinococcus marmoris*, *Deinococcus claudionis*, *Deinococcus radioresistens*, *Hymenobacter algoricola*, *Hymenobacter elongatus*, *Hymenobacter gelipurpurascens*, and *Hymenobacter psychrotolerans* for.

Description of *Deinococcus citri* ES10-3-3-1

Cell is Gram-stain-positive, non-flagellated, and coccus-shaped. Colonies are pale pinkish-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, L-alanine, D-fructose, D-fructose-6-phosphate, D-fucose, L-fucose, L-galactonic acid lactone, D-galacturonic acid, D-gluconic acid, α-D-glucose, glucuronamide, D-glucuronic acid, glycerol, D-mannitol, D-mannose, D-melibiose, 3-methyl glucose, pectin, glycyl-L-protine, D-serine, D-sorbitol, sucrose, and D-turanose are utilized as sole carbon source. But acetic acid, acetoacetic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellobiose, citric acid, dextrin, formic acid, D-galactose, gelatin, gentiobiose, D-glucose-6-phosphate, L-glutamic acid, L-histidine, α-hydroxybutric acid, β-hydroxy-D,L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, α-D-lactose, D-malic acid, L-malic acid, D-maltose, β-methyl-D-glucoside, methyl pyruvate, mucic acid, myo-inositol, propionic acid, L-pyroglutamic acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-salicin, L-serine, stachyose, D-trehalose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is reduced at pH 6 but not at pH 5; the dye is reduced in the presence of 1% NaCl, aztreonam, nalidixic acid, potassium tellurite, rifamycin SV, D-serine, tetrazolium blue, and tetrazolium violet; but not in the presence of 1% sodium lactate, 4% NaCl, 8% NaCl, fusidic acid, guanidine HCl, lincomycin, lithium chloride, minocycline, niaproof 4, sodium bromate, sodium butyrate, troleandomycin, and vancomycin. Strain ES10-3-3-1 (=NIBRBAC 000003990) was isolated from a soil sample, Namyangju-si in Gyeonggi-do, Korea.

Description of *Deinococcus grandis* KKM10-2-2-1

Cells are Gram-stain-positive, non-flagellated, and short rod-shaped. Colonies are pinkish-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, acetic acid, L-alanine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, D-cellobiose, D-fructose, D-fructose-6-phosphate, D-fucose, L-galactonic acid lactone, D-galactose, D-galacturonic acid, gelatin, D-gluconic acid, α-D-glucose, D-glucose-6-phosphate, glucuronamide, D-glucuronic acid, L-glutamic acid, glycerol, L-histidine, α-keto-glutaric acid, D-lactic acid methyl ester, L-malic acid, D-maltose, D-mannitol, D-mannose, D-melibiose, 3-methyl glucose, pectin, glycyl-L-protine, L-pyroglutamic acid, quinic acid, L-rhamnose, D-serine, L-serine, D-sorbitol, stachyose, and sucrose are utilized as sole carbon source. But, acetoacetic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, bromo-succinic acid, citric acid, dextrin, formic acid, L-fucose, gentiobiose, α-hydroxybutric acid, β-hydroxy-D,L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, L-lactic acid, α-D-lactose, D-malic acid, β-methyl-D-glucoside, methyl pyruvate, mucic acid, myo-inositol, propionic acid, D-raffinose, D-saccharic acid, D-salicin, D-trehalose, D-turanose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is reduced at pH 6 but not at pH 5; the dye is reduced in the presence of minocycline, tetrazolium blue, and tetrazolium violet, but not in the presence of 1% NaCl, 1% sodium lactate, 4% NaCl, 8% NaCl, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, minocycline, nalidixic acid, niaproof 4, potassium tellurite, D-Serine, sodium bromate, sodium butyrate, troleandomycin, and vancomycin. Strain KKM10-2-2-1 (=NIBRBAC000003991) has been isolated from a soil sample, Gangnam-gu in Seoul, South Korea.

