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-154T (with 99.8% similarity), *Deinococcus grandis* DSM 12784T (99.0%), *Deinococcus marmoris* DSM 12784T (98.8%), *Deinococcus claudionis* PO-04-19-125T (98.7%), and *Deinococcus radioresistens* 8A1T (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-A23a1 (99.1% similarity), *Hymenobacter elongatus* VUG-A112T (99.1% similarity), *Hymenobacter gelipurpurascens* Txg1T (99.1% similarity), and *Hymenobacter psychrotolerans* Tibet-IIU11T (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 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 roseosalvarius* 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-154T (AB558498; 99.85% 16S rRNA gene sequence similarity), *Deinococcus grandis* DSM 12784T (Y11329; 99.00% similarity), *Deinococcus marmoris* DSM 12784T (JNIV01000230; 98.81% similarity), *Deinococcus claudionis* PO-04-19-125T (EF635406; 98.80% similarity), and *Deinococcus radioresistens* 8A1T (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-A23aT (EU155009; 99.18% 16S rRNA gene sequence similarity), *Hymenobacter elongatus* VUG-A112T (GQ454797; 99.10% similarity), *Hymenobacter gelipurpurascens* Txg1T (Y18836; 99.13% similarity), and *Hymenobacter psychrotolerans* Tibet-IIU11T (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 were designated as single strains.

<table>
<thead>
<tr>
<th>Strain ID</th>
<th>Most closely related species</th>
<th>Similarity (%)</th>
<th>Isolation source</th>
<th>Medium</th>
<th>Incubation conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES10-3-3-1</td>
<td><em>Deinococcus citri</em></td>
<td>99.3</td>
<td>soil of Namyangju-si</td>
<td>R2A</td>
<td>25°C, 3 d</td>
</tr>
<tr>
<td>KKM10-2-2-1</td>
<td><em>Deinococcus grandis</em></td>
<td>99.0</td>
<td>soil of Gangnam-gu</td>
<td>R2A</td>
<td>25°C, 3 d</td>
</tr>
<tr>
<td>Ant11</td>
<td><em>Deinococcus marmoris</em></td>
<td>99.1</td>
<td>soil of Dongdaemun-gu</td>
<td>R2A</td>
<td>25°C, 3 d</td>
</tr>
<tr>
<td>JM10-4-1-3</td>
<td><em>Deinococcus claudionis</em></td>
<td>98.8</td>
<td>soil of Dongdaemun-gu</td>
<td>R2A</td>
<td>25°C, 3 d</td>
</tr>
<tr>
<td>KMS4-11</td>
<td><em>Deinococcus radioresistens</em></td>
<td>99.8</td>
<td>soil of Gangnam-gu</td>
<td>R2A</td>
<td>25°C, 3 d</td>
</tr>
</tbody>
</table>
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. 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.](image)