Description of *Deinococcus marmoris* Ant11

Cells are Gram-stain-positive, and short rod or coccus-shaped. Colonies are circular and pale red-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, acetoacetic acid, D-fructose-6-phosphate, D-galactose, glucuronamide, D-glucuronic acid, and L-histidine are utilized as sole carbon source. But acetic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, L-alanine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellobiose, citric acid, dextrin, formic acid, D-fructose, D-fucose, L-fucose, L-galactonic acid lactone, D-galacturonic acid, gelatin, gentiobiose, D-gluconic acid, α-D-glucose, D-glucose-6-phosphate, L-glutamic acid, glycerol, α-hydroxybutric acid, β-hydroxy-D, L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, α-D-lactose, D-malic acid, L-malic acid, D-maltose, D-mannitol, D-mannose, D-melibiose, β-methyl-D-glucoside, 3-methyl glucose, methyl pyruvate, mucic acid, myo-inositol, pectin, propionic acid, Glycyl-L-protine, L-pyroglutamic acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-salicin, D-serine, L-serine, D-sorbitol, stachyose, sucrose, D-trehalose, D-turanose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is reduced at pH 5 and pH 6; the dye is reduced in the presence of minocycline, tetrazolium blue, and tetrazolium violet, but not in the presence of 1% NaCl, 1% sodium

lactate, 4% NaCl, 8% NaCl, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, nalidixic acid, niaproof 4, potassium tellurite, rifamycin SV, D-Serine, sodium bromate, sodium butyrate, troleandomycin, and vancomycin. Strain Ant11 (=NIBRBAC 000003985) has been isolated from a soil sample, Dongdaemun-gu in Seoul, South Korea.

Description of *Deinococcus claudionis* JM10-4-1-3

Cells are Gram-stain-positive, non-flagellated, and short rod-shaped. Colonies are pale pinkish-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, L-alanine, D-fructose, D-fructose-6-phosphate, D-fucose, L-fucose, L-galactonic acid lactone, D-galacturonic acid, D-gluconic acid, α-D-glucose, glucuronamide, D-glucuronic acid, glycerol, D-mannitol, D-mannose, D-melibiose, 3-methyl glucose, pectin, glycyl-L-protine, D-serine, D-sorbitol, sucrose, and D-turanoseare utilized as sole carbon source. But acetic acid, acetoacetic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellobiose, citric acid, dextrin, formic acid, D-galactose, gelatin, gentiobiose, D-glucose-6-phosphate, L-glutamic acid, L-histidine, α-hydroxybutric acid, β-hydroxy-D, L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, α-D-lactose, D-malic acid, L-malic acid, D-maltose, β-methyl-D-glucoside, methyl pyruvate, mucic acid, myo-inositol, propionic acid, L-pyroglutamic acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-salicin, L-serine, stachyose, D-trehalose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is reduced at pH 6 but not at pH 5; the dye is reduced at 1% NaCl, aztreonam, nalidixic acid, potassium tellurite, rifamycin SV, D-serine, tetrazolium blue, and tetrazolium violet; but not in the presence of 1% sodium lactate, 4% NaCl, 8% NaCl, fusidic acid, guanidine HCl, lincomycin, lithium chloride, minocycline, niaproof 4, sodium bromate, sodium butyrate, troleandomycin, and vancomycin. Strain JM10-4-1-3 (=NIBRBAC000003992) has been isolated from a soil sample, Dongdaemun-gu in Seoul, South Korea.

Description of *Deinococcus radioresistens* KMS4-11

Cells are Gram-stain-positive, non-flagellated, and short rod or coccus-shaped. Colonies are circular and pink-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, D-fructose-6-phosphate, and glucuronamide are utilized as sole carbon source. But acetic acid, acetoacetic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, L-alanine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellobiose, citric acid, dextrin, formic acid, D-fructose, D-fucose, L-fucose, L-galactonic acid lactone, D-galactose, D-galacturonic acid, gelatin, gentiobiose, D-gluconic acid, α-D-glucose, D-glucose-6-phosphate, D-glucuronic acid, L-glutamic acid, glycerol, L-histidine, α-hydroxybutric acid, β-hydroxy-D, L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, α-D-lactose, D-malic acid, L-malic acid, D-maltose, D-mannitol, D-mannose, D-melibiose, β-methyl-D-glucoside, 3-methyl glucose, methyl pyruvate, mucic acid, myo-inositol, pectin, propionic acid, Glycyl-L-protine, L-pyroglutamic acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-salicin, D-serine, L-serine, D-sorbitol, stachyose, sucrose, D-trehalose, D-turanose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is not reduced at pH 5 and pH 6; the dye is reduced in the presence of minocycline, sodium butyrate, tetrazolium blue, and tetrazolium violet; but not reduced in the presence of 1% NaCl, 1% sodium lactate, 4% NaCl, 8% NaCl, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, nalidixic acid, niaproof 4, potassium tellurite, rifamycin SV, D-serine, sodium bromate, troleandomycin, and vancomycin. Strain KMS4-11 (=NIBRBAC 000003983) has been isolated from a soil sample, Gangnam-gu in Seoul, South Korea.