<table>
<thead>
<tr>
<th>Strain ID</th>
<th>Most closely related species</th>
<th>Similarity (%)</th>
<th>Isolation source</th>
<th>Medium</th>
<th>Incubation conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>KKM10-2-7-2</td>
<td><em>Hymenobacter algoricola</em></td>
<td>99.1</td>
<td>soil of Gangnam-gu</td>
<td>R2A</td>
<td>25°C, 3d</td>
</tr>
<tr>
<td>JM10-2-5</td>
<td><em>Hymenobacter elongatus</em></td>
<td>99.2</td>
<td>soil of Dongdaemun-gu</td>
<td>R2A</td>
<td>25°C, 3d</td>
</tr>
<tr>
<td>JM10-2-6-2</td>
<td><em>Hymenobacter gelipurpurascens</em></td>
<td>99.3</td>
<td>soil of Dongdaemun-gu</td>
<td>R2A</td>
<td>25°C, 3d</td>
</tr>
<tr>
<td>KKM10-2-3</td>
<td><em>Hymenobacter psychrotolerans</em></td>
<td>98.8</td>
<td>soil of Gangnam-gu</td>
<td>R2A</td>
<td>25°C, 3d</td>
</tr>
</tbody>
</table>
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.
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 cocccus-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-glucuronic acid, α-D-glucose, glucuronamide, D-glucuronic acid, glycerol, D-mannitol, D-mannose, D-melibiose, 3-methyl glucose, pectin, glycol-L-proline, D-serine, D-serine, D-sorbitol, D-turanose, and sucrose are utilized as sole carbon source. But, acetoclastic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-β-D-glucosamine, α-amino-butyric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellulbiose, citric acid, dextrin, formic acid, D-galactose, gelatin, gentiobiose, D-glucose-6-phosphate, L-glutamic acid, L-histidine, α-hydroxybutyric acid, β-hydroxy-3-D,L-butyrinic acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-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, Glycyl-L-protine, L-pyroglutamic acid, quinic acid, L-rhamnose, and sucrose are utilized as sole carbon source. But, acetoclastic acid, N-acetyl-D-galactosamine, N-acetyl-D-mannosamine, N-acetyl-β-D-glucosamine, bromo-succinic acid, citric acid, dextrin, formic acid, L-fucose, gentiobiose, α-hydroxybutyric acid, β-hydroxy-3-D,L-butyrinic 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, L-serine, 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-β-D-glucosamine, α-amino-butyric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellulbiose, citric acid, dextrin, formic acid, D-galactose, gelatin, gentiobiose, D-glucose-6-phosphate, L-glutamic acid, L-histidine, α-hydroxybutyric acid, β-hydroxy-3-D,L-butyrinic acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-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, Glycyl-L-protine, L-pyroglutamic acid, quinic acid, L-rhamnose, and sucrose are utilized as sole carbon source.

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, rifamycin SV, D-serine, 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, rifamycin SV, 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 cocccus-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-β-D-glucosamine, α-amino-butyric acid, D-arabitol, L-arginine, D-aspartic acid, L-aspartic acid, bromo-succinic acid, D-cellulbiose, citric acid, dextrin, formic acid, D-fructose, D-fucose, L-fructose, L-galactonic acid lactone, D-galacturonic acid, gelatin, gentiobiose, D-glucose-6-phosphate, L-glutamic acid, L-histidine, α-hydroxybutyric acid, β-hydroxy-D,L-butyrinic acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid, D-lactic acid methyl ester, 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, L-serine, D-serine, D-serine, D-sorbitol, sucrose, and D-turanose are utilized as sole carbon source.

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, rifamycin SV, 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.
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, Dong-daemun-gu in Seoul, South Korea.