Description of *Hymenobacter algoricola* KKM10-2-7-2

Cells are Gram-stain-negative, non-flagellated, and short rod-shaped. Colonies are circularand pale pinkish-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, acetoacetic acid, D-fructose, D-fructose-6-phosphate, L-fucose, L-galactonic acid lactone, D-galactose, glucuronamide, D-glucuronic acid, L-histidine, and D-raffinose are utilized as sole carbon source. But acetic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, L-alanine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellobiose, citric acid, dextrin, formic acid, D-fucose, D-galacturonic acid, gelatin, gentiobiose, D-gluconic acid, α-D-glucose, D-glucose-6-phosphate, L-glutamic acid, glycerol, α-hydroxybutric acid, β-hydroxy-D, L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, α-D-lactose, D-malic acid, L-malic acid, D-maltose, D-manni-

tol, D-mannose, D-melibiose, β-methyl-D-glucoside, 3-methyl glucose, methyl pyruvate, mucic acid, myo-inositol, pectin, propionic acid, Glycyl-L-protine, L-pyroglutamic acid, quinic acid, L-rhamnose, D-saccharic acid, D-salicin, D-serine, L-serine, D-sorbitol, stachyose, sucrose, D-trehalose, D-turanose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is not reduced at pH 5, pH 6; the dye is reduced in the presence of minocycline, potassium tellurite, tetrazolium blue, and tetrazolium violet; but not reduced in the presence of 1% NaCl, 1% sodium lactate, 4% NaCl, 8% NaCl, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, nalidixic acid, niaproof 4, rifamycin SV, D-serine, sodium bromate, sodium butyrate, troleandomycin, and vancomycin. Strain KKM10-2-7-2 (=NIBRBAC000003986) has been isolated from a soil sample, Gangnam-gu in Seoul, South Korea.

Description of *Hymenobacter elongatus* JM10-2-5

Cells are Gram-stain-negative, non-flagellated, and short rod-shaped. Colonies are circular and pale pinkish-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, acetoacetic acid, D-fructose-6-phosphate, glucuronamide, D-glucuronic acid, L-histidine, and L-malic acid are utilized as sole carbon source. But acetic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, L-alanine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellobiose, citric acid, dextrin, formic acid, D-fructose, D-fucose, L-fucose, L-galactonic acid lactone, D-galactose, D-galacturonic acid, gelatin, gentiobiose, D-gluconic acid, α-D-glucose, D-glucose-6-phosphate, L-glutamic acid, glycerol, α-hydroxybutric acid, β-hydroxy-D, L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, α-D-lactose, D-malic acid, D-maltose, D-mannitol, D-mannose, D-melibiose, β-methyl-D-glucoside, 3-methyl glucose, methyl pyruvate, mucic acid, myo-inositol, pectin, propionic acid, glycyl-L-protine, L-pyroglutamic acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-salicin, D-serine, L-serine, D-sorbitol, stachyose, sucrose, D-trehalose, D-turanose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is reduced at pH 5 and pH 6; the dye is reduced in the presence of minocycline, potassium tellurite, D-serine, sodium butyrate, tetrazolium blue, and tetrazolium violet; but not in the presence of 1% NaCl, 1% sodium lactate, 4% NaCl, 8% NaCl, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, nalidixic acid, niaproof 4, rifamycin SV, sodium bromate, troleandomycin, and vancomycin. Strain JM10-2-5 (=NIBRBAC000003987) has been isolated from a soil sample, Dongdaemun-gu in Seoul, South Korea.

Description of *Hymenobacter gelipurpurascens* JM10-2-6-2

Cells are Gram-stain-negative, non-flagellated, and short rod-shaped. Colonies are circular and pale red-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, γ-amino-butryric acid, D-arabitol, bromo-succinic acid, D-fructose-6-phosphate, D-fucose, L-fucose, L-galactonic acid lactone, D-galactose, gelatin, gentiobiose, α-D-glucose, glucuronamide, D-glucuronic acid, glycerol, L-histidine, β-hydroxy-D, L-butyric acid, α-D-lactose, D-maltose, D-mannose, D-melibiose, β-methyl-D-glucoside, methyl pyruvate, myo-inositol, Glycyl-L-protine, D-salicin, sucrose, D-trehalose, and D-turanose are utilized as sole carbon source. But acetic acid, acetoacetic acid, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, L-alanine, L-arginine, D-aspartic acid, L-aspartic acid, D-cellobiose, citric acid, dextrin, formic acid, D-fructose, D-galacturonic acid, D-gluconic acid, D-glucose-6-phosphate, L-glutamic acid, α-hydroxybutric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, D-malic acid, L-malic acid, D-mannitol, 3-methyl glucose, mucic acid, pectin, propionic acid, L-pyroglutamic acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-serine, L-serine, D-sorbitol, stachyose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is reduced at pH 5 and pH 6; the dye is reduced in the presence of aztreonam, lincomycin, minocycline, nalidixic acid, rifamycin SV, D-serine, sodium butyrate, tetrazolium blue, and tetrazolium violet; but not in the presence of 1% NaCl, 1% sodium lactate, 4% NaCl, 8% NaCl, fusidic acid, guanidine HCl, lithium chloride, niaproof 4, potassium tellurite, sodium bromate, troleandomycin, and vancomycin. Strain JM10-2-6-2 (=NIBRBAC 000003988) has been isolated from a soil sample, Dongdaemun-gu in Seoul, South Korea.

Description of *Hymenobacter psychrotolerans* KKM10-2-3

Cells are Gram-stain-negative, non-flagellated, and short rod-shaped. Colonies are circular and pale red-colored after 3 days of incubation on R2A at 25°C. In the GN3 microplates, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-neuraminic acid, N-acetyl-β-D-glucosamine, bromo-succinic acid, citric acid, dextrin, formic acid, L-fucose, gentiobiose, p-hydroxy-

phenylacetic acid, inosine, α-D-lactose, β-methyl-D-glucoside, 3-methyl glucose, methyl pyruvate, myo-inositol, D-raffinose, D-trehalose, and D-turanose are utilized as sole carbon source. But acetic acid, acetoacetic acid, L-alanine, γ-amino-butryric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, D-cellobiose, D-fructose, D-fructose-6-phosphate, D-fucose, L-galactonic acid lactone, D-galactose, D-galacturonic acid, gelatin, D-gluconic acid, α-D-glucose, D-glucose-6-phosphate, glucuronamide, D-glucuronic acid, L-glutamic acid, glycerol, L-histidine, α-hydroxybutric acid, β-hydroxy-D, L-butyric acid, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, D-malic acid, L-malic acid, D-maltose, D-mannitol, D-mannose, D-melibiose, mucic acid, pectin, propionic acid, glycyl-L-protine, L-pyroglutamic acid, quinic acid, L-rhamnose, D-saccharic acid, D-salicin, D-serine, L-serine, D-sorbitol, stachyose, sucrose, and Tween 40 are not utilized.

In sensitivity tests, the tetrazolium redox dye is reduced at pH 6 but not at pH 5; the dye is reduced in the presence of aztreonam, lincomycin, minocycline, nalidixic acid, potassium tellurite, rifamycin SV, D-serine, tetrazolium violet, and troleandomycin; but not in the presence of 1% NaCl, 1% sodium lactate, 4% NaCl, 8% NaCl, fusidic acid, guanidine HCl, lithium chloride, niaproof 4, sodium bromate, sodium butyrate, tetrazolium blue, and vancomycin. Strain KKM10-2-3 (=NIBRBAC 000003989) has been isolated from a soil sample, Gangnam-gu in Seoul, South Korea.

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