**Description of Deinococcus claudonis 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-galacturonic acid lactone, D-galacturonic acid, D-glucuronic acid, α-D-glucose, D-gluconic acid, γ-amino-butyric acid, D-arabinol, L-arginine, D-aspartic acid, L-asparagine, D-bromocresol green, D-cellobiose, citric acid, D-glucose, D-glucuronic acid, D-glucuronic acid, L-glutamic acid, L-histidine, β-hydroxybutyric acid, β-hydroxy-D,L-butyric acid, p-hydroxy-phenylacetic acid, inosine, α-keto-butyric acid, α-keto-glutaric acid, L-lactic acid, D-malic acid, D-malic acid, D-maltose, D-mannitol, D-mannose, D-melibiose, 3-methyl glucose, pectin, glycyl-L-proline, D-serine, L-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, α-D-glucose, D-glucose, α-D-glucose, D-glucosamine, D-glucuronamide, D-glucuronamide, D-galactose, D-galacturonic acid, D-galacturonic acid, D-galacturonic acid, D-gluconic acid, α-D-glucose, D-glucose-6-phosphate, D-glucuronic acid, L-glutamatic acid, glycerol, L-histidine, α-hydroxybutyric 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, propionic acid, Glycyl-L-proline, L-prolylglutamic 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 reduct at pH 6 but not at pH 5; 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 JM10-4-1-3 (= NIBRBAC 000003992) 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 pinkish-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-butyric acid, D-arabinol, L-arginine, D-aspartic acid, L-aspartic acid, D-bromocresol green, D-cellobiose, citric acid, dextrin, formic acid, D-fructose, D-fucose, L-fucose, L-galacturonic acid lactone, D-galactose, D-galacturonic acid, gelatin, gentiobiose, D-glucuronic acid, α-D-glucose, D-glucose-6-phosphate, D-glucuronic acid, L-glutamatic acid, glycerol, L-histidine, α-hydroxybutyric 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, propionic acid, Glycyl-L-proline, L-prolylglutamic 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 reduct 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 circular and 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-galacturonic acid lactone, D-galactose, D-gluconic acid, D-gluconic acid, L-glutamic acid, α-D-glucose, D-glucose-6-phosphate, D-glucuronic acid, L-glutamatic acid, glycerol, L-histidine, α-hydroxybutyric 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, propionic acid, Glycyl-L-proline, L-prolylglutamic 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 reduct 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 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-butyric acid, D-arabitol, L-arabinose, D-aspartic acid, L-aspartic 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-glucuronic acid, α-D-glucose, D-glucose-6-phosphate, L-glutamic acid, glycin, α-keto-butyrlic acid, α-keto-glutaric acid, L-lactic acid, D-lactic acid methyl ester, D-lactic acid, D-malate, D-mannitol, D-mannose, D-melibiose, β-methyl-D-glucoside, 3-methylglucose, methyl pyruvate, mucic acid, myo-inositol, pectin, propionic acid, glycy-L-proline, L-pyrogultric acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-salicylic 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, 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, 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-butyric 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-lactic acid, α-D-lactose, D-malose, D-mannose, D-melibiose, β-methyl-D-glucoside, 3-methylglucose, methyl pyruvate, mucic acid, myo-inositol, pectin, propionic acid, glycy-L-proline, L-pyrogultric acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-serine, L-serine, D-sorbitol, stachyose, 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-glucuronic acid, D-glucose-6-phosphate, L-glutamic acid, α-hydroxy-butyric acid, p-hydroxy-phenylactic 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-methylglucose, mucic acid, pectin, propionic acid, L-pyrogultric 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, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, niaproof 4, potassium tellurite, sodium bromate, tetrazolium cyanide, and vancomycin. Strain JM10-2-6-2 (= NIBRBAC000003988) 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-β-D-glucosamine, bromo-succinic acid, citric acid, dextrin, formic acid, L-fucose, gentiobiose, p-hydroxy-phenylactic 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-methylglucose, mucic acid, pectin, propionic acid, L-pyrogultric acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-serine, L-serine, D-sorbitol, stachyose, 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-glucuronic acid, D-glucose-6-phosphate, L-glutamic acid, α-hydroxy-butyric acid, p-hydroxy-phenylactic 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-methylglucose, mucic acid, pectin, propionic acid, L-pyrogultric 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, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, niaproof 4, potassium tellurite, sodium bromate, tetrazolium cyanide, and vancomycin. Strain JM10-2-6-2 (= NIBRBAC000003988) 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-β-D-glucosamine, bromo-succinic acid, citric acid, dextrin, formic acid, L-fucose, gentiobiose, p-hydroxy-phenylactic 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-methylglucose, mucic acid, pectin, propionic acid, L-pyrogultric acid, quinic acid, D-raffinose, L-rhamnose, D-saccharic acid, D-serine, L-serine, D-sorbitol, stachyose, 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-glucuronic acid, D-glucose-6-phosphate, L-glutamic acid, α-hydroxy-butyric acid, p-hydroxy-phenylactic 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-methylglucose, mucic acid, pectin, propionic acid, L-pyrogultric 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, aztreonam, fusidic acid, guanidine HCl, lincomycin, lithium chloride, niaproof 4, potassium tellurite, sodium bromate, tetrazolium cyanide, and vancomycin. Strain JM10-2-6-2 (= NIBRBAC000003988) has been isolated from a soil sample, Dongdaemun-gu in Seoul, South Korea.
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-butyric 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, D-fructose, D-fructose-6-phosphate, D-fucose, L-galactonic acid, glycyl-L-proline, 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, naldixic acid, potassium tellurite, rifampicin, S. Hymenobacter norwichensis sp. nov., isolated from a soil sample, Gangnam-gu in Seoul, South Korea.

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